CONTENTS

1 INTRODUCTON

1.1 BACKGROUND

MTR Corporation Limited (MTRC) is planning to construct the West Island Line (WIL), which consists approximately of a 3.3 km alignment to extend the Island Line (ISL) from the existing Sheung Wan Station (SHW) to the new Kennedy Town Station (KET), via two new intermediate stations, Sai Yin Pun (SYP) and University (UNV).

A significant length of the WIL tunnels, adits and station boxes will be excavated in rock. The amount of rock to be extracted will be approximately 480,000 m^3. A significant amount of explosives will be required for the construction of rock caverns, tunnels and adits for the WIL.

To enable a timely delivery of explosives to site and in order to meet the proposed construction work programme, an Explosive Storage Magazine (Magazine) is required. The purpose of the Magazine is to maintain construction activities in case of delivery interruptions by Mines Division (Mines) from the Geotechnical Engineering Office (GEO), Civil Engineering and Development Department (CEDD). Mines will deliver explosives and initiation devices (detonators) to the Magazine on a daily basis. The transportation of explosives by Mines is under Mines responsibility and falls outside the scope of this EIA.

The appointed contractors of MTRC will transport explosives in maximum 200 kg lots in licensed trucks, from the Magazine to a particular construction site for the daily or twice-daily blasts depending on requirements for construction.

The proposed Magazine is planned as an underground cavern to be built beneath Mount Davis and located near a disused Government Facility Site with an entrance adjacent to Victoria Road. It is proposed to use an existing flat platform of land to access the underground magazine.

Under Section 5(7) of the Environmental Impact Assessment (EIA) Ordinance (Cap. 499) (EIAO), the Director of Environmental Protection (Director) from the Environmental Protection Department (EPD) has issued a Study Brief No. ESB-130/2005 for this project (EIA Study Brief). Section 3.4.6 of the EIA Study Brief requires a Hazard to Life assessment to be conducted for the overnight storage of explosives on the construction site and credible and applicable hazardous scenarios within the boundaries of the construction site during transport, storage and use of explosives for blasting operations.

ERM-Hong Kong, Limited (ERM) was commissioned by MTRC to undertake the Hazard to Life Assessment for the storage, transport and use of explosives during the WIL Construction Stages and propose risk mitigation measures if necessary. The criteria and guidelines for assessing Hazard to Life are stated in Annexes 4 and 22 of the Technical Memorandum (EIAO-TM Criteria).

The Hazard to Life assessment requirements of the EIA Study Brief are shown below.

Figure 1.1 *EIA Brief – Hazard to Life Requirement*

3.4.6 Hazard to Life

If there is overnight storage of explosives on construction site and the storage location is in close proximity to populated areas and/or Potentially Hazardous Installation site(s), the Applicant shall follow the criteria and guidelines for evaluating hazard to life as stated in Annexes 4 and 22 of the TM in conducting hazard assessment for construction stage and include the following in the assessment:

(i) Identification of all credible and applicable hazardous scenarios within the boundaries of the construction site during transport, storage and use of explosives for blasting operations;

(ii) Execution of a Quantitative Risk Assessment to determine risks to the surrounding population in both individual and societal terms;

(iii) Comparison of individual and societal risks with the Criteria for Evaluating Hazard to Life stipulated in Annex 4 of the TM, to determine the acceptability of the assessed risk;

(iv) Identification and assessment of practicable and cost effective risk mitigation measures to demonstrate the compliance with the Risk Guidelines; and

(v) The methodology of hazard assessment shall be agreed with the Director taking into account relevant previous studies.

This section of the EIA presents:

- The basis for the assessment;
- Description of the detailed methodology;
- The results for each QRA step; and
- The assessment of the risk against the EIAO-TM Risk Criteria.

In accordance with the study brief, a methodology statement was submitted to EPD for agreement. The details of the methodology are elaborated further in various sections of this report.

1.2 *Scope of Hazard to Life Assessment*

The hazard to life assessment addresses, in particular, the following:

- Use of Explosives during the Construction of the WIL, including:
    - Use of Cartridged Emulsion Explosives;
    - Use of Bulk Emulsion Explosives;
    - Use of blasting accessories including detonators and boosters;
- Use of Explosives during the Construction of the Magazine, including:
    - Use of Cartridged Emulsion Explosives;
    - Use of Bulk Emulsion Explosives;

    - Use of blasting accessories including detonators and boosters;
- Storage of Explosives at the Magazine (blasting explosives, boosters and detonators);
- Transport of Explosives, including:
    - Handling of Explosives at the Magazine;
    - Transport of Explosives from the Magazine to the construction site; and
    - Handling of Explosives at the delivery points.

1.3 HAZARD TO LIFE ASSESSMENT OBJECTIVES AND RISK CRITERIA

The main objective of this Hazard to Life Assessment is to demonstrate that the Risk Criteria set in Annex 4 of the EIAO-TM will be met during the construction phase of the West Island Line and to identify, where applicable, practical mitigation measures to ensure the EIAO-TM criteria are met.

The study will particularly focus on the following:

- Identification of hazardous scenarios within the boundaries of the construction site during transport, storage and use of explosives for blasting operations;
- Preparation of a Quantitative Risk Assessment (QRA) to estimate risks to the surrounding population in both individual and societal terms;
- Comparison of individual and societal risks with the Criteria for Evaluating Hazard to Life stipulated in Annex 4 of the EIAO TM to determine the acceptability of the assessed risk (i.e. the Hong Kong Risk Guideline (HKRG));
- Identification and assessment of practicable and cost effective risk mitigation measures to demonstrate the compliance with the Risk Guidelines.

1.3.1 Risk Criteria

The risk guidelines and societal risk guidelines specified in Annex 4 of the EIAO-TM are shown below.

Individual Risk (IR)

Individual risk is defined as the frequency of fatality per year to a specific individual due to the realisation of specified hazards, with account taken of temporal factors.

The maximum level of off site individual risk should not exceed 1 in 100,000 per year, ie $1x10^{-5}$ per year.

Societal risk

Societal risk is defined as the risk to a group of people due to all hazards arising from a hazardous operation. The simplest measure of societal risk is the Rate of Death or Potential Loss of Life (PLL), which is the predicted equivalent fatalities per year.

Societal risk is also expressed in the form of an F-N curve, which represents the cumulative frequency (F) of all event outcomes leading to N or more fatalities. This representation of societal risk highlights the potential for accidents involving large numbers of fatalities.

The societal risk guidelines expressed in the form of FN curve is shown in *Figure 1.2*. There are three regions identified:

- Unacceptable region;
- ALARP region where risk is tolerable providing it has been reduced to a level As Low As Reasonably Practicable;
- Acceptable region where risk is broadly acceptable.

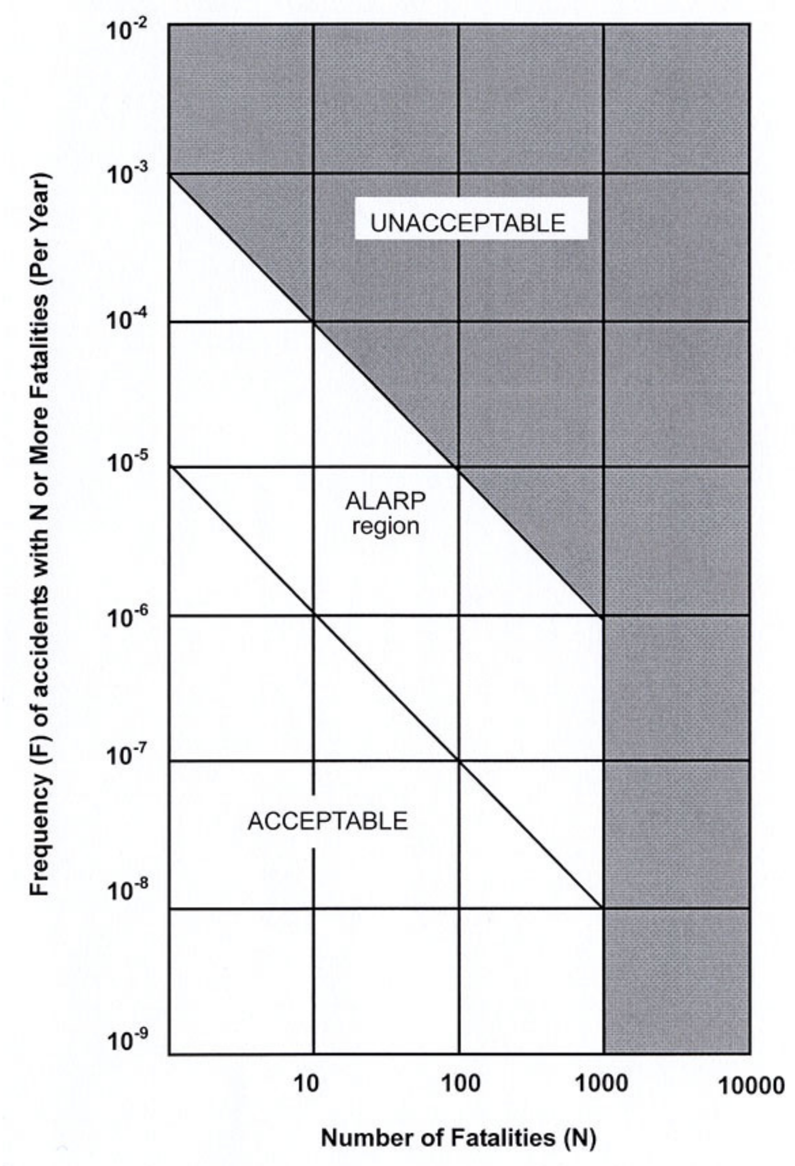
The risk guidelines incorporate a special requirement (as seen in *Figure 1.2*), that no hazardous scenario can cause more than 1,000 fatalities. If so, the risks are deemed 'unacceptable' and need to be reduced regardless of the cost.

Application of Criteria

The risk guidelines specified in the EIAO TM apply only to risk of fatality due to storage, use or transport of explosives. Injures are not considered in the assessment and similarly, hazards due to operations within the construction site and magazine operation other than those involving explosives are also not considered.

The risk guidelines have been generally applied for only public off site of a hazardous installation. However, in the context of this study, the risk guidelines are applied to the public outside the construction site and magazine. Risk to workers on the project construction site, MTRC staff or its contractors have not been included in the assessment.

Figure 1.2 Societal Risk Criteria in Hong Kong



1.4 STRUCTURE OF THE APPENDIX 10

The Appendix 10 " Risk Assessment for Transport, Storage and Use of Explosives" is structured as follows:

Section 1:	Introduction including scope, objectives and risk criteria
Section 2:	Project Description and Basis for the Assessment
Section 3:	Hazard to Life Assessment Methodology
Section 4:	Population Estimates
Section 5:	Hazard Identification
Section 6:	Frequency Assessment
Section 7:	Consequence Assessment
Section 8:	Risk Summation
Section 9:	Conclusion & Recommendations
Section 10:	References

Annexes

Annex A:	Blasting Process
Annex B:	Accident Review
Annex C:	Population Data
Annex D:	Traffic Survey Report
Annex E:	Use of Explosives - Frequency Assessment Details
Annex F:	Use of Explosives – Human Factor Assessment & Reduction Technique
Annex G:	Use of Explosives – Blasting Route and Slopes Details

2 PROJECT DESCRIPTION AND BASIS FOR THE ASSESSMENT

2.1 PROJECT OVERVIEW

The construction of the WIL project is scheduled to commence in early 2009 for completion in 2014.

The SHW-to-SYP section will probably be constructed using soft ground tunnelling techniques, requiring ground treatment.

West of SYP will be constructed using the drill-and-blast method, except the station box for KET which will be constructed using the cut-and-cover method, although blasting will be required towards the eastern end of the station box at lower levels. Therefore, an approximate of 3.3 km of the alignment from SHW to KET station overrun tunnel will be subject to the assessment for the use of explosives.

The amount of rock to be extracted is approximately 480,000 m^3. The rock excavation strategy as well as the interfaces between the various contractors is shown in *Figure 2.1*.

2.2 EXPLOSIVE TYPES FOR WIL

2.2.1 *Proposed Explosives*

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

- Cartridged Emulsion Explosives; and
- Site-Sensitised Bulk Emulsion Explosives.

Both of the cartridged and bulk emulsions contain mainly ammonium nitrate (single salt), water, and a hydrocarbon such as fuel oil. Cartridged emulsion also contains 2-3% aluminium powder, which is added to increase the explosion temperature and hence its power.

Cartridged emulsion will be delivered from the Explosive Magazine to the various construction sites by the appointed contractors using licensed trucks.

Cartridged emulsion explosives will be used during the 'trial blast' phase of the project and are expected to be used in relatively small quantities. Once successful trial blasts have been concluded it is expected that Contractors will prefer to use bulk emulsion explosives for safety, economic and flexibility reasons. However, for the purpose of this study it has been assumed that the entire WIL alignment and associated magazine shall be constructed using cartridged emulsion explosives only. This represents the worst case scenario as the amount of explosives required to be stored and transported will be significantly reduced if bulk emulsion is used.

Bulk emulsion precursor will be transported to the blast sites within the Adits/Tunnels by the appointed third party supplier. It only becomes classified as an explosive after being sensitized at the blast location or working face, by the addition of a gassing agent as it is pumped into the blastholes.

Bulk emulsion pumping equipment in Hong Kong has an accuracy of ± 100 grams. Mines have previously approved its use down to a charge weight (MIC) of 100 grams at the Ocean Park Funicular Tunnel and the Drainage Services Department (DSD) Hong Kong West Drainage project.

In much lesser explosive quantities, detonators, boosters and detonating cords will be used to initiate the blast at the working face, depending on the blast requirement. Detonators approved for use in Hong Kong are of the Non-Electric Type, ie. initiated by shock tube.

2.2.2 *Explosives Properties*

Explosives that are relevant to the WIL project can be classified into two (2) types:

- blasting explosives; and
- initiating explosives.

Their properties are shown in *Table 2.1*.

Table 2.1 Explosive Types

Type	Explosion Type	Use	Example
High explosives	Detonation	General blasting, Shattering rock/structures	Emulsion explosives, Primers/Boosters, Detonating cord
Initiating explosives	Detonation	Initiation of secondary explosive	Detonators

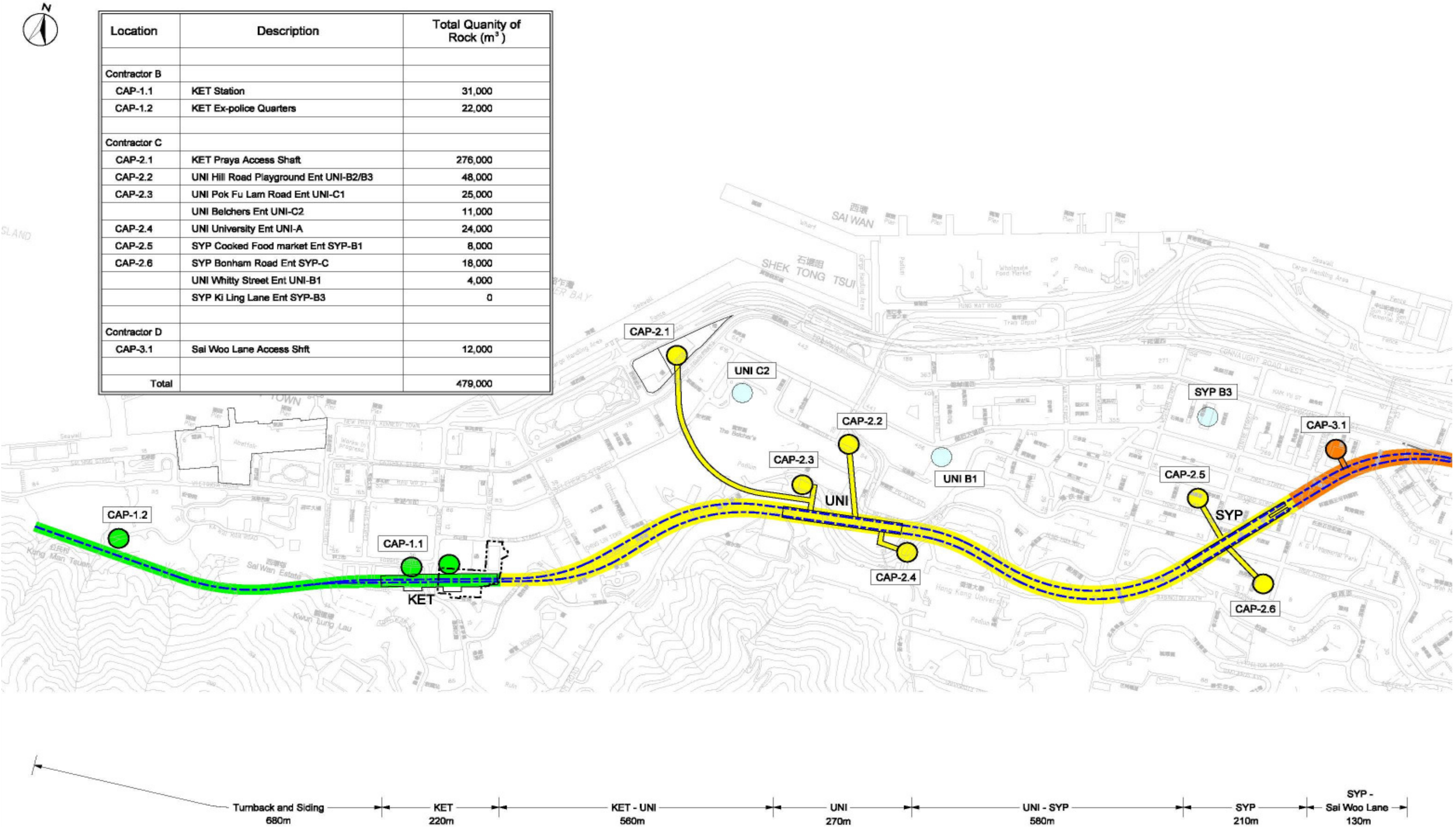
Explosives Classification

The hazards implicit in the storage, transportation and use of explosives are described by their dangerous goods classification.

For the purpose of this study, explosives will be classified in accordance with the United Nations Dangerous Goods classification system because all the references world-wide use that system and all the base analytical data is based on that system. In the United Nations system, explosives are Class 1 Dangerous Goods, and the Hong Kong equivalent is Category 1 dangerous goods under the Control of Dangerous Goods Ordinance, Cap. 295.

Dangerous Goods of UN Class 1 (Explosives) are assigned to one of six divisions, depending on the type of hazard they present (see *Table 2.2* below) and to one of thirteen compatibility groups, which identifies the kinds of explosive substances and articles (see *Table 2.3,* only details for those

Location	Description	Total Quanity of Rock (m^3)
Contractor B		
CAP-1.1	KET Station	31,000
CAP-1.2	KET Ex-police Quarters	22,000
Contractor C		
CAP-2.1	KET Praya Access Shaft	276,000
CAP-2.2	UNI Hill Road Playground Ent UNI-B2/B3	48,000
CAP-2.3	UNI Pok Fu Lam Road Ent UNI-C1	25,000
	UNI Belchers Ent UNI-C2	11,000
CAP-2.4	UNI University Ent UNI-A	24,000
CAP-2.5	SYP Cooked Food market Ent SYP-B1	8,000
CAP-2.6	SYP Bonham Road Ent SYP-C	18,000
	UNI Whitty Street Ent UNI-B1	4,000
	SYP Ki Ling Lane Ent SYP-B3	0
Contractor D		
CAP-3.1	Sai Woo Lane Access Shft	12,000
Total		479,000



Legend:

- Extent of Tunnel by Contractor B
- Extent of Tunnel by Contractor C
- Extent of Tunnel by Contractor D
- Isolated Entrances

Figure 2.1

Rock Excavation Strategy

Environmental Resources Management

ERM

compatibility letters that are relevant to the WIL project are shown) that are deemed to be compatible.

Table 2.2 UN Class 1 Explosive Hazard Divisions

Hazard Division	Definition	Example
1.1	Substances and articles which have a mass explosion hazard	Lead Azide, boosters/primers, detonators / blasting caps
1.2	Articles which have a projection hazard but not a mass explosion hazard	Military mortar shells
1.3	Substances or articles which primarily have a fire hazard and either a minor blast hazard or minor projection hazard or both.	Propellant powder
1.4	Articles which present no significant hazard outside their packaging	Packaged sporting ammunition, some detonators in appropriate packaging
1.5	Very insensitive substances which have a mass explosion hazard	Sensitised bulk emulsion
1.6	Extremely insensitive articles which do not have mass explosion hazard	Military explosives

Table 2.3 UN Class 1 Explosive Compatibility Letters

Compatibility letter	Definition	Example
B	An article containing a primary explosive substance and not containing two or more protective features	Detonators
D	Secondary detonating explosive substance without means of initiation and without propelling charge	Primers/Boosters, Cartridged emulsion, Detonating cord, Sensitised bulk emulsion
S	Substance or article so packed or designed that any hazardous effects arising from accidental functioning are limited to the extent that they do not significantly hinder or prohibit fire fighting or other emergency response efforts in the immediate vicinity of the package	Detonators

2.2.3 *Cartridged Emulsion*

The cartridged explosive is designed as small diameter packaged emulsion, which can be used for both priming and full column applications, particularly in underground mining. It is used for mining, quarrying and general blasting work.

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. It is classified as a UN Class 1.1D explosive and Dangerous Goods (DG) Category 1 explosive under the Hong Kong classification system. It has a TNT equivalence of 0.96 kg of TNT per kg of emulsion.

