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8 Hazard to Life

8.1 Legislation

8.1.1 Objectives

8.1.1.1 In accordance with Section 3.4.9 of the EIA Study Brief (ESB-352/2022), a hazard to life assessment should be conducted to evaluate the risks associated with the existing Tai Lam Chung No.2 Chlorination Station (TLCCS) and the use of explosives to the Project during the construction and operation phases.

8.1.1.2 The Hazard to Life Assessment requirements are detailed in Appendix L of the EIA Study Brief and are shown below in **Appendix 8.1**.

8.1.2 General

8.1.2.1 The relevant legislation and associated guidance applicable to the Project for the Hazard to Life assessment include the following:

- Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM); and
- Dangerous Goods Ordinance (Cap. 295).

8.1.3 Technical Memorandum on Environmental Impact Assessment Process

8.1.3.1 As set out in Annex 4 of the EIAO-TM, the criterion for hazard to human life is to meet the Hong Kong Risk Guidelines (HKRG) (see **Diagram 8.1**). The risk guidelines are expressed in terms of individual and societal risks as shown below:

Individual Risk:	Maximum level of off-site individual risk should not exceed 1 in 100,000 per year i.e. $1x10^{-5}$ per year.
Societal Risk:	With the population increases, the societal risk will be increased. The societal RG is presented graphically in below. 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 RG 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 reasonably practicable" (ALARP). It seeks to ensure that all practicable and cost-effective measures that can reduce risk will be considered.

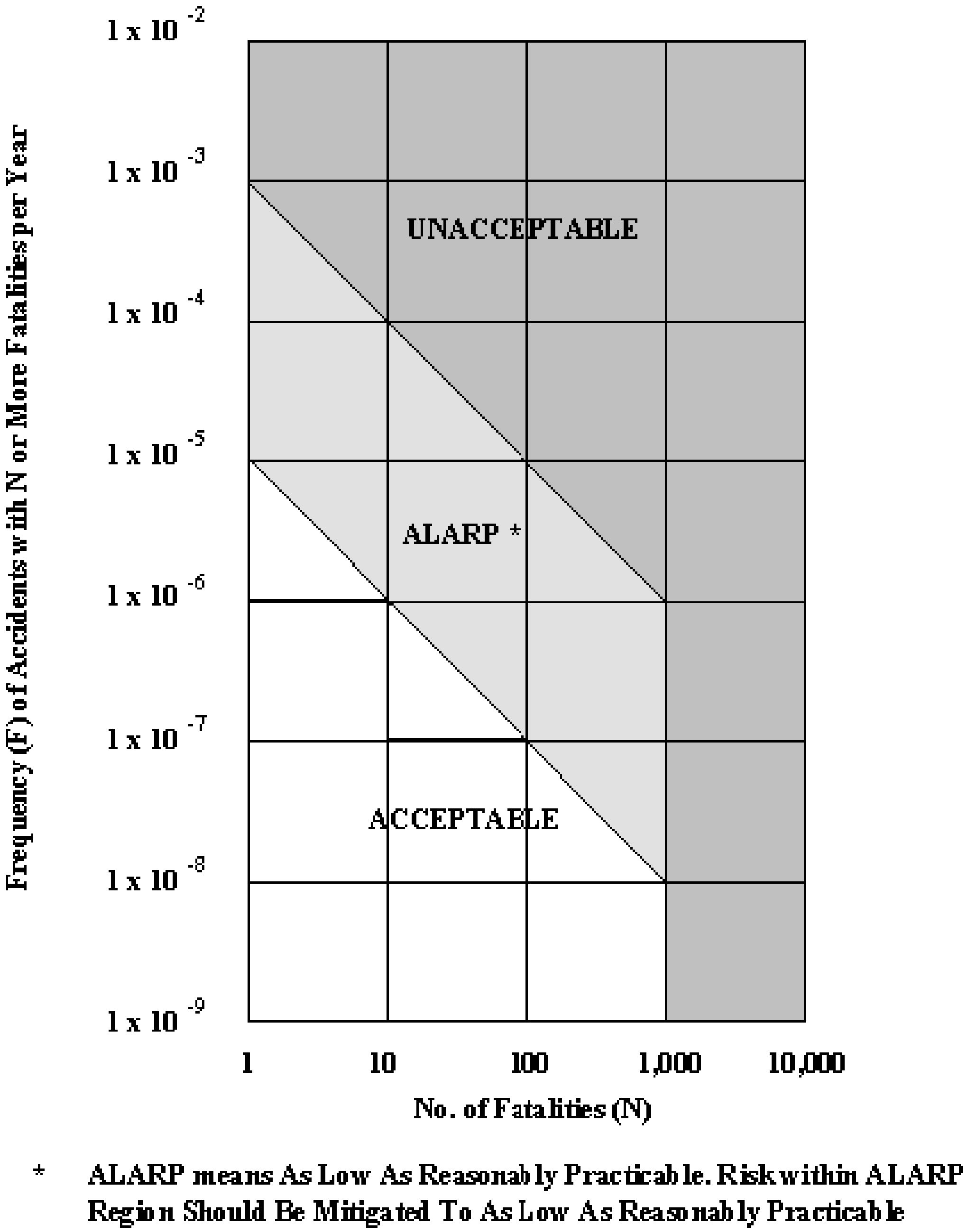

Diagram 8.1 Societal Risk Criteria in Hong Kong

8.1.4 Dangerous Goods Ordinance

8.1.4.1 The conveyance of explosives by public roads in HKSAR is governed by the Dangerous Goods Ordinance (Cap. 295). A conveyance permit is required for transport on public roads. Also, the road vehicle carrying explosives should be of an approved type.

8.1.4.2 Storage of explosives is governed by the Dangerous Goods (Control) Regulations (Cap. 295G). Under the regulation, a license is required for the storage of explosives.

8.1.4.3 The QRA for the storage, transport and use of explosives related to the construction phase of the Project, in which blasting activities are required. There will be no explosives handled during the operational phase. Hence, this chapter presents the QRA for the following:

- Storage of explosives at the proposed temporary magazine including handling of explosives within the temporary magazine site;
- Transport of explosives to the delivery points; and
- Use of explosives including handling of explosives from the delivery points to the blast face.

8.2 Project Description

8.2.1 Project Overview

8.2.1.1 As discussed in **Section 2**, the objective of the Project is to enhance the connectivity between the North West New Territories (NWNT) and the North Lantau to meet the future traffic demands generated by the future developments in both regions. The Project will be a strategic highway to support the proposed developments in the NWNT. It will also provide the third vehicular access to Lantau in addition to the existing Tsing Ma and Kap Shiu Mun Bridges and the Tuen Mun-Chep Lap Kok Link (TM-CLKL).

8.2.1.2 The Project stretches from Lam Tei to North Lantau and comprises sections of tunnels, viaducts, at-grade roads and a long span suspension bridge (i.e. Tsing Lung Bridge). It connects to several strategic routes such as Kong Sham Western Highway (KSWH) and Yuen Long Highway (YLH) at its northern end, Tuen Mun Road (TMR) at So Kwun Wat and Tsing Lung Tau, North Lantau Highway, Lantau Link, the proposed Tuen Mun Bypass (TMB), the proposed Tsing Yi-Lantau Link (TYLL), the proposed Hong Kong Island West-Northeast Lantau (HKIW-NEL) Link and the proposed Road P1. Tsing Lung Bridge spans across Ha Pang Fairway, connecting Tsing Lung Tau to North Lantau.

8.2.1.3 Referring to **Section 2**, the construction works would start from 2026 while the tentative start date of blasting works is envisaged to be Q1 2027.

8.2.2 Blasting Requirement for this Project

8.2.2.1 **Section 2** presents the consideration of options and construction methodologies. The following table shows the latest construction methodologies for the tunnel sections envisaged at this stage.

Table 8.1 Summary of Construction Methodologies for this Project

Section	Construction Methodology	Remark
Tunnel Sections		
Lam Tei Tunnel (LTT)	Drill-and-blast and Mined Tunnelling (approximately 4.2km long)	Main Alignment
Tai Lam Chung Tunnel (South Section) (TLCT)	Drill-and-blast and Mined Tunnelling (approximately 1.7km long main tunnel and approximately 0.6km long bifurcation section)	Main Alignment
So Kwun Wat Link Road Tunnel (SKWLR)	Drill-and-blast and Mined Tunnelling (approximately 1.6km long)	Main Alignment
Tai Lam Chung Tunnel (North Section) (TLCTN)	Drill-and-blast and Mined Tunnelling (approximately 0.4km long)	Main Alignment
Surface Blasting for Site Formation		
Site 1: Lam Tei Quarry (LTQ) main cut slopes for approach viaducts	Drill-and-blast, chemical breaking, mechanical breaking and soft ground excavation (approximately 480,000m^3)	Main Alignment

Section	Construction Methodology	Remark
Site 2: LTT North Portal	Drill-and-blast, chemical breaking, mechanical breaking and soft ground excavation (approximately 480,000m^3)	Main Alignment
Site 3: The site formation at the northern landfall of the TLB including the Bridge anchorage	Drill-and-blast, chemical breaking, mechanical breaking and soft ground excavation (approximately 357,000m^3)	Main Alignment
Site 4: North Lantau cutting (including the bridge anchorage and site formation)	Drill-and-blast, chemical breaking, mechanical breaking and soft ground excavation (approximately 1,950,000m^3)	Main Alignment
Others		
LTQ underground magazine	Drill-and-blast and Mined Tunnelling (approximately 0.4km long)	Lam Tei Quarry Magazine
Connection adit for the Ventilation Building at TLCT South Portal	Drill-and-blast and Mined Tunnelling (approximately 0.3km long)	Ventilation duct connection

8.2.2.2 It can be seen from the above table that among the entire 12km long alignment, around 8km of the tunnel sections, LTQ underground magazine and connection adit for ventilation building would both be constructed by drill-and-blast and mined tunnelling for the required alignment profiles to suit local geological ground conditions.

<u>Tunnel Sections</u>

8.2.2.3 The cross-sectional areas for tunnel sections of drill-and-blast tunnel vary between approximately 125m^2 and 200m^2. According to typical engineering design and geology, the first 50 to 150m section from tunnel portal would likely be constructed by cut-and-cover and mined tunnelling methods to establish a tunnel portal area for blast enclosure installation. The length of tunnel requiring drill-and-blast would vary depending on the tunnel to be constructed and would vary from approximately 400m for the TLCTN to 4.2km for the LTT. The portal would also be contained within a hoarded construction compound to allow access and management of the portal entrance. Hence, the blast locations would be confined within the tunnel section and behind the blast door instead of at the portal. The maximum typical height of the tunnel sections is approximately 11 to 12 m and special bifurcation sections are also required in the TLCT which could reach approximately 13 to 14m high. In the case of the TLCT bifurcation, the tunnel face would likely be split into heading and bench excavations and so the explosive quantities required would not increase for these blast faces. The required quantity of packaged explosives per blast face would ranging from 35 to 50 Trinitrotoluene (TNT) equivalent (eqv.) kg and the daily explosives requirement would be 80 to 130 TNT eqv. kg per workfront.

<u>Surface Blasting</u>

8.2.2.4 Surface blasting works would also be required at several rock cut slope sites along the alignment where large portions of rock will be excavated. The size of these cuttings ranges from smaller portal excavations to the large cutting on North Lantau to establish the southern Tsing Lung Bridge anchorages and the connections to the existing Route 8. A summary of the surface blasting works is summarised in **Table 8.1**.

8.2.2.5 Surface blasting is anticipated to be excavated in a bench system with one blast per day utilising daily delivery of explosives and will be delivered to the blasting site directly by the Mines Division. The transportation of explosives directly to sites is under Mines Division's purview and falls outside the scope of this EIA. Benches are anticipated to be approximately 5,750m^3 with a corresponding bench height of 6m per blast. The surface blasting benches will be covered with blasting cages, blast mats and blasting screens to limit flyrock potential.

Lam Tei Quarry Magazine

8.2.2.6 Underground blasting would be required to construct this underground magazine sites. The explosive stored in magazine site will be transferred to the portal area directly. There would not be any off-site transportation of explosives. The explosives for the construction of the Lam Tei Quarry Magazine site are delivered by Mines Division to the site directly.

Connection Adits

8.2.2.7 Blasting works are also required at the connection adit (approximately 75 to 120m long) to connect to the ventilation building at the south of TLCT. The adit is in hard rock conditions and would be constructed by the drill-and-blast method. The cross-sectional area of the connection adit for tunnel ventilation is approximately 90m^2. The daily explosives requirement would be approximately 30 TNT eqv. kg.

8.2.3 Explosive Types

Proposed Explosives

8.2.3.1 Standard explosives to be adopted consist of emulsion explosives, either as initiating explosives (pre-packaged cartridge) or as bulk emulsion sensitized by gassing to render it into an explosive as it is pumped into the blast hole at the time of charging the face.

8.2.3.2 Both cartridged emulsion and bulk emulsion mainly contain ammonium nitrate, water and a hydrocarbon such as fuel oil. The cartridged emulsion may also contain 2 to 3% aluminium powder to increase the explosive temperature and its explosion power.

8.2.3.3 Cartridged emulsion will be transported from the designated explosive magazine to the construction site by the contractor using licensed trucks.

8.2.3.4 Bulk emulsion precursor will be delivered to the blasting site within the access tunnel by the appointed third party supplier. It will only be classified as an explosive after being sensitized at the blast location or working face and the addition of a gassing agent as it is pumped into the blastholes.

8.2.3.5 Detonators, cartridged emulsion, boosters and detonating cords will be used to initiate the blast at work face depending on the blast requirement. Both approved electronic and non-electric detonators will be used in this Project.

Explosives Properties

8.2.3.6 Properties of the two types of explosives to be used in this Project are shown in **Table 8.2**.

Table 8.2 Properties of Explosives

Type	Function	Use	Example
Initiating explosives	To initiate main blasting explosives	Initiation of secondary explosive	Detonating cords, detonators and boosters
Blasting explosives	Used as main blasting explosives	General blasting, Shattering rock / structures	Cartridges emulsion, bulk emulsion, ANFO[1]

Note:
[1] ANFO stands for Ammonium Nitrate-Fuel Oil.

Cartridged Emulsion

8.2.3.7 Cartridged emulsion explosives contain an oxidising agent which is a combination of ammonium nitrate (single salt), water, and a hydrocarbon such as fuel oil. It contains high quantity of water which is around 10 to 14% typically. The mixture is complete with small amounts of emulsifiers, normally less than 1% in order to keep the water and oil mixture homogeneous.

8.2.3.8 It is classified as a UN Class 1.1D explosive and DG Class 1 explosive under the Hong Kong classification system, and has a TNT equivalence of 0.96, i.e. 0.96 kg of TNT per 1 kg of emulsion.

8.2.3.9 It is packaged in a range of plastic films with the tips clipped at each end to form a cylindrical sausage or wrapped in waxed paper which can be used for both priming and full column applications such as mining, quarrying and general blasting work. Cartridged emulsion is detonator sensitive, so it does not require the use of booster to cause its detonation.

Bulk Emulsion Precursor

8.2.3.10 The composition of bulk emulsion is similar to that of cartridged emulsion but without the existence of aluminium. The bulk emulsion precursor has a density of 1.38 to 1.40 g/cc. It is not considered as an explosive until sensitization at the blast face and so is classified as a UN 5.1 oxidizing substance which yields oxygen readily to stimulate the combustion of other materials.

8.2.3.11 It is stable under normal conditions and there would not be major fire hazard. The major hazard of bulk emulsion precursor is due to its oxidizing properties which can cause irritation of eyes and skin. It may explode when under prolonged fire, supersonic shock or very high energy projectile impact.

8.2.3.12 Since it is stable under normal conditions, the storage and transport of bulk emulsion precursor will not be included with the scope of this study.

Bulk Emulsion and Ammonium Nitrate-Fuel Oil (ANFO)

8.2.3.13 Bulk emulsion will be mainly used for excavation of rock in tunnel and surface blasting while site mixed ANFO will also be used if needed.

8.2.3.14 Bulk emulsion precursor is sensitized at the blast site with the addition of a gassing solution and then it is added to the charging hose downstream from delivery pump.

8.2.3.15 The gassing solution will reduce the density of the bulk emulsion precursor to 0.8 to 1.1 g/cc which will cause the production of nitrogen gas bubbles that aid the propagation of the detonation wave and sensitize the emulsion. Once the emulsion is sensitized and gassed, it can be detonated with the assistance of a small booster and a detonator.

8.2.3.16 Bulk emulsion explosives and site mixed ANFO would only be classified as UN 1.5D explosive and Class 1 DG (explosives) after being sensitized and gassed during blasting onsite. Hence, non-sensitized bulk emulsion explosives or site mixed ANFO at magazine site and during transportation are not classified as explosives.

8.2.3.17 Moreover, the bulk emulsion should be pumped into the blast hole and completely fill the hole once it is mixed onsite.

Detonating Devices

8.2.3.18 Detonators are small devices that are used to safely initiate blasting explosives in a controlled manner. Although there are many different types of detonators such as safety use, electronic and non-electric detonators will be studied in this assessment as they would be used in this Project.

8.2.3.19 Detonators can be classified as 1.1B, 1.4B and 1.4S under Dangerous Goods (Application and Exemption) regulation (Cap. 295E).

8.2.3.20 Detonators and detonating cords are used to initiate the blasting. Although detonator is a device that contains the most sensitive types of explosives in common use, it is packaged in a manner such that they may be handled and used with minimal risk.

8.2.3.21 Detonators are manufactured with built-in delays of various durations so that it can facilitate effective blasting and enable shots to be initiated once but to fire sequentially. Hence, it can enhance the practical effects of the blast. The detonator to be used in this Project will be millisecond delay period detonator.

8.2.3.22 For non-electric detonators, the delay time of a detonator is based on the burning time of the delay element which is a pyrotechnic ignition mixture pressed into a 6.5mm diameter steel tube. It first causes the primary explosion of a small amount of lead azide and the primary explosion will then trigger secondary explosion which is usually Pentaerythritol tetranitrate (PETN). The delay time is affected by the length of steel tube and the compaction of the pyrotechnic mixture within in. When designing the blasting of a blast face, the general principle is to select the required detonators to ensure that each blasthole will detonate more than 8ms apart.

8.2.3.23 Thin and flexible tubes with explosive core are called detonating cord. It has the effect of a detonator along its entire length and is suitable for initiating other explosives that are detonator sensitive like boosters and cartidged emulsion. It can be used for synchronizing multiple charges to detonate different charges and to chain multiple explosive charges together. The detonating cord is usually compressed with powdered PETN and it is initiated by the use of a blasting cap.

8.2.3.24 For electronic detonators, it comprises an instantaneous detonator and an electronics module. The electronics module can be field programmable to suit different time delays and has higher accuracy than non-electric detonators. Programmable delays typically range from 0 to 10 seconds in 1 millisecond increments. The time delays are assigned electronically using unique identification tags at the excavation face and each ID is traceable using RFID scanning at the excavation face for checking before detonation.

Charges and Delays

8.2.3.25 A majority of drill-and-blast tunnels and surface cuttings for the Project are expected to be excavated using bulk emulsion to be initiated by non-electric detonators. For both tunnels and surface blasting, it is assumed in this assessment that the maximum instantaneous charge (MIC) for any single detonation will be almost 10 TNT eqv. kg.

8.2.3.26 It is assumed that where the MIC is restricted to less than 1 TNT eqv. kg, cartridges initiated by electronic detonators would be selected to provide additional confidence in the MIC per delay and remain within the quoted PPV limits. Where MIC is greater than 1 TNT eqv. kg, it is expected that the bulk explosives will be charged with a single 200g emulsion cartridge or a mini cast booster per blasthole to initiate the bulk explosive.

8.2.3.27 The selection of either bulk emulsion or cartridge explosives are considered to have a significant effect on the required total quantities of explosive per blast.

8.2.3.28 However, it is important to note that bulk emulsion is classified as Class 5.1 under the Dangerous Goods Ordinance and is considered to become an explosive (Class 1) only after sensitization by gassing as it is pumped into blast holes.

8.2.3.29 Therefore, it comes under the regulation of the Fire Services Department as a flammable substance, and the storage requirements are less stringent. A licence from the Commissioner of Mines is required for manufacture of an explosive at the blast face, where the emulsion is sensitized by gassing and becomes an explosive at that stage.

8.2.3.30 Therefore, the requirement for Project magazine sites is only to cater for the storage of items classified as Class 1 (explosives), which include cartridge explosive and detonators. In this way, by maximizing the use of bulk emulsion and minimizing the required use of the items categorized as explosive when delivered to site, the Project transport and storage requirement for explosives is minimized in the interest of safety.

8.2.3.31 In order to facilitate a smooth blasting, perimeter holes will be lightly charged, using either detonating cords or string loading of emulsion. Detonating cords must be delivered to site as Class 1 DG (explosives). The typical quantity used per perimeter blasthole is two strips of 40g per metre detonating cord.

8.2.3.32 Each blasthole will also require a detonator, and these are also delivered to site as Class 1 DG (explosives). Each detonator typically contains up to 1g of explosive as the base charge. A small quantity of detonators or light (5g per metre) detonating cord is also required to complete the hook-up of all the individual blasthole detonators.

8.2.3.33 The boosters, detonating cord and detonators would need to be delivered to site as Class 1 DG (explosives). These are commonly all called packaged explosive, to distinguish them from bulk emulsion, which is not a Class 1 DG (explosives) when stored or delivered to site.

8.2.3.34 The lower limit for the use of bulk emulsion is determined by the accuracy of the proposed bulk emulsion pump. According to the latest design, the lowest charge weight for the use of bulk emulsion is 1 TNT eqv. kg.

8.2.4 Magazine Requirement and Selection Process

Magazine Requirement

8.2.4.1 In view of the tight construction programme to commission the Project by 2033, the blasting operation is required to be continuous. As Mines Division would not deliver the required explosive quantities on public holidays and under inclement weather conditions, any stoppage of explosive delivery would pose a significant impact to the blasting and construction programme. Therefore, explosive magazines are required.

Need for Magazine Sites

8.2.4.2 The daily explosives requirement would be 90 to 130 TNT eqv. kg for each blast site, subject to the detailed design. This result has then been adjusted to provide a maximum of 5 days storage capacity to cater for any delays in daily explosives replenishment deliveries by the Mines Division, to cover poor weather conditions, boat breakdown, etc. The required magazine capacities are therefore at least 1000 to 1400 TNT eqv. kg. As discussed in **Section 2**, there are 3 temporary explosive magazine sites to be share-used between the Project and TMB. These 3 temporary explosive magazine sites include an underground magazine site in Lam Tei Quarry and 2 surface sites at Siu Lam and Pillar Point. A summary of storage requirement is provided in **Table 8.3**.

Table 8.3 Storage Requirement for Temporary Explosive Magazine

Magazine	Work Front	Explosives	
		Daily (TNT eqv. kg)	Average Storage (TNT eqv. kg)
Lam Tei Quarry	LTT North Portal	90	450
	TMB Northern Tunnel North Portal (as a concurrent project by the same Project Proponent)	100	500
Siu Lam / Pillar Point	LTT South Portal	90	450
	TLCT (South Section) and TLCT (North Section)	130	650
	SKWLR East Portal	100	500
	SKWLR West Portal	100	500
	TMB Northern Tunnel South Portal (as a concurrent project by the same project proponent)	100	500

Note:

The explosive quantities are based on the latest blasting design and a certain margin has been reserved for calculating the magazine storage. Thus, the quantities may be higher than that in the **Table 8.7**.

8.2.4.3 It should be noted that these quantities are based on the use of 125g emulsion cartridge as primers. They also do not account for other situations which might require additional explosives quantities, such as areas of low MIC, less than 1 TNT eqv. kg allowable MIC, or additional blasting for connecting passages, niches etc. which may be additional to the regular blast faces for adits, tunnels and open blasting.

External Separation Distances

8.2.4.4 Other than the requirements from the Mines Division, the criteria for separation distances to protected works and/or buildings for Hazard Type 1 explosives, as specified in UK Health and Safety Executive's (HSE) "The Explosive Regulation 2014, Statutory Instrument 2014 No.1638, United Kingdom" (for a brick-built mounded store for 250 to 300 and 300 to 350 kg storage)[1] are shown in **Table 8.4**. The separation distance criteria for Siu Lam and Pillar Point magazine sites were based on 250 to 300 kg and 300 to 350 kg storage respectively.

Table 8.4 External Separation Distance for Different Quantities of Explosives

Protected Works / Buildings	**Distance (m) from Magazine Site**	
	250 to 300kg Explosives	**300 to 350kg Explosives**
Building	170	172
Major Road	161	172
Minor Road / Railway / Reservoir	80	86
Building within the magazine sites	16	18

8.2.4.5 For underground magazines, minimum chamber separation distances are required to prevent or control the communication of explosives or fires between chambers. According to DoDM 6055.09-V2-E5.8.4, there are three modes by which an explosion or fire can be communicated: rock spall, propagation through cracks or fissures, and airblast or thermal effects travelling through connecting passages.

8.2.4.6 The DoDM 6055.09-M-V2 Equation V2.E5.T2-3 indicates that the minimum separation distance required to prevent hazardous rock spall effects is given by the equation below for moderately strong to strong rock with chamber loading densities less than 48.1kg/m^3:

$$D_{cd} = 0.99Q^{1/3}$$

Where Q Maximum charge weight per delay interval in kilograms

8.2.4.7 By assuming the quantity of explosives per niche is 200kg, the calculated separation distance between separate niches is 5.8m.

8.2.4.8 To avoid propagation through cracks and fissures, site investigation would be made to ensure that such joints or fissures do not extend from one chamber location to an adjacent one. Moreover, blast doors are provided at the entrance to each niche to prevent airblast or thermal effects travelling through connecting passages.

Other Factors

8.2.4.9 The magazine site selection has considered a total of 4 candidate sites which are located at Lam Tei Quarry, Siu Lam, Pillar Point and Tai Shu Ha and they are depicted in **Appendix 8.2**. Apart from the separation distances, the following points had also considered:

[1] According to UK HSE's Explosives Regulations 2014, the external separation distances are considered based on the quantity of explosives for each individual store where store means a building, enclosed area or metal structure in which explosives are, or are to be, stored. The storage for the proposed magazine sites used in this Project would be 300 kg and 350 kg per store for Siu Lam and Pillar Point magazine sites respectively.

- Access for Mines explosives delivery vehicles (road condition / width / gradient / public road networks to site / etc.);
- Land availability (ownership / existing landuse /planned development); and
- Site constraints.

8.2.4.10 After considering the candidate sites with the factors mentioned above, one of the sites (i.e. magazine site located at Tai Shu Ha) was found to have some constraints as it has been proposed by other project which made it impracticable for this Project.

Selected Sites

8.2.4.11 The potential magazine sites are located at Lam Tei Quarry, Siu Lam, Pillar Point and Tai Shu Ha. **Appendix 8.2** shows the selection of site based on consideration of the requirements and constraints.

8.2.4.12 Tai Shu Ha Magazine Site is unlikely available as it has been proposed for Northern Link (NOL) project by MTR Corporation Limited.

8.2.4.13 Therefore, Lam Tei Quarry Magazine Site, Siu Lam Magazine Site and Pillar Point Magazine Site are preferred and selected for this Project due to its land availability, lesser public objection, remote location and established design standard. A further advantage of selecting for Lam Tei Quarry and Siu Lam magazine sites is that they are closer to the proposed blasting sites with less transportation time to deliver explosives to the construction site.

8.2.4.14 However, due to the constraint of the separation distance in Siu Lam with the existing reservoirs, the maximum capacity is limited to 1200 TNT eqv. kg. Since the Pillar Point magazine was previously proposed as part of the Tuen Mun West Bypass (TMWB) project, Pillar Point magazine site is proposed to serve other work fronts and store the extra explosives which are not able to be stored in Siu Lam magazine site.

8.2.4.15 The Lam Tei Quarry magazine is proposed as an underground magazine which will be explained in **Section 8.2.4.20** at the northern slope of the Lam Tei Quarry and will primarily serve the work fronts for the LTT North Portal of Route 11.

8.2.4.16 The Siu Lam magazine site is proposed as a reinstatement of the historical Siu Lam magazine used for the Express Rail Link (XRL) project. The magazine is intended to serve multiple southern work fronts as part of the construction. It primarily serves the Project work fronts due to the geographical location of the magazine, but in high quantity demand time periods, could also serve the work fronts for TMB.

Summary on the Design and Locations of the Explosives Magazine Sites

8.2.4.17 As discussed above, three separate magazines are proposed for this Project, which are located in Lam Tei Quarry, Siu Lam and Pillar Point. The work fronts served by different magazines are summarized in the table below:

Table 8.5 Work Fronts Distribution for Proposed Explosive Magazines

Magazine	Work Fronts
Lam Tei Quarry (underground)	LTT
Siu Lam	LTT

Magazine	Work Fronts
	SKWLR
	TLCT
Pillar Point	SKWLR
	TLCT

8.2.4.18 To allow for blasting to be carried out continuously every day and to provide a buffer if there is delivery interruption to the magazines by the Mines Division, each magazine is designed to store sufficient quantities of explosives for five days. The storage quantity for each magazine has been determined with sufficient margin by the design consultant based on estimated project explosives consumption and it is summarised in **Table 8.6**.