Like all explosives, cartridged emulsion consists of a mixture of oxidisers and fuel. What makes emulsion unique is the high quantity of water it contains – typically around 10-14%. The oxidisers are typically ammonium nitrate, calcium nitrate or sodium nitrate. The fuels are waxes or oils like diesel fuel. The mixture is complete with small amounts of emulsifiers (less than 1%), which keep the water and oil mixture homogeneous.

Cartridged emulsion is detonator sensitive, and hence it does not require the use of a booster to cause it to detonate.

When cartridged emulsion explosives are used, the required number of sticks equivalent to the MIC will be loaded into each blasthole.

2.2.4 *Bulk Emulsion Precursor*

Bulk Emulsion has a similar composition to Cartridged Emulsion, except that it does not contain aluminium. The bulk emulsion precursor has a density of 1.38-1.40 gms/cc. It is not considered an explosive and is classified as UN 5.1 oxidising agent and Dangerous Goods Ordinance (Cap. 295) Category 7 Strong Supporters of Combustion. This material is stored in a Category 7 store, which falls under the jurisdiction of the Fire Services Department (FSD), and not Mines Division.

Bulk emulsion precursor is stable under normal conditions and there is no major fire hazard before sensitization. Hazard associated with bulk emulsion precursor is mainly due to its oxidizing properties causing irritation to eyes and skin. Explosion is considered possible only under prolonged fire, supersonic shock or high energy projectile impact.

Storage and transport of bulk emulsion precursor is not included within the scope of this study.

2.2.5 *Bulk Emulsion*

Bulk emulsion may be used instead of cartridged emulsion to excavate rock by tunnel blasting. Bulk emulsion precursor is sensitised at the blast site by the addition of a gassing solution (usually Acetic/Citric acid). This is added to the charging hose downstream from delivery pump.

A delivery pump is used for the loading of the bulk emulsion into the blastholes. There are two different types of pump driving mechanisms, which are:-

- Pneumatic; and
- Hydraulic.

A hydraulic driven pump has an delivery accuracy of ± 100 g, compared to a pneumatic driven pump with an accuracy of ≥ 200 g. Gassing solution is injected into the precursor to reduce the density to 0.8 to 1.1g/cc at the discharge end of the loading hose. This sensitises the emulsion by producing nitrogen gas bubbles that aid the propagation of the detonation wave. Hence, the bulk emulsion does not become an explosive until it is pumped into the blastholes at the working blast face. The sensitised emulsion can then be detonated with the assistance of a small booster and a detonator. The bulk emulsion, once it is gassed is classified as UN 1.5D explosive or a Dangerous Goods (DG) Category 1 explosive under the Hong Kong classification system.

Bulk Emulsion explosives which are pumped into blastholes completely fill the blasthole and thus are 'fully coupled' to the rock. This results in improved explosive performance and enables Bulk Emulsion explosives of lower power (cf. Cartridged Emulsions) to be utilized.

2.2.6 Detonating devices (detonators, detonating cord, primers)

Detonators

Detonators are small devices that are used to safely initiate blasting explosives in a controlled manner. There have been many types of detonators in the past (safety fuse, electrical, and others) however, this study is limited to Non-electric, or Shock Tube detonators, because these are the only type that will be used. Detonators are classified as either UN 1.1B, 1.4B, or 1.4S, or DG Category 1 explosive under the Hong Kong classification system.

Although detonators contain the most sensitive types of explosives in common use, they are constructed in a manner such that they may be handled and used with minimal risk. They are packaged in a manner that, if accidentally initiated, they should have no serious effects outside the package.

Detonators are manufactured with in-built delays that are of various duration. This is to facilitate effective blasting to allow shots to be initiated at one time but to fire sequentially, thereby enhancing the practical effects of the blast. The detonators to be used in this project will be either millisecond delay period detonators (MS Series) or half second delay detonators (Long Period or LPD).

The delay time of a detonator is controlled by the burning time of a pyrotechnic ignition mixture pressed into a 6.5mm diameter steel tube, which is the delay element. This element causes the primary explosion, which is typically a small amount of lead azide, to detonate. This in turn, causes the secondary, or output, explosive to detonate, which is usually PETN (Pentaerythrite tetranitrate). The quantity of PETN within each detonator is approximately 0.9g. Each detonator has a delay time that is based upon the length of steel tube and the compaction of the pyrotechnic mixture within it. In designing the blasting of a tunnel face, the general principle is to select the required detonators to ensure that no two blastholes will detonate less than 8 ms apart.

The ignition of the pyrotechnic mixture is achieved by the use of shock tubes. This is a small diameter plastic tube that has a light dusting of explosive powder to the inside surface along its length. When ignited by a hot, high pressure impulse the explosive powder combusts at a rate of over 2000 m/s, and causes ignition of the detonator pyrotechnic mixture.

Detonating Cord

Detonating cord is a thin, flexible tube with an explosive core. It has the effect of a detonator along its entire length and is suitable for initiating other explosives that are detonator sensitive, such as boosters. It can be used for synchronising multiple charges to detonate different charges almost simultaneously. It is used to chain together multiple explosive charges. Typical uses include mining, drilling, and demolitions. The core of the cord is a compressed powdered explosive, usually PETN, and it is initiated by the use of a blasting cap. Detonating cord will initiate most commercial high explosives (e.g. dynamite) but will not reliably initiate less sensitive blasting agents like bulk emulsion or ANFO on its own. A small charge (or booster), usually of PETN or TNT, is required to bridge between the cord and a charge of insensitive blasting agent like bulk emulsion or ANFO.

Explosive Primer or Booster

The small quantity of explosive in a detonator is usually inadequate to reliably initiate many bulk explosives so they are used in conjunction with larger, less sensitive explosives to boost the explosion. When a booster is "primed" with a detonator it is called a primer. These explosives are used as part of the initiating system to initiate the main blasting explosives. The booster typically contains PETN or Pentolite, a mixture of TNT and PETN, and is detonator sensitive. It is classified as UN 1.1D.

2.3 *OVERVIEW OF BLASTING*

2.3.1 *The Blasting Process*

Supply of Detonators and Cartridged Emulsion Explosives

Detonators are imported into Hong Kong. Destructive product sample tests are conducted by the manufacturer before each order leaves the factory. These tests record the actual delay firing time of each sample detonator and must fall within the manufacturers upper and lower tolerances as dictated by their quality control and quality assurance (QC /QA) system. In the event that the tested sample falls outside of the delay time control, or tolerance limits the batch will be destroyed. The delay time, detonator shock tube length, batch number and date of manufacture are printed on each vacuum bag (inner packaging) and the delay time is printed on the aluminium shell and the coil tag of each detonator, where the detonator shock tube length is also shown. The detonator order will be imported into Hong Kong and stored at the Mines Division Kao Shat Wan (KSW) explosives magazine. Users will then order from Mines for delivery to their on-site explosives magazine or to their blasting site.

Cartridged emulsion explosives are imported into Hong Kong and stored at the KSW magazine and delivered to end users by Mines Division on a daily basis.

Blast Design

The design of the blast will consider the quantity and type of explosives needed including MIC (maximum instant charge), number of detonators required, as well as the sensitive receivers at the blasting location. The blast design will be produced by the blasting engineer using computer aided tools, checked and approved by the project Registered Engineer (RE), and then endorsed by Mines Division prior to implementation. The blast plan will contain information covering the dimensions of the face to be blasted, MIC, location (chainage) size of blastholes, type and number of delay detonators required, powder factor (kg / m^3), which is defined as the ratio of mass of explosives used to the volume of rock removed by the blast,. The blast design will ensure that each detonator will initiate at a different time delay to allow sequential breaking of the rock.

Blast Loading and Execution

Immediately prior to loading, the required and approved amount of explosives, cast boosters, detonating cord and detonators for the blast will be collected by the Registered Shotfirer and delivered to the blasting site by licensed contractors' vehicle. The collection of the correct quantity of explosives, cast boosters, detonating cord and detonators from magazine will be checked by the Registered Shotfirer, a representative from the supervising consultant (ie. Resident Site Engineer, (RSS)), a representative from the Contractor, and sometimes a representative from Mines Department.

To ensure that blasting of different sectors of the blast face occurs in the correct sequence and not simultaneously, the shock tubes from the detonators associated with a particular sector may be 'bunched' together and wrapped, or 'looped', with detonating cord. A bunch block is then attached to the detonating cord. A bunch block contains approximately 0.3 g of explosive, is sufficient to initiate the detonating cord, which in turn ignites the shock tubes around which the cord is wrapped. The shock tube tail of the bunch block is itself be ignited by a surface connector.

A surface connector has a smaller mass of explosive (0.11 g) than a bunch block, which whilst it is insufficient to initiate the detonating cord, it is sufficient to ignite shock tubes. A bunch block and detonator cord combination is used to ignite a bundle of shock tubes because a surface connector can only hold up to a maximum of 8 shock tubes. Two surface connectors may be linked in series, with their connected bunch blocks in parallel, to ensure the staggering of the individual detonations across the entire blast face. The bunch block typically has no delay time, as the delay is provided by the surface connector to which its initiating shock tube is connected.

For each blast, generally, 3-5 surface connectors will be used, (each having a delay time of 9 and 17 ms), and 4-6 bunch blocks (0 ms) per blast. A typical blast round usually takes 4 to 5 seconds for completion.

A detailed step-by-step method of blasting loading and execution is given in *Annex A*.

2.3.2 *Safe Operating Practices*

Vibration Monitoring

It is a requirement to monitor every blast in Hong Kong to record blast induced ground vibrations. Each blast is influenced by a controlling sensitive receiver which may be a building, slope or utilities. The controlling sensitive receiver, and its allowable peak particle velocity (PPV) will dictate the MIC that can be used for any blast.

When each and every blast is designed, the first parameter to be established is the controlling sensitive receiver, its allowable PPV, its radial distance from the blast and the allowable MIC calculated.

As the excavation advances on a blast-by-blast basis the controlling sensitive receiver may change or remain constant. However, the allowable MIC may decrease or increase depending on the radial distance between the blast and the controlling sensitive receiver.

A dedicated Geotechnical Engineer is responsible for ensuring that the controlling and other nominated sensitive receivers for each blast are monitored to record the PPV in mm/sec. In addition, there may be instances where it is necessary to record air overpressure generated by blasting activities.

Trial Blasts

Trial blasts will be carried out for the first series of blasts for the tunnels and adits and different areas or sectors of the project if required. The trial blasts will be used to determine rock characteristics and to collect data to enable site specific constants to be calculated for future vibration (in terms of Peak Particle Velocity, PPV) prediction, and to ensure the blasting monitoring and control procedures are effective.

Trial blasts are conducted with cartridged emulsion explosives.

Advance Notice of Blasts

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

With respect to public complaints, the usual practice is for the Resident Engineer (RE) to brief the District Council on the project and to notify the public via the District Council that there will be blasting and other construction activities during the project. At the same time, the RE will advise the District Council of the process for lodging and filing complaints. Complaints are usually channelled via the RE.

Public Safeguards

Public safeguards during a construction project take many forms such as:

- Site hoarding
- Security guards
- Warning signage
- District Council Meetings/briefings by the RE
- Public Relations Programmes by the RE

Additionally, various government departments and industry occasionally provide safety training and inspection, for example

- Construction Industry Training Authority (CITA)
- Labour Department

Safety Management System

Contractors are required by Law to have a comprehensive Safety Management System, usually ISO-9000 and this is implemented and supervised by on-site safety teams. Independent third party auditors make annual checks of documentation and safety records.

2.3.3 Typical Tunnel and Adit Blasting for WIL

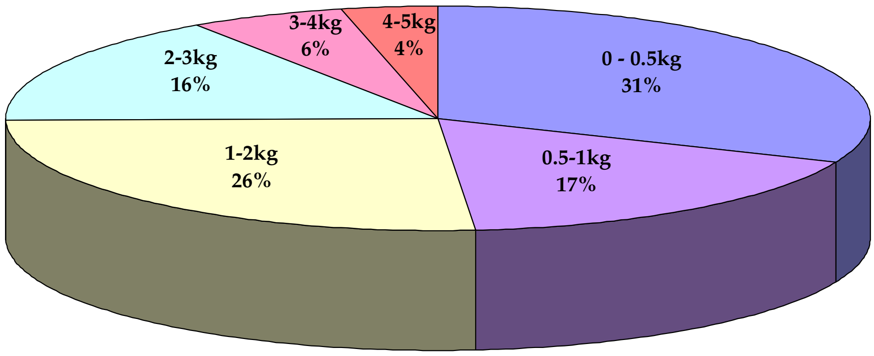
The tunnel blast face is typically divided into 4 to 6 sectors containing a total of 65 to 120 blastholes. These blastholes comprise 20 to 36 perimeter holes that run along the curved outer edge of the tunnel face, with further blastholes along the base of the tunnel face that are termed lifters. The 45 to 84 production holes are distributed within the sectors on the blast face.

The blast is designed to first cut a central core from the rock face. This is achieved by the centre 'cut', which comprises three relief holes and six loaded 'cut' holes around the lower centre of the blast face. The purpose of this centre 'cut' is to provide a void, or relief, before other production holes are blasted allowing the rock to fall away from the face into the space provided by the centre cut. Each sector is then detonated in a pre-determined sequence based on the detonator time delay and the sector time delay. The order of blasting is that the cut will be detonated and ejected first, followed by the production / lifter holes and finally the perimeter holes will detonate to provide a smooth tunnel profile.

The perimeter holes will be typically loaded with a Maximum Instant Charge (MIC) of 0.53 kg / hole (4.0 m deep blasthole), while the production holes will be loaded with an MIC of 0.5-5.0kg / hole depending on the allowable MIC and the blasthole depth.

The distribution of design MIC for the WIL alignment is shown in *Figure 2.2*. It can be seen that more than 70% of the design MIC is less than 2 kg.

Figure 2.2 *Distribution of Design MIC for the WIL Alignment*



A review of the allowable MIC's over the length of the entire WIL project (tunnels, adits and station boxes), indicates that the WIL project will require approximately 5,660 individual blast rounds for completion.

Depending on the radial distance to the controlling sensitive receiver(s) and the resultant MIC, the maximum blast length would be 3 to 4 m, while the minimum would be about 0.5 m, for each blast round.

2.3.4 *Typical Station Block Blasting for WIL*

The station excavation will involve the blast face consisting of up to 6 sectors. The initial blast will provide the centre 'cut' to allow the collapse of the rock from the surrounding sectors of the blast face. An upper central 'pilot' section is subsequently blasted from the station face, followed by upper outer strips either side of the central pilot section. Finally, the base section of the working face is extracted by one or more bench blasts.

2.4 DESIGN OF THE EXPLOSIVE MAGAZINE

The proposed magazine is sized for a maximum storage equivalent of about two days of forecast daily explosive consumption at peak output. It consists of 9 niches, 8 of which are designed to store up to 300 kg of Category 1 explosive each. A separate niche will be used to store detonators. The amount of detonators to be stored will be about 7-9kg net explosives quantity (NEQ).

The following design codes were used as a reference in the design of the magazine:

- US Department of Labor, Mine Safety and Health Administration, Title 30 Code of Federal Regulations, Parts 1 through 199, July 2003 (CFR30);

- AS2187.1 – 1998 Explosives – Storage, transport and use Part 1 Storage; and

- US Department of Defense, DoD 6055.9-STD, DoD Ammunition and Explosives Safety Standards, Oct 2004.

The proposed Magazine is planned as an underground cavern to be built beneath Mount Davis and located near a disused Government Facility Site with an entrance adjacent to Victoria Road (see *Figure 2.3*). It is proposed to use an existing flat platform of land to access the underground magazine.

The advantages of the proposed location are:

- the site is as far as practicable from any densely populated areas;

- good rock cover;

- good accessibility from Victoria Road to all areas of the site;

- minimal public road usage to the principal construction access shafts;

- public areas (mainly Victoria Road) and the Works will be shielded from direct blast effects by the orientation of the portals, in the unlikely event that a magazine explosion should occur;

- multiple magazines (for all contractors) can all be located together to facilitate security.

The magazine is sized to contain a buffer stock to offset a possible interruption in Mines deliveries due to weather, sea conditions or other unforeseen circumstances.

The two entrances of the magazine complex will be protected by reinforced concrete barrier walls and covered with absorbent material designed to catch any explosion debris and to reduce the effects of air overpressure in the unlikely event of an accidental explosion within the magazine.

Security of the explosives kept on site is an acknowledged priority. As this is a public report, details of security arrangements are provided separately. Other safety precautions of the magazine are described in [31].

2.5 CONSTRUCTION OF THE PROJECT MAGAZINE

The construction of the tunnels and storage niches of the underground magazine will largely use site sensitized bulk emulsion explosives. Cartridged emulsion will be also required during the trial blasting phase. All explosives materials will be delivered to the site on a daily basis by Mines to enable a mid-afternoon blasting time. There will be no storage of explosive on-site.

Bulk emulsion precursor will be delivered on-site by the appointed third party supplier.

The construction of the magazine adit / tunnel will adopt the following general procedure:

1. Construct access to portal area;

2. Construct the portal site formation;

3. Form the tunnel portal and excavate beneath Victoria Road by non-blasting methods;

4. Install permanent support structures as required;

5. Install temporary protective blast doors at the tunnel portals;

6. Excavate the next 10 m of tunnel using the heading and bench or pilot and strip drill and blast methods;

7. Excavate the remaining adit / tunnel using full face drill and blast; and

8. Complete the fitting out of the magazine tunnels and portal facilities.

The initial excavation of the magazine access tunnel will be by mechanical methods. This will extend for 40 m until the tunnel has passed beneath Victoria Road. This is to minimise the possible risks to Victoria Road and its adjacent slopes due to ground shock during the construction of the magazine. After this, the construction of the magazine will primarily use site-sensitized bulk emulsion and cartridged emulsion explosives. Cartridged emulsion explosives and initiation systems will be delivered to the construction site on a daily basis by Mines.

2.6 *CONSTRUCTION OF THE WIL TUNNELS AND ADITS*

The construction of the WIL tunnels will be similar to the construction of the underground Magazine. After commissioning of the underground magazine the proposed delivery-storage-blasting cycle will consist of the following elements:

1. Weekday morning deliveries of explosives and initiating systems to the underground magazine by Mines as needed.

2. Storage in the underground magazine niches. Each contractor will have one or more dedicated explosive stores

3. Transfer from the explosives niche(s) to the main construction access shafts of the excavation utilizing public roads via routes as indicated in *Figure 2.5*.

4. Transfer from the access shafts to the working face(s) of the excavation via underground adits.

5. Load and fire the face(s) to be blasted. Regular times of initiation to be kept to wherever possible (say 7am, 12:30pm, 7pm). It has been

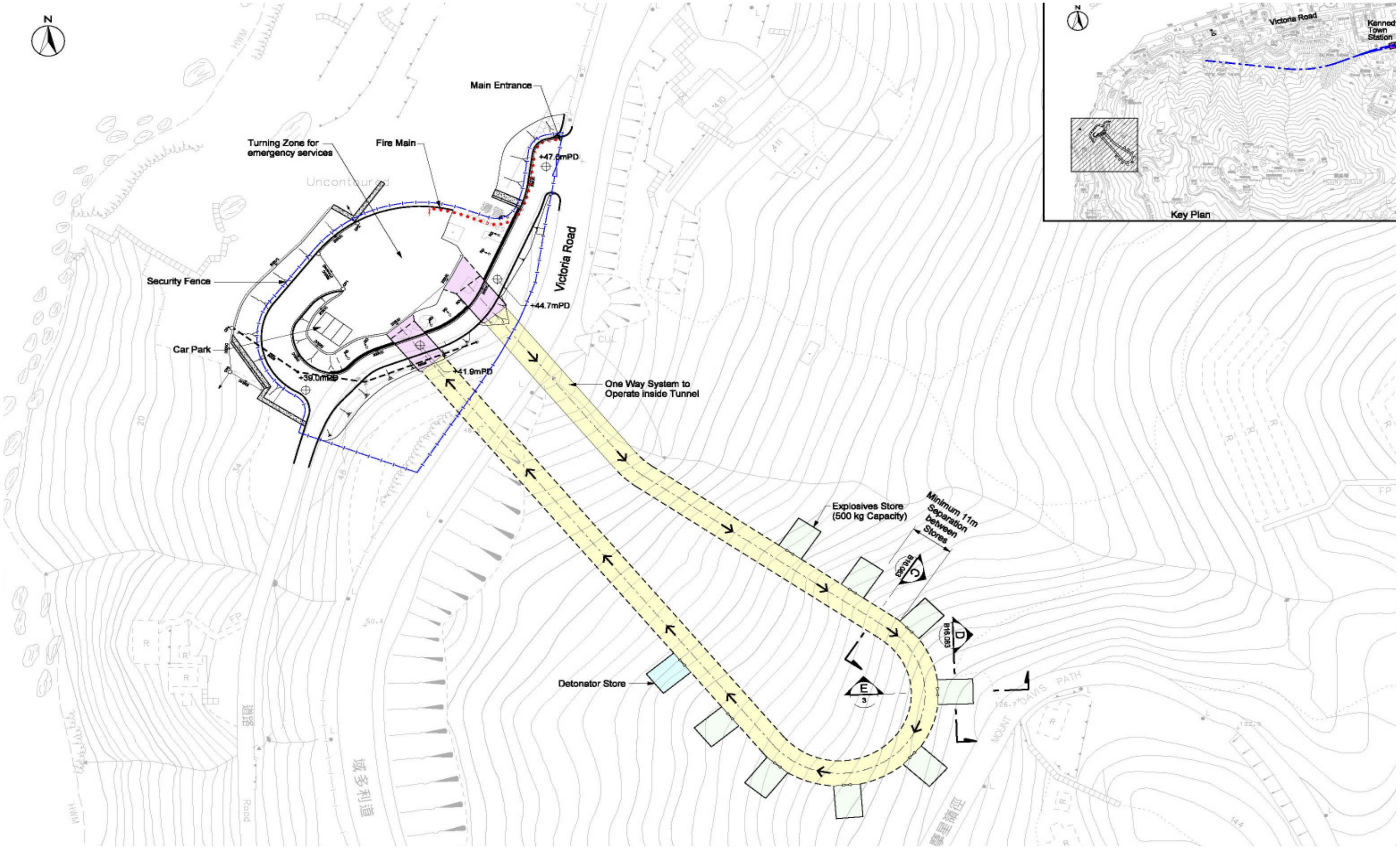
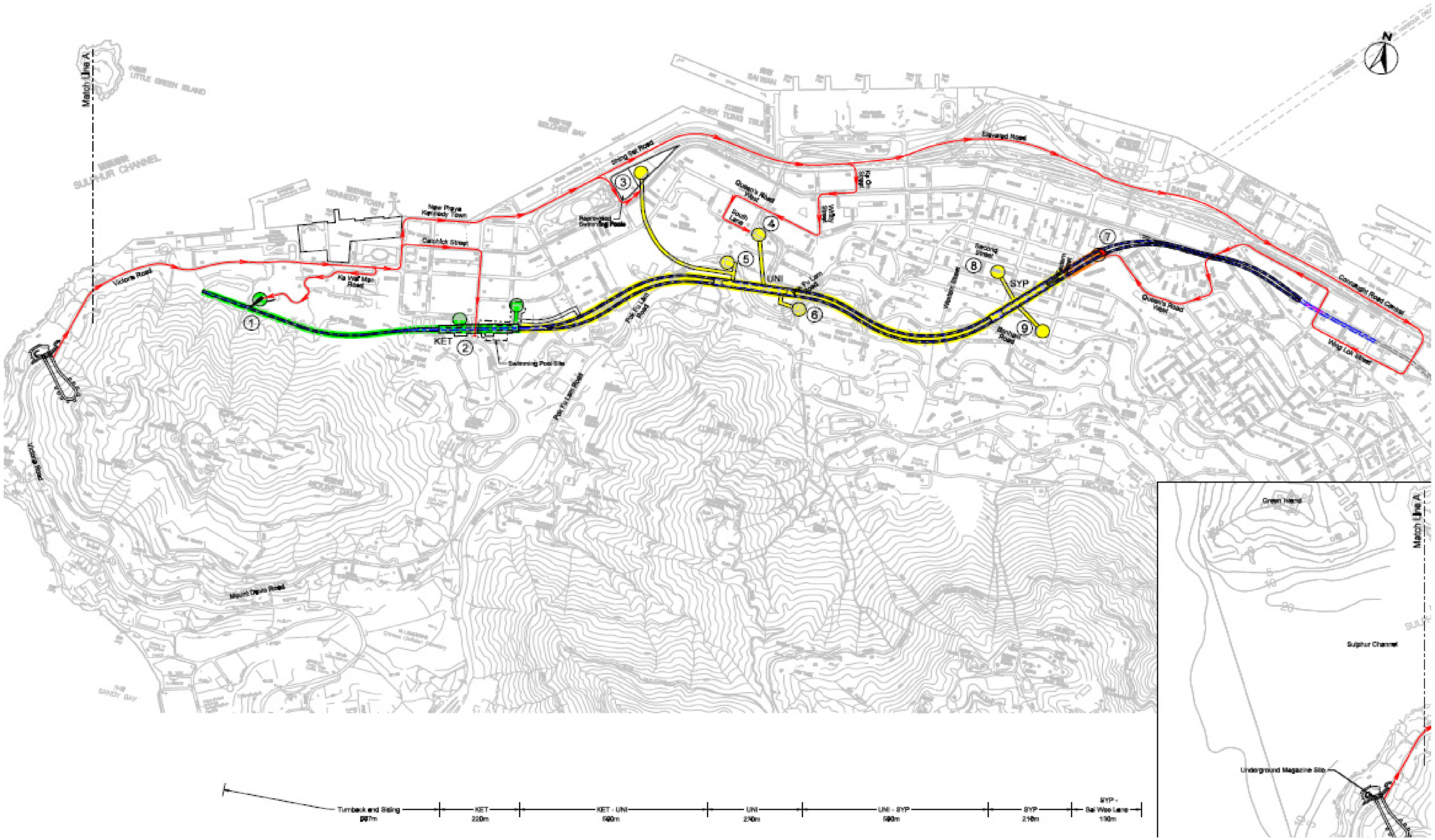


Figure 2.3

Magazine Location and Layout

Environmental Resources Management

ERM



Legend:		
Green	Extent of Rock Tunnel by Contractor B	
Yellow	Extent of Rock Tunnel by Contractor C	
Orange	Extent of Rock Tunnel by Contractor D	
Red line	Traffic Routes	

Figure 2.5

Proposed Explosive Delivery Routes from Underground Magazine

Environmental Resources Management

ERM

estimated that at peak rates, one or two blasts will be carried out each day at selected locations. 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.

2.7 TRANSPORT OF EXPLOSIVES AND INITIATION SYSTEMS

2.7.1 Overview

Generally the explosives and initiating system requirements for a particular drill and blast project are delivered on a daily basis by Mines Division, arriving at the designated site at around 12 noon – 1:00 pm. This means that blasts can only be fired mid-late afternoon, and limits the project to one blast face / day.

When approved by Mines Division, a dedicated on-site explosives magazine can be constructed to service the particular needs of a project. This enables more than one blast face / day assuming the drill and blast cycle can be completed each 12 hours.

Mines Division limit the amount of explosives that a Contractor can transport from the magazine to the blast site to 200 kg. However, the amount of explosives that will be transported during the project construction phase is a maximum of 125 kg of cartridged emulsion, which is equivalent to 120 kg of TNT, based on estimated peak explosive usage. In some circumstances this limit necessitates more than 1 trip to deliver the required volume of explosives for a blast.

Detonators shall be transported in a separate licensed vehicle and are never to be carried with explosives.

The project magazine allows any unused explosives or detonators from a blast to be returned to their magazine niches. If the magazine is unavailable, then any unused cartridged emulsion explosives must be destroyed by burning, and excess initiating systems (detonators) shall be destroyed by linking them into the subject blast.

2.7.2 Transport Strategy

Bulk emulsion precursor will be delivered directly to site by the appointed third party supplier. It should be noted that bulk emulsion precursor is not an explosive. It will not become an explosive until after being sensitized at the blast face while being pumped into blastholes.

The overall intent is that Mines Division will deliver explosives daily to a maximum of one construction site and the project magazine, from where explosives will be transferred to the point of use by the contractors.

- Two deliveries will be made each day to most of the delivery points. The first delivery each day will be made in the early morning when roads will be relatively quieter.

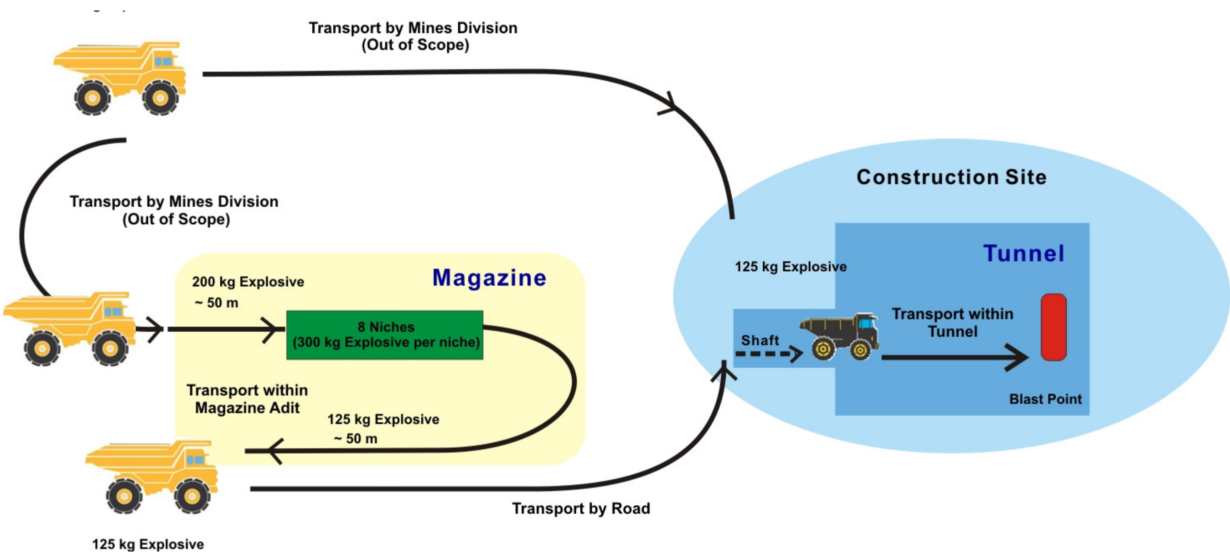
- Loads will be limited to a maximum of 125kg per truck, which is the maximum load expected for the project.

Each contractor will have at least two licensed explosive trucks to facilitate delivery to their designated storage niche(s).

Explosives will then be transferred to the relevant niche by the relevant contractor using their licensed truck. No more than one truck will be allowed within the magazine complex at any one time.

The transport strategy for the explosives is shown in *Figure 2.4*.

Figure 2.4 Transport Strategy for the Explosives



Explosives and detonators will be transported separately from the underground magazine to the designated access shafts / blasting sites by the contractors' licensed delivery vehicles under the escort of armed security guards. Deliveries of explosives will take place during non-peak traffic hours where possible.

Only access points 1 to 4 and 7 will be used for explosive deliveries (see *Figure 2.5*).

To minimise the transport risk, the following principles have been observed in planning delivery routes between the magazine and the various sites:

- Routes have been planned to avoid areas of high population density and Potentially Hazardous Installations (PHIs) wherever possible.

- Two deliveries will be made each day to most of the delivery points / access shafts (see *Figure 2.5*). The first delivery each day will be made in the early morning when roads will be relatively quieter.

- Loads will be limited to a maximum of 200 kg per truck in accordance with the permit issued by Mines Division. However, the maximum explosive load is 125 kg based on peak explosive use during the construction phase.

- The quantity of Category 1 cartridged emulsion explosives on the roads has been minimised by using bulk emulsion precursor, which will be sensitised at the blast face

- Bulk emulsion precursor will be delivered directly to site by the appointed third party supplier. It should be noted that bulk emulsion precursor is not an explosive. It will not become an explosive until after being sensitised at the blast face while being pumped into blastholes

2.7.3 *Safety Features of Transport Vehicles*

The transport truck for explosives will be licensed by Mines Division and will meet all regulatory requirements for that transport.

The licensed explosives delivery vehicles will have the following safety features:

- Diesel powered;
- Battery and fuel isolation switches;
- Forward mounted exhaust with spark arrestor;
- Two fire extinguishers;
- Lockable wood lined steelor aluminium receptacles mounted on the vehicle tray; and
- Fold down / up explosives warning signs and rotating flashing light.

2.7.4 *Details of Cartridged Emulsion Deliveries*

The Cartridged Emulsion Explosives will be delivered to the various construction sites using the public roads as shown in *Figure 2.5*. The proposed site delivery points are the access shafts at:

1. Ex-police quarters, Kennedy Town;
2. Kennedy Town Swimming Pool (Smithfield Road);
3. Site at Kennedy Town Praya;
4. Site at end of South Lane; and
7. Site at Sai Woo Lane.

Other access points will not be used for delivery of explosives from the magazine.

According to the current programme of work, delivery of cartridged emulsion explosives to points 1, 2, 3, 4 and 7 will be required from 2009 to 2011. Construction Phase I will require delivery of cartridged emulsion to Points 1 to 4 and 7 while Construction Phase II will only require delivery of cartridged emulsion to Points 3 and 4. There will be no overlap between the two phases.

The maximum amount of anticipated daily deliveries of cartridged emulsion by the contractors to points 1, 2, 3, 4 and 7 for Construction Phase I is summarised in *Table 2.4* below, while the maximum anticipated daily delivery to points 3, 4 for Construction Phase II is summarised in *Table 2.5*. The deliveries to point 7 will either be carried out in the morning or in the afternoon. In addition to the cartridged emulsion, detonating cords and cast boosters, will be stored and transported. These have been included in the weight figures in *Table 2.4* and *Table 2.5*. The proposed delivery routes to the delivery points are shown in *Figure 2.5*.

The explosives delivery quantities are summarised in *Table 2.4* and *Table 2.5* for Construction Phase I and Phase II respectively. Construction Phase I has the highest transport frequency per year and hence been selected as the basis of the QRA.

Table 2.4 Explosives Delivery Quantities – WIL Construction Phase I

Contractor	Delivery Point	Daily AM Delivery (kg/day)	No of Trips AM	Daily PM Delivery (kg/day)	No of Trips PM	Consumption (kg/day)
Contractor B	1 – Ex-police-quarters, Kennedy Town	80	1	0	0	80
	2 – Kennedy Town Swimming Pool	80	1	0	0	80
Contractor C	3 – Site at the Kennedy Town Praya	125	2	125	2	500
	4 – Site at the end of South Lane	80	1	80	1	160
Contractor D	7 – Site at the Sai Woo Lane	80*	1*	0*	0*	80

* Delivery may be carried during PM instead of AM

Table 2.5 Explosives Delivery Quantities – WIL Construction Phase II

Contractor	Delivery Point	Daily AM Delivery (kg/day)	No of Trips AM	Daily PM Delivery (kg/day)	No of Trips PM	Consumption (kg/day)
Contractor C	3 – Site at the Kennedy Town Praya	80	1	80	1	160
	4 – Site at the end of South Lane	80	1	80	1	160

2.7.5 Transport Route

Explosives are transported from the magazine to the access shafts / blasting sites using the routes as shown in *Table 2.6* below.

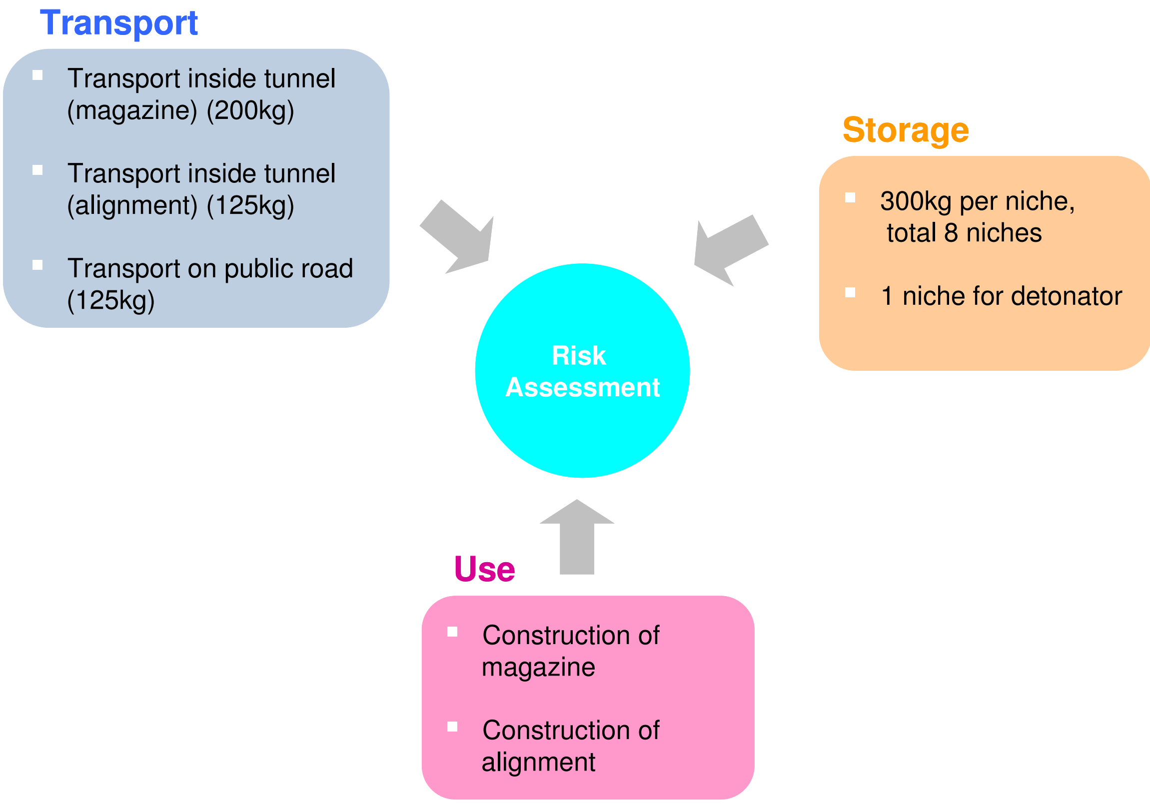
Table 2.6 Delivery Routes for Explosives to the Blasting Site

Delivery Point - Destination	Route
1 – Ex-police-quarters, Kennedy Town	Victoria Road – Ka Wai Man Road
2 – Kennedy Town Swimming Pool	Victoria Road – Cadogan Street – Catchick Street – Smithflied Road
3 – Site at the Kennedy Town Praya	Victoria Road – Cadogan Street – New Praya, Kennedy Town – Shing Sai Road – Sai Cheung Street – Kennedy Town Praya
4 – Site at the end of South Lane	Victoria Road – Cadogan Street – New Praya, Kennedy Town – Shing Sai Road – Connaught Road West – Ka On Street – Des Voeux Road West – Whitty Street – Queens Road West – Woo Hop Street – South Lane
7 – Site at the Sai Woo Lane	Victoria Road – Cadogan Street – New Praya, Kennedy Town – Shing Sai Road – Connaught Road West / Central – Rumsy Street – Wing Lok Street – Morrision Street – Connaught Road West – Queens Street – Queen Street West

It is recognised that the above routes involve transport through densely populated high rise residential areas. This is taken into account in the risk assessment.

The overall methodology for the Hazard to Life Assessment addresses the risk associated with the storage, transport and use of explosives for the WIL construction (see *Figure 3.1*).

Figure 3.1 Three Components of the Risk Assessment



The potential effects considered to pose a risk to the general population include excessive ground vibrations, overpressure and other effects such as projectiles.

The methodology takes into account for relevant previous studies including:

- The territory wide study for the transports of explosives [1];
- Hazard to Life Assessment section of the Ocean Park EIA [2];
- Hazard to Life Assessment section of the Penny's Bay Rail Link EIA [3].

The elements of the QRA are shown schematically in *Figure 3.2*. It includes the following steps.

- Relevant data on the proposed storage magazine, the transport from the magazine and the use of explosives at the blast face, as well as population and vulnerable receptors, such as slopes, retaining walls etc., in the vicinity of the tunnel construction and proposed transport routes were collected and reviewed.

- A structured study, involving a "what-if" analysis, was conducted to identify all the hazards associated with the storage, transport and use of the proposed blasting explosives. A review of literature and accident databases was also undertaken. These formed the basis for identifying all the hazardous scenarios for the QRA study.

- The frequencies, or the likelihood, of the various outcomes that result from the hazards associated with the storage and transport of blasting explosives were taken from published references; such as the UK HSE, TNO, or from previous EIA QRAs that have been accepted by the relevant authority. Where necessary, these frequencies are modified to take account of local factors.

- The frequencies of scenarios associated with the use of explosives at the blast face were established using fault tree analysis, in conjunction with a human factor assessment to evaluate human error probabilities.