Table 8.6 Storage of Explosives for Each Magazine Site

Magazine	Storage of Explosives
Lam Tei Quarry (underground)	1000 TNT eqv. kg
Siu Lam	1200 TNT eqv. kg
Pillar Point	1400 TNT eqv. kg

8.2.4.19 Lam Tei Quarry magazine site would only serve the work fronts with Lam Tei Quarry, while Siu Lam and Pillar Point magazine sites would serve all the remaining work fronts. Therefore, they are designed for a total storage capacity of 2,600 kg and 16,000 detonators which correspond to the total requirements of all the work fronts except those located at Lam Tei Quarry.

Lam Tei Quarry Site

8.2.4.20 It is proposed as underground magazine as the existing land is near to a burial ground and a relatively steep slope. Hence, it is not available as an above-ground magazine site. The potential magazine site is required to store 950 (rounded to 1,000) TNT eqv. kg of explosives and 5,200 detonators.

8.2.4.21 The Lam Tei Quarry Magazine Site (**Diagram 8.2**) has been designed based on the rock cover approach in DoDM 6055.09-M-V5 utilising niche design of 200kg per niche. A minimum of 5 niches are required for the storage class of 1000kg. A separate niche will be used to store detonators.

8.2.4.22 A total of 11 niches would be constructed when respecting the minimum rock cover distance between adjacent niches and adopting obstructed line of sight between niches according to AS2187.1-1998. The niches would also be arranged such that they have no line of sight to the magazine portal and are set back from the entrance.

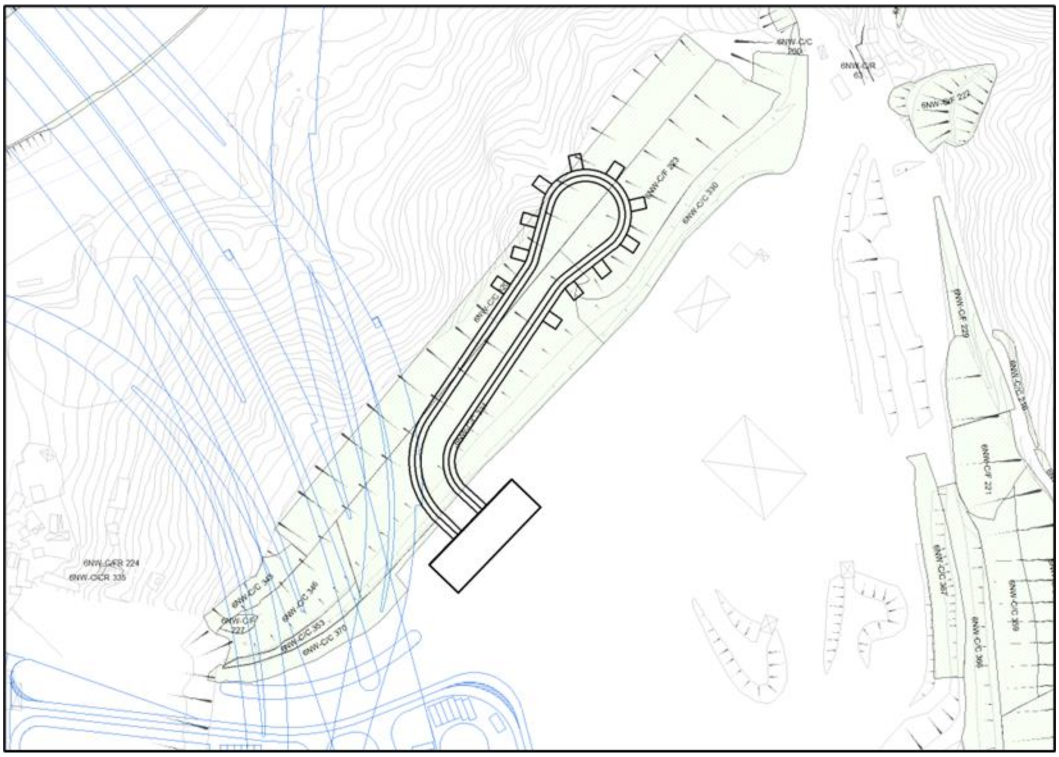

Diagram 8.2 Lam Tei Quarry Magazine Site Layout

Siu Lam Site

8.2.4.23 A single site configuration has been considered that comprises four magazine compounds, each with a single structure storing 300kg explosives. Due to the constraint of the separation distance to the existing reservoirs and building, the maximum capacity is limited to 1,200 TNT eqv. kg of explosives and approximately 7,400 detonators.

8.2.4.24 The site is located in an area of low population density, with little surrounding infrastructure. Based on the UK HSE's Explosives Regulations 2014, the minimum separation distances[2] for Class B (i.e. reservoir), Class C (i.e. major road) and Class D (i.e. building) are 80m, 161m and 170m respectively. The nearest building is located at 259m away from the proposed magazine site while Siu Lam Fresh Water Supplies Reservoir is located at 85m away. Both the building and the reservoir fulfil the minimum separation distance. Moreover, each magazine store is separated from other stores a distance of 16m which has fulfilled the minimum separation distance of Class G (i.e. building within the magazine site).

8.2.4.25 The risk induced by the usage of explosives to the workers in the fresh water supplies reservoir is considered insignificant because the maintenance workers would only visit the fresh water supplies reservoir when maintenance works are required. Moreover, liaison regarding the transportation of explosives would be arranged with Water Supplies Department (WSD) during construction phase to minimise the risk impact. A preliminary magazine design plan for Siu Lam site is provided in **Diagram 8.3**.

[2] According to HSE ER 2014, the separation distance is based on the amount of explosives in a store which "a store" means a building, enclosed area or metal structure which explosives are, or are to be, stored.

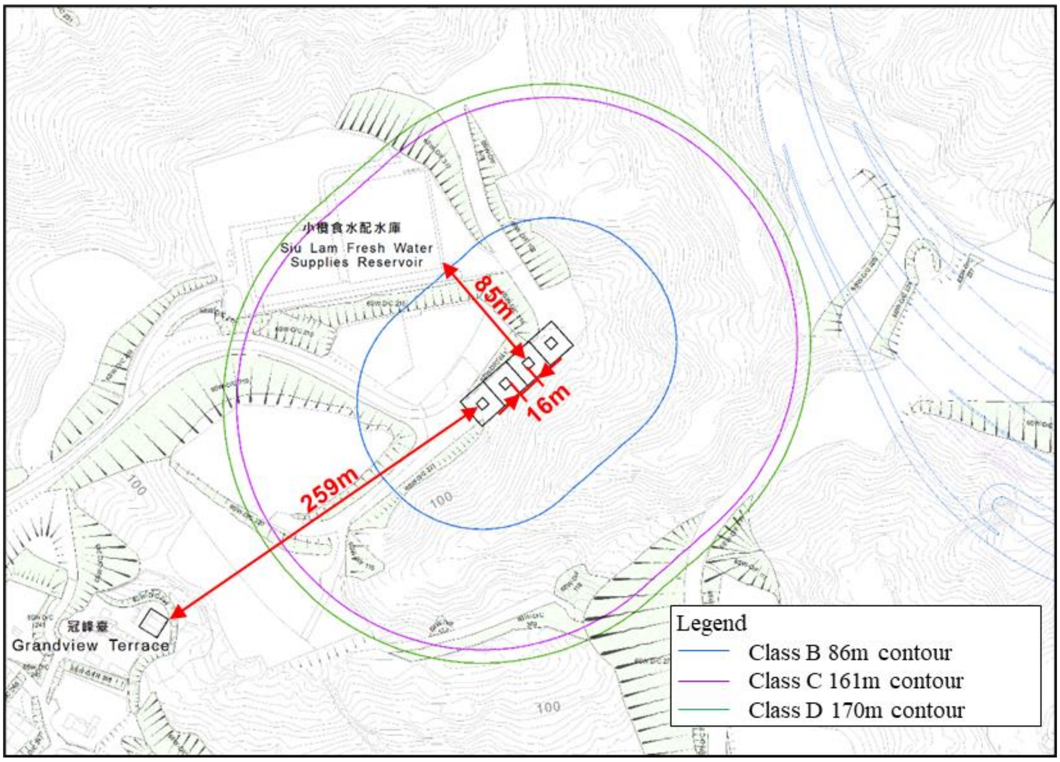

Diagram 8.3 Siu Lam Magazine Site Layout

Pillar Point Site

8.2.4.26 The site is located in area of low population density. In order to comply with the separation distance requirements of the UK HSE's Explosives Regulations 2014, a configuration has been adopted that comprises 4 magazine structures storing 350 TNT eqv. kg of explosives each. Based on the UK HSE's Explosives Regulations 2014, the minimum separation distances for Class B (i.e. reservoir), Class C (i.e. major roads) and Class D (i.e. building) are 86m, 172m and 172m respectively. The nearest distances from the magazine storage to Tuen Mun West No.2 Service Fresh Water Reservoir, the nearest major road and building are 88m, 208m and 280m respectively which all comply with the separation distance. Each store is separated from other stores a distance of 18m which has fulfilled the minimum requirement of Class G (i.e. building within the magazine sites). A preliminary magazine design plan for this site is provided in **Diagram 8.4**.

8.2.4.27 The risk induced by the usage of explosives to the workers in the fresh water service reservoir is considered insignificant because the maintenance workers would only visit the fresh water service reservoir when maintenance works are required. Moreover, liaison regarding the transportation of explosives would be arranged with WSD during construction phase to minimise the risk impact. The Pillar Point magazine site is designed with a storage capacity of 1,400 TNT eqv. kg and around 8,600 detonators.

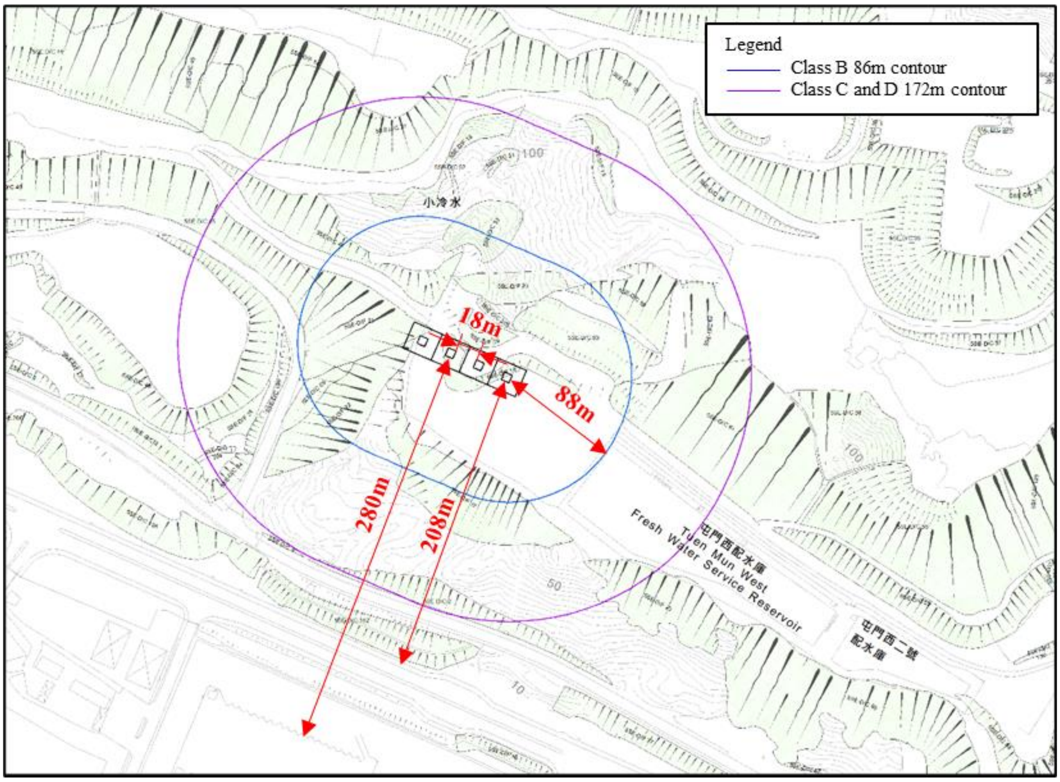

Diagram 8.4 Pillar Point Magazine Site Layout

8.2.5 Statutory/Licensing Requirements and Best Practice

<u>Use of Explosives</u>

8.2.5.1 Bulk emulsions and ANFO are commonly manufactured at the blast sites and use immediately for rock blasting. Under Section 16 of the Dangerous Goods (Control) Regulation, Cap. 259G, a manufacture (blasting) license is required to manufacture nitrate mixture, i.e. Group 2 Schedule 1 Dangerous goods (S1DG), within a blasting site. The Commissioner of Mines is the Authority for issuing the license.

8.2.5.2 The owner of the Manufacturing Unit (MU) must apply to the Commissioner of Mines for a manufacture (blasting) license on specific blasting sites in writing with the completed application form which requires the following information:

- The operation manual and procedures for manufacturing explosives;
- Procedures for safe handling and use of the manufactured explosives;
- Procedures for disposal of any waste product;
- A risk assessment on overheating, build-up of excessive pressure within the pump, etc., and the associated control measures to prevent the hazards occurring during the manufacturing process;
- An emergency response plan to deal with incidents affecting the safe operation of the MU and the hazards during the transport of the bulk products used for the manufacture of explosives and an emergency contact list; and

- Technical and safety information set out in Annex A of the "Guidance Note No. GN1 Licensing an Explosives Manufacturing Unit (MU) at a Blasting Site".

8.2.5.3 For surface or underground transport by vehicles, the transporting unit (TU) carrying an MU shall comply with the following requirements:

- It shall have a diesel-powered engine;
- It shall be roadworthy with a valid vehicle license issued by the Commissioner for Transport;
- The TU shall be equipped with an emergency stop at an easily accessible position;
- All cables to rear lights shall be fitted within fire resisting conduits;
- The TU shall be equipped with three 6kg or four 5kg dry chemical powder fire extinguishers;
- The TU shall be equipped with personal protective equipment, which shall be worn by all operators appropriate to the products being handled, in accordance with the MSDS;
- No explosives, detonators or other dangerous goods shall be carried on the TU; and
- Where mechanical track haulage is used for underground transport, the electric locomotive shall pull the trailer carrying the MU as close as possible to the blast face. The locomotive shall be equipped with:
  - effective headlights and rear lights, and
  - adequate earthing provisions.

8.2.5.4 Ammonium nitrate (AN) is used for manufacturing bulk emulsion explosives and ANFO at blast sites. AN is classified as Dangerous Goods Category 5 – Strong supporters of combustion under Regulation 3 of the Dangerous Goods (Application and Exemption) Regulations, Cap. 295E. A license issued by Fire Services Department is required for the storage of DG Category 7 is required according to "A Guide to Application for Dangerous Goods License and Approval".

<u>Storage of Explosives</u>

8.2.5.5 Explosives are classified as Class 1 Dangerous Goods, and the Commissioner of Mines shall have the control and management of every depot subjected to Section 13C of Dangerous Goods Ordinance (Cap. 295). The storage for explosives must be within a licensed Mode A Store and to obtain the license, certain safety and operational criteria must be met to the approval of Mines.

8.2.5.6 To obtain a licensed Mode A Store for the magazine sites, they will need to meet the general requirements stated in the "Guidance Note No. GN 8 How to Apply for a Mode A License for Storage of Schedule 1 Dangerous Goods (Blasting Explosives)" from Mines Division, GEO CEDD.

8.2.5.7 The typical pre-licensing requirements for issuing of a Mode A License for an explosives magazine are listed below:

- For a public works project, a certificate for the completion of the proposed Mode A Store, signed by a Registered Professional Engineer (Civil and Structural) and the Engineer's / Project Manager's Representative for the Contract;
- Training records for all personnel involved in the transport, handling and storage of blasting explosives and supervising the safety and security of blasting explosives for the site;
- A certificate signed by a registered electrical worker and a registered electrical contractor certifying that the lightning conductors function properly and comply with BS EN 62305;
- If the vehicles are used for transport of the blasting explosives outside the project site boundary, the vehicles must meet the requirements in Mine Division's Guidance Note GN No.2 "Approval of an Explosives Delivery Vehicle";
- Confirmation that the warning sign(s), notice(s) and placard(s) have be erected/displayed in accordance with section 38 of the Dangerous Goods (Control) Regulation (Cap. 295G);
- Confirmation that the Shot Firer has been provided with a portable lightning detector for use during the handling and transport of blasting explosives;
- Confirmation that the Hong Kong Police Force has approved the security aspects of the Store, including the security company providing armed security guards and the standing instructions for management/administration of the store;
- Confirmation that the Fire Services Department has approved the firefighting aspects of the store;
- Confirmation that the Environmental Protection Department has issued the Environmental Permit for the Project, including the proposed Mode A Store; and
- Confirmation that no high-tension overhead cables carrying 440V are within 45 m of a surface store/portal area of an underground store and that no overhead cables of 1 kV or above are within 75 m of the store/portal area, and that all other types of electrical cables should, except for lighting and firefighting installation connections, be run underground from a point at least 15 m away from the store.

8.2.5.8 The typical construction for a Mode A Store is stated below:

- The store should consist of a single storey stand-alone structure made of substantial brickwork, masonry or concrete to a design approved by the Commissioner of Mines in each case;
- All hinges and locks must be made of non-ferrous metal;
- No ferrous metal must be left exposed in the interior of the Mode A store;
- The interior and exterior walls of the Mode A store must be painted white;

- The outer side of the steel door of the Mode A store must be painted red. No ferrous metal must be exposed on the inner face of the door forming part of an interior of the Mode A store;
- A warning sign legibly showing the English words "DANGER - EXPLOSIVES" and the Chinese characters "危險 - 爆炸品" in white against a background in red must be displayed outside or adjacent to every entrance to the Mode A store. The English words and Chinese characters must not be less than 100 mm in height;
- As far as practicable, the rood of the store should be made of lightweight materials to limit the potential for injury from debris in the event of an explosion;
- A security fence surrounding the Mode A store must be installed and set back a least 6 m from the store. The fence should be 2.5 m high, stoutly constructed of chain link fencing with a mesh size not exceeding 50 mm. The fence should be firmly fixed to metal or concrete posts and topped with a 0.7 m high outward overhang of razor wire. The base of the fence located between the posts should be secured with pegs to prevent intrusion;
- The area between the security fence and the Mode A store must be cleared of all vegetation. Vegetation clearance must also apply to a minimum distance of 1 m on the exterior of the fence. A uniform cross-fall of at least 1 in 100 away from the store to a drainage system must be constructed;
- The road leading to the Mode A store must have a concrete surface and it should be constructed and maintained so that 11 tonne trucks (about 8.9 m long and 2.5 m wide) can use it under all weather conditions. A suitable turning circle or other alternative means for these trucks to turn must be provided so that the trucks can be driven up to the gate of the security fence;
- A guardhouse should be provided. For surface Mode A store, security guards should be on duty outside the inner security fence adjacent to the gate when there is no receipt or issue of blasting explosives inside the Mode A store. A separate outer security fence should be installed to protect this guardhouse. For an underground Mode A store, the guardhouse should be positioned inside the security fence to guard the entrance gate and the portal to the underground magazine;
- Inside the guardhouse, an arms locker constructed as an integral part of the house and fitted with a lock is required;
- A telephone should be provided for use by the guard in the guardhouse. A watchdog should normally be provided for the store. In this regard, the Hong Kong Police Force may agree to alternative site-specific security provisions, e.g. CCTV;
- Firefighting installations consisting of at least four 6 litre foam and one 4.5 kg dry powder fire extinguishers to be positioned on two racks and four buckets of sand should be provided at the nearest convenient locations to the Mode A store doors; and

- Regular inspections of vegetation and trees surrounding the Mode A store shall be arranged to maintain security and to mitigate the risk of fire affecting the store.

<u>Transport of Explosives</u>

Supply of Detonators and Cartridged Emulsion Explosives

8.2.5.9 Detonators are imported into Hong Kong. Destructive tests are conducted by the manufacturer before shipping to the client and the test result must fulfil the requirement of their quality control and quality assurance (QC/QA) system. If the test sample does not fulfill the standards, the batch of the detonators will be destroyed. The inner packaging of the detonators will print the delay time, detonator shock tube length, batch number and the date of manufacture.

8.2.5.10 After imported to Hong Kong, the detonators will then be stored at the Mines Division Kau Shat Wan (KSW) explosives depot. Users will place orders from the Mines Division for delivery to their on-site explosives magazine or to their blasting site on a daily basis as appropriate.

Application for Approval of an Explosives Delivery Vehicle

8.2.5.11 The explosives delivery vehicle should comply with the regulations stated in the "Guidance Note No. GN2 Approval of an Explosives Delivery Vehicle" published by the Mines Division.

8.2.5.12 The safety requirements for approval of an explosives delivery vehicle and requirements for signage on vehicle are listed below:

- The vehicle must:
  - be powered by a diesel engine;
  - comply with the Road Traffic (Construction and Maintenance of Vehicles) Regulations, Chapter 374;
  - be kept clean, in sound mechanical condition and roadworthy; and
  - be licensed to carry the maximum number of persons required for the delivery convoy. Subject to the agreement obtained from the Mines Division and the Police, an armed security guard may not be required if an approves Global Positioning System (GPS) has been installed in the vehicle.

- Cargo compartment:
  - The cargo compartment of the vehicle, including the floor, must be constructed from sheet metal, at least 3mm thick, and lined internally with plywood, at least 13mm thick, and there must be no exposed ferrous metal in the interior of the cargo compartment;
  - The interior of cargo compartment, including doors, must be kept in good condition and free from defects or projections that could damage to the explosives or their packaging;
  - Electric wiring or electrical devices must not be installed inside the cargo compartment;
  - The doors of the cargo compartment must be capable of being securely locked using a padlock. The padlock must meet BS EN 12320 Security Grade 4 or above requirements, or equivalent;

  - Proper means of stowage must be provided to secure the loads during transport; and
  - If the vehicle is designed to carry both detonators and other types of blasting explosives at the same time, additional requirements, given in AEISG (2014), are required.
- Safety provision
  - The driver’s cabin must be separated by not less than 150mm from the cargo compartment of the vehicle;
  - The exhaust system must be located as far from the cargo compartment as possible, preferably at the front of the vehicle. The Transport Department must approve any modification to the exhaust system;
  - An emergency fuel cut-off device must be located at an easily accessible position with a label, in Chinese and English, prominently and legibly stating: “EMERGENCY ENGINE STOP 緊急死火掣”;
  - For a typical vehicle with a gross vehicle weight of 9 tonnes or above, four fire 5 extinguishers, comprising two 2.5kg dry powder and two 9-litre foam fire extinguishers of an approved type, with certificates, must be provided. They must be mounted in front and on both sides of the rear body, in easily accessible positions, using securely mounted brackets and quick release clamps;
  - A fire suppression system must be fitted to the engine bay of vehicles, complying with the AS5062-2016;
  - All electrical installations must be designed, constructed and protected so that they cannot cause any ignition or short-circuit under normal conditions of use, and to ensure that the risk of this occurring will be minimized in the event of a traffic accident. All electrical wiring and fittings must be shrouded in fire resisting conduits;
  - The fuel tank must be located below the cargo compartment of the vehicle. It must be protected from accidental damage and designed to prevent accumulation of spilt fuel on any part of the vehicle;
  - Fire resistant material must be fitted between the wheel arches and the cargo compartment;
  - Detonators and other types of blasting explosives must not be loaded or transported within the same cargo compartment of the vehicle, unless the cargo compartment fulfils the additional requirements as specified in Annex B of the “Guidance Note No. GN2 Approval of an Explosives Delivery Vehicle”;
  - A hand-held lightning detector must be provided in the vehicle to detect lightning before and during loading and unloading of explosives. Should lightning be detected within a distance of 16km from the loading/unloading point by the hand-held detector, loading or unloading of explosives must cease until the lightning signal has cleared; and
  - For a typical vehicle with a gross vehicle weight of 9 tonnes or above, two strobe beacons approved by the Transport Department must be installed on top of the cargo compartment.
- Signage on vehicle:
  - Whenever the vehicle is carrying explosives, it must display on both sides and on the rear door of the cargo compartment, placards (minimum

250mm x 250mm) showing the label of the highest Hazard Code of explosives;

- o Placards showing “EMPTY 空車” or blank placards must be displayed when the vehicle is empty; and
- o The vehicle must be painted white with a warning in Chinese and English, at least 150mm high, as follows: “DANGER-EXPLOSIVES” and “危險－爆炸品”. The warning must be in red or black and displayed on both sides and rear face of the cargo compartment. If possible, the warning must also be displayed on the front face of the vehicle.

8.2.6 Construction Cycle and Programme

8.2.6.1 After commissioning of the magazines, the proposed delivery-storage-blasting cycle will consist of the following elements:

- Delivery of explosives and initiating systems to magazine by the Mines Division as needed;
- Storage in the magazine sites;
- Transfer from the explosive sites to the portals utilizing public roads or construction access roads;
- Transfer to the working faces of the excavation; and
- Load and fire the face(s) to be blasted. Blasts in a particular area will be initiated from a common firing point once all personnel are clear and entry routes to each blast site are secured. All blasts are to be carried out underground.

8.2.7 Transport of Explosives and Initiation Systems

Explosives Transport Strategy

8.2.7.1 Bulk emulsion or ANFO will be manufactured on-site by an appointed third party supplier.

8.2.7.2 It is noted that transport of explosives is needed to deliver the explosives from Government explosive depots to the proposed magazine sites and from the proposed magazines to the Project construction sites.

8.2.7.3 According to the latest arrangement, the Mines Division would deliver explosives and detonators to the proposed magazine sites at Lam Tei Quarry, Siu Lam and Pillar Point.

8.2.7.4 Explosives will be transferred from the relevant stores by the relevant contractor and two licenced explosive delivery trucks will be required for each delivery which one will transport detonators only and other will transport a cargo of cartridged emulsion and detonating cord.

8.2.7.5 The explosives in the proposed magazine sites will then be withdrawn by the contractors as required and delivered to their designated construction sites for blasting. No more than one truck convoy loaded with explosives is generally expected within the magazine complex at any one time.

Explosives Transport Requirement

Current Construction Programme

8.2.7.6 The approach adopted to derive the total number of trips and the total initiating explosives to be transported per trip is as follow:

- As far as practicable, the explosives (i.e. cartridged emulsion and detonating cord) required for all blast faces of a given work area operated by the same contractor will be transported on the same explosive delivery truck when the blasting programmes for the blast faces of the work area overlap. Detonators are transported on dedicated trucks at the same time;
- Since potential progress issues may be arising during the construction stage which may cause the delay or change of programme, it may not be possible to adhere strictly to the envisaged construction programme which may result in difference of the actual blasting time and separate deliveries of explosives;
- The quantity of Class 1 explosives on the roads has been minimised by using bulk emulsion and/or ANFO, which will be manufactured on-site. The on-site manufacture of ANFO and bulk emulsion will require the transportation of Class 5.1 oxidising substances which falls outside the scope of the study;
- It is assumed that the project will mostly require a separate explosive delivery from the relevant magazine to each delivery point; and
- The actual construction programme will depend on the detailed design and contractors. It may also depend on the actual achievable progress rates which may vary due to specific site conditions.

Base Case Scenario for QRA

8.2.7.7 Based on the envisaged construction programme and sequence of works as described in **Section 2**, the explosives are assumed to be transported every day.

8.2.7.8 The delivery frequency has been estimated on the basis that, 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 for a given delivery point.

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

8.2.7.10 For a yearly estimation, it is estimated there will be around 3600 transportations per year for both Siu Lam and Pillar Point Magazines. The details of transportation regarding these two magazines are summarised in the table below. The on-site transportation of explosives from Lam Tei Quarry Magazine site to different portals are not considered as the population within the influence zone are considered as on-site population which would not be considered in this assessment.

Table 8.7 Details of transportation from Siu Lam and Pillar Point Magazines

From	To	Volume (TNT eqv. kg)	Frequency (hrs)[1]	No. of transportation / year
Siu Lam	SKWLR West Portal (if not delivered from Pillar Point magazine)	80	18	487
	SKWLR East Portal (if not delivered from Pillar Point magazine)	80	18	487
	LTT South Portal (if not delivered from Pillar Point magazine)	90	23	381
	TLCT (North Section) West Portal	100	29	303
	TLCT (South Section) North Portal	130	29	303
	TLCT (South Section) South Portal	130	29	303
Pillar Point	SKWLR West Portal (if not delivered from Siu Lam magazine)	80	18	487
	SKWLR East Portal (if not delivered from Siu Lam magazine)	80	18	487
	LTT South Portal (if not delivered from Siu Lam magazine)	90	23	381

Note:

[1] Frequency is the time interval between two blasts.

Worst Case Scenario for QRA

8.2.7.11 This study also covers the worst case scenario that there is a possibility for the construction programme to be different from the envisaged one due to construction uncertainties or contractor’s method of working, which may increase the number of delivery trips and return trips. Therefore, based on approved EIA Study on Hong Kong Section of Guangzhou – Shenzhen – Hong Kong Express Rail Link (AEIAR-143/2009, XRL EIA), the QRA results for the base case scenario will be increased by 20% to represent the worst case scenario as the nature for transportation and storage of explosives in XRL EIA is similar to this Project.

8.2.7.12 In this Project, it is possible that the explosive load required for each delivery will be higher than that indicated in the designed construction programme due to particular site conditions and blasting requirements.

8.2.7.13 In this worst case scenario, explosives may also be delivered at peak day times. The worst case is therefore adopted in the QRA as a conservative approach.

Explosive Transportation Routes

8.2.7.14 Explosives and detonators will be transported separately but in convoy from the magazine to the designated access shafts/blasting sites by the contractors' licensed delivery vehicles under the escort of armed security guards.