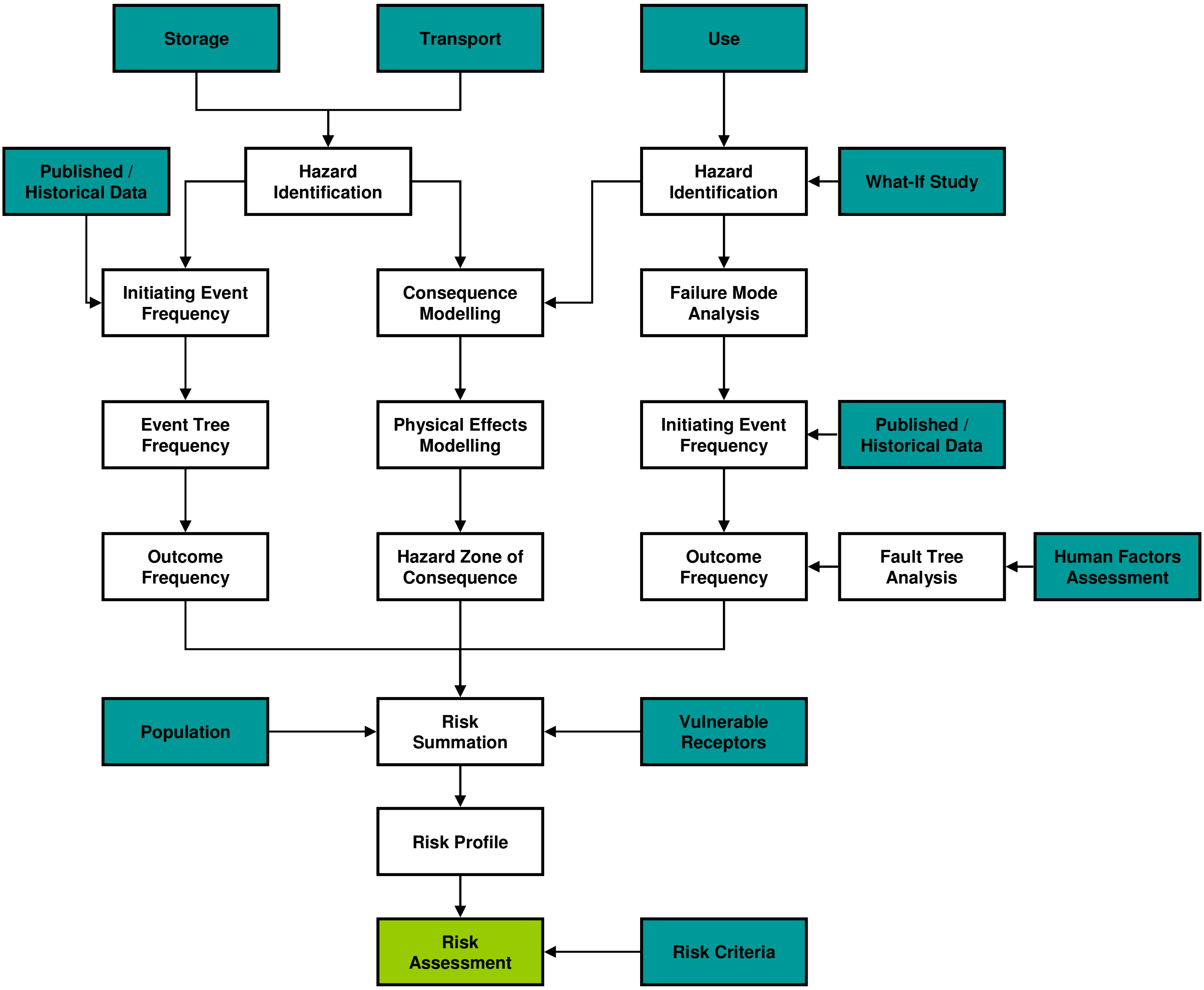
- For all identified hazards the frequency assessment has been documented and the consequences of the event were modelled.

- The consequence model employed by the QRA varied depending on the location of any explosion, i.e. above or below ground, and upon the receiver, i.e. slope, building or person.

- The consequence and frequency data were subsequently combined using ERM's proprietary software Riskplot ™ to produce the required risk estimates.

- Finally, the results from the risk assessment were compared to the HKRG. Recommendations have been made where required to ensure compliance with relevant best practice, and to reduce the hazard by strengthening various vulnerable receptors.

Figure 3.2 Schematic Diagram of QRA Process



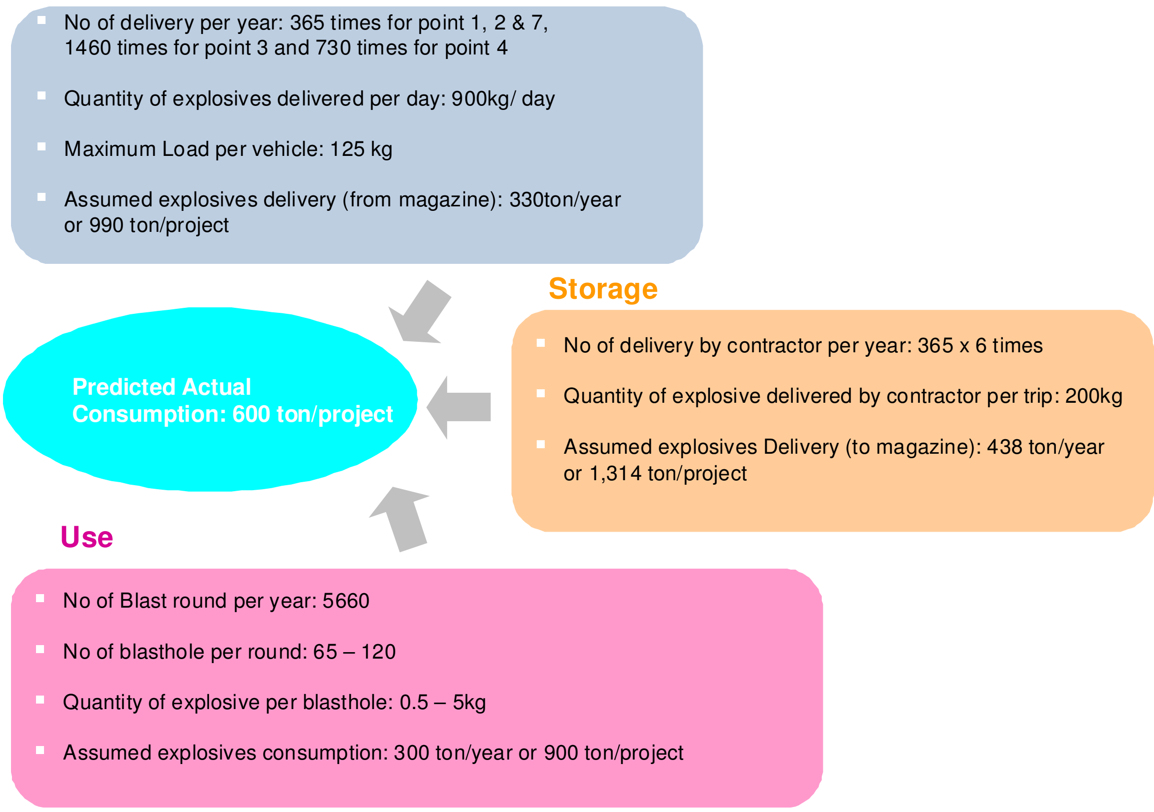
3.1 GENERAL ASSUMPTIONS OF THE STUDY

The study has assumed that cartridged emulsion is being used throughout the WIL project (see *Figure 3.3*). This represents the a worst case scenario, as the use of bulk emulsion, which is more likely to be used, will significantly reduce the amount of explosive material that is required to be stored and transported. It is estimated that in reality, no more than 20% of the blasts will use cartridged emulsion. However, all trial blasts will use cartridged emulsion.

When bulk emulsion explosives are used on a daily basis by Contractors, the volume of cartridged emulsion explosives being transported along public roads will reduce dramatically to between 15 – 30 kg per trip. This amount of cartridged emulsion is based on their use as a primer or booster for the bulk emulsion. However, it should be noted that the number of detonators required will not change with the use of bulk emulsion.

Hence, the risk estimated by this study can be considered as upper bound and the actual risks will be lower.

Figure 3.3 Consumption of Explosives for the WIL



Notes: The quantities assumed for use, transport, storage for the QRA are higher than the predicted actual consumptions, to account for the peak consumption in a year for conservative purpose

4 POPULATION ESTIMATES

4.1 POPULATION ESTIMATE NEAR THE EXPLOSIVE MAGAZINE

The nearest public inhabited building, 410 Victoria Road, is 64m to the north east at its closest point to the magazine tunnel. This building is approximately 110m to the north of the nearest explosives storage chamber.

In addition Victoria Road is 67m to the west of the nearest explosive storage chamber at its closest point.

4.1.1 *Nearby Populations*

The possible persons at risk to an incident within the explosives magazine are located in:

- Nearby occupied buildings;
- Road vehicles and pedestrians on Victoria Road; and
- Boats operating in the West Lamma Channel and Sulphur Channel.

Occupied Buildings

The area surrounding the proposed magazine site is sparsely populated. However, there are some inhabited buildings situated to the North just off Victoria Road. These are presented in *Table 4.1*.

Table 4.1 Population for Occupied Buildings for Consequence Assessment for Storage of Explosives

Number	Building name	Street Name	Population	
			Day	Night
1	Abandoned building	410 Victoria Road	0	0
2	Caritas Jockey Club Hostel Mount Davis	405 Mount Davis Cottage Area	200	200
3	Chee Sing Kok Social Centre of the Humanity Life	404 Mount Davis Cottage Area	200	200

Road Users

The road population density has been obtained from the 2000 – Based District Traffic Model (BDTM). A growth factor of 1% per year to the construction year is included.

The road population density was calculated using the formula:-

Population Density = P N / (1000 W V)

where P is the average number of persons per vehicle, assumed to be equal to 3
W is the road width, m
V is the vehicle speed, km/hr
N is the number of vehicles counted

The following table lists the road population density used in the study:

Table 4.2 ***Road Population Density for Consequence Assessment for Storage of Explosives***

Road Name	Road Population Density (persons/m2)	
	AM	PM
Victoria Road – North of Magazine	0.0071	0.019
Victoria Road – South of Magazine	0.0051	0.014

The pedestrian population density on the footpaths is assumed to be 0.15 persons/m^2 during the morning non peak hours and 0.25 person/m^2 during peak hours. It is assumed that there are no pedestrians between 10pm and 6 am.

A high density value of 0.5 persons/m^2 is equivalent to a footpath level of service D, as defined by the Highway Capacity Manual. This level of service provides for a reasonable smooth flow of pedestrians, but friction and interaction between the pedestrians is likely. This is considered to be very conservative for the footpaths alongside Victoria Road at the location of the magazine. Therefore, a value of 50% of this level is assumed for peak hours only and 33% for other times.

However, for the assessment of fatalities caused by slope failure the Transport Department Annual Traffic Census 2007 was used for the station 2206 located on Victoria Road between Smithfield Road and Mount Davies Road. The average daily traffic values have been inflated by 1% per year to represent the likely traffic during the construction and operation of the magazine in 2009.

Table 4.3 ***Annual Average Daily Traffic for Victoria Road between Smithfield Road and Mount Davies Road***

Number	Road name			Annual Average Daily Traffic	
		From	To	West	East
2206	Belchers Street and Victoria Road	Smithfield Road	Mount Davies Road	4,020	3,450

Waterways

The exit portals of the magazine are facing North West looking over the West Lamma Channel, near the entrance to the Sulphur Channel that separates Green Island and Hong Kong Island. The distance of the magazine entrance and exit portals to the coastline is 70m, with the shipping navigation channel a further 150m from the shoreline.

4.2 *POPULATION ALONG EXPLOSIVES DELIVERY ROUTES*

The proposed route for the transport of explosives would involve the explosives truck passing through densely populated high rise commercial areas, in particular Des Voeux Road, Wing Lok Street and Connaught Road. Also situated along the route are a number of residential buildings, schools, outdoor recreation areas and educational institute (Kennedy Town Centre).

The risk assessment focuses on the high rise blocks, representing the largest concentration of people indoors (people indoors are relatively more vulnerable to the effects of an accidental explosion than those outdoors). All of the buildings along the delivery route (see *Annex C*) have been entered individually into the risk 'model', so as to accurately represent the population. A population density approach has been adopted for modelling the presence of pedestrians and road users.

Population data have been collected by a combination of survey, the Code of Practice for Fire Safety, Planning Department Zoning Plans and the census. Three types of population have been considered:

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

Assumptions used in estimating population are listed in *Table 4.4*.

Table 4.4 Population Assumptions

Type of Population	Assumption	Remarks
Residential Building	3 persons / flat	Governments Territorial Population and Employment Data Matrices (TPEDM) indicates current Persons Per Unit (PPU) in Kennedy Town, University and Sai Ying Pun are 2.61, 2.995 and 2.46 respectively. A value of 3 has been adopted as a conservative assumption.
Commercial Building	9 m^2/person	Code of Practice for the Provision of Means of Escape in Case of Fire indicates 9m^2/person as a minimum requirement.
Footpath	0.5 persons /m^2	Density figure of 0.5 persons/m^2 is defined as footpath Level Of Service (LOS) in the Highway Capacity Manual. this is considered as a reasonable conservative density for the footpaths in the study area and is supported by surveys carried out during the preliminary design stage which indicated lower values..
Education Institute	500 persons / hall	

4.2.2 *Pedestrian Population*

The 0.5 persons/ m^2 is the assumed pedestrian population density as per *Table 4.4* . For morning delivery, a density figure of 0.25 persons/m^2 is adopted for the footpaths from Ka On Street to South Lane (to delivery point 4) and the footpaths along Queens Road West, Second Street and Bonham Road (near delivery point 7) to account for the reduced footpath population density as morning delivery will be made in very early hours, ie. before 0630. A density figure of 0.15 persons/m^2 is used for all other footpaths. This value is considered conservative when compared with the Traffic Impact Assessment (Working Paper WP TT07) [14].

In the Traffic Impact Assessment, pedestrian flow had been assessed at locations near the planned station entrances. Results are extracted in *Table 4.5* below. For those survey locations along the delivery routes (highlighted yellow in *Table 4.5*), the survey results indicated that the a.m. and p.m. peak pedestrian densities are lower than those adopted in this study. The higher density figures, as specified in *Table 4.5*, are nevertheless adopted to maintain a reasonably conservative estimate, and cater for fluctuation of population density along the routes (e.g. at bus stops).

Table 4.5 Pedestrian Density Extracted from WP TT07

Survey Location	Road width	AM Peak 15 min		PM Peak 15 min	
		Pedestrian flow (ped/15-min)	Population Density (pers/m2)	Pedestrian flow (ped/15-min)	Population Density (pers/m2)
KET1-1	2.5	70	0.03	40	0.02
KET5-1	2.6	290	0.11	330	0.13
KET6-1	3.1	260	0.08	270	0.09
KET7-1	2.3	80	0.03	40	0.02
KET8-1	2.7	50	0.02	30	0.01
KET9-1	2.9	100	0.03	10	0.00
KET10-1	2.7	310	0.11	130	0.05
KET15-1	2.7	340	0.13	320	0.12
KET16-1	3	330	0.11	390	0.13
KET17-1	3	350	0.12	470	0.16
KET18-1	3	180	0.06	190	0.06
UNI1-1	2.6	140	0.05	140	0.05
UNI4-1	2.6	30	0.01	60	0.02
UNI4-2	1.5	80	0.05	110	0.07
UNI5-1	3.3	110	0.03	170	0.05
UNI6-1	2.8	50	0.02	30	0.01
UNI11-1	4.4	400	0.09	540	0.12
UNI12-1	2.1	230	0.11	240	0.11
UNI13-1	3.8	300	0.08	550	0.14
UNI14-1	3.8	290	0.08	410	0.11
UNI15-1	4.6	330	0.07	420	0.09
SYP3-1	2.8	130	0.05	70	0.03
SYP4-1	1.6	360	0.23	260	0.16
SYP5-1	1.8	110	0.06	60	0.03
SYP8-1	1.6	70	0.04	40	0.03
SYP10-1	1.9	20	0.01	20	0.01
SYP11-1	1.8	70	0.04	60	0.03
SYP12-1	1.5	40	0.03	100	0.07

Survey Location	Road width	AM Peak 15 min		PM Peak 15 min	
		Pedestrian flow (ped/15-min)	Population Density (pers/m2)	Pedestrian flow (ped/15-min)	Population Density (pers/m2)
SYP12-2	1.5	40	0.03	100	0.07
SYP13-1	1.2	90	0.08	50	0.04
SYP14-1	3.2	110	0.03	110	0.03
SYP14-3	3.1	110	0.04	110	0.04
SYP15-1	3.3	230	0.07	240	0.07
SYP15-3	3.3	220	0.07	240	0.07
SYP16-1	3.5	200	0.06	190	0.05
SYP16-3	4.2	210	0.05	180	0.04
SYP17-1	3.8	280	0.07	180	0.05

Note: the yellow-highlighted survey locations are located along the planned delivery routes

4.2.3 *Road Population*

Also represented in the risk model is the population associated with traffic on the roads. The traffic density information used in this study is based on the 2000-Based District Traffic Model (BDTM). Where appropriate, data from the 2006 traffic census is used to supplement the BDTM data. A growth of 1% per year to the year of construction has been assumed in the analysis for delivery to various points. As the morning delivery will be carried out before 0630, the AM road population has been reduced by 70% (and 50% in market area where some early morning loading / unloading activities are envisaged) to account for the especially light traffic at that time. However, the full peak traffic density is used for PM period. This is considered to be a conservative assessment as it will cause a slight overestimate of the risk as the delivery is to be carried out outside peak hours. Road population density used in this study is given in *Annex C.*

A traffic survey was conducted by MCAL in April 2008 to assess the traffic population densities at 8 key road sections in Sheung Wan, Sai Ying Pun and Kennedy Town for the transport route (see *Annex D*). The survey results were compared with the general traffic population densities from the BDTM model. Most of the survey data are found comparable to the BDTM data, whilst noticeable difference was observed for the following sections.

1. Catchick Street between Smithfield Road and Davis Street;
2. Des Voeux Road West between Water Street and Whitty Street for refinement of the QRA;
3. Queen’s Road West between New Street and Eastern Street.

It was therefore proposed to the use the traffic survey results for the above sectors for the risk assessment. The traffic population figures presented in *Annex C* includes the specific traffic survey results.

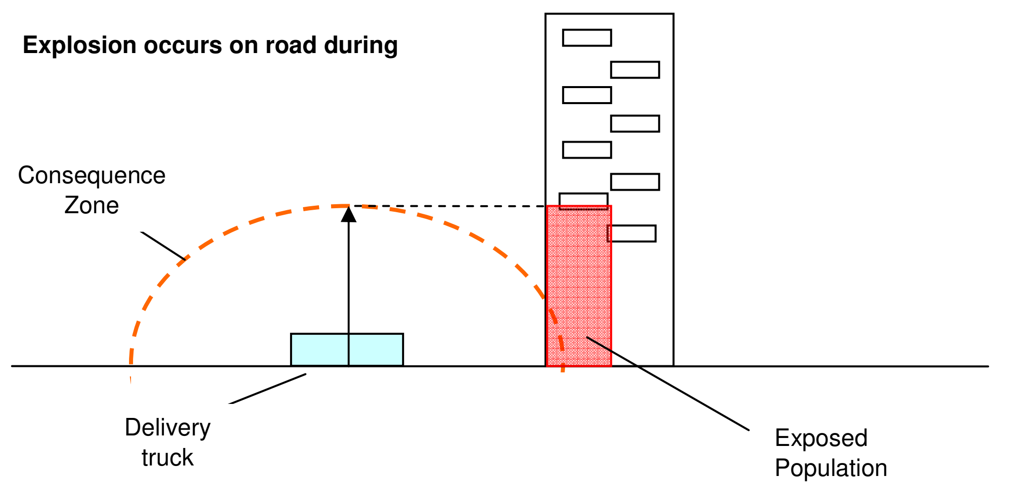
4.2.4 *Building Population*

The consequence assessment has determined the maximum hazard zone for 1% fatality level of 42m for the detonation of the 125kg (maximum delivery quantity) of cartridge explosives in a licensed vehicle. Accordingly, population within the first 12 floors of a building may be affected.

The hazards due to an explosion during the transport of explosives are principally overpressure and flying debris. For the purpose of this study, it is considered that people at the rear of the building facing the road will not be impacted by overpressure or flying debris.

The hazard footprint was overlaid on the population polygons (road lanes, pavement areas and building areas) to establish overlap areas from which the number of fatalities could be estimated. Ideally, a spherical vulnerability model should be adopted. However, for simplification purpose, a conservative cylindrical model was used to estimate the number of persons which could be impacted by each consequence contour. The consequence distances were estimated and the population up to 36m for transport of explosives from magazine to delivery point 01, 02, 04 and 07, and 42 m for the delivery to point 03 , as given in *Table 7.8* (assumed to be equivalent to 10 floors and 12 floors respectively) was considered within the cylinder. This represents the 1% probability of fatality limit.

Figure 4.1 *Consideration of Population Inside Building*



Population details for buildings along the transport route are given in *Annex C*.

4.3 *Population Considered for the Use of Explosives*

All the sensitive receivers, including buildings, slopes, utilities and other structures within a distance of 100m along the blasting route have been considered in this assessment.

This distance is equivalent to a peak particle velocity value of approximately 35 mm/sec based on a worst case scenario of the simultaneous detonation of 6 charges within the blast face. Assuming that the maximum charge per blasthole is 5kg, then the total maximum simultaneous charge weight is 30 kg. Therefore, the peak particle velocity at 100m is estimated as (see *Section 7.2.6*):-

$PPV = K (D / Q^{0.5})^{-1.22}$

$PPV = 1200 (100 / 30^{0.5})^{-1.22} = 34.7mm/s$

The limit for the cosmetic damage to buildings lies between 25mm/s and 50mm/s depending on its construction. For slopes, this level of PPV will not cause significant slope movement. This is consistent with GEO Guide 4 [9] Section 5.7.1 which states "As a general guide, blast vibration from subsurface works are normally not potentially damaging at distance of more than 50m."

Figure 4.2 provides a three-dimensional view of the blasting chainage and sensitive receivers for the WIL alignment considered in the study. Those features considered as sensitive receivers are described in *Section 4.3.1*.

The sensitive receivers are represented by a point or a number of points in the analysis. The whole alignment is also represented by points at every 10-m chainage interval.

The latitude and longitude (ie 'Northing' and 'Easting') of every point shown in *Figure 4.2* are based on the 'Hong Kong 1980 Grid' coordinate system in Hong Kong. The plot of 'Northing' (y-axis) and 'Easting' (x-axis) is shown as the horizontal plane in this figure. The level of a point refers to the elevation of the relative receiver with respect to the Principal Datum (the unit is mPD), and is shown as z-axis in this figure.

Similarly, three-dimensional view of the blasting chainage and sensitive receivers for the magazine store considered in the study is shown in *Figure 4.3*.