8.2.7.15 To minimise the transport risk, the following principles have been adopted in planning transportation routes between the magazine site and the various construction sites:

- Routes have been planned to avoid areas of high population density and Potentially Hazardous Installations (PHIs) wherever possible;
- Explosive truck convoys for each work area will maintain, as far as possible, separation headway of around 10 minutes; and
- The quantity of Class 1 explosives on the roads has been minimised by using bulk emulsion and/or ANFO wherever possible, which will be manufactured on-site. The manufacture of ANFO and bulk emulsion will require the transportation of Class 5.1 oxidizing substances, which fall outside the scope of this QRA.

8.2.7.16 The initiating explosives will be delivered from the two magazines (i.e. Siu Lam and Pillar Point magazines) to the various work areas using the public roads, while the initiating explosives within Lam Tei Quarry Magazine will be transported by using the access road which is not a public road.

8.2.8 Review of Potentially Hazardous Installations in the Vicinity

8.2.8.1 According to the EIA Study Brief (ESB-352/2022), hazard assessment regarding the risk induced from the Project to Tai Lam Chung No.2 Chlorination Station (TLCCS) is required. Therefore, a review has been conducted to identify any Potentially Hazardous Installations (PHIs) that their Consultation Zones (CZs) would overlap with the Project alignment (approximately 20km long), above-ground structures and the associated temporary work sites and works areas.

8.2.8.2 TLCCS is located to the northwest of Tai Lam Correctional Institution. It has a 1km CZ and would overlap with the Project. The length of the R11 alignment within the CZ is only approximately 2.3km (the entire alignment is about 20km). According to the latest construction methodology (see **Section 2**), this part of the Project alignment within the CZ would be a tunnel section to be constructed by drill-and-blast method.

8.2.8.3 As TLCCS is currently classified as a PHI at the time of preparing this EIA, the Project Proponent has proactively approached WSD to collate the latest development plan of this PHI.

8.2.8.4 According to the latest information provided by WSD, the liquid chlorine store will no longer be required after Q2 of 2024 based on their latest programme. Therefore, it is anticipated that TLCCS will be ready to be de-listed from PHI Register in Q3 of 2024.

8.2.8.5 As discussed in **Section 2**, the construction of the Project would tentatively commence by 2026 and for target completion by 2033. Hence, TLCCS would already be delisted from the PHI Register by the time when the construction works commence.

8.2.8.6 As TLCCS would be delisted from the PHI Register prior to construction commencement of the Project elements within the CZ, a QRA will not be required. A close liaison would be maintained with WSD to update the programme of delisting from the PHI Register.

8.2.9 Review of Hazard to Life Impact Associated with the Construction of the Tsing Lung Bridge over the Ha Pang Fairway

8.2.9.1 As discussed in **Section 2**, the Tsing Lung Bridge section of the Project would take the form as a suspended bridge spanning across Ha Pang Fairway along which vessels of different types (e.g. DG vessels) would navigate. Any significant reduction in the width of Ha Pang Fairway would also reduce the navigable area on marine vessels and may have certain impacts on potential marine safety.

8.2.9.2 The design team of the Project has been very cautious in minimising the environmental impacts caused during both the construction and operational phases of the Project. As far as the potential impacts on marine traffic and the associated risk are concerned, the original reclamation at To Kau Wan in North Lantau has been totally avoided. Besides, the reclamation at Tsing Lung Tau has also been minimised to approximately about 2ha of land area, which would be used as the pier for Tsing Lung Bridge. The practicability of avoiding reclamation in Tsing Lung Tau totally has also been fully considered. However, as explained in **Section 2**, given the constraints from various circumstances, it is inevitable to have a relatively small reclamation at the southern coastline along Tsing Lung Tau. This small reclamation area would be used to accommodate the northern pier of Tsing Lung Bridge. While a small reclamation is required at Tsing Lung Tau, the design has also avoided any piers within Ha Pang Fairway. The construction methodology would also ensure that the deck segments of Tsing Lung Bridge would also be launched using proven technology that the bridge deck will be made of steel, segmental pre-fabricated off-site and transported to the site by barge for lifting and installation. It can therefore be seen that the design of the construction methodology has exercised the best practicable efforts to avoid and minimise the marine traffic impacts and hence the associated risk during the construction phase. On this basis, the risk associated with marine vessels during the construction phase is considered as insignificant and mitigation measures are not required.

8.2.9.3 During the operational phase, there would not be further reduction in the width of Ha Pang Fairway and the Project would not induce additional marine traffic. Hence, the Project would not induce any risk associated with marine traffic, and hence mitigation measures are not required in this aspect.

8.2.10 Concurrent Projects during Construction Phase

8.2.10.1 **Section 2** has identified the predicted concurrent projects. The following sections discuss the cumulative impacts from the concurrent projects.

<u>Tuen Mun Bypass (TMB)</u>

8.2.10.2 TMB would be constructed concurrently with the Project.

8.2.10.3 According to the latest design of TMB, tunnel blasting and magazine sites are required. Thus the cumulative risk from the use, overnight storage and transportation of explosive during the construction of TMB would need to be assessed.

8.2.10.4 Although the impact induced from use of explosives of TMB would not have much effect on this Project, shared use of the proposed explosive magazines and the transportation from these proposed explosive magazines to the blasting site would be overlapped, cumulative impact is still anticipated and would be assessed.

8.2.10.5 Moreover, even though two projects (TMB and Route 11) are two separate Designated Projects (DPs), they would be implemented by the same project proponent and there are synergy for the design of these two projects to minimize the environmental and risk impacts during their construction and operational phases as well as providing trainings and drills to the construction workforce for efficient evacuation as precautionary measures at any risk events.

<u>Proposed Lam Tei Underground Quarry</u>

8.2.10.6 Lam Tei Underground Quarrying (LTUQ) is still under design stage, and detailed information is yet to be confirmed during the preparation of this QRA.

8.2.10.7 In addition, LTUQ is a separate DP and the respective project proponent is still carrying out the design and the corresponding QRA. According to their latest implementation programme, the EIA study of Underground Quarrying at Lam Tei, Tuen Mun (LTUQ EIA) would be submitted after the EIA for both R11 and TMB. Hence, the QRA would consider the impact from this Project and TMB as its concurrent projects and include the cumulative impact according to their Study Brief (ESB-355/2022). The QRA study of LTUQ EIA would also follow the requirements and criteria set out in Annex 4 of the EIAO-TM to determine the acceptability.

8.2.10.8 Moreover, interface meetings between LTUQ, TMB and the Project have been and would continue to carry out to agree on the design interface of each project to minimise the impact of each project and the cumulative impact.

<u>Other Concurrent Projects</u>

8.2.10.9 Since there are no other concurrent, planned or committed projects leading to any other hazardous events, it is considered that there will be no potential cumulative impacts expected to arise during the Project cycle.

8.3 Hazard to Life Assessment Methodology

8.3.1 Study Approach

8.3.1.1 The assessment consisted of the following six main tasks:

a) **Data / Information Collection and Update**: relevant data / information essential for the hazard to life assessment were collected;

b) **Hazard Identification**: Identify hazardous scenarios associated with storage, transport and use of explosives;

c) **Frequency Estimation**: Estimate the frequencies of each hazardous event leading to fatalities with full justification by reviewing historical accident data and previous similar projects;

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

e) **Risk Assessment and Evaluation**: Evaluate the risks associated with the identified hazardous scenarios. The evaluated risks will be compared with the HKRG to determine their acceptability. Where necessary, risk mitigation measures will be identified and assessed to comply with the "as low as reasonable practicable (ALARP) principle used in the HKRG; and

f) **Identification of Mitigation Measures**: Review the recommended risk mitigation measures from previous studies, practicable and cost-effective risk mitigation measures will be identified and assessed as necessary. Risk outcomes of the mitigated case will then be reassessed to determine the level of risk reduction.

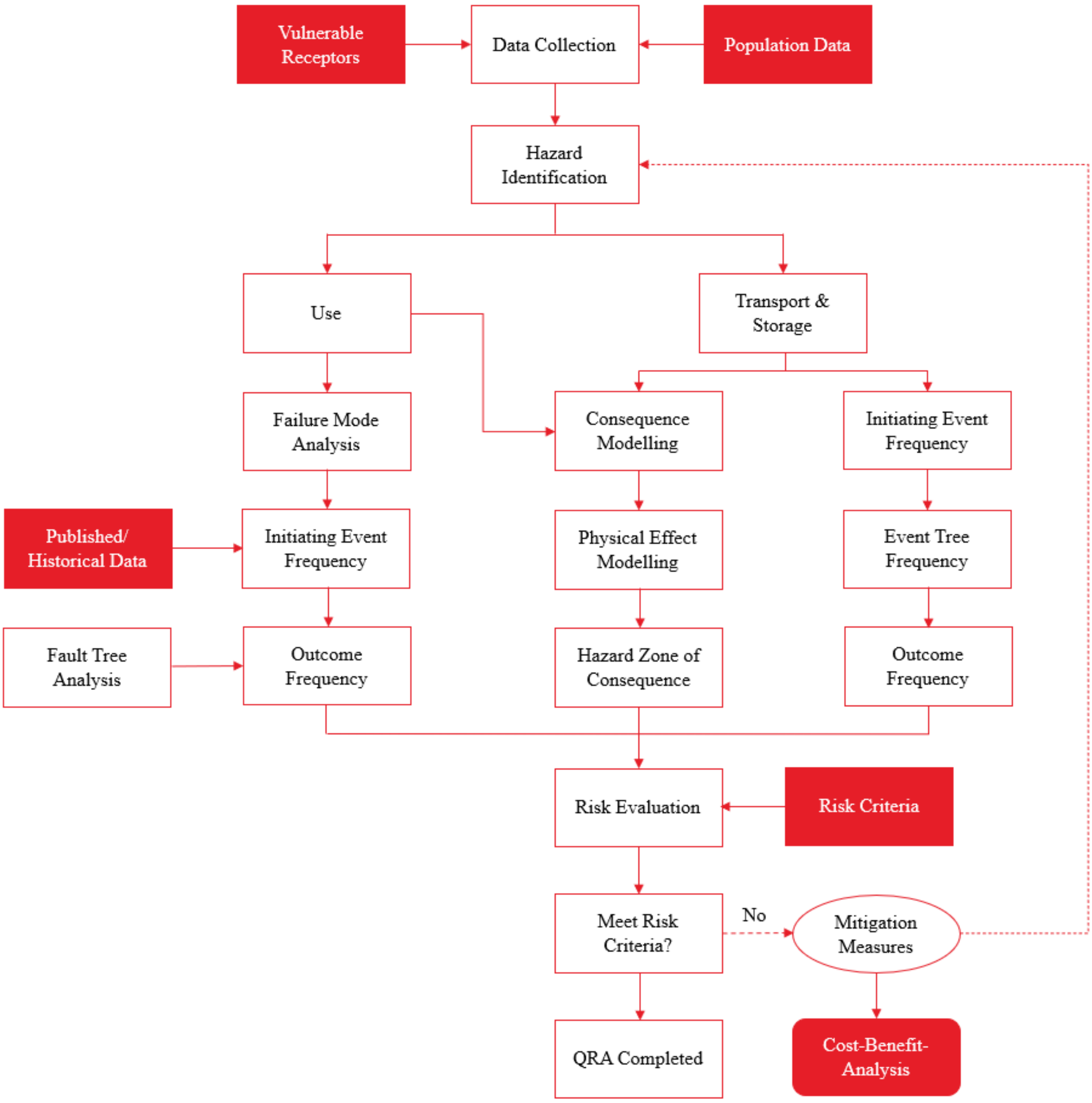

Diagram 8.5 Schematic Diagram of QRA Process

8.3.2 Domino Effects of High Pressure (HP) Town Gas Transmission Pipelines

8.3.2.1 The Hong Kong and China Gas Company (HKCG) operates and supplies town gas to the majority of Hong Kong households, and also to commercial and industrial customers. The major components for town gas are hydrogen, methane, carbon dioxide and a small amount of carbon monoxide. Majority of town gas is produced from Tai Po Production Plant and it is supplied through a network of high pressure (HP) underground town gas transmission pipelines to various districts of Hong Kong.

8.3.2.2 The HP underground town gas transmission pipelines start from Tai Lam Offtake and Pigging Station Tai Lam Chung River, pass through Castle Peak Road – New Tai Lam and Tuen Mun Road, then run along the Tai Lam Chung River. The transport route of explosives is in close vicinity of a section of the HP gas pipelines in Tai Lam Chung River. The shortest separation distance between the transport route of explosives and the pipelines is around 20m which falls within the 150m CZ of HP pipelines. Since the Project will not result in a significant increase in population, a QRA study regarding the potential risks associated with the HP pipeline is not required.

8.3.2.3 However, failure of explosives may be triggered by the thermal outcomes from town gas release when the explosives carrying vehicle hit the point of pipelines failure. This assessment will study the domino effects of the failure of HP underground town gas transmission pipelines affecting the failure of the transport of explosives.

8.3.2.4 The pipelines failure due to ground vibration and the subsequent release consequences are the major hazards for the HP underground town gas transmission pipelines. The failure of pipelines will be treated as secondary and/or tertiary hazards as discussed in **Section 8.6.4**.

8.4 Estimation of Population

8.4.1 Assessment Area

8.4.1.1 **Diagram 8.2** to **Diagram 8.4** have showed the locations of the proposed explosive magazine sites. Given that the maximum influence distance of the hazardous scenarios (see **Table 8.29**) is less than 70m, an assessment area comprising a 100m influence zone along the portals and openings, magazine sites and along the transportation routes is considered. This would introduce some conservatism into the assessment.

8.4.2 On-site population

8.4.2.1 On-site population refers to the construction workforce that would be deployed to the project work sites during the construction period. The construction workforce is regarded as voluntary risk taker. The Contractor would be required by the Project Proponent to conduct all necessary and relevant training sessions for the construction workforce and inform them for their understanding to the risk including loss of life during the construction. As far as risk is concerned, the construction workforce within the site would be provided with training and drills regarding the potential risk due to the use of explosive, and the associated safety measures/practices including but not limited to emergency excavation if necessary. Hence, the construction workforce for the Project is regarded as voluntary risk takers and hence is taken as on-site population in this QRA.

8.4.2.2 Similarly, as the Project Proponent of the Project would also be responsible for the construction of TMB. It is understood that the same set of training / drills would also be implemented by the contractor or TMB. Hence, the construction workforce of TMB is also considered as on-site population in this QRA.

8.4.2.3 As discussed in **Section 8.2.10**, LTUQ is a separate DP and the respective design / EIA are still being developed and finalized. Nevertheless, it is understood that the future operator of LTUQ would implement the best practices to optimize its environmental performance including those relating to risk. Where necessary, training and drills would also be provided to their workforce. Moreover, it is understood that the project proponents of the Project, TMB and LTUQ would continue the close liaison during the subsequent stages to ensure the cumulative risk is optimized as far as practicable.

8.4.2.4 Subject to the liaison of the three concurrent projects R11, TMB and LTUQ, a Hazard Management Plan would be formulated with a view to aligning the understanding of the risk of the three projects so that all the working populations at Lam Tei Quarry area, which includes the workforce induced under the construction and operational stage of three projects, could be considered as on-site populations in the QRA for all the three projects. The measures stipulated in the Hazard Management Plan may include, but not limited to, the adjustment of the blasting schedules of the three projects to minimize the potential cumulative impact, provision of common trainings and drills to the workforce of all the three projects, etc. The Hazard Management Plan, which would be agreed among the three projects, would be submitted to EPD for agreement prior to the tender invitation of construction phases of R11, TMB and LTUQ, whichever is earlier.

8.4.2.5 Hence, this QRA would consider the construction workforce and operator of LTUQ as on-site population as well.

8.4.3 Offsite Population

8.4.3.1 Four types of population are considered along the transportation routes and within the influence zone of the tunnel and surface blasting:

- Pedestrian population on footpaths and pavements next to the transportation routes;
- Road population;
- Railway population; and
- Building population.

Land and Building Population

8.4.3.2 Buildings within a 200m corridor (i.e.100m on both sides of transport route) and within the influence zone of tunnel and surface blasting were included in the assessment. Population in each building is analysed individually.

8.4.3.3 The population data including residential, industrial and transient population are updated based on the following information to determine the projected population for assessment.

- The Task Force Planning Dataset (TFPD) from the Task Force on the Review of Planning Data for Traffic Impact Assessment for Major Development Projects at Strategic Level;
- Census and Statistics Department's 2021 Population Census;
- Annual reports of relevant schools; and
- Traffic forecast for assessment year.

8.4.3.4 The TFPD has been adopted for the projection which is based on the base Year 2019.

8.4.3.5 The assessment year, i.e. Year 2033, is the year of maximum traffic flow within the construction period of the Project. According to TFPD, the population and growth rate of different Planning Data Zone (PDZ) for Tuen Mun District for residential and non-residential between the base year and Year 2033 is listed in **Table 8.8**. Considering that negative population growth and significantly large population growth due to new development planning is found in some Planning Data Zone of Tuen Mun, the population in Year 2033 are assumed to be the same as the base year.

Table 8.8 Population and Growth Rate of different Planning Data Zone for Tuen Mun District

Planning Data Zone	Resident Population Annual Growth Rate (%)	Non-Residential Population Annual Growth Rate (%)
158	0	0
159	0	0.7
160	0	0.6
161	5.0	0
166	0.2	0.7
258	0	0
360	0	0
438	0	0.7
439	2.0	0.4
441	0	0
157	0	0
156	0	0

Notes:

[1] The annual growth rates for Zone 157, 158, 258, 360 and 438 for residential are assumed to be 0 due to significantly large population growth.

[2] The annual growth rates for Zone 156, 159, 160 and 441 for residential population are assumed to be 0 due to negative population growth.

[3] The annual growth rates for Zone 258 and 438 for non-residential population are assumed to be 0 due to significantly large population growth.

[4] The annal growth rates for Zone 156, 157, 158, 161 and 441 are assumed to be 0 due to negative population growth.

<u>Road population</u>

8.4.3.6 The traffic density information used in this QRA is based on the traffic forecast. A population density approach was adopted for estimating the population within vehicles on the road. The occupants inside the vehicles were conservatively estimated as indoor population.

Flowing Traffic Population

8.4.3.7 The traffic density information used in this QRA was based on the latest 2021 Annual Traffic Census (ATC, 2021) and the information provided by the Traffic Consultant. Road population density was calculated using the following relations:

$$Population\ Density\ (persons/m^2) = AADT \times P/\ 1000\ /\ 24\ /\ V\ /\ W$$

Where	AADT	is The Annual Average Daily Traffic
	P	is the average number of persons per vehicle
	W	is the road width in meter, based on actual data
	V	is the vehicle speed in km/hr

Traffic Jam Condition

8.4.3.8 During the transportation of explosives, it is possible that the traffic flow might be disrupted when an explosion initiation occurs on the explosives carrying vehicle. If a traffic accident is severe enough to lead to a vehicle fire, a traffic jam could be developed before the fire spreads to the explosive load causing initiation. The road with traffic jam condition will have a higher population density in general when compared to free-flowing traffic because the separation distances between vehicles are reduced significantly.

8.4.3.9 The occupancies for each vehicle type and vehicle mix are taken from the Annual Traffic Census (ATC) for 2021. One core station (**Table 8.9**) is selected to represent the transport route from the magazine site to the construction site.

Table 8.9 Core Stations Considered

Core Station	Description
5012	Tuen Mun Road (From Sham Tseng to Tsing Long Highway – Ting Kau Bridge)

Railway Population

8.4.3.10 The railway population considered in this assessment included the on-train population of the Light Rail Transit (LRT). The railway population on the LRT was estimated based on the design capacity of a LRT vehicle in LC Paper No. CB(4)854/15-16(07) and the train frequency, the calculated railway population on the LRT was considered to be conservative and was adopted for all the assessment scenarios; while the railway population of the Project was estimate based on the average train loading and the train frequency during the peak hour.

8.4.3.11 The population along a railway segment was calculated using the following formula:

$$Railway\ Population = \frac{No.of\ person\ per\ train \times No.of\ trains\ per\ hour \times Length\ of\ Railway\ Segment}{Travelling\ Speed}$$

8.4.3.12 The population associated with the railway traffic was modelled as 100% indoor.

Pedestrian Population

8.4.3.13 Pedestrian flow on the pavement is assessed along the explosives transportation routes through site survey conducted in Dec 2022 and Jan 2023. The pedestrian density is estimated by the following equation:

$$Pavement\ population\ density\ (persons/m^2) = P\ /\ 1000\ /\ Q\ /\ W$$

Where P is the number of pedestrians passing a given point in one hour

W is the road width (m)

Q is the pedestrian speed (km/hr)

8.4.3.14 The assumption for pavement population density is attached in **Table 8.10** and the detailed assumption for each road is written in **Appendix 8.3**.

Table 8.10 Pavement Population Density

Area	Pavement Population Density (person/m^2)
Lung Fu Road	0.0042
Tuen Mun Town Center	0.0145
Gold Coast	0.0116
So Kwun Wat	0.0088
Tai Lam	0.0035

8.4.4 Time Periods and Occupancy

8.4.4.1 Four time-modes would been adopted to take into account the temporal changes in population within the assessment area. Detailed description and frequency per year for each time variation mode is presented in **Table 8.11**. The temporal population distribution makes referenced to XRL EIA as its assessment area is similar to the area of this Project which they were based on extensive surveys, AADT and site surveys. Moreover, the occupancy of buildings during each time period is based on extensive surveys conducted by ERM in 2006 which has also been adopted by other EIAs such as approved EIA study on Sha Tin Cavern Sewage Treatment Works (AEIAR – 202/2016, STC STW EIA) and EIA report for South Island Line (East) (AEIAR-155/2010, SIL EIA). Temporal population distribution of different time modes is shown in **Table 8.12**.

Table 8.11 Definition of Time Variation Mode

Time Variation Mode (TM)	Description	Period	Weighting per week	Frequency per year [1]
TM 1	Weekday Day	Monday to Friday (09:00 to 18:00)	45 hours	0.268
TM 2[2]	Peak Traffic Hours	Monday to Sunday (07:00 to 09:00 and 18:00 to 20:00)	28 hours	0.167
TM 3	Weekend Day	Saturday and Sunday (09:00 to 18:00)	18 hours	0.107
TM 4	Night	Monday to Sunday (20:00 to 07:00)	77 hours	0.458

Notes:

[1] The frequency per year for each time variation mode is calculated as follows:

For example TM1, assuming the week day represents a period from Monday to Friday (09:00 to 18:00), frequency per year = 45 / (24*7) = 0.268

[2] Excavation of a tunnel by drill-and-blast is a cyclic procedure and according to the latest blasting design, the cycle times for different work fronts are according to the frequency provided in **Table 8.7**.

Table 8.12 Temporal Population Distribution Factor

Type	Weekday Day	Peak Traffic Hour	Weekend Day	Night
Residential	20%	50%	80%	100%
Educational	100%	10%	55%	0%
Road traffic population	60%	100%	60%	15%
Temple	50%	10%	100%	0%
Recreational / Open Space	70%	10%	100%	10%
Office (Administration) / Commercial	100%	10%	100%	10%
Industry	100%	10%	55%	10%
Open Storage	100%	1%	51%	0%
Car Park	70%	100%	70%	10%
Government Station	100%	10%	55%	10%
Petrol Station	50%	100%	50%	1%
Railway	60%	100%	60%	15%
Fire Station	100%	100%	100%	100%
Pedestrian	100%	100%	100%	100%

Note:

[1] Reference from Approved EIA Study on Hong Kong Section of Guangzhou – Shenzhen – Hong Kong Express Rail Link (AEIAR-143/2009, XRL EIA).

8.4.5 Features Considered in this QRA

8.4.5.1 The following sets of features were considered as sensitive receivers in the Blast Assessment Report:

Man-made slopes and Retaining walls

8.4.5.2 These features include cut slopes, fill slopes, retaining walls and a combination of these. The slopes are covered with all types of facing, including shotcrete, chunam, stone facing and vegetation.

8.4.5.3 A number of man-made slopes have been identified near the blast faces as shown in **Appendix 8.4**. These features are considered in this assessment.

Natural Terrain Hillside and Boulders

8.4.5.4 The project site is surrounded by natural terrains, so natural terrain within 250m will be considered in this assessment.

Existing Buildings and Structures

8.4.5.5 All the buildings and structures within 250m from the Project site are considered in this QRA.

Utilities

8.4.5.6 There is a HP underground town gas transmission pipelines near Tai Lam Chung in the vicinity of this Project (see **Diagram 8.8**). As discussed in **Section 8.3.2**, the shortest separation distance between the transport route of explosives and the pipelines is around 20m. As the lager predicted PPV from the construction of this pipelines segment is 24 mm/s which is lower that the criterion of 25mm/s stated in Geoguide 4. Thus, impact on the pipeline is not considered in this QRA.

8.5 Hazard Identification

8.5.1 Overview

8.5.1.1 Hazard identification consists of a review of the following:

- Properties of the explosives;
- Scenarios presented in previous relevant studies;
- Historic accidents; and
- Discussion with explosives and blasting specialists.

8.5.2 Accidental Initiation due to Hazard Properties of Explosives

Explosive Types and their Properties

8.5.2.1 The physical properties for the explosives to be stored and transported in this project are shown in **Table 8.13**.

Table 8.13 Types and Properties of Explosives

Explosive Type	TNT equivalent	Melting Point (1 °C) @ 1 atm	Auti-ignition Point (1 °C) @ 1 atm	UN Hazard Division
Cartridged Emulsion	0.96	170	230 – 265	1.1D
PETN (provided for detonating cord)	1.4	135 – 145	190	1.1D
PETN (provided within detonators)	1.4	120	190	1.1B
Booster	1.1	70 – 75	-	1.1D

8.5.2.2 Explosives can be considered as 'initiated' when a self-sustaining exothermic reaction is induced. Initiated explosives can result in severe burning without progression to explode, a deflagration or a detonation. A deflagration may transit to detonation but the mechanism of transition of this phenomenon is still under research.

8.5.2.3 Deflagration-to-detonation transition is the general process by which a subsonic combustion wave becomes a supersonic combustion wave (Schultz, Wintenberger and Shepherd, 1999). The difference between detonation and deflagration is their travelling speed which detonation is a shock reaction where the flames travel at supersonic speeds while deflagrations are where the flames are travelling at subsonic speeds (Nolan, 2014).

8.5.2.4 However, either kind of the explosion can cause significant damage to surroundings which may lead to substantial fatalities and injuries. Therefore, it should be considered in the QRA.

8.5.2.5 When the explosives are stored in the temporary magazine site, its chance to be initiated accidentally is low as the surrounding environment of the storage as the storage environment is unlikely to experience extremes of heat, shock, impact or vibration with sufficient intensity to trigger a detonation.

8.5.2.6 Therefore, the most common situation of an accidental initiation is the introduction of fire. Other scenarios that may cause initiation include severe impact and friction.

8.5.2.7 Overall, the level of explosion should at least consider as deflagration due to casualty concerns. To cause a deflagration, the explosives should be, at least but not only, subject to a stimulus which could be:

- Local stimulus: to generate a ‘hot spot’ such as sparks, friction, impact and electrostatic discharge;
- Shock stimulus: due to shock or high velocity impact such as bullet impact and detonation of other explosives; or
- Thermal stimulus: mass heating leading to exothermic reaction (intense heat or fire).

8.5.2.8 However, for the types of explosives used in this Project, not all of these causes are necessarily leading to deflagration or detonation.

8.5.2.9 In this study, accidental initiation of explosives has been categorized as either fire or non-fire induced.

Hazard Properties of Emulsion Type Explosives

8.5.2.10 ANFO emulsion explosives contain Ammonium Nitrate (AN), which is a powerful oxidizing agent. Although initiation of emulsion based explosives would not be triggered due to friction or impact found in normal handling, it can be triggered from heat and confinement or severe shock from other explosion. The sensitivity of AN based explosives to deflagration or detonation is increased with the increase of temperature.

8.5.2.11 There are two broad categories of emulsions:

- Packaged emulsion (sensitized); and
- Bulk emulsion precursor (void-free liquid).

8.5.2.12 Cartridged emulsion are sensitized by either adding gassing solution or plastic microspheres to fulfil their intended function during manufacturing process, so that they can be transported under an sensitized state. Bulk emulsions are sensitized at the point of use of sites. Therefore, the difference of chemical properties between these two emulsions is mainly due to the presence of sensitizer.

8.5.2.13 Matrix or bulk emulsion (no voids) is not shock-sensitive because there is no known mechanism for the shock front to propagate. Moreover, a very high pressure is required to heat a void-free liquid.

8.5.2.14 In normal atmosphere conditions, a local stimulus generating ‘hot spots’ including sparks, friction, impact, static electricity extreme ambient temperature does not cause packaged emulsions (sensitized) to readily deflagrate in normal atmosphere conditions. An additional pressure in excess of 5 bars above atmospheric pressure is required in the “deflagrating mass” in order to generate a deflagration which may subsequently transit to a detonation.

8.5.2.15 The behaviour of packaged emulsion following a shock or thermal stimulus is discussed in the following sections.

8.5.3 Accidental Packed Emulsion Initiation by Fire

8.5.3.1 Pools of molten AN may be formed in a fire and may explode if they are contaminated with other materials such as copper particularly. AN may also melt and decompose in a fire with the release of toxic fumes which mainly contains oxides of nitrogen. When the temperature of AN reaches beyond 140°C (AECOM, 2014) or under molten state, its sensitivity to local stimuli increases.

8.5.3.2 Several tests have demonstrated that the explosives may ignite and burn, deflagrate and in some cases even detonate when they are subjected to fire engulfment. The time for an explosive to ignite is dependent to its physical characteristics and chemical composition.

8.5.3.3 Due to its high water content, cartridged emulsions are often considered less sensitive to fire engulfment via initiation. On the other hand, the water content of cartridged emulsions will be evaporated when disclosed to heat or fire. If the cartridged emulsions are exposed to heat or fire with high enough energy levels for a long duration and the confinement pressure increases, it may lead to initiation of cartridged emulsions.

8.5.3.4 When there is fire surrounding the explosive load, the temperature of any reactive media will clearly be raised and cause evaporation of components such as water. The rate of temperature increases and evaporation depends on the design of the cargo container wall and the fire extent. The outer wall of the cargo container would have direct contact with the flame and heat will be transferred to the explosive load in the course of time.

8.5.3.5 It is considered that emulsions are harder to be initiated than ANFO as its water content is higher than ANFO, so longer time is required as the water inside emulsions needed to be evaporated first before triggering the initiation of it.

8.5.3.6 The consequences of an accidental explosion due to thermal stimulus could be a thermal explosion (cook-off) or detonation or some combination of the two.

8.5.4 Accidental Packaged Emulsion Initiation by Means Other than Fire

8.5.4.1 Non-fire initiation mechanisms are separated into two common distinct groups: mechanical and electrical groups. Mechanical group included both shock and friction initiation and it is difficult to distinguish them in most accidental situations. It has been stated in approved EIA report for West Island Line (AEIAR-126/2008, WIL EIA) and SIL EIA that some non-emulsion explosives can be initiated mechanically at an impact velocity as low as 15m/s with the absence of piercing. If the explosives are pierced, the required velocity will probably be far less than 15m/s due to localized heat generation subjected to frictional rubbing between layers of explosives, and it is known as 'stab-initiation'.

8.5.4.2 On the other hand, cartridged emulsion is insensitive to initiation via impact which is demonstrated from the bullet impact test from a high velocity projectile. Initiation will occur if the ignition energy level is above its minimum level. The minimum ignition energy levels range between 0.015J and 1.26J in general.

8.5.4.3 The required ignition energy level for the vast majority of explosives, including cartridged emulsions is far exceeded by contact with mains electricity. Comparing the energy levels possible from batteries or alternators fitted to motor vehicles, or that due to static build-up on clothing with the required energy level to initiate most commercial explosives, it is typically much less than that required. Therefore, only very sensitive explosives are likely to ignite from these electrical energy sources. As a result, electrical energy is not a possible energy source for the types of explosives intended to be used in this project.

8.5.4.4 Possible causes of degradation of cartridged emulsion may be water loss and prolonged temperature cycling above and below 34°C. These causes would lead to potential caking or a change in ammonium nitrate crystalline state and increase in volume, but neither potential caking nor increase in volume would become the cause of detonation by means other than fire.

8.5.5 Hazard Properties of Detonating Devices

8.5.5.1 Detonating devices may be triggered and explode when exposed to heat or flame, or with friction, impact, heat, low-level electrical current or electrostatic energy. Detonation produces shrapnel, while hazardous gases or vapours produced in fire include lead fumes, nitrogen oxides and carbon monoxide and the type of gases produced depend on the material used in the detonators.

8.5.5.2 PETN is the main explosive component contained in detonating devices including detonating cord and detonators. Detonators also contain a primary explosive such as lead azide substance which is very sensitive to initiation.

8.5.5.3 The sensitivities of PETN inside the detonating cord is similar to that of NG based explosives but generally more sensitive than emulsions.

8.5.5.4 PETN has the potential to deflagrate at ambient pressure following a local stimulus. Local initiation can lead to deflagration under ambient pressure or higher and may lead to detonation afterwards. It has a comparatively small failure diameter for detonation as an explosive, i.e. having the smallest physical size of a cylindrical charge of high explosive which sustains a high order steady-state detonation.

8.5.5.5 By comparing PETN with emulsions, PETN can be initiated by shock instantly but at the same time, its shock sensitivity is lower than that of NG based explosives. The detonation of PETN requires at least 10 times the energy level used for NG based explosives based on the results of the bullet impact test.

8.5.6 Accidental Initiation Associated with Storage at Magazine

8.5.6.1 The possible means of accidental initiation of the explosives by fire for the proposed magazine are as follows:

- Inadequately controlled maintenance work (e.g. hot work);
- Poor housekeeping (e.g. ignition of combustible waste from smoking materials);
- Inappropriate methods of work;
- Electrical fault within the store, which ignites surrounding combustible material resulting in a fire; or
- Arson.

8.5.6.2 The possible means of accidental initiation of the explosives by means other than fire for the proposed magazine include the followings:

- Dropping of explosives during handling (for the detonators only); or
- Crushing of explosives under the wheels of vehicles during loading or offloading (for detonators and detonating cord only).

8.5.6.3 The detonators supplied are packaged within plastic separating strips, so that the initiation of a single detonator will not propagate to the adjacent detonator. The detonators Packaged in this manner are classified as Class 1.1B explosives and its total mass is negligible in terms of explosive mass.

8.5.7 Accidental Initiation Associated with Transportation from Magazine

8.5.7.1 The cartridged emulsion and detonating cord will be transported together within the same truck in the same compartment.

8.5.7.2 Since the vehicle cargo is designed based on the guidance note mentioned in **Section 8.2.5**, it is designed to minimize all sources for local stimulus, only a significant crash impact or a fire will cause a concern to the explosives. According to a study reported by the Advisory Committee on Dangerous Substances (1995), a low traffic speed is not likely to cause a concern to the explosives.

8.5.7.3 However, low speed traffic accident but with a low probability is considered possible in this assessment due to conservative approach. Based on the review with explosives professionals and bullet tests, the impact energy required to detonate PETN or emulsion based explosives is one order of magnitude higher than NG. As NG was considered as the basis for determining the probability of initiation under impact conditions in previous studies (assessed at 0.001), its probability can be reduced by one order of magnitude based on the impact energy consideration (AECOM, 2014).

8.5.7.4 The major leading causes for response of the explosives to an accidental fire are time (typically 5 to 10 minutes) and possibility to full fire development on the vehicle and the amount of heat transferred to the loads. For the case of emulsion explosion and based on the accident statistics, at least another 30 minutes are required for the explosives to reach critical conditions. This duration may be significantly reduced for the case of mixed loads of cartridged emulsions and detonating cords but exact time cannot be predicted based on the transport accident data for detonating cord (ERM, 2009).

8.5.7.5 The approach of explosives used in this project as transported was considered to be similar to the XRL Study. In the XRL Study, a review was conducted on the explosive properties with assistance from specialists in the explosives industry. The main findings for emulsion based explosives are as follows.

8.5.7.6 “The radical change in explosive properties at higher temperatures compared to the original emulsion must be taken into account. At high temperatures (i.e. higher than melting point), emulsion explosives would lose water content which may result in a refined explosive (small droplet/ crystal size AN). This could lead to a thermal explosion, deflagration or detonation and the probability of 0.1 may not therefore be applicable to emulsion. Also, some limited accident statistics have some bearing on this hazard scenario: these accidents may include a combination of both thermal and mechanical stimuli, which would likely have resulted in explosion or detonation. The consensus was that the probability of an explosion for the case of an emulsion was less than 0.5 but further refinement of this upper estimate would require additional data and more detailed analysis." (ERM, 2009).

8.5.8 Incident Review

8.5.8.1 Reported safety incidents involving explosives for commercial and industrial applications have been reviewed in the following sections. The incident records are extracted from the UK Health and Safety Executive (UK HSE)'s Explosives Incidents Database Advisory Service (EIDAS), US Mine Safety and Health Administration (MHSA), Western Australia's Department of Consumer and Employment Protection (DOCEP) and Hong Kong SAR Government's Annual Controlling Officers Report.

8.5.8.2 To highlight the causative factors to the incidents, they were sorted into two main categories which are listed below:

- Incidents involving storage of explosives; and
- Explosive transport incidents.

<u>Explosive Storage Incidents</u>

8.5.8.3 According to a UK study written by Merrifield (1998), 79 major incidents associated with explosives manufacture and storage were identified from 1950 to 1997. A total of 16 major incidents were related to storage of explosives.

8.5.8.4 13 of them were due to the storage of gunpowder, ammunition, nitroglycerine and fireworks. One of the incidents was related to the storage of detonators and was caused by the corrosion of detonators, and the remaining two incidents were because of the storage of blasting explosives. Malicious activity is one of the reasons causing these incidents which involve blasting explosives.

8.5.8.5 From the above study, it can be seen that the protection of explosives from malicious human activity and the elimination of possible ignition sources are crucial for maintaining storage facilities.

8.5.8.6 Some identified initiating causes of accidents in storage facilities are listed below:

- Impact;
- Friction;
- Overheating;
- Electrical effects (lightning/static discharges);
- Sparks;
- Spontaneous reactions; and
- Malicious action/mishandling.

8.5.8.7 To avoid incidents happening in the storage area, the only actions we can do are maintaining good housekeeping practice, eliminating potential ignition sources and putting explosives into safe and secure storage space.

8.5.8.8 However, not all of these causes are applicable to the types of explosives used in this Project. These are further discussed in **Section 8.6**.

Explosive Transport Incidents

8.5.8.9 In Hong Kong, transport related incident records on vehicles carrying explosives have not been found. However, a minor incident happened at Queens Road West which involved a Mines Division truck in September 2010. Fortuitously, the crash impact was not significant, so that the integrity of the explosives was not affected.

8.5.8.10 The incident records from CEDD website and different news platform in Hong Kong have been reviewed up to Year 2022 and there were no incident records related to road transport of explosives.

8.5.8.11 The EIDAS database obtained most of the worldwide incidents related to the transport of commercial explosives reported from 1950 to 2017.

8.5.8.12 It has identified a transport incident related to emulsion in which a tyre fire on a truck has spread to the explosive load and detonated, producing a massive hole. This incident did not cause any fatality as the truck crew had time to leave the truck and maintain a safe distance before the tyre fire reached the emulsion load and exploded.

8.5.8.13 There were also some incidents involving mixed cargoes of emulsion or watergel carried with other types of explosives. The EIDAS database also found out 2 fire incidents associating explosives carrying vehicles in Australia in 1998 and 2007 respectively and all of these incidents did not cause any injuries or fatalities.

Explosive Usage Incidents

8.5.8.14 The incidents from 2000 to 2017 obtained from the EIDAS database has also been reviewed and there were 3 incidents caused by the use of explosives. The first incident took place in India in 2007 which a worker was injured when the electric detonators he was carrying exploded and the worker had been contracted to blast rocks. The second incident happened in 2008 which an explosion occurred in Russia during the pneumatic loading of an ANFO into underground holes. This incident caused 13 fatalities and 5 injuries. The other incident occurred in 2012 and it caused 1 fatality due to an explosion occurred in the powder feeder of the shock tube extrusion line which has communicated back to the magazine and detonated a few seconds later.

8.5.8.15 From 2013 to 2022, the total number of blasts in Hong Kong is 23,388 blasts which included both underground and surface blasts. During this period, there was only 1 flyrock incident (i.e. incidents involving the ejection of rock fragments beyond the site boundary) occurred. During the blasting, a rock fragment was suspected and threw from blast area. It travelled approximately 20m and landed on the backyard of a workshop. The cause of flyrock flew over the 6-metre rock fence was due to high vibration force generated during the blasting. No injuries, fatalities or damage to the surrounding property were recorded in this flyrock incident.

8.5.9 Scenarios for Hazard Assessment

8.5.9.1 The following hazardous scenario are identified for the hazard assessment.

Explosives Magazines

8.5.9.2 A magazine site typically contains more than one explosive stores. For instance, Siu Lam Magazine and Pillar Point Magazine will both have 4 stores while Lam

Tei Quarry Magazine site has 11 niches. Within each store or niches, explosives and detonators are stored in separate compartments. The stores are designed with separation and enclosed walls so that initiation of the contents of one store will not affect other stores.

8.5.9.3 Therefore, the possible hazardous scenarios with the storage of explosives would be the detonation of the full contents of one store. The following scenarios are considered in this assessment:

- Detonation of a full load of explosives on a delivery truck within the magazines access road; and
- Detonation of the full quantity of explosives within a store.

8.5.9.4 The above scenarios are adopted to all the proposed magazine sites.

8.5.9.5 The explosives transport within the magazine sites has conservatively considered the maximum load and the maximum delivery frequency throughout the Project as a simplification.

8.5.9.6 The explosives loads considered are listed in **Table 8.14**.

Table 8.14 Explosives Storage Quantities

Magazine	Mass of explosives per site (TNT eqv. kg) [1,2]	No. of stores	TNT equivalent per store (kg)
Siu Lam	1200	4	300
Pillar Point	1400	4	350
Lam Tei Quarry	1000	11	100[5]

Notes:
[1] Assumed 40% detonating cord and 60% cartridged emulsion based on a typical pull length.
[2] Detonating cord are made of PETN.
[3] Each detonator contains about 0.9g PETN.
[4] 1kg of cartridged emulsion equals 0.96kg of TNT, and 1kg of PETN equals 1.4kg of TNT.
[5] A minimum of 1 niche will be used for the storage of detonators.

Transport of Explosives

8.5.9.7 The hazardous scenario considered for transport of explosives is accidents involving explosives delivered and transferred from magazine to each delivery point, i.e. the gate of each work site, which cause the detonation of a full load of explosives on an explosives carrying vehicle. Delivery within the work site is classified as on-site transportation and included in use of explosive.

8.5.9.8 Explosion of the detonator load during transport is not quantified for the following reasons:

- They are transported on a separated truck within the same convey; and
- The detonator packages are classified as HD 1.4B[3] or HD 1.4S[4] (articles which present no significant hazard outside their package). This packaging

[3] HD1.4B – Division 1.4: any substance or article which presents no significant hazard. This Division comprises substances and articles which present only a small hazard in the event of ignition or initiation during transport.; Compatibility Group B: Article containing a primary explosive substance and not containing two or more

can limit the consequences potentially leading to fatalities remain within the explosive truck boundaries. The UK CFRA has estimated the consequences for small quantities of explosives in workrooms. For a detonator load of less than 200g per trip to be transported in XRL, an accidental explosion will lead to approximately 1% chance of eardrum rupture at a distance of 3.5 metres; approximately 50% chance of eardrum rupture at 1.5 metres. If a person is very close to the explosion such as holding the explosives, he would have a high probability to be killed (CFRA, 2008).

Scenarios Considered in the Assessment

8.5.9.9 The assessed scenarios are summarized in the following table:

Table 8.15 Scenarios Considered in this Assessment

Tag	Scenario	Explosives load (TNT eqv. kg)	No. of trips per year	Remarks
Storage of Explosives				
01	Detonation of full load of explosives in one store in Siu Lam Magazine Site	300	-	Total of 4 stores
02	Detonation of full load of explosives in one store in Pillar Point Magazine Site	350	-	Total of 4 stores
15	Detonation of full load of explosives in one niche in Lam Tei Quarry Magazine Site	90	-	Total of 11 niches
Transport of Explosives (this Project)				
03	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of LTT South Portal	90	381	-
04	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TLCT North Portal	130	303	-
05	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TLCT South Portal	130	303	-
06	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of SKWLR East Portal	80	487	-
07	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of SKWLR West Portal	80	487	-
08	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TLCTN	100	303	-

effective protective features. Some articles, such as detonators for blasting, detonator assemblies for blasting and primers, and cap-type, are included event thought they do not contain primary explosives.

[4] Compatibility Group S: Substance or article so packaged or designed that any hazardous effects arising from accidental functioning are confined within the S1DG package unless the package has been degraded by fire, in which case all blast or projection effects 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.

Tag	Scenario	Explosives load (TNT eqv. kg)	No. of trips per year	Remarks
09	Detonation of full load of explosives in one contractor truck on public roads – from Pillar Point magazine site to delivery point of SKWLR East Portal	80	487	-
10	Detonation of full load of explosives in one contractor truck on public roads – from Pillar Point magazine site to delivery point of SKWLR West Portal	80	487	-
11	Detonation of full load of explosives in one contractor truck on public roads – from Pillar Point magazine site to delivery point of LTT South Portal	90	381	-
Transport of Explosives (from Tuen Mun Bypass)				
T03	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TMB Northern Tunnel South Portal	80	487	-
T04	Detonation of full load of explosives in one contractor truck on public roads – from Pillar Point magazine site to delivery point of TMB Northern Tunnel South Portal	80	487	-

8.5.9.10 The transport of explosives from Lam Tei Quarry Magazine Site is not considered as the transportation route is within the project boundary which the population is considered as on-site population. The on-site transportation of explosives from Lam Tei Magazine Site to blast face is considered as on-site transportation under use of explosives. The aboveground transportation route is shown in the **Diagram 8.6** below.

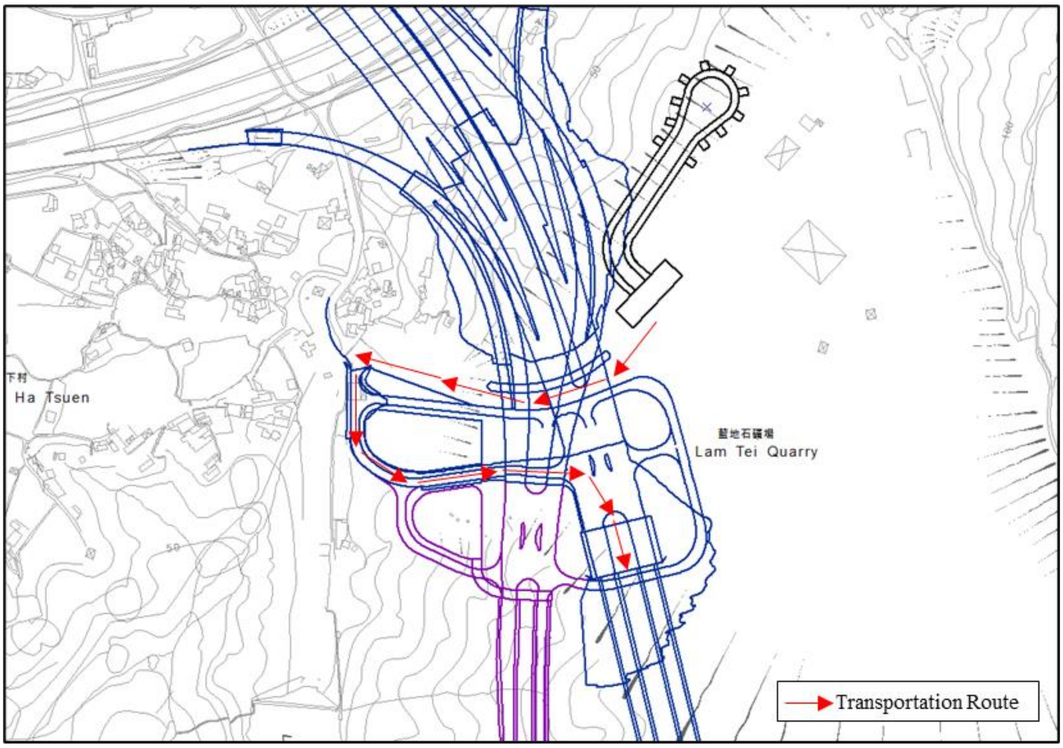

Diagram 8.6 On-site Transportation Route from Lam Tei Quarry Magazine Site to Lam Tei Tunnel North Portal

Use of Explosives

8.5.9.11 Possible hazardous scenarios regarding the use of explosives are:

- Higher vibration generated by the blast face due to human errors and other reasons such as manufacturing defects causing deviation from the confirmed design;
- Higher vibration and air overpressure due to the detonation of a full load of explosives in one contractor truck from the delivery point to the tunnel portal at on-site transportation within the site boundary;
- Higher vibration due to detonation of a full load of explosives in one contractor truck from the tunnel portal to blast face at on-site transportation within site boundary; and
- Higher vibration, air overpressure and flyrocks associated with the use of explosives for surface blasting.

Hazards from the Blasting Process

8.5.9.12 The permitted vibration level of the sensitive receivers will determine the design of the blast face and is expected not to cause any damage to the sensitive receivers. However, vibration higher than expected may be induced by potential hazards arising in the event of deviations from the confirmed design occurring.

8.5.9.13 The relevant failure scenarios at the blast face which may lead to higher than expected ground vibration includes the manufacture of detonators and surface connectors, design of the blast, installation of detonators and surface connectors and loading of explosives. The details are presented in **Appendix 8.5**.

Hazards from Transport of Explosives to Blast Faces

8.5.9.14 For tunnel and adit blasting, cartridged emulsions, detonators and detonating cords are transported onsite from the delivery point, i.e. the gate of each work site, to the portal and then to the blast faces through the access tunnel by a licensed (contractor operated) diesel vehicle.

8.5.9.15 For surface blasting, cartidged emulsions, detonators and detonating cords are transported on-site from the delivery point to the blast benches by a licensed (contractor operated) diesel vehicle.

Ground Vibration Associated with the Use of Explosives

8.5.9.16 Ground vibration is a potential hazard if the stress wave intensity is high enough to induce a high level vibration during rock excavation. Peak particle velocity (PPV) will be used as an indicator of damage to structures and it is assumed that reinforced concrete structures in good condition can encounter a PPV of 50mm/s without any risk of damage. Nonetheless, the PPV can be amplified by the peak ground motion and the PPV experienced by the structure. Hence, a PPV of the ground motion of 25mm/s is widely used to prevent damage to buildings.

8.5.9.17 Ground vibrations induced by this stress wave have a peak velocity that is related to the instantaneous charge weight (MIC) and the distance from the blast source. **Diagram 8.7** presents the typical range of charge weights and predicted vibration levels using the MD vibration constants.

8.5.9.18 It is considered that structures in vicinity to the blasting site are unlikely to be subjected to PPV levels greater than 100mm/s or 229mm/s for structural damage and object falling (see **Section 8.7.3**) for normal blasting operations.

		Chargeweight per delay (MIC) (kg)													
		60	50	40	30	20	10	8	6	5	4	2	1	0.5	0.25
		Predicted PPV (mm/s)													
Radial Distance from Blast (m)	160	16.02	14.33	12.51	10.49	8.19	5.37	4.69	3.93	3.52	3.07	2.01	1.32	0.86	0.57
	140	18.85	16.86	14.72	12.35	9.64	6.32	5.51	4.63	4.14	3.61	2.37	1.55	1.02	0.67
	120	22.75	20.35	17.76	14.90	11.64	7.63	6.66	5.58	5.00	4.36	2.86	1.87	1.23	0.80
	100	28.42	25.42	22.19	18.62	14.54	9.53	8.31	6.98	6.24	5.45	3.57	2.34	1.53	1.00
	90	32.31	28.91	25.23	21.17	16.53	10.83	9.45	7.93	7.10	6.19	4.06	2.66	1.74	1.14
	80	37.31	33.38	29.13	24.44	19.09	12.51	10.91	9.16	8.19	7.15	4.69	3.07	2.01	1.32
	70	43.91	39.29	34.29	28.77	22.46	14.72	12.85	10.78	9.64	8.42	5.51	3.61	2.37	1.55
	60	52.99	47.41	41.38	34.72	27.11	17.76	15.50	13.01	11.64	10.16	6.66	4.36	2.86	1.87
	50	66.19	59.23	51.69	43.37	33.87	22.19	19.37	16.25	14.54	12.69	8.31	5.45	3.57	2.34
	40	86.91	77.76	67.86	56.94	44.46	29.13	25.42	21.33	19.09	16.66	10.91	7.15	4.69	3.07
	30	123.44	110.45	96.40	80.88	63.16	41.38	36.11	30.30	27.11	23.66	15.50	10.16	6.66	4.36
	20	202.44	181.13	158.08	132.64	103.58	67.86	59.23	49.69	44.46	38.80	25.42	16.66	10.91	7.15

Green	5mm/s
Yellow	13mm/s
Orange	25mm/s
Red	>25mm/s

Diagram 8.7 Charge Weight per Delay (MIC) verses Distance per Blast

8.5.9.19 There can be different levels of damage considered for structures based upon previous records for ground vibrations and ground frequencies which has been identified by Geoguide 4.

8.5.9.20 It identifies that blast ground vibration acceptance criteria depends on the type of structure, technical installations and occupancy, as well as the dominant frequency of the vibration. Blast ground vibrations normally have a frequency of 20 to 200 Hz which exceeds the natural frequency of most buildings. The dominant frequency depends on the medium transmitting the vibrations and can be some 40 Hz for soil, 40 to 70 Hz for sift or broken rock and 100 to 200 Hz for hard rock (Tamrock, 1989).

8.5.9.21 The natural frequency of tall buildings estimated can be expressed as the following equation:

$$Natural\ Building\ Frequency = 46/Height\ of\ the\ building\ (m)$$

8.5.9.22 If the ground motion frequency is similar to natural building frequency, it may lead to a larger motion of the building but this usually occurs when low frequency ground motion occurs over a long period of time (i.e. earthquakes last for 30 seconds to minutes) rather than the usual 4 to 9 seconds for a tunnel blast.

Flyrocks due to Blasting

8.5.9.23 As one of the major hazards from poorly managed and controlled blasting operations is flyrock while some of the blast locations are in close proximity of the pedestrians, roads and supporting plants of LTUQ, the consequence of flyrock is considered separately. Flyrock is defined by the Institute of Makers of Explosives as a rock that has been propelled by the blast area (which is determined by the blaster) by the force of an explosion. Flyrock is caused by a mismatch of the distribution of explosive energy, type of confinement of the explosive charge, and the mechanical strength of the rock. It is recorded that injuries from flyrock and lack of security in the blast area in the US accounted for more than two-third of all injuries recorded in surface mining over period 1978 to 2002.

8.5.9.24 There are many reasons that can lead to flyrock and a summary of the key factors affecting past flyrock accidents is summarised in **Table 8.16**.

Table 8.16 Factors leading to Flyrock Accidents based on the historical data

Factors to cause flyrock accidents	Description
Poor Design of Blasting Parameters	Blasting Overload Unreasonable Burden Too Short Stemming Improper Delay Time
Operation Negligence	Inaccurate Drilling Poor Stemming Quality Wrong Firing Sequence
Unknowable Natural Conditions	Lack of knowledge and accurate technology to identify and recognize the specific anomaly or weakness in the rock structure, which can lead to subsequent flyrock problem.

8.5.9.25 From Year 2013 to Year 2022, there were 23,388 blasts completed in Hong Kong, including 20,340 underground blasts and 3,048 surface blasts. During this period, there was one flyrock incident reported as discussed in **Section 8.5.8.15**. The probability of a blast-induced flyrock failure is 3.28E-04 per blast (i.e. 1/3,048).

Scenarios Considered in the Assessment

8.5.9.26 The assessed scenarios are summarized in the following table:

Table 8.17 Scenarios Considered in this Assessment

Tag	Scenario	Explosives load (TNT eqv. Kg)	No. of trips per year
Surface Blasting			
SU01	Higher vibration, air overpressure due to 2 to 6 MIC and flyrocks due to 1 to 6 MIC detonated at the same time during surface blasting of Site 1: LTQ main cut slopes for approach viaducts (within R11 project boundary)	20 – 60	-
SU02	Higher vibration, air overpressure and flyrocks due to 2 to 6 MIC detonated and flyrocks due to 1 to 6 MIC at the same time during surface blasting of Site 2: LTT North Portal (within both TMB and R11 project boundary)	20 – 60	-
SU03	Higher vibration, air overpressure and flyrocks due to 2 to 6 MIC and flyrocks due to 1 to 6 MIC detonated at the same time during surface blasting of Site 3: The site formation at the northern landfall of the TLB including the Bridge anchorage (within R11 project boundary)	20 – 60	-
SU04	Higher vibration, air overpressure and flyrocks due to 2 to 6 MIC and flyrocks due to 1 to 6 MIC detonated at the same time during surface blasting of Site 4: North Lantau cutting (including the bridge anchorage and site formation) (within R11 project boundary)	20 – 60	-
Tunnel Blasting			
TU01	Higher Vibration due to 2 to 6 MIC detonated at the same time during tunnel blasting of LTT North Portal	20 – 60	-

Tag	Scenario	Explosives load (TNT eqv. Kg)	No. of trips per year
TU02	Higher Vibration due to 2 to 6 MIC detonated at the same time during tunnel blasting of LTT South Portal	20 – 60	-
TU03	Higher Vibration due to 2 to 6 MIC detonated at the same time during tunnel blasting of TLCT North Portal	20 – 60	-
TU04	Higher Vibration due to 2 to 6 MIC detonated at the same time during tunnel blasting of TLCT South Portal	20 – 60	-
TU05	Higher Vibration due to 2 to 6 MIC detonated at the same time during tunnel blasting of SKWLR East Portal	20 – 60	-
TU06	Higher Vibration due to 2 to 6 MIC detonated at the same time during tunnel blasting of SKWLR West Portal	20 – 60	-
TU07	Higher Vibration due to 2 to 6 MIC detonated at the same time during tunnel blasting of TLCTN	20 – 60	-
On-site Transportation			
TO01	Detonation of full load of explosives in one contractor truck during on-site transportation – from Siu Lam magazine site to delivery point of LTT South Portal	90	381
TO02	Detonation of full load of explosives in one contractor truck during on-site transportation – from Siu Lam magazine site to delivery point of TLCT North Portal	130	303
TO03	Detonation of full load of explosives in one contractor truck during on-site transportation – from Siu Lam magazine site to delivery point of TLCT South Portal	130	303
TO04	Detonation of full load of explosives in one contractor truck during on-site transportation – from Siu Lam magazine site to delivery point of SKWLR East Portal	80	487
TO05	Detonation of full load of explosives in one contractor truck during on-site transportation – from Siu Lam magazine site to delivery point of SKWLR West Portal	80	487
TO06	Detonation of full load of explosives in one contractor truck during on-site transportation – from Siu Lam magazine site to delivery point of TLCTN	100	303
TO07	Detonation of full load of explosives in one contractor truck during on-site transportation – from Pillar Point magazine site to delivery point of SKWLR East Portal	80	487
TO08	Detonation of full load of explosives in one contractor truck during on-site transportation – from Pillar Point magazine site to delivery point of SKWLR West Portal	80	487
TO09	Detonation of full load of explosives in one contractor truck during on-site transportation – from Pillar Point magazine site to delivery point of LTT South Portal	90	381

8.6 Frequency Analysis

8.6.1 Overnight Storage of Explosives

8.6.1.1 A generic failure frequency of $1e^{-4}$ /year has been adopted for the QRA. This frequency has also been used in SIL EIA, XRL EIA and Shatin to Central Link – Tai Wai to Hung Hom Section (AEIAR-167/2012, SCL (TAW-HUH) EIA). Apart from the generic failure, external accidents that caused outside the magazine site but would also induce hazard accidents including the following:

- Explosion during manual transfer from store to contractor's collection truck;
- Lightning;
- Aircraft crashing;
- Hill fire;
- Earthquake; and
- Escalation (explosion of one magazine storeroom triggers another).