Figure 4.2 Blasting Chainage and Sensitive Receivers Considered for the Construction of WIL Alignment (Side Review)

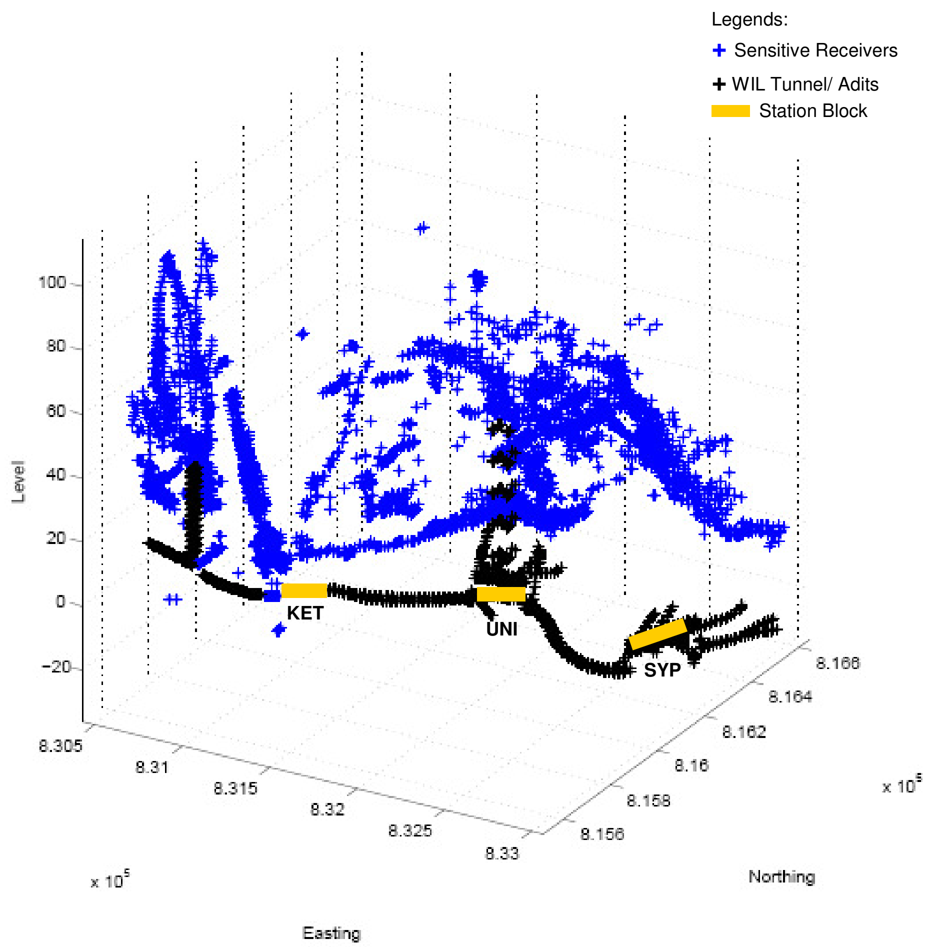
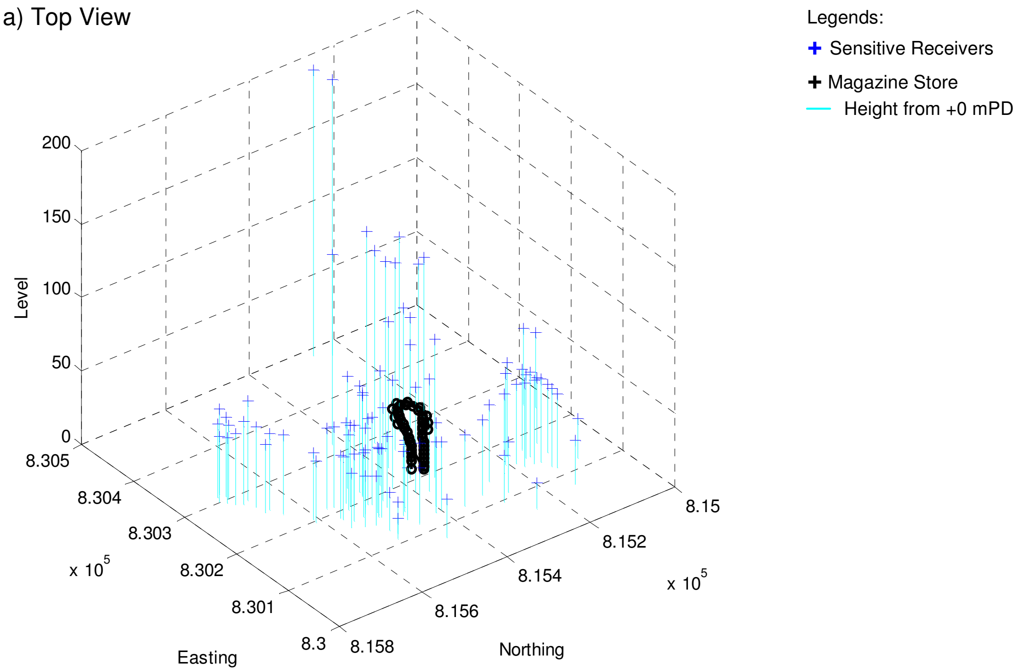
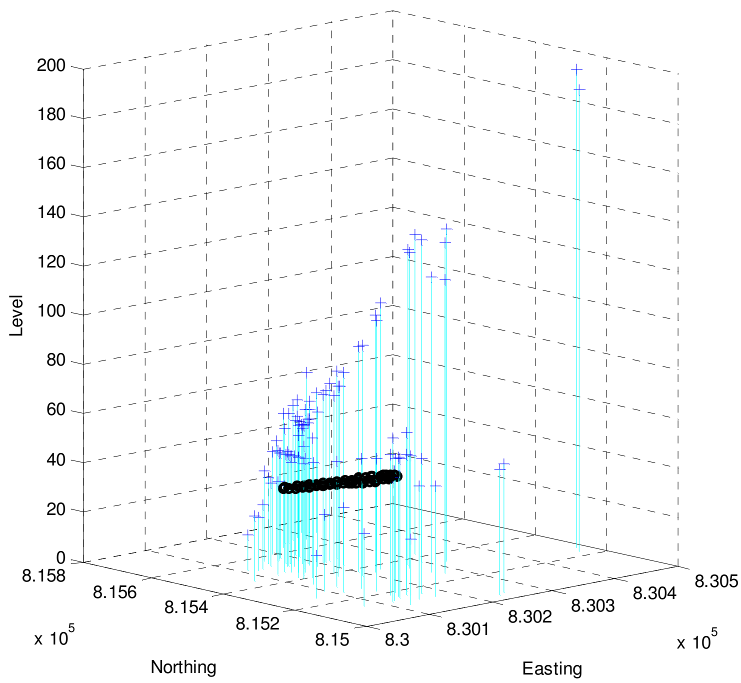


Figure 4.3 ***Blasting Chainage and Sensitive Receivers Considered for the Construction of the Magazine (Top View and Side View)***

a) Top View



b) Side View



4.3.1 *Features Considered for the Study*

The following sets of features were considered as sensitive receivers in the Blast Assessment Report [4]-[6]:

- Man Made Slopes and Retaining walls
  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.

- Natural Terrain Hillside and Boulders
  There are no natural terrain hillsides or pockets of natural terrain within the influence zone of WIL alignment. In addition there are no boulders located above the proposed blasting zone. The nearest natural terrain is Lu Fung Shan which is located more than 100m in plan from the southern side of UNV station.

  The only relevant boulders for the WIL project are located near the proposed magazine in Mount Davis. Several site inspections of natural hillside were carried in 2008 as part of blast assessment [4]-[6]. Twenty-four boulders were identified at the hillside above the magazine. However, none of them are located above any occupied building and their conditions have been considered to be well embedded.

- Existing Buildings and structures
  Since the WIL alignment is proposed along an urban area and the whole area has been developed with buildings and structures. This item includes all buildings and structures within the 100 m from the WIL alignment and magazine.

- Utilities
  There are numerous underground utilities facilities near the proposed WIL alignment. The facilities include gas pipes, electricity cables, telephone cables, cable television services, stormwater drains and sewage pipes, such as gas main, fresh water main

- Other facilities
  These refer to features other than those listed above but have been included in the Blast Assessment Report [4]-[6] as sensitive receivers. These include elevated roads, disused tunnel networks near SYP and UNV, etc.

The features were identified by desktop or site survey as part of the Blast Assessment. Every feature was represented by one or more coordinates in a 3-dimensional plane (Northing, Easting, and Elevation) based on data given in the Blast Assessment Report. More than 5000 feature points were identified for this WIL project.

5 HAZARD IDENTIFICATION

5.1 OVERVIEW

Hazard identification consisted of a review of:-

- explosive properties;
- scenarios presented in previous relevant studies;
- historical accidents; and
- discussions with blasting specialists.

In addition, an expert panel review was commissioned by ERM/MTRC to review the key assumptions/ uncertainty for the risk assessment for the storage, transport and use of explosives in the context of the WIL Quantitative Risk Assessment. The review was held at ERM office in Hong Kong on 21-23 July 2008 [10].

5.2 ACCIDENTAL INITIATION DUE TO HAZARD PROPERTIES OF EXPLOSIVE

5.2.1 *Hazard Properties of Ammonium Nitrate*

The family of emulsion explosives typically contains over 78% ammonium nitrate, which is a powerful oxidising agent. Ammonium nitrate will not explode due to friction and impact found in normal handling. However, it can be detonated under heat and confinement or severe shock, such as that from an explosive. The sensitivity of ammonium nitrate to detonation is increased by elevated temperature or by contamination.

In a fire, pools of molten ammonium nitrate may be formed, and if the molten mass becomes confined it may explode, particularly if it becomes contaminated. In a fire ammonium nitrate may melt and decompose with the release of toxic fumes (mainly oxides of nitrogen).

5.2.2 *Accidental Initiation of Explosives*

Explosives are considered 'initiated' when a self sustaining exothermic reaction is induced. Such a reaction results in either a violent burning with no progression to explosion, a deflagration or detonation. The main difference between a deflagration and detonation is that a detonation produces a reaction front travelling at greater than sonic velocity. Both explosion types can cause extensive injury and damage. However, the blast wave produced by a detonation is much more destructive than that associated with deflagration.

Where explosives are stored under controlled conditions in purpose built and operated magazines or stores, the likelihood of accidental initiation in situ is remote. This is because the storage environment is unlikely to experience extremes of heat, shock, impact, or vibration in sufficient intensity to initiate detonation. The most common means of accidental initiation is principally the introduction of fire. Other means of initiation include severe impact and friction.

In this study, accidental initiation of explosives has been categorised as either fire or non-fire induced. The following sections briefly describe the initiation mechanisms and events judged applicable for this analysis. Those mechanisms and events excluded are mainly associated with static discharge and exposure of 'within specification' explosives to extremes of ambient air temperature. Static discharge can be excluded based on the large ignition energy required to initiate detonation of the cartridged emulsion. For example, the maximum static discharge from a person is in the order of 30mJ. Whilst this is sufficient to ignite flammable vapours it is incapable of causing an initiation of cartridged emulsion. In addition, the explosive magazine is underground so extremes of ambient temperature are not considered likely within the magazine. Therefore, static discharge and ambient air temperature extremes are excluded as it is not considered possible to initiate emulsion based explosives by these means.

5.2.3 *Accidental Initiation by Fire*

Numerous tests demonstrate that, when subjected to fire engulfment, many explosives ignite and burn to deflagration, and in some cases detonate. The time for an explosive to ignite is dependent upon its physical characteristics, chemical composition, and the conditions under which it is stored or handled.

Cartridged emulsion is unlikely to be a fire hazard under normal conditions, because of its high water content. However, when exposed to fire the water content of the emulsion will be driven off, leading to possible initiation if the energy levels are high enough and of long duration. It is generally considered that these explosives are insensitive to fire engulfment as a means of initiation, and are more likely to burn rather than explode when compared to other types of explosives.

5.2.4 *Accidental Initiation by Means Other Than Fire*

Non-fire initiation mechanisms are commonly divided into two distinct groups; impact and electrical energy. The term 'impact' encompasses both shock and friction initiation, because in most accidental situations, it is difficult to distinguish between them. It has been recorded that some explosives can initiate (in the absence of piercing) at an impact velocity as low as 15 m/s. If the explosives are pierced, for example by a sharp metal object, then it is likely that the required velocity will be far less than 15 m/s. This is due to localised heat generation resulting from frictional rubbing between layers of explosive, and is referred to as 'stab-initiation'. However, the cartridged emulsion is believed to be insensitive to initiation via impact, as demonstrated by the bullet impact test from a high velocity projectile.

All explosives have a minimum ignition energy level, above which initiation will occur. Typically, minimum ignition energy levels range between 0.015 J and 1.26 J. For the vast majority of explosives, including cartridged emulsions, the required ignition energy level is far exceeded by contact with mains electricity. In comparison, the energy levels possible from batteries or alternators fitted to motor vehicles, or that due to static build-up on clothing, is typically much less than that required to initiate most commercial explosives (eg 0.02 J or less). Hence, only very sensitive explosives are likely to ignite from these electrical energy sources. Therefore, electrical energy is not a possible energy source for explosives intended to be used in this project.

Degraded, damaged or off specification emulsion explosives are less sensitive to initiation than good quality explosives. Possible degradation of cartridged emulsion is from water loss and prolonged exposure to higher temperatures, which leads to potential caking or a change in ammonium nitrate crystalline state and increase in volume. Both modes of degradation do not lead to the possible detonation of the cartridged emulsion.

5.2.5 Hazard Properties of Detonating Devices

These detonating devices may detonate when exposed to heat or flame, or with friction, impact, heat, low-level electrical current or electrostatic energy. Detonation produces shrapnel. Hazardous gases/vapours produced in fire are lead fumes, nitrogen oxides and carbon monoxide. However, these gases depend on the type of material used in the detonators.

5.3 ACCIDENTAL INITIATION ASSOCIATED WITH STORAGE AT MAGAZINE

For the proposed magazines, the possible means of accidental initiation of the explosives by fire are as follows:

- inadequately controlled maintenance work (eg hot work);
- poor housekeeping (eg ignition of combustible waste from smoking materials);
- inappropriate methods of work;
- electrical fault within the store, which ignites any surrounding combustible material resulting in a fire; or
- arson.

Possible means of accidental initiation of the explosives by means other than fire are as follows:

- dropping of explosives during handling (for the detonators only);
- crushing of explosives under the wheels of vehicles during loading or off-loading (for detonators, cast boosters and detonating cords only).

The detonators are supplied packaged within plastic separating strips, such that the initiation of a single detonation will not propagate to the adjacent detonator. Packaged in this manner the detonators are classified as Class 1.4B explosives. The total mass of detonators is negligible in terms of explosive mass.

There is no increased risk of explosion of cartridged emulsion packages arising from misoperation during handling. This is due to the inherently safe properties of emulsion.

5.4 GROUND VIBRATION ASSOCIATED WITH USE OF EXPLOSIVES

Ground vibration induced by stress wave during rock excavation could be potentially hazardous if the vibration level is high enough to cause damage. Peak Particle Velocity (PPV) is generally used as an indicator of vibration leading to potential damage. It is generally considered that structures in good condition can withstand a PPV of 50mm/s without any risk of damage [25].

Ground vibration is governed by the distance from the blast face to the feature and the charge weight (MIC). A plot of the PPV level versus design MIC is shown in *Figure 5.1*.

Based on the Blast Assessment Report [4]-[6], the MIC has been designed according to the defined criterion in terms of PPV, for each category of features. A PPV of 25mm/s has been adopted for buildings based on MTR project specification and by the Hong Kong SAR General Specification for Civil Engineering Works. Utility operators in Hong Kong were consulted for their criterion during the blast assessment; generally the vibration limits are lower for some particular sensitive installations, such as water mains, and are detailed in *Table 5.1* below.

It is not expected to have any aboveground buildings subject to a vibration level higher than 25mm/s in the design.

Nevertheless, high vibration can still occur in the event of accident or unforeseen ground condition. For example if the actual site ground conditions significantly deviate from those predicted, an exceedence may be observed.

As shown in *Figure 5.1*, a feature of a lower acceptable PPV level may become the controlling sensitive receiver for a particular tunnel section even if it may not be the nearest feature. It is therefore worth noting that along the WIL alignment, there is a lot of historical buildings or other critical sensitive receivers, such as temples and monument, which have a very low maximum allowance vibration limit (~5mm/s) for the purpose of building preservation. When these features become the controlling sensitive receivers for the design of certain tunnel sections, the design MIC will be low and thus the vibration level susceptible by other feature (such as buildings and slopes) will reduce. This can be considered as an inherent safe feature for the blasting design.

Figure 5.1 Variation of PPV at Different Charge Weight

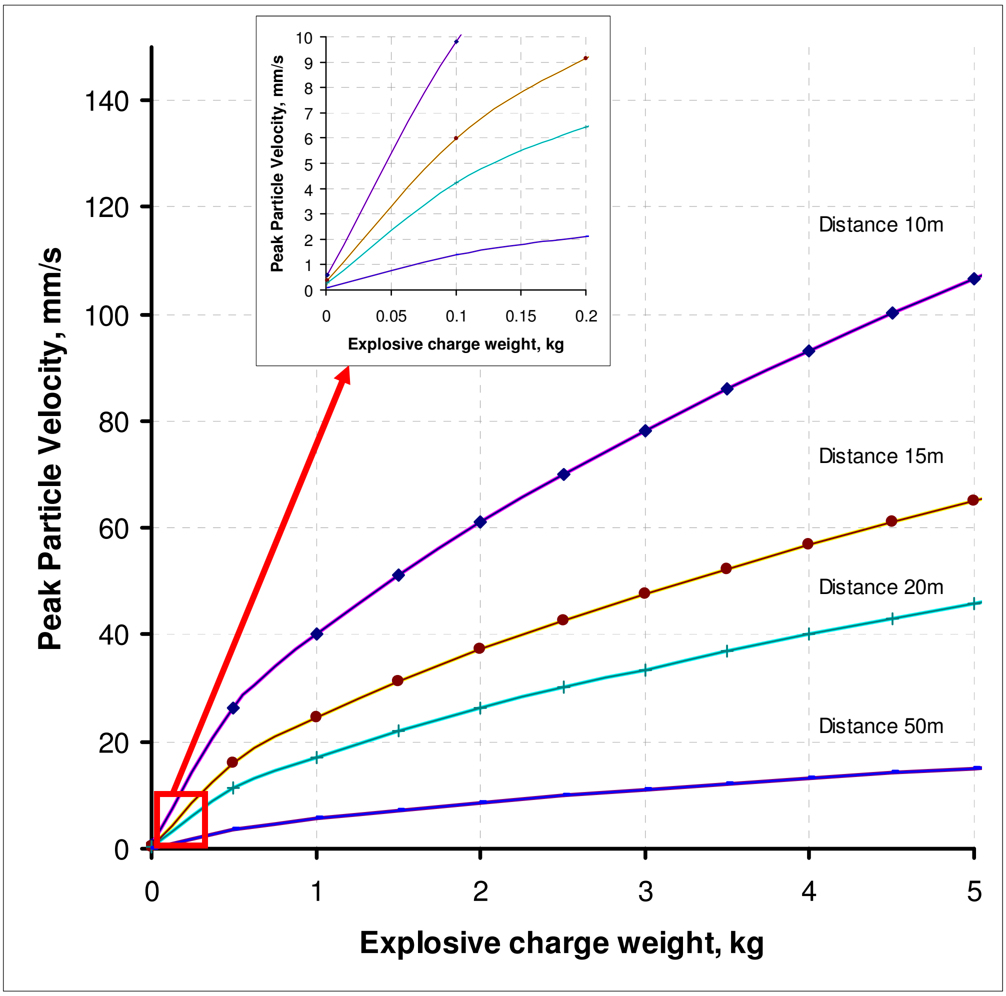


Table 5.1 Design PPV Limits for Utility Installations

Category	Facility	PPV (mm/sec)	Max Amplitude
General Building and Structure	-	25	Not specified
Historical Building and Monuments	-	5 - 25	Not specified
Utilities	Water retaining structures/water tunnels	13	0.1 mm
	Water mains/ other structures and pipes	25	0.2 mm
	All gas installations	25	0.2 mm
	Gas pipes	25	
	Gas governors / Tunnels	13	0.1 mm
	Sub-stations	6.28	0.02 mm
	Cables	12 - 25	Not specified
Others	Tram Way	25	Not specified
	Highway Structures & Road Drains	25	Not specified

5.5 *REVIEW OF INCIDENTS*

This section presents a review of reported safety incidents involving explosives (in industrial applications). Records were retrieved mainly from the UK Health and Safety Executive (UK HSE)'s Explosives Incidents Database Advisory Service (EIDAS), US Mine Safety and Health Administration (MHSA) and Western Australia's Department of Consumer and Employment Protection (DOCEP). The records provided are also supplemented with information obtained from various sources. Analysis of accident data are provided in the following sections.

For the purpose of this study, incidents were sorted according to the following categories to highlight causative factors to the incidents:

- Incidents involving storage of explosives
- Explosive transport incidents
- Explosive Use Incidents

Annex B provides a summary of relevant incidents for each of the categories above.

5.5.1 *Explosive Storage Incidents*

In the UK a study of the risks associated with explosives manufacture and storage was undertaken based on the 79 major incidents identified during the period of 1950 to 1997 [21]. A total of 16 were attributed to the storage of explosives. Thirteen (13) incidents related to the storage of gunpowder, ammunition, nitroglycerine, and fireworks. A further incident occurred in 1970 involved the storage of detonators and was attributed to corrosion of the detonators themselves. The remaining two (2) incidents related to the storage of blasting explosives in 1954 and 1964. One of these incidents involving blasting explosives was attributed to malicious activity, whilst the cause of the remaining incident in 1954 was not identified.