Explosion During Manual Transfer from Overnight Storage to Contractor's Collection Truck

8.6.1.2 Transfer of explosives from magazine site to contractor's collection truck would be carried out by hand and no tools would be involved. Thus there is no significant cause of explosives mishandling specific to the project magazine site as compared to international practice and assumed to be covered in the generic failure frequency.

Lightning

8.6.1.3 Design of facilities should provide protection within lightning conductors to safeguard the facilities from direct lightning strikes with the grounding to be inspected regularly. Lightning protection installations should follow the standards IEC 62305, BS EN 62305, AS/NZS 1768, NFPA 780 or equivalent standards. Therefore, the potential of lightning strike to cause damage and lead to failure event would be unlikely. Failures due to lightning strikes are taken to be covered in the generic failure frequency.

Aircrafts Crashing

8.6.1.4 Aircrafts crashing due to airway accidents from arrival/departure flight paths would be taken into account. The same method is also adopted in STC STW EIA. Since the calculated failure rates are much smaller than an order of 10E-9, failure caused by aircraft crash is not further considered in the assessment.

Hill Fire

8.6.1.5 In autumn and winter when the humidity is low and rainfall is scarce, vegetation in the countryside becomes dry and hill fires often occurs in these seasons which may potentially affect the proposed magazine. There are about 0.78% of vegetation areas affected by fire each year between 2017 to 2018 and 2020 to 2021, or equivalently, the frequency of a hill fire affecting a specific site is 0.0078/ year. Information of hill fire are listed below.

Table 8.18 Hill Fire Data for Hong Kong

Year	Area Affected (Ha)	% of Total Country Park Affected
2017-2018	106	0.24%
2018-2019	197	0.44%
2019-2020	425	0.96%
2020-2021	660	1.49%

8.6.1.6 However, considering that the explosive magazine site design, fire resistance materials such as bricks, cement rendering, steel doors and the ground surface is to be constructed of concrete or stone could prevent fire ingress to the explosives as well as the land within the compound will be cleared of vegetation to remove combustible materials, the chance of explosives being initiated due to hill / vegetation fire is considered to be negligible. Thus the generic explosion frequency is considered to have included hill fire scenarios.

Earthquake

8.6.1.7 The generic failure frequency adopted is based on historical incidents that include earthquakes in their cause of failure. Since Hong Kong is not at disproportionate risk from earthquakes compared to similar explosives magazines worldwide (Hong Kong is approximate 600km away from the nearest Circum-Pacific Seismic Belt which runs through Japan, Taiwan and the Philippines), it is considered that it is not necessary to address the failure due to earthquake separately.

Escalation

8.6.1.8 Ardeer Double Cartridge (ADC) test is a test to determine the sensitivity of a charge of explosive to initiation by another charge located at a known distance apart but in line with the first charge. According to pervious approved EIAs such as XRL EIA and STC STW EIA, it is not considered possible that an explosion within one magazine store will directly initiate an explosion within an adjacent store (i.e. leading to mass explosion). Therefore, the direct propagation by blast pressure wave and thermal radiation effects of an explosion within one store initiating an explosion within the adjacent store is considered. However, the ground vibration induced may damage the adjacent stores and leads to subsequent explosion. A building can withstand a vibration level lower than 229mm/s without significant structural damage. Ground vibration distance can be calculated as below[5]:

$$A = \mathrm{K}Q^{d}R^{-b}$$

Where A is the vibration threshold (mm/s) = 229mm/s
K is rock constant = 1200
Q is the mass of explosive detonated of each storage in the magazine discussed in

5 Reference: Approved EIA Study on Hong Kong Section of Guangzhou – Shenzhen – Hong Kong Express Rail Link

Table 8.14.

R is the distance between the blast and measuring point (m)

d is charge exponent = 0.5

b attenuation exponent = 1.22

8.6.1.9 The above equation applies to explosives fully coupled with hard rock as typically found in Hong Kong. For aboveground magazine stores, the magazine store building will provide some confinement which would result in explosion energy being transmitted through the ground by ground shock effects due to the direct contact of explosives with the ground. Therefore, the same approach is conservatively adopted to evaluate the ground shock effects in the absence of other relevant correlation. This gives a K value circa 200 for this Project considering the amount of explosives to be stored in each store at each aboveground magazine site.

8.6.1.10 Applying the above equation and the ground coupling correlation of the ERM (2008) study, the distance of ground vibration threshold generated from the proposed magazine site is only about 10m which is less than the 16m minimum separation distance between stores. Hence, the possibility of explosives within adjacent stores being initiated is negligible.

8.6.1.11 For the underground magazine, although direct propagation, by blast pressure wave and thermal radiation effects, of an explosion within one niche initiating an explosion within the adjacent niche is not considered, an explosion within one niche may cause damage with the adjacent niche such as rock spall. This rock spall, which is caused by the transmission of a shock wave in the surrounding rock, may result in the initiation of the adjacent niche due to impact of the explosives with the falling rocks. Therefore, increasing separation distance will significantly reduce the likelihood of rock spall.

8.6.1.12 The degree of shock wave transmission through the rock will depend on factors such as the rock type and the loading density of explosives within the niche. The niche loading density is approximately $1.92kg/m^3$ which is calculated by dividing the design quantity of explosives (200kg) to the volume of a niche ($\sim105m^3$).

8.6.1.13 The minimum separation distance between separate niches calculated in **Section 8.2.4.5** is 5.8m. Since the actual chamber separation distance is 12m, this QRA does not consider it is possible to initiate adjacent niche's explosives due to rock spall following an explosion within a magazine niche.

8.6.2 Transport of Explosives

8.6.2.1 Deflagration or detonation explosion may be induced during the transportation of explosives from the proposed magazine to the construction sites. The QRA study from WIL EIA has identified the causes of potential accidental explosion during transportation.

8.6.2.2 Spontaneous fire (non-crash fire), fire after a vehicle crash (crash fire) and impact initiation in crash (crash impact) can cause accidental explosion, while spontaneous explosion may happen if the cargo load contains 'unsafe explosives'. The causes for initiating accidental explosions are summarized below:

- Non-crash fire: This cause category includes any explosion instance where the explosive load has been subject to thermal stimulus which is not the result of a vehicle collision. Events in this category, not only include instances where the explosive load is directly engulfed in the fire but also events where thermal stimulus occurs by ways of heat conduction and convection;

- Crash fire: This cause category is similar to the non-crash fire category but only includes fires resulting from a vehicle collision;
- Crash impact: This cause category includes all instances of vehicle collisions with a sufficient energy to significantly affect the stability of the explosives and which could have the potential to cause an accidental explosion; and
- Spontaneous explosion (‘Unsafe Explosive’): This cause category includes explosions resulting from breach of regulations caused by badly packaged, manufactured and/or ‘out-of-specification’ explosives during normal transport conditions.

8.6.2.3 The transport of explosives relating to commercial and non-commercial activities in port has first been assessed in the study published by Advisory Committee on Dangerous Substances (ACDS, 1995). The basic event frequencies extracted from the study of ACDS was then adjusted in the DNV studies to address the risk induced by the transport of commercial explosives by the Mines Division trucks. The adjusted frequencies from DNV study for transport of explosives in trucks operated from the magazine to construction sites have been widely used in different approved EIA study such as WIL EIA, XRL EIA, SIL EIA and STC STW EIA. Some minor modifications for the frequencies were made based on the explosives’ properties, vehicle impact frequencies and the design features of the explosives carrying vehicles.

8.6.2.4 The fault trees and event trees are updated with the latest traffic data in The Annual Traffic Census 2021 public by Transport Department. The fault trees are shown in **Appendix 8.6** and summarized as below:

Table 8.19 Frequency of Transport of Explosives

Item	**Expressway (/km/year)**	**Non-expressway (/km/year)**
Explosive Load Initiation Due to Impact (incorporated at frequency of “Contractor Truck Explosion Frequency”)	2.10E-12	9.92E-12
Contractor Truck Explosion Frequency per Truck per km	6.86E-10	7.95E-10

Note:

[1] Excavation of a tunnel by drill-and-blast is a cyclic procedure and the cycle time is according to the latest blasting design stated in **Table 8.7**.

8.6.3 Use of Explosives

8.6.3.1 The frequency assessment for the use of explosives consists of two parts which are the occurrence frequency of higher ground vibration due to errors in the blasting process and the occurrence frequency of higher vibration and air overpressure due to the transport of cartridges from the shaft to the blast site.

Frequency of Higher Vibration due to Errors in the Blasting Process

8.6.3.2 The main causes are due to human errors for all the failure scenarios identified in the high-level failure mode analysis during the blasting process which include errors in design manufacturing, installation, checking and recovery.

8.6.3.3 A fault tree analysis has been used to determine the failure rates or probabilities for the hazardous scenarios for Use of Explosives. Human Error Assessment and Reduction Technique (HEART) is carried out to determine the human error probabilities for the events.

8.6.3.4 HEART is a technique used in the field of Human Reliability Assessment (HRA), for the purposes of evaluating the probability of a human error occurring throughout the completion of a specific task. In this assessment, HEART is adopted to quantify human error probabilities by evaluating the relationships between humans, their specific tasks, performance shaping/human factors and error producing conditions.

8.6.3.5 With reference to the approved STC STW EIA, failure scenarios associated with the use of explosives include the following:

- Higher vibration due to 2 MIC detonated at the same time;
- Higher vibration due to 3 MIC detonated at the same time;
- Higher vibration due to 4 MIC detonated at the same time;
- Higher vibration due to 5 MIC detonated at the same time;
- Higher vibration due to 6 MIC detonated at the same time; and
- Higher vibration due to cut hole error.

8.6.3.6 For 2 MIC case, higher failure probability between bulk and cartridged emulsion was considered as an integral part of the models of overcharge of emulsion more than required as either one of the two emulsions will be used for a blast face in the fault tree. Thus, the overload was considered as one of the causes leading to a maximum of 2 MIC detonated simultaneously.

- More cartridged sticks loaded into a production hole than required and
- More bulk emulsion explosives loaded into a production hole than required.

8.6.3.7 For 3 and 4 MIC case, the following failure cases have been considered:

- For 3 MIC case, charge overload with one error other than overload (i.e. design error in time delay, detonator put into a wrong sector, manufacture defect for a detonator, manufacture defect for a surface connector, incorrect connection of surface connector, etc.) will lead to 3 MIC detonated at the same time; and
- For 4 MIC case, charge overload with two errors other than overload will lead to 4 MIC detonated at the same time.

8.6.3.8 For cases more than 4 MIC, i.e. 5 and 6 MIC, each frequency increase in MIC is about 2 orders of magnitude lower. For a conservative approach, the cases of 5 MIC and 6 MIC detonation occurring simultaneously has been conservatively assumed to be the same as 4 MIC detonation.

8.6.3.9 The probability of the second human error of the same type was conservatively assumed as 0.01 to account for the potential dependency of human errors. This assumption has also been adopted in approved WIL and STC STW EIA.

8.6.3.10 Detailed fault tree analysis is shown in **Appendix 8.4** and the modelled results are summarised as below.

8.6.3.11 Scenarios considered in this assessment for tunnel blasting is presented in **Table 8.20.** Scenarios considered in this assessment for surface blasting is shown in **Table 8.21**.

Table 8.20 Scenarios Considered in this Assessment

Scenario (For Tunnel Blasting)	Frequency (/year)
Higher vibration due to 2 MIC detonated at the same time	2.90E-05
Higher vibration due to 3 MIC detonated at the same time	2.46E-07
Higher vibration due to 4 MIC detonated at the same time	2.57E-09
Higher vibration due to 5 MIC detonated at the same time [1]	2.57E-09
Higher vibration due to 6 MIC detonated at the same time [1]	2.57E-09
More cartridged sticks loaded into a production hole than required	4.39E-06
More bulk emulsion explosives loaded into a production hole than required	1.41E-06

Notes:
[1] There is about 2 order of magnitude lower of each MIC. For a conservative approach, the frequency of 5 MIC and 6 MIC detonation occurring simultaneously has been conservatively assumed to be the same as 4 MIC detonation.
[2] Assume mischarge of explosives only occurs in one blast face.

Table 8.21 Scenarios Considered in this Assessment

Scenario (For Surface Blasting)	Frequency (/year)
Higher vibration due to 2 MIC detonated at the same time	1.21E-05
Higher vibration due to 3 MIC detonated at the same time	1.08E-07
Higher vibration due to 4 MIC detonated at the same time	1.08E-09
Higher vibration due to 5 MIC detonated at the same time [1]	1.08E-09
Higher vibration due to 6 MIC detonated at the same time [1]	1.08E-09
More cartridged sticks loaded into a production hole than required	5.10E-06
More bulk emulsion explosives loaded into a production hole than required	1.24E-06

Notes:
[1] There is about 2 order of magnitude lower of each MIC. For a conservative approach, the frequency of 5 MIC and 6 MIC detonation occurring simultaneously has been conservatively assumed to be the same as 4 MIC detonation.
[2] Assume mischarge of explosives only occurs in one blast face.

8.6.3.12 According to the latest design, there would be a maximum of 13 blasts per day for tunnel blasting and 4 blasts per day for surface blasting, i.e. 1 blast per surface blasting site.

Frequency of Higher than Expected Vibration and Air Overpressure due to Onsite Transport of Explosives

8.6.3.13 The overall frequency of accidental initiation during transportation is 7.95E-10 per truck-route-km per year as presented in **Table 8.19**. This value is considered as conservative as speed control will be implemented within the site during the onsite transport of explosives and the traffic within the site should not be heavy as only one truck will be allowed in the site at any given time. Hence, no reduction factors will be considered regarding the probability of fire following a vehicle crash and impact initiation in crash.

8.6.3.14 Since the transport length within the tunnel will vary due to different entry, the average transport length was assumed half the total length for all deliveries in accordance with STC STW WIA. The calculated frequency for onsite transportation is shown in **Table 8.22**.

Table 8.22 Frequency of higher than expected vibration and air overpressure due to onsite transport of explosives

Area	Initial Freq. (/km-year)	No. of Deliveries	Road Length (km)	Frequency (/year)
LTT North Portal	7.95E-10	381	2.4	3.63E-07
LTT South Portal	7.95E-10	381	3.6	5.45E-07
TLCTN	7.95E-10	303	1.1	1.32E-07
TLCT North Portal	7.95E-10	303	2.5	3.01E-07
TLCT South Portal	7.95E-10	303	1.4	1.69E-07
SKWLR East Portal	7.95E-10	487	2.5	4.84E-07
SKWLR West Portal	7.95E-10	487	0.9	1.74E-07

Frequency of flyrocks associated with the use of explosives for surface blasting

8.6.3.15 The estimated external event failure from flyrock on pedestrian could be calculated as follows:

1. Determination of the probability for flyrock hitting nearest pedestrian (P_f):
   - Probability of flyrock reaching distance of nearest pedestrian road (P_{fz})
   - Probability of flyrock outside site boundary P_{fo} = 5% (which is based on the shortest distance between the blasting point and site boundary)

   $P_{fz} = P_f * P_{fo}$ or

   $P_f = (P_{fz} / P_{fo})$

   Where P_f for different sites is ranging from 0.1 to 1

2. Determination of ratio of view angle of pedestrian from the proposed surface blasting site (360 deg) (P_v):
   - The angle from the closest blasting location to pedestrian is x deg.

   $P_v = x / 360$

   Where x is about 2^o for a person at the pedestrian and Pv is about 0.006

3. Determination of the probability of flyrock reaching nearest pedestrian for 1 to 6 MIC (as 1 MIC must occur and it would also induce flyrock, thus 1 MIC is also considered) = P_h P_f P_v

   Where the probability of a blast induced flyrock failure P_h = 3.28E-04 per blast.

8.6.3.16 Scenarios considered in this assessment for surface blasting of 1 to 6 MIC is presented below:

- Site 1: 1.82E-07/blasting operation

- Site 2: 1.82E-06/blasting operation
- Site 3: 1.82E-06/blasting operation
- Site 4: 1.82E-06/blasting operation

8.6.4 Domino Effect of Town Gas Underground High-Pressure Pipeline

8.6.4.1 As discussed in **Section 8.3.2**, there is a high-pressure pipeline running along Tai Lam Chung River. According to Electrical and Mechanical Services Department (EMSD)'s Guidance Note on Quantitative Risk Assessment Study for High Pressure Town Gas Installations in Hong Kong (HP Guidance), the failure frequency of underground high pressure pipeline is 1E-5 /km/year. The event outcome frequency of fireball and jet fire is 1.73E-6/km/year (**Appendix 8.7**). These outcomes would trigger failure of explosives. The alignment of the pipeline which is in close vicinity of transport routes is shown in **Diagram 8.8**.

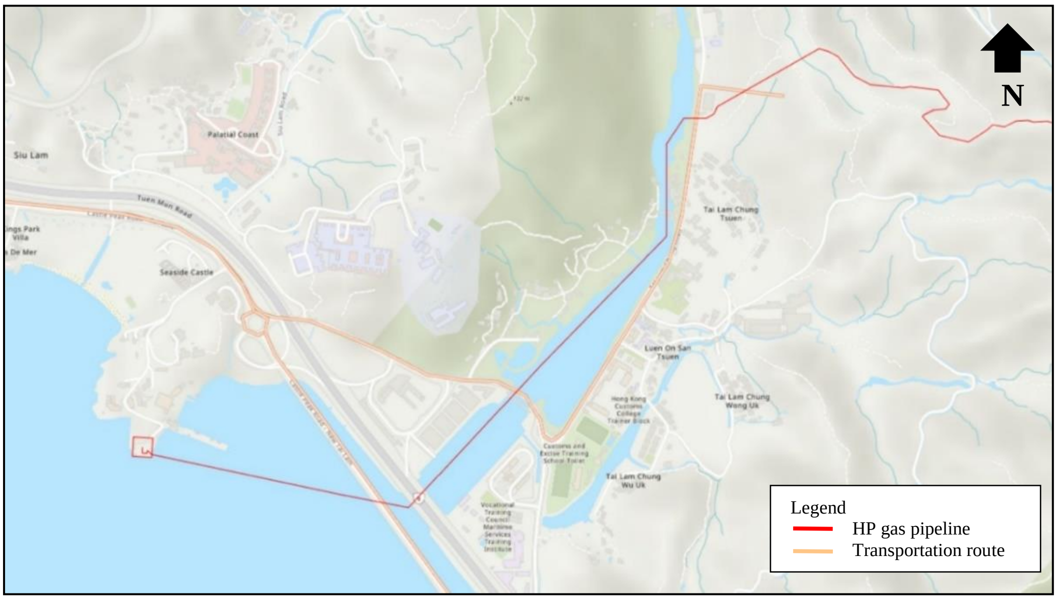

Diagram 8.8 Alignment of HP Pipeline overlapping with transport route

8.6.4.2 The average travel speed of explosive truck is about 50 km/hr and the interface section is about 2km long. The explosives vehicles would only be present within the interface section for 2 minutes. Time fraction of an explosive truck within the interface section is about 4.57E-6 /year or 2.18E-6 /km/year. The domino effect of underground high pressure pipeline would be about 3.77E-12 /km/year which is about 2 orders lower than accidental explosion during transport as discussed above. Moreover, for the HP underground town gas transmission pipelines, a minimum earth cover of 1.1m is provided, with consideration of the separation distance from the transport route of explosives and the protection from the earth cover, it is presumed that probability of the failure of the transport of explosives triggering failure of HP underground town gas transmission pipelines is very unlikely and this will not be further considered in the QRA.

8.7 Consequence Analysis

8.7.1 Overview

8.7.1.1 The damage from bulk emulsions is mostly contributed by the blast effects, while for small detonations, fragmentation is the most notable effect and only need to consider thermal radiation in low speed deflagrations.

8.7.1.2 When exposed to blast effects, people may result into three modes of injury which are primary, secondary and tertiary effects. The information relating to different levels of effects is summarised in **Table 8.23**.

Table 8.23 Different Levels of Effects when exposed to Blast Effect

Category	Characteristics	Body Part Affected	Types of Injuries
Primary	Unique to high-order explosives, results from the impact of the over-pressurization wave with body surfaces.	Gas filled structures are most susceptible i.e. lungs, *gastrointestinal tract*, and middle ear	- Blast lung (pulmonary barotrauma) - Tympanic membrane rupture and middle ear damage - Abdominal hemorrhage and perforation - Globe (eye) rupture - Concussion (Traumatic Brain Injusy without physical signs of head injury)
Secondary	Results from flying debris and bomb fragments	Any body part may be affected	- Penetrating ballistic (fragmentation) or blunt injuries -Eye penetration (can be occult)
Tertiary	Results from individuals being thrown by the blast wind	Any body part may be affected	- Fracture and traumatic amputation - Closed and open brain injury

Note:

[1] Reference from Explosions and Blast Injuries: A Primer for Clinicians published by Centers for Disease Control and Prevention (U.S.).

8.7.1.3 As discussed in **Section 8.6.3**, explosives are being used both underground and on surface which may induce the hazards posed by the overpressure wave and debris generated by the explosion.

8.7.1.4 Secondary hazards such as building failure and slope failure may be leaded by excessive ground shock, while tertiary hazards such as landslide and rupture of town gas high pressure pipelines may be further induced by secondary hazards.

8.7.2 Overnight Storage and Transportation of Explosives

8.7.2.1 Hazardous events would induce impact to both property and people and they would be exhibited in the following ways:

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

Physical Effect Modelling

Blast and Pressure Wave for Above Ground Explosion

8.7.2.2 Consequence analysis is based on the UK Explosive Storage and Transport Committee (ESTC) which considers all the effects associated with an above ground explosion including, fireball, overpressure, flying debris, broken glass, structure damage, etc. The probability of fatality of can be estimated by:

Indoor:

$$log_{1o}P = 1.827 - 3.433log_{1o}S - 0.853(log_{1o}S)^2 + 0.356(log_{1o}S)^3$$

$$for\ 3 < S < 55$$

Outdoor:

$$P = exp(-5.785S + 19.047)/100$$

$$for\ 2.5 < S < 5.3$$

Where P is the probability of fatality. Distance to 1%, 3%, 10%, 50% and 90% of fatality would be adopted for QRA

S $=R/Q^{1/3}$

R is the impact distance (m), i.e. the consequence

Q is explosives charge rate (TNT eqv. kg)

8.7.2.3 The indoor consequence model will apply to population in vehicles or buildings, while the outdoor consequence model will apply to pedestrians and cyclers.

8.7.2.4 The distance to 1%, 3%, 10%, 50% and 90% fatality contours are used in the modelling.

8.7.2.5 For indoor population, with maximum Q assumed to be around 130 TNT eqv. kg per trip as mentioned in **Table 8.7**, the impact distance for 1% fatality probability is 48m from the centre of explosion.

8.7.2.6 For outdoor population, the impact distance of 1% fatality probability by assuming Q is 130 TNT eqv. kg is around 17m.

Ground Shock Generated by Accidental Explosion in Magazine Niches

8.7.2.7 The DoD 6055.9-M-V5 provides equations for establishing the minimum safe distance for inhabited buildings from underground magazines based on the magazine loading density. The loading density of each niche is less than 48.1kg/m^3 (the actual loading density is approximately 1.92kg/m^3).

8.7.2.8 According to DoD 6055.9-M-V5 EQN V5.E5.2-2, the inhabited building distance (IBD) for low loading density storage is:

$$D_{ig} = 2.30 \times Q^{1/3}$$

Where Q Explosives mass in TNT eqv. kg

8.7.2.9 For the purpose of this study, it is assumed that the IBD is the distance at which the ground shock, or Peak Particle Velocity equals 229mm/s for strong rock which is based on DoD 6055.09-M-V5.E5.2.3.1. This represents the limit value for causing significant structural damage to a building.

8.7.2.10 Therefore, for a single chamber explosive quantity of 200kg, the safe distance, D_{ig} is around 13.5m.

Blast and Pressure Wave during the operation of Underground Magazine at Lam Tei Quarry

8.7.2.11 An explosion in an underground storage chamber may produce external airblast from two possible sources:

- The exit of blast from existing openings, i.e. magazine adits; and
- The rupture or breach of the chamber cover by the underground detonation. However, airblast hazards from a blast that ruptures the earth cover are negligible relative to the ground shock and debris hazards.

8.7.2.12 In a single chamber with a straight access tunnel leading from the chamber to the portal, which is called a "shotgun" magazine, the blast and debris are channelled to the external area as if fired from a long barrelled gun. In this situation, the distance versus the overpressure along the centreline of a single opening can be calculated using the DoD 6055.09-M-V5.E5.2-16:

$$R(\theta = 0) = 220.191 \times D_{HYD} \times ((W/V_E)^{0.5}/P_{SO})^{1/1.4}$$

$$for\ W \leq 45{,}359kg; P_{so} = 8.27kPa$$

$$R(\theta = 0) = 220.191 \times 5.38 \times ((200/2866.5)^{0.5}/8.27)^{1/1.4}$$

$$R(\theta = 0) = 101.3m$$

Where	R(θ=0)	Distance from opening along the centerline axis, m
	D_{HYD}	Effective hydraulic diameter that controls dynamic flow issuing from the opening, m
	P_{SO}	Overpressure at distance R, psi
	W	Charge weight for the maximum credible event, kg
	V_E	Total volume engulfed by the blast wavefront within the tunnel system at the time the wavefront arrives at the point of interest, m^3

8.7.2.13 The distance versus overpressure off the centreline axis of the opening can be evaluated.

8.7.2.14 However, the above equation is for use when the opening or adit from the magazine is unobstructed. The proposed design for the magazine incorporated barricade at the magazine entrance. A barricade in front of the entrance or exit into the magazine tunnel will reflect the shock wave that moves directly out from the portal. The effect of providing barricades is to reduce overpressures along the extended tunnel axis and increase the pressure in the opposite direction. This causes a more circular overpressure contour that is centred at the opening.

8.7.2.15 This magazine has design considerations in place to reduce the IBD including portal barricades, blast enclosures, complex geometry and large chamber to storage quantities ratio. According to DoDM 6055.09-M-V2, portal barricades will reduce the IBD along the extended tunnel axis by 50% and complex facility layouts can reduce IBD up to 10%. The design has both quantifiable (up to 60% reduction in IBD) and non-quantifiable (geometry and increase in storage ratio) design considerations that super-impose and provide a conservative system design principle for the explosive magazine resulting in a conservative IBD distance of 51m (approximately 50% reduction in IBD).

8.7.2.16 In addition, since the explosive weight for one niche is around 200kg, according to DoDM 6055.09-M-V5.E5.2.4, PTRD is 60% of IBD for ground shock, debris or airblast, whichever is greater. The IBD for airblast is adopted as it is the maximum IBD among them, so the public traffic route distance (PTRD) is 30.4m. This PTRD distance is mainly within the project boundary of this Project and according to the latest information, the access roads of LTUQ is not within this area and hence, access roads of LTUQ would not be affected. The buffer zones for PTRD and IBD are shown in **Diagram 8.9**.

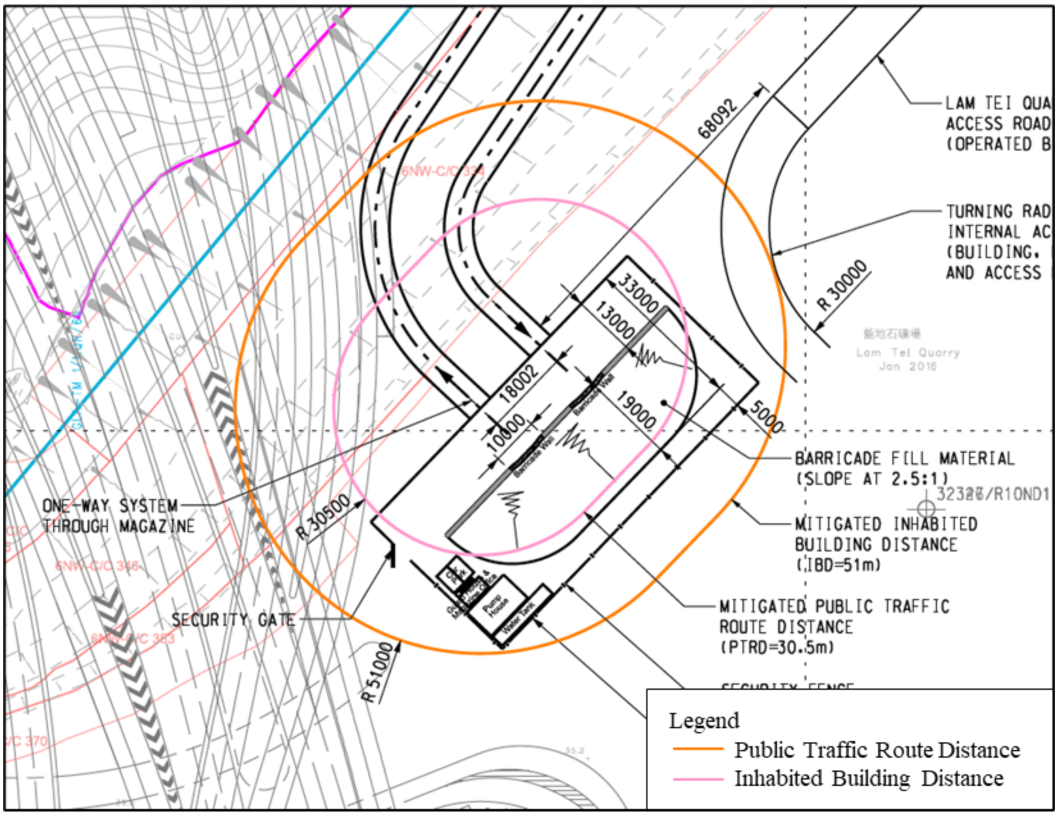

Diagram 8.9 Buffer Zone for Public Traffic Route Distance and Inhabited Building Distance

Flying Fragments or Missiles

8.7.2.17 As discussed above, the ESTC model has already considered the impact from flying debris.

Thermal Radiation

8.7.2.18 As the explosives initiate, thermal radiation will be released from the fireball generated from the explosion. There are only a few published models in the literature related to high explosive fireballs or fireballs induced from cartidged emulsion detonation. Models that are available describe the fireball duration and its diameter based on TNT or similar explosives such as nitroglycerine and PETN. In this assessment, it is assumed that the fireball correlations are applicable to cartridged emulsion containing ANFO and aluminium powder.

8.7.2.19 The diameter and duration of a fireball of explosives can be determined as the equation below. As discussed, the maximum charge rate of transport is 130 TNT eqv. kg, i.e. influence zone/radius is 8.9m, and the duration is 1.5s.

$$D = 3.5M^{0.333}$$

$$t_d = 0.3M^{0.333}$$

Where D is the diameter of fireball (m)

M is explosives charge rate (TNT eqv. kg)

td is the duration of the fireball (s)

Note:

[1] Reference from Process Industries: Hazard Identification (Lees, 1996).

8.7.2.20 For the largest explosive mass of 350kg (initiation of an entire store contents), the fireball radius is calculated to be 12.3m and duration is 2.1 seconds.

8.7.2.21 Surface emissive power (E_f) can be calculated by the equation below.

$$E_f = \frac{f_s M \Delta H_r}{4\pi(\frac{D}{2})^2 t_d}$$

Where fs is the fraction of heat that is radiated, a conservative value of 0.4 is taken[6]

ΔHr Is the heat released from the explosives (kJ/kg) approximately 40.1MJ/kg

Note:

[1] Reference from XRL EIA Study.

8.7.2.22 The surface emissive power of fireball for 350 TNT eqv. kg explosives is about 140kW/m^2.

8.7.2.23 According to "Methods of approximation and determination of human vulnerability for offshore major accident hazard assessment" by HSE UK, thermal radiation dose of a certain time can be calculated by the following equation and the suggested thermal dose of 1%, 50% and 100% fatality are 1000, 1800 and 3200 thermal dose unit (tdu) respectively. Thermal radiation dose can be calculated as below:

$$Dose = (I^{4/3}) \times t$$

Where I is incident thermal flux (kW/m2)

t Is time of exposure (s)

Note:

[1] Reference from Process Industries: Hazard Identification (Lees, 1996).

8.7.2.24 For the exposure duration of 2.1s, the incident thermal flux calculated are 102, 171 and 243 kW/m^2 for 1%, 50% and 100% fatality respectively. As the size of fireball radius is only 12.3m and would not induce off-site impact.

8.7.2.25 The same method has been applied for transportation of explosives, i.e. 130 TNT eqv. kg. For the exposure duration of 1.4s, the incident thermal flux calculated are 130, 202 and 311 kW/m^2 for 1%, 50% and 100% fatality respectively. When compared with the surface emissive power of 140kW/m^2, these levels of thermal

[6] Value 0.4 is adopted in XRL EIA.

flux will only be realized when in very close proximity to the fireball. As the size of fireball radius is only 8.9m, it can be concluded that the fireball would not induce off-site impact. Therefore, hazards from fireball are not further considered in this assessment.

Ground Shock Generated by Accidental Explosion during Transportation of Explosives

8.7.2.26 Some slopes are identified along the transport route of explosives and there is a chance that an accidental detonation of the explosives can trigger a landslide or a boulder fall. This kind of incidents is identified as a secondary hazard.

8.7.2.27 The transportation and storage of explosives will be carried out above-ground while the use of explosives (i.e. transportation within tunnel) will be performed underground. The pressure wave induced from above-ground explosion will be lower than that of underground due to less confined space. Therefore, the consequence induced by above-ground explosion is considered less significant compared to the risk induced by the overpressure wave and the fragments produced by the explosion.

8.7.2.28 It can be calculated by the following equation:

$$A = K(R/Q^d)^{-b}$$

Where	A	Predicted particle velocity in mm/s
	K	A ‘rock constant’, assumed to be 200
	Q	Maximum charge weight per delay interval in kilograms
	R	Distance in meters between the blast and the measuring point
	d	Charge exponent, assumed to be 0.5
	b	Attenuation exponent, assumed to be 1.22

Note:

[1] Reference from Geoguide 4 – Guide to Cavern Engineering (CEDD, 2018).

Cratering

8.7.2.29 An explosion in an underground storage niche may produce external airblast from two sources which are the exit of blast from existing openings such as the magazine adits and the rupture or breach of the chamber cover by detonation. The DoDM 6055.09-M-V5 defines a critical chamber cover thickness as:

$$C_c = 0.99Q^{1/3}$$

8.7.2.30 The maximum load to be transported within the magazine is 200kg, therefore the critical cover thickness is 5.8m while the minimum rock cover is 14m above the access tunnel. Therefore, cratering is not considered likely in the event of detonation of the full load of a magazine vehicle travelling directly below.

Secondary Hazards

Impact on Buildings

8.7.2.31 As mentioned before, the shortest distance from the nearest building and the magazine sites is around 250m and this separation distance is substantially exceeds the 1% fatality distance. Furthermore, the magazine sites are not within the CZ of any PHIs and is not near to any other vulnerable risk receptors.

Impact on Slope and Boulders

8.7.2.32 There are some slopes identified along the transport route of explosives and within the influence zone of use of explosive as mentioned in **Section 8.7.2.18**. A landslide or a boulder fall may be triggered by the explosion on an explosives carrying vehicle. The findings from WIL EIA suggested that any landslide or boulder fall would only impact the same area along that road that was already affected by the primary explosion consequences.

8.7.2.33 On the other hand, there are some natural terrains near to all three proposed magazine sites. It is possible that an explosion inside the storage of the magazine would trigger a landslide or a boulder fall, but the landslide or boulder fall event would only impact in the area that is close to the magazine site which was already affected by the primary explosion consequences. Therefore, no significant additional fatality would occur, so secondary hazard is not further considered.

Impact on High Pressure Underground Town Gas Transmission Pipelines

8.7.2.34 As mentioned in **Section 8.3.2**, there is a HP underground town gas transmission pipeline running along San Tin Highway and Yuen Long Highway.

8.7.2.35 Leakage or rupture of a gas pipeline can be induced by a higher ground vibration than expected from an accidental explosion or during the blasting process. The typical maximum allowable PPV for town gas pipelines is 25mm/s PPV and it is considered that this level of PPV would not cause significant damage to the pipeline.

8.7.2.36 Since the pipeline is around 20m away from the transport route of the explosives and is located below ground, there is not hazard from thermal or air blast pressure effects. Moreover, there would be no shockwave transmitted into the ground as the accidental detonation would occur above ground. Therefore, the gas transmission pipeline would be able to hold up a ground vibration up to 25mm/s safely without causing any hazards.

8.7.3 Use of Explosives (Tunnel Blasting)

<u>Primary Hazards</u>

Ground Shock/Vibrations Generated by Rock Excavation using Explosives

8.7.3.1 Ground vibration induced by blasting generally occurs as a cyclic wave motion within the ground. This creates movement of the ground that can be measured as velocity, acceleration or displacement, and at different frequencies.

8.7.3.2 The effects of ground vibration due to blasting would be assessed based on the formula from the United States Bureau of Mines, and the recommended value of rock transmission constant and attenuation exponent from Mines Division (Li and Ng, 1992). The local vibration attenuation constants K=644 and b=1.22 are used for an initial assessment when predicting vibrations and for producing vibration contours in blasting assessment reports. These constants are based on the upper 84% confidence level. However, for a more conservative approach, the rock constant K is considered as 1200 which is the upper limit from Geoguide 4.

8.7.3.3 The vibrations that result from a blast may be calculated using an equation of the form:

$$P = K(R/\sqrt{W})^{-B}$$

Where PPV Peak Particle Velocity (mm/s)

K is rock transmission constant which is 1200

R is distance between blasting point and measuring point (m)

W is maximum charge weight per delay (kg)

B is attenuation exponent which is 1.22

8.7.3.4 This formula allows a prediction of the effects of ground vibration due to blasting. When combined with an assessment of the safe vibration level for any affected sensitive receiver, it allows an estimate of the MIC that would not exceed the prescribed limits.

8.7.3.5 Peak Particle Velocity Criteria (PPVc) for difference sensitivity are difference and discussed in following sections.

Ground Shock/ Vibrations Generated during Transport of Explosives within the Access Tunnel

8.7.3.6 The methodology to evaluate the ground shock due to detonation of full load of explosives within the access tunnel is the same as **Section 8.7.2** while the value of K is assumed to be 200 to represent the “decoupling” of explosives during transport in the cavern.

Blast Effects including Overpressure and Debris from Accidental Explosion while Transferring Explosives from Portals to Blast Faces

8.7.3.7 The ESTC model was employed when assessing the likelihood of fatalities due to blast effects. This approach is also adopted in WIL EIA, SCL EIA and STC STW EIA.

8.7.3.8 During the construction of tunnels, an initiation of explosives during transport within the tunnel is considered as an explosion at the tunnel portal since so decay factor was considered for a blast wave propagating from the blast face to the portal.

Secondary Hazards

Effect on Buildings

8.7.3.9 According to Geoguide 4, the maximum vibration limits for buildings is 25mm/s to prevent cosmetic damage. Although the value for the peak velocity of 25mm/s has been used for many years, the PPV that induces significant structural damage and results in potential fatalities is also required for the purpose of this assessment.

8.7.3.10 Blasting Vibrations and Their Effects on Structures from the US Bureau of Mines Bulletin 656 has analysed the blasting results obtained in Sweden and has concluded the damage level of a building with different PPVs. The results obtained from the report are summarised in the table below:

Table 8.24 Damage Level due to Ground Vibration

Damage Level	Peak Particle Velocity, mm/s (in/s)
No noticeable damage	70 (2.8)
Fine cracking and fall of plaster	110 (4.3)
Cracking	160 (6.3)

Damage Level	Peak Particle Velocity, mm/s (in/s)
Serious cracking	231 (9.1)

8.7.3.11 Apart from the report from the US Bureau of Mines Bulletin 656, Explosives Safety Standards (Nicholls, Johnson, & Duvall, 1971) has also reviewed the maximum particle velocity induced in the ground shall not exceed 229mm/s or 9.0in/s in strong rock for the protection of residential buildings against significant structural damage by ground shock.

8.7.3.12 Criteria adopted for building risk assessment are summarised as below:

- PPV = 229mm/s – Building structural collapse threshold; and
- PPV = 100mm/s – Object fall threshold.

8.7.3.13 The above criteria are considered as conservative as buildings will collapse only when a peak particle velocity is significantly larger than the assumed threshold limit which is 229mm/s.

8.7.3.14 When the PPV level reached 100mm/s which is the object fall threshold, it is assumed that the population within a building will have 1% of fatality level due to vibration causing falling objects which has also been adopted in STC STW EIA and WIL EIA.

Building Collapse Models for Explosion/Earthquake

8.7.3.15 To estimate the number of fatalities due to falling objects, different assumptions are required such as the number of objects with the potential to fall, weight and size of those objects, probability of fatality when a person is hit, etc. However, the probability of objects falling due to ground vibration particularly at a low threshold value of 100mm/s is hard to predict as there are different uncertain factors such as the condition of building and presence of temporary or unauthorised structures.

8.7.3.16 The building vulnerability models for partial collapse would be adopted in this assessment which also has been used in WIL EIA and STC STW EIA. The fatalities caused by partial collapse are mainly because of the collapse of roofs, ceilings and walls which are considered as the most serious types of falling objects. These type of falling objects may cause more than 1 fatality.

8.7.3.17 A review of building damage vulnerability models for partial building collapse/damage has been carried and summarised by WIL EIA. It has concluded that the fatality rates vary from 0.01% to 1.5%, so 1% fatality rate from falling objects is considered as conservative.

8.7.3.18 However, considering the types of building in this QRA, objects with the potential to fall are assumed to be 1m^2 large. Based on the maximum population density along the transport route of 0.0145 person/m^2 found in this QRA, the resulting number of fatalities due to an object falling is taken as one for a conservative approach.

Effect on Slopes

8.7.3.19 Different registered geotechnical features have different vibration limits due to their individual features, so the following sections will discuss the methods of assessment to define the vibration limit for the different geotechnical features.

8.7.3.20 According to CEDD's GEO Technical Guidance Note No. 28 New Control Framework for Soil Slopes Subjected to Blasting Vibrations (TGN 28), PPV limit of slopes that pose ineligible risk-to-life is 25mm/s of Consequence-to-life (CTL) Categories 1 and 2 slopes. For CTL Category 3, an allowable PPV of 25mm/s is normally adopted to any slopes with this category.

8.7.3.21 Although PPV of 25mm/s is the standard and prescribed allowable PPV for the existing slopes, the vibration limits for registered geotechnical features are different for each individual feature. Therefore, 90mm/s is adopted as the PPV limit for slopes. This PPV level corresponds to 0.01% chance of a slope failure with Factor of Safety (FOS=1.1). The same criterion was also adopted in approved EIA study on XRL EIA.

8.7.3.22 Since blasting works may be conducted to some existing man-made slopes for site formation, the impacts to the slopes lying within the open blasting area would not be taken into account in this QRA.

8.7.3.23 For any slope for which it is proposed to adopt the use of the prescriptive PPV during the detailed stage, visual inspection will be carried out to confirm that there are no signs of distress or instability, or any other stability concerns. Those guidance criteria have been used in this Report.

8.7.3.24 The analysis of the effects of vibration on the stability of slopes is based on the guidelines detailed in GEO Report No. 15 (GEO, 1992). The critical Peak Particle Velocity (PPVc) corresponding to the maximum vibration is calculated using the following equation as stipulated in GEO Guidance documents which is considered to be a conservative estimate of the actual expected strength:

$$\boldsymbol{PPVc = K_c g/(\omega K_a)}$$

Where K_c is the critical acceleration at which the slope has a factor of safety of 1.0 against failure

g is the acceleration due to gravity (m/s^2)

ω is the circular frequency of the ground motion ($2\pi f$)

K_a is the magnification factor

8.7.3.25 The circular frequency of the ground motion(ω) is related to the frequency of vibration (f). Unlike earthquake ground motions, blasting vibration is characterized by short duration high frequency pulses, which according to Mines Division's records have a frequency content ranging typically from 30 to 100 Hz (GEO, 1992). As suggestion from GEO Report No.15, an input vibration frequency of 30 Hz will result in the lowest PPVc and hence the most critical situation. Therefore, the case of f equal to 30 Hz is adopted in the following analyses for simplicity.

8.7.3.26 The value of Kc is obtained from stability analysis of the slopes to achieve a minimum pseudo-static FOS as detailed in **Table 8.25** and corresponding to different categories of CTL of the slopes, which is in line with the current GEO practice.

Table 8.25 Summary of Adopted Pseudo-Static FOS

Consequence-To-Life Category	Adopted Pseudo-Static FOS
Cat 1	1.1
Cat 2	1.0

Consequence-To-Life Category	Adopted Pseudo-Static FOS
Cat 3	1.0

8.7.3.27 To determine the vibration level required to lead to failure of slopes due to earthquakes in Hong Kong, a formula based on Sarma 1975 as referred in in GEO Report No.15 is provided for calculating slope movement is as follow:

$$X_m = 0.25 \times C \times A_m \times T^2 \times 10^{(1.07 - 3.83Ac/Am)}$$

Where X_m is slope movement

C is function of the slope geometry and generally is a value near unity

A_m is peak acceleration

T is dominant period of the ground motion

A_c is critical acceleration required to cause sliding

8.7.3.28 For blast observations, the dominant period (T) is about 1/30 seconds with peak ground acceleration in mm/s is about 670 times the PPV in mm/s which means that the peak acceleration for a PPV of 60mm/s is about 4g or 40,000 mm/s. Therefore, the above formula can be rewritten as:

$$X_m = 0.186 \times PPV \times 10^{(1.07 - 3.83Ac/Am)}$$

8.7.3.29 However, as the formula is obtained from earthquake data which mainly consisted of several low frequency pulses instead of a singular high frequency pulse due to detonation of explosives, a factor of 0.25 is applied into the above equation to calculate slope movement for explosives detonation as a typical earthquake consists of at least 4 separate peaks while explosives movement mainly contains one. The modified Sarma equation is as below:

$$X_m = 0.0465 \times PPV \times 10^{(1.07 - 3.83Ac/Am)}$$

8.7.3.30 STC STW EIA has also derived a formula for calculate the shear displacement of slope based on Sarma equation as below:

$$X_m = 0.0465 \times PPV \times 10^{(1.07 - 3.83PPV_c/PPV)}$$

Where X_m is shear displacement (m)

8.7.3.31 Expert judgement has been used to determine the criteria for the failure of slopes based on the amount of shear displacement or slope movement. The criteria that is appropriate to this study are:

- 20mm shear displacement or slope movement causes a 0.01% chance of slope failure;
- 50mm shear displacement leading to a 10% chance of slope failure;
- 100mm shear displacement leading to a 50% chance of slope failure; and
- 200mm shear displacement leading to a 100% chance of slope failure.

8.7.3.32 Therefore, for an estimated PPV value the amount of slope movement can be calculated for a given slope or wall, and hence the probability of its failure estimated.

Table 8.26 Influence Zone of different PPVc values from 1MIC to 6MIC for Effect on Slopes

PPVc (mm/s)	Influence zone (m)						
	At blast face						Transport from tunnel portal to blast face (130kg)
	1MIC (10kg)	2MIC (20kg)	3MIC (30kg)	4MIC (40kg)	5MIC (50kg)	6MIC (60kg)	
90	26.4	37.4	45.8	52.9	59.1	64.7	21.9

8.7.3.33 All slopes would receive a shear displacement less than 20mm. For conservative approach, 0.01% chance of slope failure has been adopted.

Effect on Natural Terrains and Boulders

8.7.3.34 Landslide of nature terrains and boulders fall may occur during blasting. The Critical Peak Particle Velocity (PPVc) of a boulder will be calculated to estimate the limit of PPV that a boulder can tolerate without falling.

8.7.3.35 According to GEO Report No.15, PPVc at which the block will be driven to a state whereby peak shear stress is developed at the rock joint, can be shown to be given by:

$$\boldsymbol{PPV_c = (g/0.91\ (\delta p)\ sin\beta\ (\frac{tan\,\emptyset'_p}{2\,tan\,\beta} + \frac{tan\,\beta}{2\,tan\,\emptyset'_p}))^{(1/2)}}$$

8.7.3.36 In terms of the initial static factor of safety $F_s = \tan \emptyset'_p \,/\, \tan\beta$:

$$\boldsymbol{PPV_c = (g/0.91\ (\delta p)\ sin\beta\ (Fs/2\ + 1/(2Fs) - 1))^{(1/2)}}$$

Where g is acceleration due to gravity (9.8m/s2)

δp is joint displacement at peak stress

β is joint sip angle (30º)

Fs is initial static factor of safety (2)

8.7.3.37 A sensitivity analysis approach is adopted to calculate the PPV limit of boulders that may be resting on the natural terrain as rock boulders can exist in various locations of the natural terrain. Conservative rock parameters and critical angle of natural terrain are assumed in the analysis and the calculate PPV limit of boulders is 90mm/s which is also adopted in WIL EIA.

8.7.3.38 Rock boulders ranging from 1m to 5m in size are assessed for their critical vibration level to initiate movement and it is found that smaller boulders will result in a lower PPV limit and this has been adopted for further analysis. Based on the observed natural terrain slope angle, a global factor of safety of 2 is applied to the calculated vibration limit to assign the allowable PPV of rock boulder.

8.7.3.39 Boulder survey will be carried out and the assessment of specific boulder hazard will be undertaken for all areas of natural terrains within the 5mm/s vibration contour zone. For those areas where existing boulder survey is available, the risk of instability will be individually assessed if the boulders are resting on slope larger than 30°. After the individual assessment of the boulders, those boulders identified as having potential instability will be stabilized or protective measures will be installed before the commencement of blasting.

8.7.3.40 According to the GEO reported landslide inventory, there was no landslide incidents related to failure of natural terrain within the hillside catchments affected by the blasting works. The only reported landslide incident related to natural terrain was beyond the blasting influence zone.

8.7.3.41 The residual risk of natural terrain landslide due to blasting is usually low with the ground surface vibration due to the blasting limited to 25mm/s, provided that no blasting would be carried out during periods of high rainfall. In fact, no blasting will be permitted during the periods of Black / Red rainstorm warnings, or Typhoon Signal T3 or higher.

8.7.3.42 Conservative rock parameters and critical angle of natural terrain, boulder size is 5m are assumed which are also adopted in STC STW EIA. The calculated PPVc is 90mm/s. Boulders are assumed to have 1% chance to fall when it experiences a ground vibration greater than PPVc calculated. This potentially exists for the errors during transport from tunnel portal to blast face.

Table 8.27 Influence Zone of different PPVc values from 1MIC to 6MIC for Effect on Boulders

PPVc (mm/s)	Influence zone (m)						
	At blast face						Transport from tunnel portal to blast face (130kg)
	1MIC (10kg)	2MIC (20kg)	3MIC (30kg)	4MIC (40kg)	5MIC (50kg)	6MIC (60kg)	
90	26.4	37.4	45.8	52.9	59.1	64.7	21.9

Tertiary Hazards

Landslide Consequence

8.7.3.43 The travel distance of landslide debris is affected by the mechanism of its failure. For instance, a landslide induced by rainfall would be expected to travel further than the one caused by blasting because soil and rock under liquid manner tends to travel further away. Hence, the travel distance for rainfall induced landslides is based on the inclination of 15° to 30°. For the travel angle of a typical rain induced landslide involves a landslide volume less than 2000m^3, it generally ranges from 30° to 40° which is stated in the GEO Report No.81.It is assumed that a landslide caused will detonation of explosives will result in a travel angle of 30° due to conservative approach.

8.7.3.44 By assuming the slope is a triangular volume, the run out distance for the landslide can be approximated by the equation:

$$L = \sqrt{\frac{2V}{W \tan(30°)}}$$

Where L is the run out distance in m

V is the slip volume in m^3; and

W is the slip width in m

Boulder Fall Consequence

8.7.3.45 The consequence of boulder fall is according to the methodology introduced in the GEO Report No.81.The probability of a moving vehicle hit by a falling rock with a diameter greater than 150mm is based on the fraction of the road occupied by the vehicle which is defined as:

$$P(S{:}H) = (AADT \times Length\ of\ the\ vehicle) / (Average\ vehicle\ speed \times 24{,}000)$$

Where AADT is the annual average daily traffic

Length of the vehicle is assumed to be 5m

Average vehicle speed is assumed to be 30 miles/hr (i.e. 48 km/hr); and

Conversion factors for unit is 24,000

8.7.3.46 The above equation is then modified to calculate the probability of a pedestrian getting hit by a falling rock with a diameter greater than 150mm as below:

$$P(S{:}H) = \frac{Number\ of\ pedestrians\ per\ day \times Width\ of\ a\ person}{Average\ walking\ speed \times 24{,}000}$$

Where Number of pedestrians per day is obtained by site survey

Width of a person is assumed to be 1m

Average walking speed is assumed to be 5 km/hr; and

Conversion factors for unit is 24,000

8.7.3.47 The probability that a rock hits a vehicle or a pedestrian is then given by:

$$P(S) = 1 - \{1 - P(S{:}H)\}^{Nrf}$$

8.7.3.48 It is assumed that the probability of loss of life of an occupant given a vehicle is hit by a rock is 0.2. The probability may be affected by the size of the rock, the number of occupants within the vehicle and the construction of vehicle.

8.7.3.49 Moreover, the stopping distance of the vehicle can also affect the consequence of a vehicle hitting a falling boulder. The value of stopping distance can then be replaced as the average length of the vehicle and a probability of fatality to an occupant is assumed to be 0.1.

8.7.3.50 With reference to WIL EIA and STC STW EIA, it was suggested that the fatality of pedestrians hit by falling boulders is 100%.

8.7.3.51 Since several buildings were found near potential boulders, the affected population are calculated by the proportion of the area of a boulder to the floor area of the buildings as shown in the following equation:

$$Affected\ population = \frac{Area\ of\ a\ boulder}{Floor\ Area\ of\ the\ building} \times Poulation\ per\ floor$$

8.7.3.52 It is assumed that the fatality of an occupant given a building is hit by a rock is 20% and it is referenced from the probability of loss of life of an occupant inside a New Territories house hit by a boulder given in “Territory Wide Quantitative Risk Assessment of Boulder Fall Hazards: Stage 2 Final Report” (Manusell Geotechnical Services, 2001).

8.7.4 Use of Explosives (Surface Blasting)

<u>*Primary Hazard*</u>

Ground Shock/Vibration Induced from Blasting

8.7.4.1 The methodology to evaluate the ground shock due to detonation of full load of explosives is the same as **Section 8.7.3**, i.e. Ground Shock/Vibrations Generated by Rock Excavation using Explosives.

Blast and Pressure Wave for Above Ground Explosion

8.7.4.2 As discussed in **Section 8.7.2.2**, consequence analysis is based on the UK Explosive Storage and Transport Committee (ESTC) which considers all the effects associated with an above ground explosion including, fireball, overpressure, flying debris, broken glass, structure damage, etc.

8.7.4.3 Futhermore, Davies (1995) investigated that the flyrock range distribution based on the UK and Hong Kong data and found that the flyrock distance is distributed exponentially. The formula for estimating the flyrock speed of the blocks coming from the face is presented as follow:

$$V = K[B/(E_1)^{1/3}]^{-1.17}$$

Where V is the flyrock speed in m/s

B is the depth of the rock perpendicular to the explosive in m which is assumed as 3m

K is the coefficient expressing the probability of attaining the estimated speed

E_1 is the linear energy of the explosive charge expressed in MJ/m which is assumed as 15.92 MJ/m for 1MIC

8.7.4.4 Blanchier (2013) suggested that the variation of coefficient K would follow a normal distribution.

Table 8.28 Variation of coefficient K

Probability of speed attainment	50%	5%	1%	0.1%	0.01%
Coefficient K	14	25	32	40.7	50.4

8.7.4.5 With the speed available, the maximum range of flyrock can be calculated using the equation below.

$$X = V\cos\alpha[V\sin\alpha\,(V^2\sin^2\alpha + 2gh)^{1/2}]/g$$

Where α Is the angle to the horizontal ground, 30 deg is adopted for maximizing the value for maximum range of flyrock X

8.7.4.6 The typical size of the fragment after blasting is less than $0.2m^3$. For conservative assessment, the outdoor fatality due to flyrock hitting is taken to be 1 while the indoor fatality rate is assumed to be 0 due to the structural protection.

<u>Secondary Hazard</u>

Effect on Buildings

8.7.4.7 As ground vibration would also be induced from surface blasting and cause building collapse which is similar to tunnel blasting, the approach to assess the impact on buildings is identical to the one mentioned in **Section 8.7.3**.

Effect on Slopes

8.7.4.8 Also, ground vibration would cause slope failure which is similar to tunnel blasting. Thus, the methodology to evaluate the impact on slopes is the same as **Section 8.7.3**.

Effect on Natural Terrains and Boulders

8.7.4.9 In addition to assessing the potential impact on man-made features, the blasting assessment also undertook a review of the potential impact that blasting could have on the stability of natural terrains hillsides in the vicinity of the surface blasting site. The approach to assess the impact on natural terrain is similar to tunnel blasting (**Section 8.7.3)**.