Based on the above study, and on the hazards of the explosive materials, it is apparent that the protection of explosives from human activity, and the elimination of possible ignition sources are critical to maintaining storage facilities. From a review of the above records, some of the 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.

Avoidance of incidents in storage area can only be assured by maintaining good housekeeping practice, eliminating potential ignition source and allocating safe and secure storage space for explosives.

5.5.2 *Explosives Transport Incidents*

The UK database identified one transport incident which caused one fatality, multiple injuries and significant property damage. The 1989 '*Peterborough incident*' involved a vehicle carrying mixed explosives (Cerium fusehead and emulsion) [15]. The explosion was initiated by fire and explosion from a box of Cerium fusehead combs destined for a local fireworks manufacturer. The combs were in unauthorised and unsafe packages. This incident initiated enactment of more stringent safety guidelines in the UK, specifically the Road Transport (Carriage of Explosives) Regulations of 1989, which came into force just 3-months after the incident.

Australia is a significant user and transporter of explosives, consuming approximately 900,000 tonnes of explosives per year (approximately 8% of the world's annual consumption of explosives per year). Of this total, approximately 3000 tonnes (0.3%) is non-bulk explosive (boosters or cartridged emulsion) (Industry estimates). Western Australia consumes approximately 30% of Australia's explosives and publishes accident data [16]. In that time there was one accident reported: a vehicle carrying blasting explosive and detonators overturned [17]. No ignition (i.e., no fire or no explosion) occurred.

In that period there were several accidents involving ammonium nitrate or Ammonium Nitrate Emulsion (UN3375) (Class 5 dangerous goods, used as a precursor for manufacturing explosives). All thee incidents involved articulated vehicle overturns with no fire or explosion. None of these incidents are directly comparable to the situation in HK where explosives vehicles are not articulated. Some fires involving explosive mixing vehicles were also recorded, in Western Australia, but none of these incidents has resulted to fatality or injury.

In the US, explosives transport has had a good safety record. In a recent study released by National Institute of Occupational Safety and Health (NIOSH) [18], analysis of data from 1998 to 2006 revealed that accidents related to the transport of explosives and ammonium nitrate used in mining and construction have resulted in only 5 major injuries, 11 minor injuries, and no fatalities. The safe history of explosives and ammonium nitrate transport is attributed to diligent efforts by government, labour and industry.

5.5.3 *Explosive Use Incidents*

Annex B provides a summary of incidents arising from use of explosives that have been caused by mishandling, premature blast, misfiring, overcharging, etc. Other incidents which have led to serious consequence i.e., flyrocks, damage to property and other severe blast effects, are also included in this table.

The major hazard from blasting operations has been mainly from flyrocks. Flyrock is defined by the Institute of Makers of Explosives as a rock that has been propelled beyond 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 [19]. The lack of security in blast area has also led to several safety incidents, i.e., due to persons getting struck by blasted rocks. In the US, injuries from flyrocks and lack of security in the blast area accounted for more than two-thirds of all injuries, recorded in surface mining during the period from 1978 to 2002.

Blast doors will be provided over vertical shaft or on adits/ tunnels, and kept closed during blasting. The effect of flyrock is not considered to have any potential impact to the public.

Data from Hong Kong, i.e., from incidents recorded by GEO from 1997 to 2007, reveal that out of the 7 incidents, 6 are due to flyrocks (*Table 5.2*). Three of which, has caused injuries. One incident is associated with blast induced slope failure. However, all of these incidents relate to surface blasting activities and are therefore not applicable to this study.

Table 5.2 Blasting Incidents in Hong Kong (1997-2003)

Year	Date	Site	Incident type / Probable Causes	Consequence
1997	4-Dec-97	Sau Mau Ping, Kowloon	Blast induced slope failure	No injury or damage. Road blocked.
1999	9-Jul-99	Sau Mau Ping, Kowloon	Flyrock (250m)	Injury to 1 person
	14-Sep-99	Sau Mau Ping, Kowloon	Flyrock (260m)	Injury to 3 persons and damage to properties
2001	19-May-01	Sau Mau Ping, Kowloon	Flyrock (250m)	No injury or damage
2003	17-Feb-03	Jordan Valley, Kowloon	Flyrock (115m)	Damage to properties
	6-Jun-03	Jordan Valley, Kowloon	Flyrock (230m)	Injury to 9 persons and damage to properties
	26-Jun-03	Penny's Bay, Lantau Island	Flyrock (150m)	No injury or damage

5.6 *SCENARIOS FOR HAZARD ASSESSMENT*

The following hazardous scenario were identified for the hazard assessment:

5.6.1 *Proposed Magazine*

The construction of the magazine is covered by *Section 5.6.3*.

For the operation of the explosives magazine the possible scenarios identified are:

- A fire leading to the detonation of a full load of explosives within the magazine access tunnel whilst transferring explosives to or from the appropriate storage chamber; and
- A fire within any niche causing the detonation of the full quantity stored.

5.6.2 *Transport of Explosives*

Hazardous scenarios considered for the transport of explosives are:

- Accident involving explosives delivered and transferred from magazine to delivery point 1
- Accident involving explosives delivered and transferred from magazine to delivery point 2
- Accident involving explosives delivered and transferred from magazine to delivery point 3 – Construction Phase 1
- Accident involving explosives delivered and transferred from magazine to delivery point 3 – Construction Phase 2
- Accident involving explosives delivered and transferred from magazine to delivery point 4
- Accident involving explosives delivered and transferred from magazine to delivery point 7

5.6.3 *Use of Explosives*

Hazardous scenarios considered for the use of explosives are presented below:

Hazards from the Blasting of a Face

The design of the blast face is determined by the permitted vibration level of the sensitive receivers, and is expected not to cause any damage to the sensitive receivers. However, potential hazards may arise in the event of deviations from the confirmed design occurring, which may lead to higher than expected PPV values.

A high-level failure mode analysis of the blasting lifecycle covering manufacture of detonators and surface connectors, design of the blast, installation of detonators and surface connectors, and loading of explosives was carried out. The details are presented in *Annex E*. The review has investigated all relevant failure scenarios at the blast face, leading to higher than expected ground vibration.

The effects of overpressure and debris are not considered to have the potential to impact members of the public as a blast door will be provided and closed during blasting of faces. Blast doors fitted either over vertical shafts or on adits/tunnels are fabricated to withstand a pressure pulse of 2 Bar (29 psi / 200 kPa). The doors are vented to relieve explosion overpressure and their design is certified by an Independent Checking Engineer (ICE).

The following possible hazardous scenario arising from blasting was identified for risk assessment:

- Higher vibration generated by the blast face due to human errors and other reasons such as manufacturing defects causing deviation from the confirmed design

Hazards from Transport of Explosives to Blast Faces

Bulk emulsion trucks will contain bulk emulsion precursor which is an oxidising agent and not sensitised to detonation. The truck is provided with an automatic shutdown system to ensure a safe shutdown of the precursor pump in case the pump deviates from its operating conditions, such as high pressure or temperature. Furthermore, the bulk emulsion explosive is quite insensitive and will not detonate in the absence of the primer. The precursor and gassing pumps at the truck will not be permitted to operate until all the detonators and primers have gone into the blastholes. The shock tube will not be connected to the exploder (electric detonator initiator) until the face has completed setup and checked, all personnel retreated to safe location, the truck left the tunnel and the blast door closed.

The cartridge cases delivered to site will be conveyed to the tunnel using appropriate and certified lifting system (such as man-cage) through the shaft. The lifting system is provided with safety lock to prevent fall of the explosives in case of lifting mechanism failure.

The shafts to the tunnel will be located at soft ground and vertical to the tunnel. The cartridge cases will be transported by a diesel vehicle within the tunnel.

The following possible scenario was identified for risk assessment:

- Higher vibration and air overpressure due to the detonation of a full load, 125kg, of explosives within the tunnel whilst transferring explosives to the appropriate blast site.

6 FREQUENCY ASSESSMENT

6.1 STORAGE OF EXPLOSIVES

6.1.1 *Frequency of Accidental Initiation in Magazine*

Estimation of the frequency with which accidental initiation of explosives occurs is subject to considerable uncertainty. Previous major studies undertaken in Hong Kong and elsewhere (eg the Hazard Assessment of the Government Explosives Depot at Kau Shat Wan and the Quantitative Risk Assessments undertaken for UK Ministry of Defence sites) have attempted to reduce this uncertainty by identifying the various contributing causes of accidental initiation and constructing fault trees to estimate the overall frequency of accidental initiation. Even with this detailed approach significant uncertainty remains; eg in the frequency of accidental initiation due to out of specification explosives, or the probability of accidental initiation due to impact or friction. However, this uncertainty is caused by reliance on historical data collected on explosives that are not related to the operations or the explosives that are to be used in the WIL project.

The probability of an explosion within the store depends on several factors that include:-

a) The inherent sensitivity of the explosive substances stored;

b) The types of handling processes employed;

c) The managerial and procedural safeguards, including safety culture, training and supervision of staff; and

d) The site security measures employed.

Historical accident records from the UK were used to estimate the frequency of accidental initiation of explosives under storage conditions. These records showed that there had been nine (9) major explosions over the period 1950 to 1999. It estimated that 27,000 storehouse-years had accrued over this period giving:-

9/27,000 = 3 x 10^{-4} per storehouse-year.

However, if the dataset was restricted to involving local authority type stores and the period after the enactment of the Health and Safety at Work Act in 1974 to 1999, then there were three (3) incidents and 15,000 accrued storehouse-years giving an accident rate of:-

3/ 15,000 = 2 x 10^{-4} per storehouse-year.

The UK HSE states that there were considerable uncertainties regarding the number of stores that were operational over this period. However, the UK HSE working group on explosives, based on the above data, agreed to use an accident rate of 1 x 10^{-4} per storehouse-year.

However, from analysis of the 16 explosives storage incidents it is apparent that their causes were attributable to:-

a) Unstable explosive material caused by product degradation, corrosion, and contamination;

b) Escalation of an incident e.g. grass/gorse fire or explosion, elsewhere on or off the site; and

c) Malicious activities such as vandalism and robbery.

The cartridged emulsion to be used in Hong Kong is stable and is highly unlikely to undergo initiation due to degradation or impact. Increased instability caused by manufacturing errors is also considered highly unlikely due to the nature of the materials on which the emulsion is based. However, the cartridged emulsion is detonator sensitive, and hence the detonators are to be stored and transported separately, with a dedicated chamber within the magazine.

The possible initiation of the magazine storage from an external explosion or fire event is discounted due to the underground location of the magazine.

Hence, it is considered that the most significant causative event that leads to an explosion within the magazine is that posed by malicious activities, such as vandalism or robbery. The proposed security arrangements for the magazine include:

a) 2.5m high security fence topped with razor wire;

b) Electric flood lights evenly spaced along the security fence;

c) Close Circuit Television (CCTV) camera mounted at 6m above the magazine ground level;

d) 24hr security patrols with at least two (2) armed guards during the day and three (3) during the night;

e) Guard dog; and

f) A 3 key system such that the authorised shotfirer, the contractor's representative, and the magazine manager have separate keys, with all three (3) keys required for access to the chamber.

As the major causes of incidents in storage are related to malicious activity, the UK HSE suggested major accident rate of 1 x 10^{-4} per storage building year, is assumed to apply to the entire magazine storage facility. In addition, improvements in explosives stability brought by cartridged emulsion, will reduce the sensitivity of the explosives stored. The proposed security system will also reduce the frequency of initiation of an explosion due to vandalism or robbery. Referring to the TNO Purple Book [22] a frequency of 10^{-5} per year is suggested for explosives storage. However, a more conservative accident rate of $1x10^{-4}$ yr^{-1} was adopted for this study although it is acknowledged some reduction factor could be provided based on the security measures for the magazine and the more stable type of explosives being stored.

Therefore the following event frequency was adopted for the storage of explosives:

- Initiation of an explosion within a magazine 1×10^{-4} yr^{-1}.

6.1.2 Sympathetic detonation between magazine niches

It is considered impossible that an explosion within one chamber will initiate an explosion within an adjacent chamber. This is based on the results obtained from the Ardeer Double Cartridge (ADC) Test for cartridged emulsion that show that beyond a separation distance of 2 cartridge diameters the consequences of a detonation are not able to propagate.

Therefore, the direct propagation, by blast pressure wave and thermal radiation effects, of an explosion within one chamber initiating an explosion within the adjacent chamber is not considered. However, an explosion within one chamber may cause damage within the adjacent chamber 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 chamber due to impact of the explosives with the falling rocks. However, increasing separation distance will significantly reduce the likelihood of rock spall.

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 chamber. Each chamber, with the exception of the detonator chamber, is used to store 300 kg of explosives. Assuming that the chamber may contain only high explosives such as the boosters, primers or detonating cord, will mean that the TNT equivalence ratio is 1. Therefore, the chamber loading density is 300 / 125 = 2.4 kg/m^3, based on a design volume of 125 m^3 per niche. The US Department of Defense DOD Ammunition and Explosives Safety Standards DoD 6055.9-STD [11] indicates that the minimum separation distance, D_{cd}, required to prevent hazardous rock spall effects is given by the equation below (DoD eqn C5.2-4) for moderate to strong rock, with low loading densities (i.e. below 48.1 kg/m^3):-

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

Where Q is the charge mass in kg, and hence the minimum separation distance between separate chambers is 6.63 m. Above this separation distance an explosion within one chamber will not result in rock spall within the adjacent chamber.

The actual chamber separation distance is 11m. Hence, this study does not consider it is possible to initiate adjacent chamber's explosives due to rock spall following an explosion within a magazine chamber.

6.2 *TRANSPORT OF EXPLOSIVES*

It is assumed that explosives initiation during road transport can be caused by spontaneous fire (non-crash fire), fire after a vehicle crash (crash fire) and impact initiation in crash. For crash and non-crash fires, initiation requires a fire to start, the fire to spread to the explosives load and initiation to occur once the load is engulfed by the fire.

In the case of impact leading to explosives initiation, it is considered to be the possibility of explosives being spilt onto the road and subsequently being crushed by other vehicles. This event requires there to be a crash and for the explosives to subsequently initiate due to impact effects.

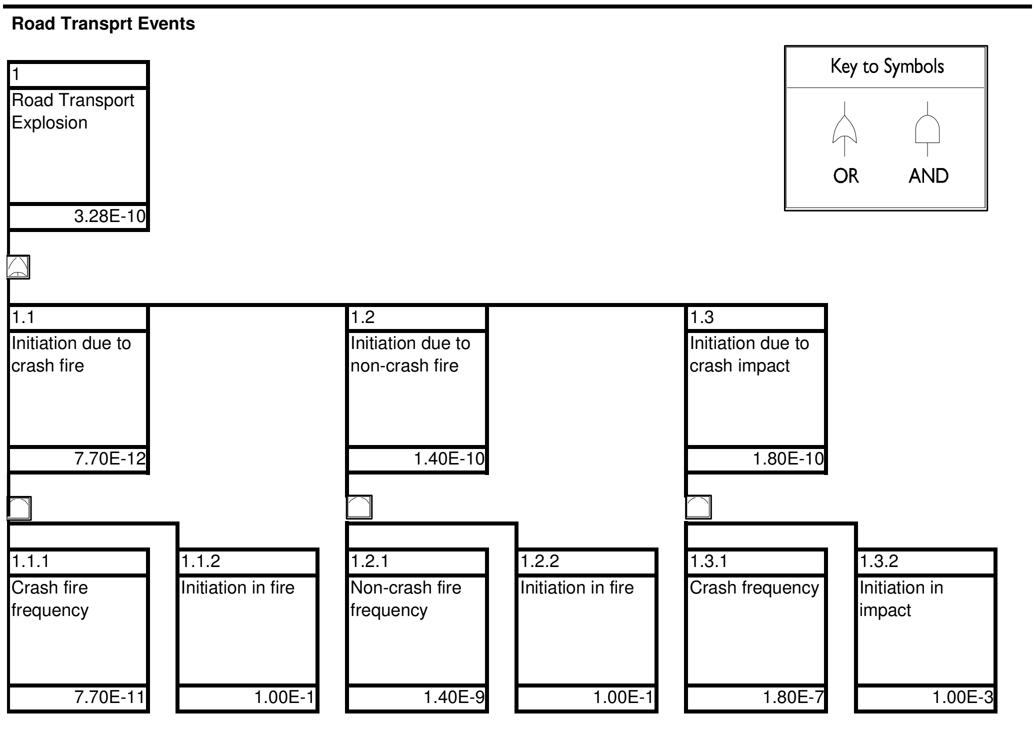
The basic event frequencies assumed for road accidents were based on that used in *The Risk Assessment of the Transport of Explosives in Hong Kong QRA Report* [3] due to its relevancy to WIL project, ie. transport of explosives in Hong Kong. It is understood that the figures shown in *Table 6.1* has been derived from the UK data but factored to account for Hong Kong conditions.

Table 6.1 Explosives Initiation Fault Tree Inputs [1]

Event	Event type	Value
Vehicle crash	Frequency	1.8×10^{-7} /km
Crash fire	Frequency	7.7×10^{-11} /km
Non-crash fire	Frequency	1.4×10^{-9} /km
Explosives initiation in fire	Probability	0. 1
Explosives initiation in impact	Probability	0.001

The fault tree model for the road transport explosion is shown in *Figure 6.1*.

Figure 6.1 Explosives Initiation Fault tree – Road Transport Events



The frequency of explosives initiation during road transport was estimated as 3.31×10^{-10}/km considering an additional 1% Increase for "unsafe explosives" (ie a factor of 1.01), as justified below.

The frequency of crash is governed by road traffic accident data. Safety measures adopted for explosives transport are factored in this assessment although improvement in recent years can reduce the frequency further. The likelihood of an explosion given impact following a crash or a fire following a crash could be conservative.

6.2.1 *Unsafe Explosives*

Background of Probability of Explosive Initiation in Hong Kong Studies

The source document which assesses the risks associated with the transport of explosives in previous Hong Kong Transport QRA Studies is "DNV 1997, The Risk Assessment of the Transport of Explosives in Hong Kong, EPD, CE63/94"[1]. This assessment considers that the following events can cause an explosion of the explosives during transport:

- Initiation due to crash impact;
- Initiation due to crash and subsequent fire;
- Initiation due to fire not related to vehicle crash; and
- Initiation due to 'unsafe explosives'.

The above mentioned assessment, which was subsequently referred in other EIA studies, considered unsafe explosive frequency to be equal to the assessed overall frequency of explosions due to other causes (all causes combined) based on the consideration that worldwide historical accident record shows that 50% of explosives are initiated by the presence of unsafe explosive conditions in the load. This accident data set included data even before 1950 which is dominated by nitroglycerine, dynamite, and military explosive applications. This report also does not distinguish water gel based explosives and emulsion based explosives. While water gel based explosives can degrade in an unsafe manner, emulsion based explosives tend to degrade in safe manner and are therefore inherently safer.

The Hazard to Life Assessment report for WIL uses the same approach but adopts a modification factor for the probability of initiation due to 'unsafe explosives' on the basis that the type of explosives (ie emulsion) used nowadays in Hong Kong are safer than those considered in the above assessment (ie watergels, etc). This section provides the basis for modifying the probability of explosive initiation due to 'unsafe explosives'.

It should be noted that in the previous Hong Kong Transport QRA studies the term 'unsafe explosives' is implicitly defined as an initiation of the explosive load in absence of fire or crash impact since the probabilities of initiation due to crash impact and fire are quantified separately. This definition may differ from definitions encountered in literature.

Historical Development of Explosives

Where commercial explosives are concerned, the term ‘unsafe explosives’ has been used historically to describe products such as Dynamite and Gelignite (generic names for nitroglycerin based explosives) which for one reason or another have become degraded. These products contain nitroglycerin (glyceryl trinitrate) which is a powerful explosive composition, highly sensitive to shock, friction and heat.

Commercial explosives containing nitroglycerin [$C_3H_5(NO_3)_3$] were first manufactured in the 1860’s and due to the absence of safer technology, were not replaced by lower sensitivity commercial explosives until the early 1980’s.

When dynamite dries out, it may exude nitroglycerin and also, the various salts in the explosive mixture may crystalise out, producing sharp crystals that may be sensitive enough to initiate the free nitroglycerin. In this form, the explosive is extremely sensitive to heat, impact, shock or static electricity.

The first commercial explosives to be manufactured and commercialized that did not contain a high risk explosive sensitizer like Nitroglycerine were manufactured by I. E. du Pont de Nemours and Company and were of the Tovex ® family of watergel explosives. Tovex ® explosives do contain an explosive sensitizer called Monomethylamine nitrate (MMAN). However, this has a much lower sensitivity to shock, friction and heat than Nitroglycerine. Such explosives were manufactured in Hong Kong at Stonecutters Island for many years.

Tovex ® explosives were the predecessor of emulsion explosives, the difference being that watergels were formulated as ‘oil in water’ whereas emulsion explosives developed from watergels by reversing the process to be formulated as ‘water in oil’ explosives.

The discovery of emulsion explosives enabled commercial explosives manufacturers to remove all explosive sensitizers from their formulations thus inherently reducing risk and improving safety in manufacture, transportation, storage and use.