8.7.5 Results of Consequence Analysis

Transport and Storage of Explosives

8.7.5.1 The consequence results for each transport and storage scenario are summarized in **Table 8.29**.

8.7.5.2 According to the latest design, the maximum amount of explosives stored at the magazine site is 1400 TNT eqv. kg (350 TNT eqv. kg storage capacity per store); the quantity of explosives of each trip is about 80 to 130 TNT eqv. kg. It is therefore assumed as the maximum transportation rate is 130 TNT eqv. kg. This 130 TNT eqv. kg is also the amount of full load of explosives in one contractor truck on access road from delivery point to tunnel portal of use of explosives.

8.7.5.3 The proposed explosives magazine is located around 260m away from the nearest building structure which has greatly exceeded the 1% fatality distance. Therefore, no significant risk of fatality due to explosives storage is expected.

Table 8.29 Summary of Results for Consequence Scenarios

Scenario	Fatality probability for Explosives	Impact distance (m)	
		Indoor	Outdoor
Storage of explosive (300 TNT eqv. kg)	90%	21.0	16.8
	50%	24.3	17.5
	10%	36.1	19.4
	3%	48.3	20.8
	1%	63.0	22.0
Storage of explosive (350 TNT eqv. kg)	90%	22.1	17.7
	50%	25.6	18.4
	10%	38.0	20.4
	3%	50.8	21.9
	1%	66.5	23.2
Storage of explosive (100 TNT eqv. kg)	90%	14.6	11.7
	50%	16.9	12.1
	10%	25.0	13.4
	3%	33.5	14.4
	1%	43.8	15.3

Scenario	**Fatality probability for Explosives**	**Impact distance (m)**	
		Indoor	**Outdoor**
Transport of explosives (80 TNT eqv. kg)	90%	13.5	10.8
	50%	15.7	11.3
	10%	23.2	12.5
	3%	31.1	13.4
	1%	40.7	14.2
Transport of explosives (130 TNT eqv. kg)	90%	15.9	12.7
	50%	18.4	13.3
	10%	27.3	14.7
	3%	36.6	15.7
	1%	47.8	16.7

Note:

[1] Distances are rounded up to one decimal place.

Use of Explosives (Tunnel Blasting)

Blast Effects due to Detonation of Full Load during the Transfer of Explosives from Delivery Point to Blast Site

8.7.5.4 Blast effects due to detonation of a full load during the transfer of explosives are summarised in **Table 8.30**.

Table 8.30 Summary of Results for Consequence Scenarios

Scenario	**Fatality probability for Explosives**	**Impact distance (m)**	
		Indoor	**Outdoor**
Transport of explosives (80 TNT eqv. kg)	90%	13.5	10.8
	50%	15.7	11.3
	10%	23.2	12.5
	3%	31.1	13.4
	1%	40.7	14.2
Transport of explosives (130 TNT eqv. kg)	90%	15.9	12.7
	50%	18.4	13.3
	10%	27.3	14.7
	3%	36.6	15.7
	1%	47.8	16.7

Effect on Building

8.7.5.5 No building was found exceeding PPV of 229mm/s and 100mm/s. Hence, the building structural element collapse and object falling is not further considered.

Effect on Slopes

8.7.5.6 A series of man-made slope features have been identified for further assessment based on the screening criterion of PPV (PPVc) =90mm/s during tunnel blasting. The data of the affected slopes are summarised in **Table 8.31**.

Table 8.31 Analysis of Slopes Exceeding Peak Particle Velocity of 90mm/s due to Accidental Initiation during the Construction of Tunnel

Slope No.	Height (m)	Length (m)	Angle (deg)	PPVc (mm/s)	Maximum PPV correspond to 0.01% slope failure (mm/s)
6SW-D/FR68	15	14	41	90	122.5
6SW-D/C188	11	72.8	40	90	115.7
6SW-D/R99	3.5	38	90	90	91.8
6SW-C/FR32	8	130	33	90	105.0
6SW-D/C93	4	36	65	90	110.4
6SW-D/FR53	21	45	30	90	94.1
6SW-D/F70	16	60	34	90	107.3
6SW-D/C409	30	375	50	90	99.6
6SW-D/C44	35	125	36	90	93.3
6SW-C/C290	3.4	30	55	90	98.1
6SW-D/FR331	5	90	27	90	92.5
6SW-C/C891	8	55	50	90	101.2

Table 8.32 Slopes Exceeding Peak Particle Velocity of 90mm/s due to Accidental Initiation during the Construction of Tunnel

Slope No.	Scenario Frequency (yr)	Expected Fatality (N)
6SW-D/FR68	2.46E-11	0
6SW-D/C188	2.46E-11	0
6SW-D/R99	2.57E-13	0
6SW-C/FR32	2.57E-13	0
6SW-D/C93	2.46E-11	1
6SW-D/FR53	2.57E-13	0
6SW-D/F70	2.57E-13	0
6SW-D/C409	2.57E-13	197
6SW-D/C44	2.57E-13	197
6SW-C/C290	2.57E-13	0
6SW-D/FR331	2.57E-13	0
6SW-C/C891	2.57E-13	1

Boulder Fall Consequence

8.7.5.7 The type of boulders considered are:

- In-situ Boulders: In-situ boulders are those boulders which have not been displaced since their formation. In-situ boulders include rock outcrops and corestones.
- Transported Boulders: Transported boulders comprise talus or colluvial boulders that have come to rest in the past at a particular location, and may or may not be unstable depending upon the circumstance of their locations, e.g. degree of embedment, local slope angle, etc.

8.7.5.8 The most susceptible type of boulder to ground vibration as well as other environmental factors is the colluvial type. The minimum PPV to cause a landslide failure with 0.01% chance is 90mm/s for the weakest slope. It is assumed that colluvial boulders at this vibration level could be more susceptible to roll. The chance of boulder being dislodged from its position and rolling down the hill has been conservatively assumed as 1%. This is conservative when compared to the criteria used for object falling (100mm/s) from building.

8.7.5.9 Boulder falls frequency and probability of the falling boulders hitting a vehicle or a person are calculated. The results and expected fatalities for boulder fall due to errors in blast faces during the construction of tunnel or accidental detonation of explosives during transport within tunnels are summarised in **Table 8.33**.

Table 8.33 Occurrence Frequencies for a Falling Boulder Striking a Vehicle/ Pedestrian for Accidental Initiation of Explosives from 2MIC to 6MIC due to Errors in Blast Faces

Scenario/Street Name	Scenario Frequency	Expected Fatality (N)
2MIC detonated at the same time		
Major Road (i.e. Tuen Mun Road)	2.95E-08	1
3MIC detonated at the same time		
Major Road (i.e. Tuen Mun Road)	2.69E-10	1
Pedestrian Pavements / Minor Roads	2.69E-10	1
4MIC detonated at the same time		
Major Road (i.e. Tuen Mun Road)	7.84E-12	1
5MIC detonated at the same time		
Major Road (i.e. Tuen Mun Road)	5.22E-12	1
Pedestrian Pavements / Minor Roads	5.22E-12	1
6MIC detonated at the same time		
Major Road (i.e. Tuen Mun Road)	2.61E-12	1
Pedestrian Pavements / Minor Roads	2.61E-12	1

Use of Explosives (Surface Blasting)

Blast and Pressure Wave for Above Ground Explosion

8.7.5.10 The results for air overpressure effects due to human errors and other errors such as manufacturing defects causing deviation from the confirmed design are summarized in **Table 8.34**.

Table 8.34 Summary of Results for Consequence Scenarios

Scenario	Fatality probability for Explosives	Impact distance (m)	
		Indoor	Outdoor
Use of explosives (Surface blasting) (2MIC – 20 TNT eqv. kg)	90%	8.5	6.8
	50%	9.9	7.1
	10%	14.5	7.9
	3%	19.6	8.4
	1%	25.6	8.9
Use of explosives (Surface blasting) (3MIC – 30 TNT eqv. kg)	90%	9.8	7.8
	50%	11.3	8.1
	10%	16.7	9.0
	3%	22.4	9.6
	1%	29.3	10.2

Scenario	Fatality probability for Explosives	Impact distance (m)	
		Indoor	Outdoor
Use of explosives (Surface blasting) (4MIC – 40 TNT eqv. kg)	90%	10.7	8.6
	50%	12.4	8.9
	10%	18.4	9.9
	3%	24.7	10.6
	1%	32.3	11.3
Use of explosives (Surface blasting) (5MIC – 50 TNT eqv. kg)	90%	11.6	9.3
	50%	13.4	9.6
	10%	19.8	10.7
	3%	26.6	11.4
	1%	34.8	12.1
Use of explosives (Surface blasting) (6MIC – 60 TNT eqv. kg)	90%	12.3	9.8
	50%	14.2	10.2
	10%	21.1	11.3
	3%	28.3	12.1
	1%	37.0	12.9

Flyrocks due to Blasting

8.7.5.11 The flyrock speed and maximum range under 2 to 6MIC scenarios for some probability ranges are listed in **Table 8.35**.

Table 8.35 Flyrock Speed and Maximum Range under 2 to 6 MIC Scenarios for some probability ranges

MIC	Probability of speed attainment	50%	5%	1%	0.1%	0.01%
	Coefficient K	14	25	32	40.7	50.4
Site 1: Lam Tei Quarry main cut slopes for approach viaducts						
2	Flyrock speed V (m/s)	14.9	26.7	34.1	43.4	53.7
	Maximum range of flyrock X (m)	60.0	124.7	175.0	248.6	345.7
3	Flyrock speed V (m/s)	17.5	31.2	40.0	50.8	63.0
	Maximum range of flyrock X (m)	72.7	154.6	219.9	316.8	446.3
4	Flyrock speed V (m/s)	19.6	34.9	44.7	56.9	70.4
	Maximum range of flyrock X (m)	83.5	181.0	260.0	378.4	538.0
5	Flyrock speed V (m/s)	21.3	38.1	48.8	62.0	76.8
	Maximum range of flyrock X (m)	93.2	205.1	297.1	435.8	623.9
6	Flyrock speed V (m/s)	22.9	40.9	52.4	66.6	82.5
	Maximum range of flyrock X (m)	102.2	227.7	331.9	490.1	705.5
Site 2: Lam Tei North Portal						
2	Flyrock speed V (m/s)	14.9	26.7	34.1	43.4	53.7
	Maximum range of flyrock X (m)	53.9	114.2	162.1	233.0	327.8
3	Flyrock speed V (m/s)	17.5	31.2	40.0	50.8	63.0
	Maximum range of flyrock X (m)	65.5	142.6	205.3	299.4	426.6
4	Flyrock speed V (m/s)	19.6	34.9	44.7	56.9	70.4

MIC	Probability of speed attainment	50%	5%	1%	0.1%	0.01%
	Coefficient K	**14**	**25**	**32**	**40.7**	**50.4**
	Maximum range of flyrock X (m)	75.6	167.8	244.2	359.8	517.1
5	Flyrock speed V (m/s)	21.3	38.1	48.8	62.0	76.8
	Maximum range of flyrock X (m)	84.6	191.0	280.2	416.2	602.1
6	Flyrock speed V (m/s)	22.9	40.9	52.4	66.6	82.5
	Maximum range of flyrock X (m)	93.0	212.8	314.3	469.8	683.1
Site 3: Site Formation at the northern landfall of the Tsing Lung Bridge including the Bridge anchorage						
2	Flyrock speed V (m/s)	14.9	26.7	34.1	43.4	53.7
	Maximum range of flyrock X (m)	66.1	135.1	188.0	264.4	364.2
3	Flyrock speed V (m/s)	17.5	31.2	40.0	50.8	63.0
	Maximum range of flyrock X (m)	79.8	166.6	234.7	334.5	466.7
4	Flyrock speed V (m/s)	19.6	34.9	44.7	56.9	70.4
	Maximum range of flyrock X (m)	91.4	194.2	276.2	397.5	559.8
5	Flyrock speed V (m/s)	21.3	38.1	48.8	62.0	76.8
	Maximum range of flyrock X (m)	101.8	219.4	314.3	456.0	646.8
6	Flyrock speed V (m/s)	22.9	40.9	52.4	66.6	82.5
	Maximum range of flyrock X (m)	111.3	242.8	350.1	511.3	729.2
Site 4: North Lantau cutting						
2	Flyrock speed V (m/s)	14.9	26.7	34.1	43.4	53.7
	Maximum range of flyrock X (m)	69.0	140.2	194.4	272.1	373.3
3	Flyrock speed V (m/s)	17.5	31.2	40.0	50.8	63.0
	Maximum range of flyrock X (m)	83.2	172.5	242.0	343.3	477.0
4	Flyrock speed V (m/s)	19.6	34.9	44.7	56.9	70.4
	Maximum range of flyrock X (m)	95.2	200.7	284.1	407.1	570.8
5	Flyrock speed V (m/s)	21.3	38.1	48.8	62.0	76.8
	Maximum range of flyrock X (m)	106.0	226.4	322.8	466.1	658.3
6	Flyrock speed V (m/s)	22.9	40.9	52.4	66.6	82.5
	Maximum range of flyrock X (m)	115.7	250.2	359.0	521.8	741.2

Effect on Building

8.7.5.12 The maximum PPV of the buildings of 140mm/s was found and thus the building structural element collapse threshold (PPV = 229mm/s) considering accidental explosion up to 6MIC is not applicable. However, some features along the alignment would reach the object falling threshold (PPV = 100mm/s, the 1% fatality threshold), the results are summarized as below.

Table 8.36 Buildings affected by higher vibration generated by accidental initiation during Surface Blasting due to human errors

Features Affected	Scenario Frequency (year) [1]	Expected Fatality (N) [2,3]
2MIC detonated at the same time		
Temporary Structure (817088, 830402)	1.21E-05	0
Temporary Structure (817099, 830390)	1.21E-05	0
4MIC detonated at the same time		
Building (817033, 830485)	1.08E-09	0

Features Affected	Scenario Frequency (year) [1]	Expected Fatality (N) [2,3]
Temporary Structure (817088, 830402)	1.08E-09	0
Temporary Structure (817099, 830390)	1.08E-09	0
5MIC detonated at the same time		
Temporary Structure (817037, 830470)	1.08E-09	0
Temporary Structure (817040, 830506)	1.08E-09	0
Building (817033, 830485)	1.08E-09	0
Temporary Structure (817088, 830402)	1.08E-09	0
Temporary Structure (817099, 830390)	1.08E-09	0
6MIC detonated at the same time		
Temporary Structure (817129, 830580)	1.08E-09	0
Temporary Structure (817047, 830528)	1.08E-09	0
Temporary Structure (817037, 830470)	1.08E-09	0
Temporary Structure (817040, 830506)	1.08E-09	0
Building (817033, 830485)	1.08E-09	0
Temporary Structure (817088, 830402)	1.08E-09	0
Temporary Structure (817099, 830390)	1.08E-09	0

Notes:

[1] This value is obtained from **Table 8.20**.

[2] Expected fatality = Population x Fatality rate

[3] 1% fatality threshold reached

Effect on Slopes

8.7.5.13 A series of man-made slope features have been identified for further assessment based on the screening criterion of PPV (PPVc) =90mm/s during tunnel blasting. The data of the affected slopes are summarised in **Table 8.37**.

Table 8.37 Analysis of Slopes Exceeding Peak Particle Velocity of 90mm/s due to Accidental Initiation during Surface Blasting

Slope No.	Height (m)	Length (m)	Angle (deg)	PPVc (mm/s)	Maximum PPV correspond to 0.01% slope failure (mm/s)
10NE-A/F18	8	5	30	90	100.3
10NE-A/C111	53	85	40	90	112.6
10NE-A/C110	53	240	50	90	99.7
10NE-A/C114	12	13	20	90	119.5
10NE-A/C113	17	4	25	90	101.3
6NW-C/C353	5	80	70	90	117.8
6SW-D/R2	6.5	60	85	90	101.9
6SW-D/F87	5	32	25	90	93.8
6SW-D/C182	2.8	63	50	90	90.9
6SW-D/F88	6	45	25	90	134.6
6SW-D/FR43	16	90	35	90	142.1
6NW-C/F223	20	150	35	90	91.3
6NW-C/C320	17	330	60	90	95.5
6NW-C/C357	8.5	52	85	90	143.6
6NW-C/C347	10	200	70	90	133.3
6NW-C/C350	10	140	60	90	96.3

Slope No.	Height (m)	Length (m)	Angle (deg)	PPVc (mm/s)	Maximum PPV correspond to 0.01% slope failure (mm/s)
6NW-C/C351	11	50	50	90	96.4
6NW-C/C346	20	80	60	90	102.6
6NW-C/C355	20.5	40	70	90	116.3
6NW-C/C356	6	179	70	90	126.8
6NW-C/C337	12	81.5	60	90	91.3
6NW-C/C338	10	35.5	60	90	90.2
6NW-C/C362	5	193	70	90	108.8
6NW-C/C334	20.5	178	60	90	117.9
6NW-C/C370	7.5	145	70	90	138.5
6NW-C/C369	7.5	355	70	90	131.5

Table 8.38 Slopes Exceeding Peak Particle Velocity of 90mm/s due to Accidental Initiation during Surface Blasting

Slope No.	Scenario Frequency (yr)	Expected Fatality (N)
10NE-A/F18	1.08E-13	0
10NE-A/C111	1.08E-11	0
10NE-A/C110	1.08E-13	0
10NE-A/C114	1.08E-11	0
10NE-A/C113	1.08E-13	0
6NW-C/C353	1.08E-11	0
6SW-D/R2	1.08E-13	0
6SW-D/F87	1.08E-13	0
6SW-D/C182	1.08E-13	0
6SW-D/F88	1.08E-11	0
6SW-D/FR43	1.08E-11	0
6NW-C/F223	1.08E-11	0
6NW-C/C320	1.08E-13	0
6NW-C/C357	1.08E-11	0
6NW-C/C347	1.08E-11	0
6NW-C/C350	1.08E-13	0
6NW-C/C351	1.08E-13	0
6NW-C/C346	1.08E-13	0
6NW-C/C355	1.08E-11	0
6NW-C/C356	1.08E-11	0
6NW-C/C337	1.08E-13	0
6NW-C/C338	1.08E-13	0
6NW-C/C362	1.08E-13	0
6NW-C/C334	1.08E-11	0
6NW-C/C370	1.08E-13	0
6NW-C/C369	1.08E-13	0

*Boulders Consequenc*e

8.7.5.14 Although some boulders may have the potential to be dislodged, there is no impact to population nearby. Hence, fatality due to a boulder hitting was not further considered.

8.7.6 Effects on Water Service Reservoir

<u>WSD Fresh Water Supplies Reservoir near the Siu Lam Magazine Site</u>

8.7.6.1 The Siu Lam Fresh Water Supplies Reservoir is situated at about 83m from the proposed explosive magazine site at Siu Lam. In previous sections, the fatality consequence model (ESTC model) was used to assess hazard to life.

8.7.6.2 Since the separation distance has fulfilled Class B distance of the UK HSE's Explosives Regulations 2014, there should be no direct risk to workers at the WSD facility from the proposed magazine site. However, the WSD facility may be damaged due to accidental detonation of magazine site which may lead to secondary hazards and cause the loss of life. Thus, the maximum storage quantity of explosives at a store will be limited at 300 TNT eqv. kg to ensure the explosion impact from initiation of this quantity of explosives would not lead to damage to the structure. The Class B distance criteria based on the UK HSE's Explosives Regulations 2014 is presented in **Table 8.39**

Table 8.39 Class B Distance of the UK HSE's Explosives Regulations 2014

Quantity of explosives (kg)	Class B Distance (m)
250 – 300	80
300 – 350	86

<u>WSD Fresh Water Service Reservoir near the Pillar Point Magazine Site</u>

8.7.6.3 Tuen Mun West No.2 Fresh Water Service Reservoir is located at about 88m from the proposed explosive magazine site at Pillar Point. Since the separation distance has fulfilled Class B distance of the Explosive Regulations 2014, there should be no direct risk to workers at the WSD facility from the proposed magazine site. However, the WSD facility may be damaged due to accidental detonation of magazine site which may lead to secondary hazards and cause the loss of life. Thus, the maximum storage quantity of explosives at a store will be limited at 350 TNT eqv. kg. to ensure the explosion overpressure from initiation of this quantity of explosives would not create an overpressure which would damage the structure.

8.7.7 Consideration of Cumulative Impacts

<u>Tai Lam Chung No.2 Chlorination Station</u>

8.7.7.1 As discussed previously, TLCCS would likely be delisted from the PHI Registers prior to the construction commencement. Hence, there would not be any cumulative hazard-to-life impacts with the use of explosives inside the drill-and-blast tunnel sections regarding the hazards induced by PHI, although the alignment of the Project has fallen within the CZ of TLCCS.

<u>Tuen Mun Bypass</u>

8.7.7.2 As discussed previously, cumulative impact from TMB has been assessed.

8.7.7.3 Since part of the transportation routes for TMB overlaps with the transportation routes of this Project, the risk induced from the transportation of explosives for TMB has also been covered in this QRA.

8.7.7.4 Moreover, as TMB will use the same magazines (i.e. Lam Tei Quarry Magazine, Pillar Point Magazine and Siu Lam Magazine) with this Project, the risk induced from the overnight storage has also included the explosives required for the construction of TMB.

Lam Tei Underground Quarrying

8.7.7.5 As discussed, detailed information is yet to be provided during preparation of this QRA, However, the EIA study of LTUQ would include this Project as its concurrent Project and consider the risk arising from this Project. Moreover, interface meetings between LTUQ, TMB and the Project have been and would continue to carry out to agree on the design interface of each project to minimise the impact of each project and the cumulative impact.

8.8 Risk Evaluation

8.8.1 Introduction

8.8.1.1 Individual risk is the frequency of fatality per individual per year due to the realization of specified hazards and is evaluated by summing the contributions to that risk across a spectrum of incidents which could occur at a particular location. The equation for the calculation of Individual Risk is shown below:

$$\Delta IR_{S,M,\varphi,i} = f_S \times P_{\mathrm{M}} \times P_{\varphi} \times P_i \times P_d \quad (per\ year)$$

Where
- f_s is the failure frequency of Loss of Containment event (LOC)
- P_M is the probability of a weather class
- $P\varphi$ is the probability of a wind direction
- P_i is the probability of an ignition event
- P_d is the probability of death

8.8.1.2 Societal risk is defined as the risk to a group of people due to all hazards arising from a hazardous installation or activity. A cumulative graph of the spectrum of the possible consequences and their frequencies is presented as an FN curve (cumulative frequency F against number of fatalities N) and the acceptability of the results can be judged against the societal risk criterion under the risk guideline.

8.8.1.3 From the above analyses, consequences and their corresponding frequencies for each representative location are summed up for the whole Project using the risk summation tools in the SAFETI 8.7 software package. By summing up all hazard events, individual risk as well as societal risk associated with the identified hazardous scenarios are obtained and compared with the criteria set out in Annex 4 of the TM-EIAO to determine their acceptability.

8.8.2 Individual Risk

8.8.2.1 The individual risk (IR) due to use, overnight storage and transport of explosives is shown in **Appendix 8.8**. For use and transportation of explosives, the maximum level of off-site individual risk does not exceed the criterion of 1e-5 per year. On comparing with the criteria in HKRG, the individual risk is acceptable.

8.8.2.2 For overnight storage of explosives, the 1e-5 per year contour line is beyond the boundary of Pillar Point and Siu Lam magazine site. However, the impact area is only on woodland areas where there is no continuous presence of people. As a result, there is no member of public will be exposed to an individual risk of 1e-5 per year, and the actual risk to any individual will be much smaller than 1e-5 per year and is deemed to be acceptable.

8.8.3 Societal Risk

8.8.3.1 Based on the frequency analysis and consequence modelling for different hazard scenarios as discussed in **Section 8.5**, the societal risk plots, i.e. F-N curves, (cumulative frequency F against number of fatalities N) have been derived and shown in **Appendix 8.9**. Total two cases had been conducted:

Table 8.40 Scenarios Considered in this Assessment

Tag	Scenario included of modelling cases
Case 1: Pillar Point Magazine site not required for storage of explosive for Route 11	
Storage of Explosives	
01	Detonation of full load of explosives in one store in Siu Lam Magazine Site
15	Detonation of full load of explosives in one niche in Lam Tei Quarry Magazine Site
Transport of Explosives	
03	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of LTT South Portal
04	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TLCT North Portal
05	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TLCT South Portal
06	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of SKWLR East Portal
07	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of SKWLR West Portal
08	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TLCTN
Transport of Explosives (for Tuen Mun Bypass)	
T03	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TMB Northern Tunnel North Portal
Case 2: Pillar Point Magazine site required for storage of explosive	
Storage of Explosives	
01	Detonation of full load of explosives in one store in Siu Lam Magazine Site
02	Detonation of full load of explosives in one store in Pillar Point Magazine Site
15	Detonation of full load of explosives in one niche in Lam Tei Quarry Magazine Site
Transport of Explosives	
04	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TLCT North Portal
05	Detonation of full load of explosives in one contractor truck on public roads – from Siu Lam magazine site to delivery point of TLCT South Portal
08	Detonation of full load of explosives in one contractor truck

Tag	Scenario included of modelling cases
	on public roads – from Siu Lam magazine site to delivery point of TLCTN
09	Detonation of full load of explosives in one contractor truck on public roads – from Pillar Point magazine site to delivery point of SKWLR East Portal
10	Detonation of full load of explosives in one contractor truck on public roads – from Pillar Point magazine site to delivery point of SKWLR West Portal
11	Detonation of full load of explosives in one contractor truck on public roads – from Pillar Point magazine site to delivery point of LTT South Portal
Transport of Explosives (for Tuen Mun Bypass)	
T04	Detonation of full load of explosives in one contractor truck on public roads – from Pillar Point magazine site to delivery point of TMB Northern Tunnel North Portal

8.8.3.2 For the use of explosives, populations affected would be mainly the population in the vicinity of the blast site, i.e. the tunnel, while the overnight storage and transport mainly affect the road population of the transportation routes. Due to the long transportation route, frequencies with higher fatalities (i.e. above 10 fatalities) are normally higher than use of explosives.

8.8.3.3 For the use of explosives, the population in the vicinity of the blast site, i.e. surface blasting site would be mainly affected. Hence, the affected population would be limited as the population nearby are mainly village houses and pedestrian road with low-density. Since the failure frequency for use of explosives is higher than that of transportation of explosives, the societal risk result with lower fatalities (<10) is higher and has entered the "ALARP" region.

8.8.3.4 For overnight storage and transportation of explosives, the population along the transportation routes would be affected mostly. Due to the long transportation route and higher population density within the 100m influence zone along the routes, higher fatalities especially the transportation routes from Pillar Point Magazine Site were observed as the vehicles would travel across populated area such as Tuen Mun Town Centre. Although transportation of explosives results in higher fatalities, the accumulative frequency is normally at 1E-05/year which is one order lower than the use of explosive. The lower frequency reflects in the risk results which Case 1 is within the "ACCEPTABLE" region while Case 2 entered the "ALARP" region due to higher population near Tuen Mun Town Centre.

8.8.3.5 As seen from **Appendix 8.9**, cumulative impact is within the "ALARP", ALARP assessment, i.e. cost-benefit analysis, is therefore conducted to demonstrate the risk will be as low as reasonably practicable and presented in following sections.

8.8.3.6 Moreover, the presented scenario has already considered the worst case by increasing the QRA results of base case scenario by 20% and assuming the explosives to be transported 7 working days a week (no holiday). Therefore, the risk under actual circumstances would be further lower.

8.8.4 Potential Loss of Life

8.8.4.1 The Potential Loss of Life (PLL) value is the summation of the product of each fN pair. The PLL values and the breakdown by time mode are shown in **Table**

8.41. The higher PLL value of use of explosives is due to the higher occurrence frequency of use of explosive as mentioned in societal risk section above.

Table 8.41 PLL Values

Scenario	PLL Value	PLL (%)
Case 1: Pillar Point Magazine site not required for storage of explosive		
Storage of Explosive	2.02E-07	0.33%
Transport of Explosive	1.34E-05	22.10%
Use of Explosive (Tunnel Blasting)	4.14E-05	68.24%
Use of Explosive (Surface Blasting)	5.65E-06	9.32%
Overall	6.06E-05	100%
Case 2: Pillar Point Magazine site required for storage of explosive		
Storage of Explosive	2.02E-07	0.25%
Transport of Explosive	3.27E-05	40.91%
Use of Explosive (Tunnel Blasting)	4.14E-05	51.77%
Use of Explosive (Surface Blasting)	5.65E-06	7.07%
Overall	7.99E-05	100%

8.8.5 Uncertainty Analysis

8.8.5.1 The hazard-to-life assessment is based on a number of assumptions as previously highlighted in various sections of this chapter. Uncertainties are discussed in following sections.

Transport of Explosives

Traffic Jam Condition

8.8.5.2 Explosive initiation following a vehicle fire could impact a queuing traffic (half jammed) conservatively assumed to occur on each lane on either side of the road. This traffic jam condition has been considered in the assessment. This approach was also adopted in XRL EIA and STC STW EIA.

Explosion Consequence Model

8.8.5.3 The ESTC models adopted would be conservative on fatalities when compared to the fatalities in past incidents relating to explosives. In the past five years, i.e. 2017 to 2021, the maximum monthly fatalities of traffic accidents was 23 in Hong Kong. On the other hand, research studies performed by the HSE indicated that the ESTC models may underpredict the fatalities caused by flying glass in highly built-up areas. However, ESTC models are still the best available model and are widely adopted in approved EIAs.

Intervention of the Explosives Truck Crew

8.8.5.4 As fire extinguishers are provided at the explosives truck, explosives truck crew is possible to control the fire developing on the truck before fully development of the fire. However, given that a fire could fully develop and critical explosive temperature can be reached within a couple of minutes, no credit was given for intervention of the explosives truck crew as a conservative approach.

Intervention of the Fire Services Department

8.8.5.5 As a fire could fully develop and critical explosive temperature can be reached within a couple of minutes, the fire would be fully developed before the fire brigade arrives. The intervention of the fire brigade is therefore limited. It is therefore considered that no credit has been given for the intervention of the fire brigade as a conservative approach.

Escape and Evacuation

8.8.5.6 Vehicle occupants and pedestrians near the accident would be easy to evacuate while people in the surrounding buildings would be relatively more difficult to evacuate. However, modelling such escape scenario would only slightly reduce the consequence and the impact on risk would be minimum. As such, no credit was given for people to escape as a conservative approach.

Explosive Initiation under Thermal Stimulus

8.8.5.7 Even the consequences are calculated by the ESTC model, there are some uncertainties associated with the probability of explosion for explosives load that composed of a mix of cartridge emulsion and detonating cords in a fire during transportation. The probability used in this assessment has been based on accident statistics applicable to ANFO which is more sensitive than emulsion and transported in a different manner. In absence of test data, this assumption is on the conservative side.

8.9 ALARP Assessment

8.9.1 Risk Results and Approach to ALARP

8.9.1.1 Once the F-N curve falls within the ALARP zone, risk mitigations should be implemented to ensure the risk level is 'as low as reasonably practicable'.

8.9.1.2 To identify whether the risk mitigations options are 'practicable', the components to be considered are the cost of the option and whether the mitigation can be implemented in the Project without affecting the construction programme.

8.9.1.3 After identifying whether the mitigation options are 'practicable', the reasonability should also be considered and it is usually reviewing the proportion between the cost of implementing the option and the achieved safety benefits.

8.9.1.4 Risk mitigation measures can be engineered measures, controls in the zones which has the most impact after assessing different hazardous scenarios presented by this Project, or operation and procedural controls.

8.9.1.5 The following section presents the approach and the outcome of the ALARP assessment.

8.9.2 Approach to ALARP Assessment

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

8.9.2.2 In this Project, CBA, if needed, would be applied by calculating the implied cost of averting a fatality (ICAF) for various mitigation measures identified. The ICAF value is calculated as follows:

$$ICAF = \frac{Cost\ of\ mitigation\ mesasure}{Recuction\ in\ PLL\ value \times Design\ life\ of\ mitigation\ measure}$$

Where PLL Potential Loss of Life (PLL) value is the summation of the product of each f-N pair

8.9.2.3 ICAF is a measure of the cost per life saved over the lifetime of the project due to implementation of a particular mitigation measure. It may be compared with the value of life to determine whether a mitigation measure is reasonably practicable to implement, i.e. if ICAF is less than the value of life, then the mitigation measure should be implemented. In this study the value of life is taken as HK$33M per person, which is the same figure as used in previous risk assessment reports including QRA of STCSTW EIA. An aversion factor is taken as 20 which is based on the methodology for application of the 'aversion factor' follows that developed by EPD (1996), as the F-N curve, although in the lower ALARP region of the Risk Guidelines, runs close to the 1000 fatalities cut-off line. The adjusted value of life using the aversion factor of 20 is thus HK$660M. This is the value to measure how much the society is willing to invest to prevent a fatality, where there is potential for an event to cause multiple fatalities.

8.9.2.4 To identify whether the mitigation measures, the Maximum Justifiable Expenditure (MJE) is estimated for determining whether a mitigation measure is justifiable. The value of MJE will be calculated by assuming the risk is reduced to zero while justifiable mitigation measures will be examined by considering its actual reduction in PLL in the calculation of safety benefit. The equation of MJE is as follows:

$$MJE = Recuction\ in\ PLL\ value \times Design\ life\ of\ mitigation\ measure \times HK\$660M$$

8.9.2.5 The mitigation measures will be considered as justifiable if the cost is less than the value of MJE and the implementation cost for this option is not more than the calculated safety benefits.

8.9.2.6 The capital and operational costs should only be included as the implementation cost of mitigation measures. Any costs related to design or change of design should be excluded.

8.9.2.7 Some mitigation measures may not be able to quantify the cost-benefits, so a qualitative approach will be used in these cases.

Maximum Justifiable Expenditure

8.9.2.8 The MJE for this project is calculated with a conservative aversion factor of 20.

$$\begin{aligned} MJE &= Value\ of\ preventing\ a\ Fatality \times Aversion\ Factor \times \\ &\quad Maximum\ PLL\ value \times Design\ Life\ of\ mitigation\ measures \\ &= HK\$33M \times 20 \times 7.99 \times 10^{-5} \times 6 \\ &= HK\$0.32M \end{aligned}$$

8.9.2.9 Where the overall PLL, i.e. 1.02E-4, is adopted while the design life is 6 years, i.e. the duration of blasting. The MJE calculated is HK$0.40M. The mitigation measure should be potentially justifiable if its cost is less than MJE which is HK$0.40M.

8.9.3 Potential Justifiable Mitigation Measures

8.9.3.1 The approach considered the identification of options pertaining in the following broad categories:

- Options of using alternative methods of construction such as Tunnel Boring Machine (TBM);
- Options of using magazines closer to the construction sites;
- Options of using different explosive types;
- Options of reducing the quantities of explosives to be used;
- Options considering improved design of the explosives carrying vehicle; and
- Options considering better risk management systems and procedures.

8.9.3.2 **Table 8.42** below summarized the mitigation measures proposed. Even the results shows that the mitigation measures are not justified, some of the mitigation measures are still adopted as good practices and detailed in **Section 8.9.6**.

Use of Alternative Methods of Construction

8.9.3.3 Using hard rock tunnel boring machines is an option for constructing hard rock tunnel. Since the TBM using in this project can only be used for soft rock and soil, if TBM is chosen to construct the whole tunnel, TBM specially for hard rock tunnel should be procured. However, this type of TBMs require several hundreds of millions of Hong Kong Dollars each which has exceeded the MJE a lot.

8.9.3.4 Although the cost for design and change of design is not included, additional work and resources will be required for studying the tunnel profile. Moreover, explosives need to be used to enlarge the circular TBM driven tunnel as the diameter of TBM tunnel is fixed.

8.9.3.5 Moreover, the availability for such TBMs is relatively low in Hong Kong and additional blasting is needed for non-circular sector which may cause several months delay of construction programme.

8.9.3.6 Therefore, this option is not practicable and justifiable for tunnelling blasting on a cost basis.

8.9.3.7 Moreover, using mechanical breaking is another possible construction method for replacing surface blasting. Although mechanical breaking can eliminate the risks induced by surface blasting such as flyrock, ground shock, the cost for mechanical breaking is much higher and the time required is much longer than surface blasting.

8.9.3.8 For instance, for mechanical breaking of Tsing Lung Tau, the time required for open blasting is around 3 months while the time required for mechanical breaking is around 20 to 30 years which would greatly affect the construction programme of this Project. Furthermore, the cost of mechanical breaking for the same area is around 2.5 times higher than the cost for open blasting.

8.9.3.9 Hence, replacing open blasting with mechanical breaking is neither practicable nor justifiable for surface blasting on a cost basis.

Use of Magazines Closer to the Construction Sites

8.9.3.10 As discussed in **Section 8.2.4,** amongst the candidate magazine sites, only 3 sites were retained as practicable, which is Lam Tei Quarry, Siu Lam and Pillar Point magazine sites.

8.9.3.11 Although Tai Shu Ha Road West magazine site has been under consideration, it has been proposed by MTR Corporation Limited for NOL project while the remaining are available for storage of explosives.

8.9.3.12 Therefore, Lam Tei Quarry, Siu Lam and Pillar Point magazine sites are selected.

Use of Alternative Explosives with Smaller Quantities

8.9.3.13 The type of explosives used in the Project is already considered as the safest type for blasting application, so no safety benefits will be obtained by selecting a different type of explosives.

8.9.3.14 In this project, PETN is used as the detonating cord with a melting point around 140°C. Although there are other detonating cord technologies available such as Research Department explosive (RDX) and High Melting Explosive (HMX), their melting points are slightly higher than that of PETN which may require more than before an explosion occurs following a fire event. However, the extra time required and risk reduction by implementing this mitigation measure would be neglected for the purpose of this assessment.

8.9.3.15 Hence, this option is not considered further.

Use of Smaller Explosives Quantities

8.9.3.16 This project has already considered the minimum amount of explosives for transportation as it will transport initiating explosives only and the bulk emulsion explosives will be manufactured on site.

8.9.3.17 It is possible to use smaller explosive charges for initiating explosives such as cast boosters and the main component of cast boosters is PETN. Although use of cast boosters can reduce the amount of explosives transported, it has a higher TNT equivalency and it does not eliminate the need for detonating cord.

8.9.3.18 The minimum cost for maximizing the use of cast boosters is several hundred thousands dollars which is much higher than MJE. Therefore, the additional cost of utilizing cast boosters would further increase its cost which make this option not justifiable on a cost basis.

8.9.3.19 Apart from its cost, there are only limited suppliers who can provide this material, so the availability of cast boosters is also another limitation causing this option not reasonably practicable.

Safer Design of the Explosives Carrying Vehicle

8.9.3.20 The design of the truck has been reviewed to identify potential improvements which can reduce the risk such as preventing the fire spreading to the explosive load. It is assumed that the explosives carrying vehicle has already followed the guideline provided by Mines Division. For example, an additional vertical fire screen with heat resistance equivalent to 3mm of steel should be installed between the vehicle cabin and the cargo compartment of contractor's truck.

8.9.3.21 Besides assuring the contractor's truck has fully complied the requirement of Guidance Note No. GN2 published by Mines Division. There are also some simple measures can be implemented. For instance, limiting the fuel tank capacity and reducing the combustible load on the explosives by using fire retardant materials wherever possible.

8.9.3.22 Since the safety benefits of these measures are difficult to evaluate quantitatively, they are included in the section regarding good practices (**Section 8.9.6**).

Reduction of Accident Involvement Frequency

8.9.3.23 The accident involvement frequency of the explosives carrying vehicle can be reduced through the training programme for both the driver and his attendants, regular "toolbox" briefing sessions, implementation of a defensive driving attitude, appropriate driver selection based on good safety record and regular medical checks.

8.9.3.24 The actual implementation of this option is provided in the recommendation section (**Section 8.9.6**).

Reduction of Fire Involvement Frequency

8.9.3.25 The fire involvement frequency can be reduced by putting better types of fire extinguishers with bigger capacity inside the explosive carrying trucks.

8.9.3.26 Moreover, it can be reduced by providing emergency plans and training to ensure that the suitable fire extinguishers are used and attempt is made to evacuate the area of the incident or securing the explosive load if possible.

8.9.3.27 The actual implementation of this option is provided in the recommendation section (**Section 8.9.6**).

Summary

8.9.3.28 In summary, most of the options considered for CBA are not practicable after comparing the implementation cost with the MJE, while the remaining options have been recommended as Good Practices Recommendation under **Section 8.9.6**.

8.9.4 ALARP Assessment Results

8.9.4.1 The evaluation of each option considered is concluded in **Table 8.42**. The mitigated IR contours and F-N curves are shown in **Appendix 8.8** and **Appendix 8.9** respectively.

Table 8.42 ALARP Assessment Results

Mitigation	Practicability	Implementation Cost	ALARP Assessment Result
Use of Alternative Methods of Construction (i.e. TBMs) for tunnel blasting	Not Practicable	>HK$ 400M	Neither practicable nor justified.
Use of Alternative Methods of Construction (i.e. mechanical breaking) for surface blasting	Practicable	>HK$ 1000M	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	-	Bulk Emulsion explosive manufactured on site has been adopted as the main or `bulk' blasting explosive to excavate rock by rock blasting to minimize the amount of explosives for transportation.
Use of Smaller Explosives Quantities	Not Practicable	>HK$0.6M	Use of cast boosters is not cost effective. However, due to the risk reduction achieved the use of cast boosters is to be maximized, which is to be encouraged. In the other hand, Project Proponent, i.e. Highways Department, would review, on an ongoing basis during the detailed design, tender and construction phases, and implement the use of cast boosters during construction to the maximum extent possible.
Safer Design of the Explosives Carrying Vehicle	Practicable	-	Due to justified implementation costs, this mitigation option has been directly incorporated in recommendations (see **Section 8.9.6**)
Reduction of Accident Involvement Frequency	Practicable	-	Due to justified implementation costs, this mitigation option has been directly incorporated in recommendations (see **Section 8.9.6**)

Mitigation	Practicability	Implementation Cost	ALARP Assessment Result
Reduction of Fire Involvement	Practicable	-	Due to justified implementation costs, this mitigation option has been directly incorporated in recommendations (see **Section 8.9.6**)

8.9.5 Recommendations

<u>Recommendations for Meeting the ALARP Requirements</u>

8.9.5.1 Recommendations are made for implementation in order to meet the EIAO-TM requirements:

- The truck should be designed and improved to reduce the amount of combustibles in the cabin. The fuel carried in the fuel tank should also be minimized to reduce the duration of any fire;
- The accident frequency of the explosive truck should be minimized through the implementation of a defensive driving attitude and a dedicated training programme for both driver and his attendants which includes regular briefing sessions. Moreover, drivers should be selected based on good safety record and provided with regular medical checks;
- The required quantity of explosives should only be transported for a particular blast to avoid any unused explosives send back to the magazine;
- The contractor should combine the explosive deliveries for a given work area as far as practicable;
- A minimum headway between two consecutive truck convoys of 10 mins should be maintained whenever practicable; and
- To reduce the explosive truck fire involvement frequency, a better emergency response and training should be implemented to ensure 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 also be equipped with bigger capacity AFFF-type extinguishers.

<u>General Recommendations</u>

- Each 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; and
- For the storage and transport of explosives, the recommendation listed below should also be considered:
    - The security plan should address different alert security level to reduce opportunity for arson or deliberate initiation of explosives;
    - Emergency plan like magazine operation manual should be developed to address uncontrolled fire in magazine area and during transport of explosives; and
    - Adverse weather working guideline should be developed to clearly define procedure for transport of explosives during thunderstorm.

8.9.6 Good Practices Recommended

Good Practices to be Implemented for Use of Explosives

8.9.6.1 While the risk levels associated with the use of explosives for this Project is minimized as much as practicable, it is prudent that the Contractor implements all the good practices to minimize the hazard-to-life even further and ensure that any blasting carried out will not adversely affect services, utilities, slopes, retaining walls, buildings and structures through ground vibrations or other effects. A summary of these good practices is given below for reference. The good practice could make reference to the latest guideline including, but not limited to, Practice Note for Authorized Persons and Registered Structural Engineers – Control of Blasting (APP-72) by Buildings Department (BD). Following are some typical items regarding good practices to blasting works extracted from the APP-72. For detail, please reference to the latest APP-72 by BD.

- Carry out checking of the contractor's blasting method statement;
- Verify on site that the ground conditions and geology are as stated or assumed in the blasting assessment, and that the provisions in the method statement and the preventive, protective and precautionary measures are adequate for the conditions as encountered on site;
- Ensure that the preventive measures, if required, have been properly carried out prior to commencement of the blasting works;
- Prepare regular reports with records of the condition of the site, sensitive receivers, adjacent grounds, structures and services etc. after each phase of blasting operation and completion of related works;
- Inspect the construction of preventive works, if required, for the sensitive receivers;
- Inspect the provision and installation of all necessary protective and precautionary measures prior to each blast, in accordance with the blast design;
- Monitor the site operations and working methods to ensure that they meet the safety requirements set out in the blasting permit; and
- Inspect and monitor the conditions of all sensitive receivers regularly and carry out reviews of the quality of monitoring for the sensitive receivers before and after each blast.

Good Practices to be Implemented for Magazine Site

8.9.6.2 While the risk levels associated with the overnight storage of explosives for this Project is minimized as much as practicable that the Contractor implements all the good practices to minimize the hazard-to-life even further and ensure that overnight storage of explosives will not adversely affect services, utilities, slopes, retaining walls, buildings and structures through ground vibrations or other effects. A summary of these good practices is given below for reference.

8.9.6.3 The good practice could make reference to the latest guideline including, but not limited to, "Guidance Note No. GN 8 How to Apply for a Mode A Store Licence for Storage of Blasting Explosives" by CEDD which has mentioned in **Section 8.2.3**.

8.9.6.4 The design, operation and maintenance of the magazine should follow the Mines Division guidelines and industry best practice. Some other good practices listed below can also be implemented:

- To ensure the undertaken work activities during the operation of the magazine are properly controlled, a suitable work control system such as an operational manual including Permit-to-Work system should be introduced;
- Good house-keeping should be maintained within the magazine and outside the magazines stores to ensure that combustible materials are not allow to accumulate and to ensure combustibles (including vegetation) are removed;
- The magazine store should not have any open drains, traps, pits or pocket which any molten ammonium nitrate could flow and be confined in the even of a fire;
- Regular checking of the magazine building should be conducted for water seepage through the roof, walls or floor;
- Caked explosives shall be disposed of in an appropriate manner;
- Permission to remain the secured fenced off magazine store area shall not be given to explosives delivery vehicles; and
- Speed limit control should be implemented within the magazine area in order to reduce the risk of a vehicle impact or incident within the magazine area.

<u>Good Practices to be Implemented for Transport of Explosives</u>

8.9.6.5 Contractor should implement all good practices to minimize the hazard-to-life even further and ensure that transport of explosives will not result in adverse impact. A summary of these good practices is given below for reference. The good practice could made reference to the latest guideline including, but not limited to "Guidance Note No. GN 2 Approval of an Explosives Delivery Vehicle" as mentioned in **Section 8.2.5** and "Guidance Note No. GN 3 Application and Handling of a Removal Permit" by CEDD:

- Typical Removal Permit Conditions
  - A placard as specified in the section 80 of Dangerous Goods (Control) Regulation must be displayed in a conspicuous place on the vehicle carrying explosives;
  - No unnecessary waiting or parking of the vehicle is permitted at any place along the transportation route;
  - The vehicle carrying the explosives is prohibited from passing through any tunnel on a public road;
  - Except with the permission in writing by the Authority, the vehicle must not carry more than 200kg net explosives content of explosives at any one time. The vehicle for moving explosives shall be a licensed vehicle equipped with effective fire-extinguishers and maintained in good running conditions at all time;
  - The vehicle shall use the intended route of transportation specified in the application for this conveyance permit;
  - The vehicle with explosives on board is prohibited from refuelling at any fuel station;

  - Conveyance of blasting explosives or entertainment fireworks shall only be undertaken by the vehicle/s and driver/s approved by the Authority and in the presence of a Resident Explosives Supervisor and a Shot Firer or a Fireworks Master/Assistant. When carrying explosives/fireworks, the approved vehicle/s shall display the correct dangerous goods placards and warning signs;
  - Explosives and detonators must be conveyed on separate vehicles or in separate compartments on the vehicle. Electric detonators must be carried in an approved and properly labelled wooden container; and
  - The Permittee is required to input the actual date and time of the use of this Permit in Centralised Explosives Licensing and Management System (CELIMS) after the conveyance of the explosives as soon as reasonably practicable. If the Permit is unused before its expiry date, the Permittee is also required to provide reason(s) for not using the Permit in CELIMS.

- Safer Design of the Explosives Carrying Vehicle
  - Fire screen could be installed between the cabin and the load of the vehicle to reduce the chance of fire escalating to the load and cause explosion.

- Reduction of Accident Involvement Frequency
  - Different administrative measures can be implemented to reduce the accident involvement frequency and increase the situational awareness of the driver during the transportation of explosives;
  - Administrative measures can include “Tool-box” talk training regarding the safety precautions when transporting explosives;
  - Ensuring that the detonators and the cartridged emulsion are under good conditions and well-intact within their packaging before transporting; and
  - Recruiting experienced driver with good safety record and checking their health condition in a regular basis.

- Reduction of Fire Involvement
  - Carrying fire extinguishers or other active fire protection devices with higher standard and higher capacity onboard of the explosives carrying vehicle;
  - Create a contingency plan with consideration of different scenarios that may occur, such as the action that the driver should take in case of fire near the explosives carrying vehicle in the middle of traffic jam;
  - Regulations for the drivers should be set, such as hot work should be prohibited when handling explosives to avoid any sources of ignition; and
  - Working guidelines should be developed to provide clear instructions to the drivers when encountering different situations like extreme weather.

<u>Continual Liaison with LTUQ</u>

8.9.6.6 As recommended in **Section 8.4.2,** the project proponents of the Project, TMB and LTUQ shall continue the close and on-going liaison to optimise the design interface of R11/TMB/LTUQ to further optimise the cumulative risk impacts.

8.9.6.7 Subject to the liaison of the three concurrent projects R11, TMB and LTUQ, a Hazard Management Plan would be formulated with a view to aligning the understanding of the risk of the three projects so that all the working populations at Lam Tei Quarry area, which includes the workforce induced under the construction and operational stage of three projects, could be considered as on-site populations in the QRA for all the three projects. The measures stipulated in the Hazard Management Plan may include, but not limited to, the adjustment of the blasting schedules of the three projects to minimize the potential cumulative impact, provision of common trainings and drills to the workforce of all the three projects, etc. The Hazard Management Plan, which would be agreed among the three projects, would be submitted to EPD for agreement prior to the tender invitation of construction phases of R11, TMB and LTUQ, whichever is earlier.

8.10 Conclusion

8.10.1.1 A QRA has been carried out to evaluate the risk induced from the overnight storage, transportation and use of explosives during construction of the Project.

8.10.1.2 A review regarding Tai Lam Chung No.2 Chlorination Station is conducted and according to the latest information available, TLCCS will be delisted prior to the commencement of construction works and will no longer classified as a Potentially Hazardous Installations. Therefore, the hazard assessment for it is no longer required as there would not be any hazard-to-life concerns.

8.10.1.3 Reviews on Tuen Mun Bypass and Lam Tei Underground Quarrying (LTUQ) have also conducted. Cumulative impact from Tuen Mun Bypass has been included in this QRA while LTUQ is yet to be included as the information is yet to be provided during preparation of this QRA. However, the subsequent EIA study of Lam Tei Underground Quarrying would consider the impact from this Project. The cumulative impacts from Tuen Mun Bypass have been included in this QRA.

8.10.1.4 The Project Proponents of the Project, TMB and LTUQ shall continue the close and on-going liaison to optimise the design of R11/TMB/LTUQ to further reduce the cumulative risk impacts. A Hazard Management Plan would be formulated with a view to aligning the understanding of the risk of the three projects R11/TMB/LTUQ.

8.10.1.5 About 8km of tunnel sections would be constructed using drill-and-blast and mined tunnelling which would require the use of explosives. To ensure timely delivery to blasting site and maintain the construction process, three temporary explosive magazine sites at Lam Tei Quarry, Siu Lam and Pillar Point for overnight storage of explosives is required. As temporary explosive magazines are needed, transport of explosives is also required.

8.10.1.6 Magazine sites would follow the relevant design requirements in terms of sufficient separation distances and the design of the storage facilities. Review suggests that the associated risk for the magazine site would be insignificant. It is assumed that Lam Tei Quarry Magazine will not involve any off-site transportation of explosives.

8.10.1.7 The maximum number of blasts for tunnel blasting and surface blasting are 13 and 4 blasts per day respectively. For the use of explosives at the drill-and-blast tunnel sections, given that the proper design and maintenance of the blasting face and provision of blast door or cover, together with the fact that the blasting would be connected inside the tunnel section and with the blast cover shut, the associated risk would be well within the acceptable region.

8.10.1.8 For the transportation risk, there is mainly low-density population within the 100m influence zones except the area near Tuen Mun Town Centre. QRA was conducted and the risks for overnight storage of explosives and transport of explosives are within the "ALARP" region separately.

8.10.1.9 For the risk for use of explosives including tunnel blasting and surface blasting, the geotechnical features near the tunnel section and surface blasting of the Project have been assessed. The risk for use of explosives is slightly within the "ALARP" zone.

8.10.1.10 Therefore, although the assessment results show that the criterion of Annex 4 of the EIAO-TM for Individual Risk is complied, the societal risk lies within the "ALARP".

8.10.1.11 It is noted that the cumulative risk level would slightly fall into the "ALARP" zone at 10 or lower fatalities. Since the cumulative risk is within the "ALARP" region, mitigation measures are required to reduce the level to 'as low as reasonably practicable'. ALARP assessment, i.e. Cost-Benefit-Analysis (CBA), is conducted in this QRA to study the cost-effectiveness of different measures. Justified mitigation measures have been recommended and the risk as well as F-N curve has been reduced.

8.10.1.12 Nevertheless, it is recommended to implement all the best practices and recommendations which are discussed in **Section 8.9.5** and **Section 8.9.6** to minimize the risk even further.

Reference

Schultz, E., Wintenberger, E., & Shepherd, J. (1999, October). Investigation of deflagration to detonation transition for application to pulse detonation engine ignition systems. In Proceedings of the 16th JANNAF Propulsion Symposium (Vol. 1, pp. 175-202). Chemical Propulsion Information Agency.

Nolan, D. P. (2014). Handbook of fire and explosion protection engineering principles: for oil, gas, chemical and related facilities. William Andrew.

AECOM. (2014). Sha Tin Cavern Treatment Works: Hazard to Life Assessment for Storage and Transport of Explosives.

Merrifield, R., & Moreton, P. A. (1998). An examination of the major-accident record for explosives manufacturing and storage in the UK. Journal of hazardous materials, 63(2-3), 107-118.

Chief Fire and Rescue Adviser. (2008). Generic Risk Assessment 5.7: Incidents Involving Explosives. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/14910/gra-5-7-pt1.pdf.

Centers for Disease Control and Prevention (U.S.). (2003). Explosions and Blast Injuries: A Primer for Clinicians. Retrieved from https://stacks.cdc.gov/view/cdc/28987.

Nicholls, H. R., Johnson, C. F., & Duvall, W. I. (1971). Blasting vibrations and their effects on structures (p. 656). Washington: US Government Printers.

Ammunition, D. O. D. (2004). Explosives Safety Standards. DoD Directive.

Sarma, S. K. (1975). Seismic stability of earth dams and embankments. Geotechnique, 25(4), 743-761.

Geotechnical Engineering Office. (1992). Assessment of Stability of Slopes Subjected to Blasting Vibration. GEO Report No. 15. Retrieved from https://www.cedd.gov.hk/filemanager/eng/content_166/er15.pdf

Dangerous Goods Ordinance (Cap. 295). (1971).

CEDD. (2022). Guidance Note No.GN 8 How to Apply for a Mode A Licence for Storage of Schedule 1 Dangerous Goods (Blasting Explosives).

CEDD. (2022). Guidance Note No.GN 2 Approval of an Explosive Delivery Vehicle.

CEDD. (2022). Guidance Note No.GN 2 Application and Handling of a Removal Permit.

ERM-Hong Kong. (2001). West Island Line: Hazard to Life Assessment for the Transport, Storage and Use of Explosives.

Planning Department. (2019). 2019-based Territorial and Employment Data Matrix.

Census and Statistics Department. (2021). 2021 Population Census.

Transport Department. (2022). The Annual Traffic Census 2021.

ERM-Hong Kong. (2009). Hong Kong Section of Guangzhou – Shenzhen – Hong Kong Express Rail Link: Hazard to Life Assessment

Merrifield, R., & Moreton, P. A. (1998). An examination of the major-accident record for explosives manufacturing and storage in the UK. Journal of hazardous materials, 63(2-3), 107-118.

CEDD. (2018). Geoguide 4 – Guide to Cavern Engineering.

Puhakka T. & Tamrock (Firm). (1997). Underground drilling and loading handbook. Tamrock.

ERM-Hong Kong. (2010). South Island Line (East): Hazard to Life Assessment for Explosives Storage and Transport.

ERM-Hong Kong. (2012). Shatin to Central link – Tai Wai to Hung Hom Section: Hazard to Life Assessment for the Transport, Storage and Use of Explosives.

AFCE. (2018). Department Annual Report 2017-2018.

AFCE. (2019). Department Annual Report 2018-2019.

AFCE. (2020). Department Annual Report 2019-2020.

AFCE. (2021). Department Annual Report 2020-2021.

HSE. (2013). Methods of approximation and determination of human vulnerability for offshore major accident hazard assessment.

Centers for Disease Control and Prevention (U.S.). (2003). Explosions and blast injuries: a primer for clinicians.

Li, U. K., & Ng, S. Y. (1992, April). Prediction of blast vibration and current practice of measurement in Hong Kong. In Proceedings of the Conference Asia Pacific—Quarrying the Rim, Hong Kong (pp. 119-135).

Nicholls, H. R., Johnson, C. F., & Duvall, W. I. (1971). Blasting vibrations and their effects on structures (p. 656). Washington: US Government Printers.

CEDD. (2010). New Control Framework for Soil Slopes Subjected to Blasting Vibrations.

Wong, H. N., & Pang, P. L. R. (1992). Assessment of stability of slopes subjected to blasting vibration. Geotechnical Engineering Office, Civil Engineering Department, Hong Kong.

ERM-Hong Kong. (1999). Slope Failures along BRIL Roads: Quantitative Risk Assessment and Ranking.

Health and Safety Executive. (2014). The Explosives Regulations 2014.

Maunsell Geotechnical Services. (2001). Territory Wide Quantitative Risk Assessment of Boulder Fall Hazards, Final Report for Stage 2 Study.

EPD. (1996). Cos Benefit Analysis in Hazard Assessment.