It is the emulsion family of explosives that are transported, stored and used in Hong Kong today. They are by far the safest commercial explosives manufactured to date and do not degrade or form extremely sensitive by-products. When degradation does occur (usually due to temperature cycling above/below 34^{O} C), emulsions become less sensitive and eventually are not capable of detonating.

Particulars of Unsafe Explosives

In the context of Hong Kong Explosive Transportation studies, an unsafe explosive is one which:

1 Has failed (or would fail) one or more of the tests prescribed in Test Series 3 and/or Test Series 4 in the United Nations Recommendations on the Transport of Dangerous Goods - Manual of Tests and Criteria (4th revised edition), and has thereby been (or would be) excluded from acceptance into Class 1 on the grounds that it is unsafe to transport; or

2 Is a classified Class 1 explosive which has deteriorated in a manner which has increased its instability and/or sensitivity to the extent that it might reasonably be expected to fail one or more of the above-mentioned tests if re-tested in its deteriorated state. Deterioration may include badly designed, badly manufactured, badly packaged or which are off-specification in some other way.

Examples of (1) would be pure nitroglycerine, or triacetone triperoxide (unless refrigerated).

An example of (2) would be the former ICI Australia (now Orica) product ANGD95 (Ammonium Nitrate Gelatine Dynamite)with substantial crystallisation and exudation (nitroglycerine) with advanced ageing.

Expert Panel Review

In developing the probability of an explosive initiation during road transport, an "Unsafe Explosives" probability is commonly used in previous QRA in Hong Kong.

An expert panel review was commissioned by ERM/MTRC to review the key assumptions/ uncertainty for the risk assessment for the storage, transport and use of explosives in the context of the WIL Quantitative Risk Assessment. The review was held at ERM office in Hong Kong on 21-23 July 2008. [40]

From the review meeting, it was concluded that "Moreton (HSC, 1995) identifies all potential causes of "Unsafe Explosives" and none of the causes is applicable to cartridged emulsion transportation."

There was however no evidence to completely rule out all unforeseen conditions.

Review of ACDS "Risks from Handling Explosives in Port" (HSC, 1995)

The original paper, HSC Advisory Committee on Dangerous Substances, *Risks from Handling Explosives in Port* [20], which defines the term 'Unsafe Explosives' was also reviewed[20] below summarize the findings.

It was found that all potential causes of 'Unsafe Explosives' are not directly applicable to cartridged emulsion transportation. A relevance factor has been assigned for all the causes which could be applicable, in some circumstances, to emulsion.

Table 6.2 Review of ACDS "Risks From Handling Explosives In Port" Appendix 3

Unsafe Condition	Description	Relevance to Emulsions	Relevance Factor for Hong Kong
(a) Unsafe packaging of impact sensitive items	Badly packaged impact-sensitive explosives items could be initiated by the knocks and jolts cargoes typically receive in transit. Such an accident occurred on a road vehicle in the UK as recently as 1989. The explosion caused one fatality and widespread damage	Class 1 (explosives) must be classified by a Competent Authority. Classification. All the transport codes (IATA for air, IMDG for sea) are based on the UN tests/publications (the so-called 'Orange Book') [4]. If it has a Class 1 classification it is deemed acceptably safe for road, rail and sea transportation. The tests include, Tests for Class 1 (Explosives) Test Series 1: Is the substance a potential candidate for Class 1 (explosives)? Gap Test (Zero Gap) Koenen Test Internal Ignition (10-g bag) Time Pressure Test Test Series 3: Is the material a forbidden substance? BOE Impact Test ABL Friction Test Thermal Stability Test Small-scale Burn Test Test Series 4: Is the article a forbidden article? Thermal Stability Test 12m Drop Test	Conservatively assumed applicable in 1% of the unsafe packaging accidents (a factor of 10% to account that emulsion is not impact sensitive and 10% to account that it is unlikely to transport unsafe packages in Hong Kong)

Unsafe Condition	Description	Relevance to Emulsions	Relevance Factor for Hong Kong
(a) Unsafe packaging of impact sensitive items (continued)		Test Series 6: Is the substance or article a Class 1.1, 1.2, 1.3 or 1.4? Single Package Test Stack Test External Fire Test Princess Incendiary Spark Test Based on the above Emulsion is not considered sensitive and has virtually no relevance to this unsafe condition. Additionally, explosives are subject to manufacturing tests and verifications: raw material specification tests, product acceptance tests including cartridge integrity, checking of packages, velocity of detonation, gap test, and on some samples, friction test, impact test and bullet test. It should be noted that the external packaging will be checked before being accepted on air cargo. It will be checked again when receiving the packages in Hong Kong and explosives with any damaged package will be rejected. The packages will be checked again by the shotfirer before use. Explosives with damaged packages will be rejected. Based on the above consideration, unsafe explosion due to unsafe packaging is considered extremely unlikely.	

Unsafe Condition	Description	Relevance to Emulsions	Relevance Factor for Hong Kong
(b) Exudation of explosives material	Exudation is a problem mainly associated with nitoglycerine-based blasting explosives, which may, under certain conditions, exude free nitroglycerine, a substance sensitive to impact and friction. Possible causes of exudation include poor quality control during manufacture, exposure to water, prolonged storage, storage at incorrect temperature and pressure on explosives cartridges. Nitroglycerine-stained packages have been found on a number of occasions within magazines in the UK, and there has been one incident in the last 25years in which exuding explosives were found on board a ship – the ship was scuttled to avoid the risk of unloading the material. Nitro-glycerine based blasting explosives are currently being phased out and replaced with inherently being safer types of explosives	Cartridged Emulsions do not contain an ingredient that is in itself an explosives sensitizer such as Nitroglycerin (cf. Dynamites / Gelignites). Emulsion becomes less sensitive on exposure to water, prolonged storage, or storage at incorrect temperature and pressure. As described above, emulsion is subject to a series of manufacturing tests and it is also of the expert opinion that manufacturing defects would lead to a less sensitive product however there is no evidence to support that such cause can be definitively ruled out. Based on the above consideration, unsafe explosion due to exudation of explosive materials is considered extremely unlikely.	Conservatively assumed applicable in 1% of the accidents involving exudation

Unsafe Condition	Description	Relevance to Emulsions	Relevance Factor for Hong Kong
(c) Poor integrity of packaging	Poor integrity of packaging may result in spillage of explosives substances. This in turn may result in the ignition of fire in the event that the spillage falls through cracks in the floorboards of a vehicle and lands on a hot surface, such as an exhaust manifold. One or two minor explosives events have occurred within UK manufacturing sites in recent times, caused by vehicles running over spilt explosives material, but no such event have occurred during transport of packaged explosives goods.	Although Cartridged Emulsions contain up to 14% water, their composition is very viscous and as such do not spill when the cartridge is ruptured or pierced. Any liquid exiting the cartridge would be limited to a solution of Ammonium Nitrate which will not burn and would evaporate in contact with a hot exhaust. As Emulsions loose water content, the explosive composition reduces in sensitivity and eventually the Emulsion becomes insensitive and will not detonate when stimulated with a primer. Also referring to above, cartridges are inspected before they leave the factory and the packages are checked several times during the transport from the factory to the construction site. Based on the above consideration, unsafe explosion due to unsafe packaging is considered extremely unlikely.	Conservatively assumed applicable in 10% of the poor integrity packaging accidents
(d) Propellant with depleted stabilizer content	Nitrate-ester based propellants with depleted stabiliser content may ignite spontaneously through the process of autocatalytic decomposition. Within the last 25 years there have been several fires in UK storehouses caused by this process. Within the last 10years there has been one incident of fire on a rail wagon caused by spontaneous ignition of nitrocellulose, a raw material used in the manufacture of propellants.	None. Military propellant.	Not applicable

Unsafe Condition	Description	Relevance to Emulsions	Relevance Factor for Hong Kong
(e) Leaks from munitions containing white phosphorus	Certain types of munitions contains white phosphorus, a substance that can spontaneously ignite on exposure to air. There have been at least two substances in the UK during the last 45years when leaks from these munitions have results in ignition of fire rail transport.	None. Military device.	Not applicable
(f) Munitions with contaminated components	Physical or chemical reaction between contaminants and explosives filling may lead to the formation of heat- and impact-sensitive explosives crystals or compounds within munitions. These munitions may then become more susceptible to accidental initiation. Migration of sensitive compounds into screw threads and non-continuous welds may further increase the susceptibility of the munitions to accidental initiation by impact. There was a major explosion in UK military port in 1950 caused by impact-induced ignition of a depth charge that has been sensitised by the presence of impurities in the main explosives filling. A similar accident occurred in Gibraltar a year later.	None. Military propellant / explosives.	Not applicable.

Unsafe Condition	Description	Relevance to Emulsions	Relevance Factor for Hong Kong
(g) Munitions with cracked warheads	The explosives filling of certain types munitions are prone to cracking. Cracking may result in migration of explosives dust into screw threads and non-continuous welds within munitions, and this may increase the susceptibility of the munitions to accidental initiation in two ways (i) impact accidents may result in nipping of dust between metal surfaces and (ii) the presence of bare explosives crystals in the cracked surface may increase the chance of an initiation proceeding to full detonation. The dangers posed by munitions with cracked warhead filling are well recognised; such munitions are normally subjected to Ordnance Board constraints, which would include restrictions on the height to which such munitions can lifted.	None. Military propellant / explosives.	Not applicable
(h) Munitions with defective electrical components	Certain types of munitions, such as torpedoes, are equipment with power supplies. There is a possibility that electrical short circuits within these types if munitions may ignite fires which may in turn initiate explosives material. So far as is known, no such accidents have occurred in the UK in post-war times	None. Military device.	Not applicable

Unsafe Condition	Description	Relevance to Emulsions	Relevance Factor for Hong Kong
(i) Spontaneous movement of sensitive items within munitions	Stresses are created when components are installed into certain types of munitions, An explosives event may occur if these stresses relieve spontaneously on some subsequent occasion. There have been a number of such accidents within UK storehouses, though, so far is known, no such accidents have occurred in ports or during transport	None. Military device.	Not applicable
(j) Defective electro explosives device (EED)	EEDs that have been badly designed manufactured or packaged, may be susceptible to initiation by radio frequency radiation. There have been a number of such accidents involving unpackaged items on firing ranges, though so far as is known, no such accidents have occurred in ports or during transport.	None. Military device.	Not applicable

Unsafe Condition	Description	Relevance to Emulsions	Relevance Factor for Hong Kong
(k) Fuze defects	Munitions fitted with defective fuze may be vulnerable to the sorts of knocks and jolts that cargoes typically receive while in transit. There are three ways in which the safety of a fuze may be compromised: (i) mis-assembly in which the fuze is assembled in a manner which "short circuits" the intended safety features; (ii) severe metal corrosion affecting components such as springs shutters etc. making inoperative the safety features that rely on the correct functioning of these components; (iii) Chemical reaction in which the chemical composition of some of the explosives compounds are changed, making them more sensitive to external stimuli, eg reaction of lead azide with copper to form copper azide.	None. Military device.	Not applicable

Table 6.3 Review of ACDS "Historical Accident Record for Transport of Explosives in Great Britain, 1950 -1994" Appendix 2

Appendix 2 Reference Number	Transport Type	Date	Location	Explosive Type	Cause of Accident	Relevance to Emulsions	Relevance Factor (see previous table)
1 (i)	Military Port	14/07/1950	Bedenham Hampshire	Ammunition Depth Charge	Fire	None. Military explosives / device	0%
1 (ii)	Military Port	16/06/1955	Portland Dorset	Ammunition Experimental Torpedo	Mechanical faults and bad preparation	None. Military explosives / device	0%
1 (iii)	Port	17/07/1969	Bootle Merseyside	Unknown Commercial Explosives	Unknown Possible Nitroglycerin leakage	None. Emulsions do not contain any ingredient that in itself is an explosives sensitizer	0%
2 (i)	Rail	04/09/1951	Feltham Greater London	Ammunition Smoke Bombs	Leak of material from inside Shell	None. Military explosives / device	0%
2 (ii)	Rail	23/04/1969	Armathwaite Cumbria	Ammunition Artillery Shells	Fire	None. Military explosives / device	0%
2 (iii)	Rail	14/04/1988	Lancashire	Nitrocellulose (this has been counted as explosive although Nitrocellulose is not an explosive)	Unsafe Explosives Nitrocellulose caught fire as it dried out	Although this is not directly relevant. This may be conservatively considered to correspond to Unsafe	1%

Appendix 2 Reference Number	Transport Type	Date	Location	Explosive Type	Cause of Accident	Relevance to Emulsions	Relevance Factor (see previous table)
						Condition (b) in previous table	
3 (i)	Road	1952	Unknown	Commercial Explosives	Fire	None. The explosives being used in 1952 would have been of the Nitroglycerin type	0%
3 (ii)	Road	1958	Unknown	Commercial Explosives	Fire	None. The explosives being used in 1958 would have been of high sensitivity type	0%
3 (iii)	Road	1959	Unknown	Commercial Explosives Safety Fuse	Fire	None. Safety Fuse contains Gunpowder which is spark and friction sensitive whereas Emulsions have a low sensitivity	0%
3 (iv)	Road	1973	Unknown	Commercial Explosives and Detonators	Fire	None. The explosives being used in 1973 would have been of high sensitivity type and explosives were mixed with detonators	0%

Appendix 2 Reference Number	Transport Type	Date	Location	Explosive Type	Cause of Accident	Relevance to Emulsions	Relevance Factor (see previous table)
3 (v)	Road	23/03/1989	Peterborough Cambridgeshire	Commercial Explosives, Fuseheads and Detonators	Unsafe explosives packaging Unsafely packages fuseheads (related to electric detonators) ignited by impact/friction leading to cargo fire and subsequent explosion.	This accident related to Emulsions mixed with electric detonators. Both mixed load and electric detonators are prohibited in Hong Kong. Therefore , loading MTRC contractor vehicle with mixed load of detonator and emulsion is a breach of prohibition with low probability. Note that Fuse Heads have a very high sensitivity compared to emulsion. This may be conservatively considered to correspond to Unsafe Condition (a) in previous table	1%

Background on Unsafe Explosive Parameters Used in Previous Hong Kong Transport QRA Studies and Conclusion

Based on the review of past accidents which formed the basis for the probability of explosive initiation due to unsafe explosives, in the source document which assesses the risk of unsafe explosives in Previous Hong Kong Transport QRA Studies[1], it is concluded that only two accidents over eleven (~20%) may have some relevance to transportation of emulsion. Each accident carries a relevance factor of 1%. This gives an overall probability of 0.2%. This is conservatively rounded up to 1%. Following the approach of previous Hong Kong QRA Studies, this 1% has been applied to the overall transport frequency.

6.3 *TRANSPORTATION WITHIN THE ACCESS TUNNEL OF THE MAGAZINE*

The construction of the West Island Line will be undertaken by a total of three different contractors. These contractors will each be responsible for the deposit and withdrawal of explosives from their assigned magazine chamber. There will be only one explosives delivery from the Mines Division per day to the magazine. On arrival at the magazine the Mines Division vehicle will be unloaded using the contractor's vehicles. The Mines Division vehicle shall not enter the magazine adits. Therefore, the contractor's will be responsible for transferring the delivered explosives into the correct magazine niche using their own vehicles, each permitted to only carry a maximum of 200 kg of explosives.

The magazine is designed to have capacity to store sufficient explosives for two days blasting activity. Therefore, the daily consumption of explosives is 1200 kg, which must also be replenished on a daily basis. The maximum vehicle capacity within the magazine access tunnels is to be limited to 200 kg. Hence the number of movements of vehicles loaded with explosives that deposit explosives within a niche is 6. However, the maximum quantity of explosives that is expected to be withdrawn from the magazine is 125 kg. Therefore, for the withdrawal of explosives there will be a daily total of approximately 10 vehicle movements. On an annual basis this equates to a total of 5,840 vehicle movements.

An overall frequency of accidental initiation of 3.31×10^{-10} per truck-km is used for assessing transport of explosives to the magazine, as described in the *Section 6.2.* This value is considered conservative for the magazine since the speed control will be exercised within the magazine, and only one truck will be allowed in the magazine at any given time. Therefore, reduction factors can be considered for the fire after a vehicle crash (crash fire) and impact initiation in crash.

The frequency of the accidental initiation of the explosives within the magazine access tunnels is based on a section of tunnel length of 30m directly below the slope 11-SW-A-C293. This 30m section of tunnel was derived based on geometric separation distance between magazine tunnel and slopes. Beyond 30m the impact on the slope due to initiation of explosives loaded onto a vehicle is not considered capable of causing a slope failure (as discussed in *Section 7.3.1*). Accidental initiation within the magazine tunnel will be based on an explosives load of 200 kg, which represents the maximum amount of explosives that can be transported using the contractor's vehicles.

The length of the magazine access tunnel that is vulnerable to failure due to an explosion of a vehicle carrying explosives is 30m. The overall frequency of accidental initiation (all causes) for the transportation of explosives is 3.31×10^{-10} per truck-km.

6.4 USE OF EXPLOSIVES

The frequency assessment for the use of explosives was derived in two parts. The first part determined the occurrence frequency of higher ground vibration generated by 5,660 blasts due to errors in the blasting process. The second part evaluated the occurrence frequency of higher vibration and air overpressure due to transport of cartridges from the shaft to the blast site.

6.4.1 *Frequency of Higher Vibration due to Errors in the Blasting Process*

For all the failure scenarios identified in the high-level failure mode analysis, majority of the causes are due to human errors during the blasting process. These could be errors in design, manufacturing, installation, checking and recovery.

Fault tree analysis was carried out to determine the overall occurrence frequencies for the failure scenario detailed in *Section 5.6.3*, whilst human factor assessment was carried out to derive the human error probabilities for the base events. The details of the fault tree analysis and human factor assessment are provided in *Annexes E* and *F* respectively.

The overall frequency of failure scenarios leading to higher vibration for the whole WIL project are summarised as below. It is noted that the occurrence frequency for simultaneous detonation of 5 and 6 MIC for the whole alignment from west of SYP to KET overrun tunnel and magazine store project were assumed same as the 4 MIC case for conservatism.

Table 6.4 ***Overall Frequency for Failure Scenarios leading to Higher Vibration for the Whole Project***

Sections	Blast Linear Length	Occurrence Frequency for multiple MIC detonated at the same time per Section (Occurrence per Project)				
		2MIC	3MIC	4MIC	5MIC	6MIC
WIL Alignment	9.3 km	4.09E-01	1.16E-03	6.86E-06	6.86E-06	6.86E-06
WIL Magazine Store	0.4 km	1.05E-02	2.73E-05	1.89E-07	1.89E-07	1.89E-07
Overall for WIL project	9.7 km	4.19E-01	1.19E-03	7.05E-06	7.05E-06	7.05E-06

Notes: The Blast Linear Length refers to the total pull length by the drill and blast operation. For the WIL alignment, the blast linear length includes the two running tunnels, two station blocks and associated adits. For the WIL Magazine Store, the blast linear length covers the access tunnel and 9 niches.

Due to the variation of MIC used for the alignment, the risk assessment for the use of explosives was carried out at every 10m chainage interval, which is in line with the interval for the MIC design in the Blast Assessment Reports [4]-[6]. The frequency of multiple MIC detonated simultaneously on a 10m interval is summarized in *Table 6.5*.

Based on the derivation given in *Table 6.5,* the calculated frequency for a 10 m section represents the average frequency for an average blast length of 1.7 m (blast linear length of 9.3 km for 5509 blasts, see *Annex E*) for WIL alignment. The consequence assessment (see *Section 7.3.3*) has identified the relevant sections of the WIL alignment which may pose object falling hazards due to ground vibration and for those sections, the MIC is generally larger than 3 kg (see *Annex G*) which corresponds to a blast length of about 2 m. Therefore, the average frequency given in *Table 6.5* will be slightly higher than the actual, and considered to be conservative for the sections of concern.

Similarly, the calculated frequency for a 10 m section in *Table 6.5* represents the average frequency for an average blast length of 2.7 m (blast linear length of 0.4 km for 149 blasts, see *Annex E*) for WIL magazine store. The blast length for the concerned sections is about 3 m. Therefore, the estimated frequency given in *Table 6.5* will be similar to the actual.

Table 6.5 Overall Frequency for Failure Scenarios leading to Higher Vibration per 10m

Sections	**Occurrence Frequency for multiple MIC detonated at the same time for 10 m (Occurrence per 10m)**				
	2MIC	**3MIC**	**4MIC**	**5MIC**	**6MIC**
WIL Alignment	4.40E-04	1.25E-06	7.38E-09	7.38E-09	7.38E-09
WIL Magazine Store	2.64E-04	6.83E-07	4.72E-09	4.72E-09	4.72E-09
Overall for WIL project	4.32E-04	1.23E-06	7.27E-09	7.27E-09	7.27E-09

6.4.2 Frequency of Higher Vibration or Air Overpressure due to Detonation of Cartridges being Transported in Tunnel

An overall frequency of accidental initiation of 3.31×10^{-10} per truck-km, as described in the *Section 6.2*, was used for assessing transport of cartridges from the shaft to the blast site via the diesel vehicle. This value is considered conservative for the tunnel since the speed control will be exercised and traffic within the tunnel is not heavier than public roads. Reduction factors were not conservatively considered for the probability of fire following a vehicle crash (crash fire) and impact initiation in crash.

The transport length will vary as the blasting proceeds. It was assumed as 500 m per delivery.

7 CONSEQUENCE ASSESSMENT

7.1 GENERAL

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

- blast and pressure wave;
- flying fragments or missiles;
- thermal radiation;
- cratering; and
- ground shock.

In the case of bulk explosions, the most damage is usually caused by the blast effects. However, for small detonations, fragmentation is the most significant effect and thermal radiation is only of interest in low speed deflagrations.

Three modes of injury can result to people when exposed to blast effects:

- Primary;
- Secondary; and
- Tertiary effects.

Primary effects involve the direct effects of the blast upon sensitive human organs such as the ears and lungs. Compared with secondary and tertiary effects, considerable overpressures are required for fatalities to occur, and consequently people need to be fairly close to the scene of the explosion for primary effects to be significant.

Secondary effects are associated with building collapse or the impact of debris and fragments from damaged building structures and the vehicle or container in which the explosives are held. Predicting injury and fatality levels due to fragments/debris from high explosives is particularly difficult.

Tertiary blast injuries may occur with whole body impacts, when people are displaced or swept away, or due to the violent movement of internal organs within the body. For people outdoors, tertiary effects are dominant.

Thus, for the cartridged emulsions to be transported and stored for this project, the blast effects will be of most concern. Also of interest are the detonators used to initiate these explosives. However, provided these are kept within their original packaging they will only explode 'one-at-a time', and will not present a mass explosion hazard. Packaged in this way, the detonators may be classified as UN Class 1.4 S.

7.2 *PHYSICAL EFFECT MODELLING*

7.2.1 *Blast and Pressure Wave for Above Ground Explosion*

The consequence models used for the assessment of the probability of fatality due to blast and pressure waves, are based on the most recent UK Explosive Storage and Transport Committee (ESTC) model defined in the HSC publication (HSC Advisory Committee on Dangerous Substances [7]).This model has been previously used as part of the Penny's Bay Rail Link Hazard Assessment Report [3] and considers all the effects associated with an above ground explosion including, fireball, overpressure, flying debris, broken glass, structure damage, etc.

People Indoors

The ESTC indoor model is based on the analysis of casualty data collated from records of a number of major incidents of accidental explosion. The data on which the model is constructed does not distinguish between those killed by blast and those killed by fragments. It is assumed that blast effects were the cause of most of the fatalities recorded in these incidents but the model implicitly makes some allowance for fragment effects. The probability of fatality for persons located inside conventional buildings for various quantities of explosives can be estimated by:-

$$\text{Log } P = 1.827 - 3.433 \text{ Log } S - 0.853 (\text{Log } S)^2 + 0.356 (\text{Log } S)^3$$

Where S is $R / Q^{1/3}$ and within limits of $3 < S < 55$.

In this study, the indoor consequence model has been assumed to be also applicable to the population present in vehicles.

People Outdoors

The outdoor model is based on a review of the available literature on primary and tertiary blast effects. The model gives the probability of death (P) as a function of range and the quantity of explosives detonated:-

$$P = \frac{e^{\left(-.5.785\left(R/Q^{1/3}\right)+19.047\right)}}{100}$$

Where R is the distance in m and Q is the explosive charge mass, kg. This model is valid in the range of $2.5 < R/Q^{1/3} < 5.3$.

The distance to probabilities of fatality of 1%, 50% and 90% was estimated. The criteria adopted in this study is consistent with the previous Penny Bay Rail Link study [3].

7.2.2 *Blast and Pressure Wave via Access Tunnel/ Shaft*

Operation of Magazine Store

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.

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 over-pressure along the centreline of a single opening can be evaluated using the DoD 6055.9-STD equation C9.7-16 [11]

$$R = 220.191\ D_{HYD}\ ((W / V_E)^{0.5} / P_{so})^{1/1.4}$$

Where R is the distance from the opening, m
D_{HYD} is the effective hydraulic diameter that controls dynamic flow issuing from the opening, $D_{HYD} = 4\ A / P$ where A is the cross-sectional area of the opening and P is the perimeter,
P_{so} is the overpressure at distance R, kPa
W is the charge weight for the maximum credible event, kg
V_E is the total volume engulfed by the blast wavefront within the tunnel system at the time the wavefront arrives at the point of interest, m^3.

The distance versus overpressure off the centreline axis of the opening can be evaluated from equation C9.7-17 of the DoD 6055.9-STD [11]

$$R(\theta) = R(\theta = 0) / (1 + (\theta / 56)^2)^{1/1.4}$$

Where $R(\theta = 0)$ is the distance along the centerline axis.

However, the above equations are for use when the opening or adit from the magazine is unobstructed. The proposed design for the magazine incorporates portal barricades at the magazine entrance and exit openings. 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. The DoD 6055.9-STD states that a portal barricade will reduce the inhabited building distance along the tunnel axis by 50%. The inhabited building distance represents the distance where damage will be caused to unstrengthened buildings, but the buildings are considered to provide a high degree of protection from death or serious injury. Therefore, it is assumed that the inhabited building distance correlates to the 1 psi (7kPa) over-pressure contour.

The impact of the portal barricades is to only slightly reduce the total Inhabited Building Distance area, which will change to a circular area, half of which is behind the opening [11]. Therefore, the over-pressure contours that result from a detonation within a chamber of the magazine have been evaluated as 50% of the calculated value obtained from the DoD equation C9.7-16 but a circular over-pressure contour is produced.

Overpressure that is sufficient to cause a fatality is based on that resulting in lung haemorrhage in people located outside. Generally the human body is capable of adapting to large changes in pressure which occur gradually. Fugelso, Weiner and Schiffman derived a probit equation based on data relating to death primarily from lung haemorrhage due to peak overpressure [8],

$Pr = -77.1 + 6.91 \ln P^o$

Where P^o is the peak over-pressure generated by the blast, Pa

Therefore, the peak over-pressures that corresponds to a 1%, 50%, and 90% fatality level are 100 kPa , 140 kPa, and 174 kPa. Therefore, for 100 kPa peak overpressure the distance is:-

$R = 220.191\ D_{HYD}\ ((W / V_E)^{0.5} / P_{so})^{1/1.4}$

$R = 220.191 \times 6.35 \times ((300 / 9337.5)^{0.5} / 100)^{1/1.4}$

R = 15 m for the 1% fatality level, 12 m for the 50% fatality level, and 10m for the 90% fatality level.

However, this is based on an unobstructed portal and does not consider the impact of the barricades. Therefore, the 1% fatality limit is represented by an extended circular shape having a radius of 9m, whilst the 50% and 90% fatality contours have a radius of 7m and 6m respectively.

Victoria Road is approximately 19m distant and 7m above the nearest magazine opening. Therefore, the over-pressure that would be likely at this distance is that equivalent to 38m when using the unobstructed DoD equation C9.7-16 assuming explosion at magazine opening, and is estimated to be 27.9 kPa. However, this value is considered to be conservative due to the raised level of the road above the magazine, which will offer a degree of protection to the road users. The impact of this level of over-pressure on the road users and pedestrians is to be assessed. Therefore, it is assumed that the likelihood of fatalities due to the reflected over-pressure can be estimated using the ESTC model for both indoor and outdoor fatalities.

Initiation of explosives in niches have been considered as explosion at the magazine barricade since no decay factor (eg decay of overpressure due to bend, reflection) was considered for overpressure wave travelling from niche to magazine opening. The barricade will however mitigate the ‘shotgun’ effect from the explosion. Therefore, the effect of explosions inside niches was considered equivalent to explosions at magazine opening without any consideration of “shotgun” effect, hence modelled with the ESTC model.

For a magazine chamber of 300 kg that is considered to be equivalent to the charge being detonated at the portal entrance, the probability of death at 19m is 10% for outdoor populations. The outdoor 90% fatality limit is reached at 17m, 50% fatality reached at 18m and the 1% fatality level is reached at 22m.

It should be noted that ESTC model has conservatively included the effect due to debris flying although the barricade is designed to capture debris. This conservative approach has been considered for simplification purpose.

For indoor fatalities, at a scaled distance of $19 / 300^{1/3} = 2.84 \text{ m/kg}^{1/3}$, the probability of fatality within a vehicle is 100%, with the 90% fatality limit reached at 21m, 50% fatality limit reached at 24m, and the 1% fatality limit reached at 63m. At a distance beyond 63m the effect to people will be limited to injury only. Therefore, a blast within the explosives magazine will have no significant consequences on the shipping nearby as the distance from the shoreline to the magazine portal is about 70m. The navigation channel in the West Lama Channel or Sulphur Channel is indeed located at 220m away from the magazine.

For the magazine chamber that is used to store the detonators, the ESTC Outdoor model yields the 90% fatality limit at 5m, 50% limit is reached at 6m, whilst the 1% fatality limit extends to 7m. For indoor fatality the 90% fatality limit is reached at 7m, 50% fatality is reached at 8m whilst the 1% fatality limit is reached at 20m.

Transport of Explosives during Construction of Tunnel/ Magazine

The blast and overpressure effects for detonation of 125 kg cartridges being transported by the diesel vehicle in the tunnel can be estimated by the DoD 6055.9-STD equation C9.7-16 stated above. The highest overpressure will be expected when the accident occurs at the bottom of the shaft.

The length of shaft for the WIL alignment can vary depending on location, typical range is between 20-40 m, but can be as deep as 80-90 m near UNV station. The typical diameter of the shaft is at least 6 m. The blasting will generally commence at the bottom of the shafts. The site boundary will be located at least 10 m from the edge of the shaft and a hoarding of about 2 m height will be provided at the boundary.

Using DoD 6055.9-STD equation C9.7-16 stated above, the distances from the opening corresponding to 1%, 50%, and 90% fatality level are about 14 m, 11 m and 9 m, assuming a shaft diameter of 6m and length of 20 m, with a blasting point at 50m from the shaft and detonation at the bottom of the shaft.

For a detonation of 125 kg cartridges at the portal of the shaft, the ESTC Outdoor model yields the 90% fatality limit at 15m, 50% limit is reached at 18m, whilst the 1% fatality limit extends to 42m. For indoor fatality the 90% fatality limit is reached at 12m, 50% fatality is reached at 13m whilst the 1% fatality limit is reached at 16m.

It can be seen that the hazard distance estimated by ESTC outdoor model is more conservative than DoD 6055.9-STD equation C9.7-16. Therefore the consequence distances obtained from the ESTC models have been used to assess the risk of transporting explosives within the tunnel during construction of tunnel/ magazine for conservatism.

7.2.3 *Flying fragments or missiles*

Fatality due to flying fragments or missiles due to above ground explosion is considered in the ESTC model, therefore no separate model for debris is required when ESTC is applied. For the proposed magazine, further consideration is made below in accordance with DoD 6055.9-STD [11] to cover the opening from magazine adits.

Marine Population near the Proposed Magazine

The storage magazine portals or adits, located below Victoria Road, face North West, directly over the West Lamma Channel, near the entrance to the Sulphur Channel that separates Green Island from Hong Kong Island.

From the magazine plot plan, the horizontal distance from the magazine portal to the coastline is approximately 70m, with an approximate distance to the ship navigation channel of a further 150m. Therefore, the distance between the portal and the navigation channel is 220m.

The consequences from an explosion within the magazine are limited by the provision of re-enforced concrete barriers or portal barricades. These will be positioned in front of the entrance and exit adits of the magazine. The barricade should be designed in accordance with the DoD 6055.9-STD. The barricade will be sloped at an angle of 15° to the vertical to deflect any blast consequences upwards. The barricade walls are to be faced with a material designed to retain any possible debris that may be propelled from the magazine adits and to absorb air overpressure.

The DoD 6055.9-STD paragraph C9.7.2.3.2.1 states that a minimum distance of 550m shall apply within 10 degrees either side of the adit centreline axis unless positive means are used to prevent or control the debris throw. The incorporation of portal barricades will significantly effect the distance that debris is thrown. Paragraph C5.2.3.2.1.6 of the DoD 6055.9-STD states that the use of barricades will lower the debris hazard to a level where quantity distance considerations for debris are not required. Also based on ESTC model, 1% fatality zone of 300kg explosives detonation is 63m and beyond this distance only effect at injury level will be expected. Therefore, for the purpose of this study the possibility of debris reaching any marine population at a distance of 70m from the portal is not considered.

7.2.4 *Thermal Radiation*

The initiation of an explosion will result in thermal radiation from a fireball as the explosives detonate. There are relatively little published models in the literature for high explosive fireballs, or those that may result from a cartridged emulsion detonation. Models that are available describe the fireball duration and diameter based on TNT or similar explosives e.g. nitroglycerine, PETN, etc. Therefore, for the purpose of this study it is assumed that the fireball correlations are applicable to cartridged emulsion containing ammonium nitrate, fuel oil and aluminium powder.

The diameter and duration of a fireball from a high explosive are given by the following equations [8]

$D = 3.5\ M^{0.333}$
$t_d = 0.3\ M^{0.333}$
where D is the fireball diameter, m
M is the mass of the explosive, kg TNT equivalent
t_d is the duration of the fireball, seconds.

Therefore, a fireball that has a radius of 11.7m and lasts for 2 seconds will result from the explosion of the contents of an entire storage chamber of 300 kg, which is the largest storage quantity of explosive in this project.

The surface emissive power (E_f) can then be calculated from the equation:

$$E_f = \frac{f_s M \Delta H_r}{4\pi r_{fireball}^2 t_d}$$

Where ΔH_r is the heat released per unit mass of the explosive, kJ/kg, which is approximately 4.01 MJ/kg for cartridged emulsion.
M is the mass of explosive, kg and
f_s is the fraction of the heat that is radiated, a conservative value of 0.4 is taken.

Therefore, the surface emissive power of the fireball is 139.7 kW/m^2.

The heat flux received by a receptor at distance from the fireball is estimated by using the equation:-

$$q'' = E_f . F_{view} \tau_a$$

Where E_f is the surface emissive power of the fireball, which is either estimated using the previous equation or is an assumed maximum value. F_{view} is the view factor, and τ_a is the atmospheric transmissivity.

For a vertical surface the view factor can be calculated from the equation [7]:-

$$F_{view} = \frac{X(r_{fb})^2}{\left(X^2 + r_{fb}^2\right)^{3/2}}$$

Where X is the distance measured along the ground from the object to a point directly below the centre of the fireball. This distance must be greater than the radius of the fireball, because actual development of the fireball often involves an initial hemispherical shape, which would engulf nearby receptors. Additionally, as the fireball lifts off the ground, the distance to near field receptors changes significantly. This means that the radiation estimates in the near field are of questionable accuracy.

At very large distances the above equation for the view factor reduces to

$F_{view} = (r/X)^2$

The atmospheric transmissivity, τ_a, reflects the proportion of radiation that is adsorbed by the water vapour and the carbon dioxide present in the atmosphere. A correlation for the estimation of transmissivity was published by F.D. Wayne [23].

$$\tau_a = 1.006 - 0.01171\log_{10}(X_{H_2O}) - 0.02368[\log_{10}(X_{H_2O})]^2 - 0.03188\log_{10}(X_{CO_2}) + 0.001164[\log_{10}(X_{CO_2})]^2$$

where

$$X_{H_2O} = \frac{2.165 P_w^o RHd}{T}$$

$$X_{CO_2} = \frac{273d}{T}$$

RH is the relative humidity and is assumed to be 85% for Hong Kong.
P^o_w is the vapour pressure of water at the atmospheric temperature, T,
And d is the distance to the fireball surface, or path length.

The probit equation for fatalities due to thermal radiation is proposed by Eisenberg [8]:

Pr = -14.9 + 2.56 ln L
Where L is the thermal dose or load defined as:
$L = t\, I^{4/3}$
Where I is the thermal radiation flux, kW/m^2
And t is the exposure duration

Therefore, the thermal dose units required for a 1%, 50%, and 90% fatality levels are 956, 2377, and 3920 s.$(kW/m^2)^{4/3}$ respectively. However, the UK HSE Safety Report Assessment Guides [24] indicate that the thermal dose units that correspond to the 1%, 50%, and 90% fatality limits are 1000, 1800, and 3200 tdu respectively. Therefore, using the HSE thermal dose criteria limits indicates that the incident radiation fluxes to cause these fatality levels are 105.7, 164, and 241 kW/m^2.

These levels of thermal flux will only be realised when in close proximity to the fireball. Therefore, as discussed above the estimate of a separation distance will be of questionable accuracy. This can be illustrated by considering the 1% fatality limit for vulnerable people i.e. children and the elderly, of 500 thermal dose units based on the UK HSE criteria. This dose level is reached at a distance of 7m, assuming the fireball is touching the ground. However, at this distance any person would still be in a position that is within the fireball as it develops from a hemi-spherical shape into a sphere, before lifting off the ground. Hence, the probability of a fatality should be taken as 100%. Therefore, it can be concluded that a fireball that results from the initiation of cartridged emulsion within the storage magazine will not pose an off-site hazard.

It is generally the case that the thermal hazards from an explosives detonation event are of less concern than the blast and fragment hazards. Therefore, the hazards of a fireball are not considered further in this assessment.

7.2.5 *Cratering*

An explosion in an underground storage chamber may produce external airblast from two sources; the exit of blast from existing openings such as the magazine adits, and the rupture or breach of the chamber cover by detonation. The DoD 6055.9-STD [11] defines a critical chamber cover thickness as:

$C_c = 1.0\ Q^{1/3}$

The maximum load to be transported within the magazine is 200 kg, therefore the critical cover thickness is 5.8 m. At the closest approach Victoria Road is 7m above the access tunnel. Therefore, cratering of Victoria Road is not considered likely in the event of detonation of the full load of a magazine vehicle directly below.

The shallowest depth of a magazine niche below the surface of Mount Davies is approximately 85m. Each magazine niche is designed to store up to 300 kg of explosives, which requires a critical cover thickness of only 6.7m. Hence, cratering at the surface of Mount Davies due to an initiation within a particular magazine niche is not considered by this study.

Similarly, cratering is not considered as a credible scenario for use of explosives during the construction of WIL alignment and magazine.

7.2.6 *Ground Shock Generated by Rock Excavation using Explosives*

The detonation of solid phase materials liberates energy by a rapid chemical reaction process, which produces and sustains a shock wave in the material. The high temperatures and pressure associated with the shock wave cause almost instantaneous reaction in the material. This reaction produces high pressures and temperatures in the expanding gas. It is this pressure that crushes surrounding rock when the explosive material is placed in a drill hole for blasting.

In areas where the explosive material is less confined the pressure will be reduced due to the increased volume into which the gases can expand. If the degree of confinement is reduced eventually the pressure will cease to crush the rock, but instead will cause rock fractures or cracking. If the level of confinement is reduced further, the pressure will cease to fracture the rock and the energy will propagate through the rock as an elastic wave causing the rock particles to vibrate. The degree of vibration of the rock particles decreases with increasing distance from the blast. However, the vibration of the rock particles can cause damage and structural failure to buildings if sufficiently strong.

The prediction of the Peak Particle Velocity (PPV) follows a propagation law which has the form [9]:-

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

Where V is the Peak Particle Velocity, mm/sec
R is the distance between the blasting source and the measuring point, m
Q is the explosive charge weight in TNT equivalence per delay, kg
K, d and b are site specific constants, termed the rock constant, charge exponent, and attenuation factor respectively. Both theoretical and empirical methods have been used to estimate values for K, d, and b.

The above equation with values of K = 644 based on the 84% confidence limit, d = 0.5 and b = -1.22 have been used for the blast design of the WIL project, in accordance with the general practice in Hong Kong and as per the guidelines developed by the Mines Division. A limit on PPV of 25 mm/s (for buildings) and similar values (for other receptors) is used as the criteria for the blast design as discussed in *Section 5.4*.

From a risk perspective, if a 84% confidence level is used for calculation of PPV, there would be a 16% probability that the PPV will exceed the acceptable PPV. Hence, it is necessary to determine a value for the rock constant, K that is appropriate for the hazard assessment.

The value for the rock constant, K, is largely related to the rock type, structure and the confinement of the blast, i.e. K will be larger for an explosive charge placed in a tight fitting blasthole than for explosives stored in a niche or chamber. The values of K for granitic and volcanic rocks in Hong Kong are in the range of 1000 to 1200 for tunnel blasting [9]. Geoguide 4 states that the values for the charge and attenuation exponents are between 0.6 to 0.8 and 1.2 to 1.6 respectively.

Rearranging the above equation yields:-

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

Where the ratio of the charge to attenuation exponent (i.e. d/b) lies within the limits of 0.5 to 0.66.

In the context of QRA, the equation used in GEO Guide 4 [9] was considered applicable. The parameters used in QRA are as follow:

K = 1200, upper range selected from GEO Guide 4

This value is conservative as it represents an upper limit for PPV for rock conditions considered applicable for Hong Kong.

d = 0.5 and b = -1.22

This slope is conservative for predicting PPV in far field for which an attenuation exponent of -1.6 to -1.2 could be considered as per GEO Guide 4.

Effect on buildings

There are various published international standards that relate to the damage levels that may be apparent from ground vibrations. However, most of these are concerned with the limit of cosmetic damage to buildings. For example, *BS 7385-2:1993 Evaluation and measurement for vibration in buildings – Guide to damage levels from ground borne vibration* [25] states that the probability of damage to buildings tends towards zero at values for the Peak Particle Velocity at 12.5mm/s or less. In addition for reinforced or framed structures the PPV value at which cosmetic damage will occur is 50mm/s. This reduces to 20mm/s for un-reinforced or light buildings at lower frequencies, increasing to 50 mm/s for frequencies above 40 Hz.

In Hong Kong the value for the peak velocity of 25 mm/s has been used for many years, and represents the maximum values normally acceptable for a building, in order to prevent cosmetic damage. However, for the purpose of this study the value of the peak particle velocity that causes significant structural damage such that a fatality or multiple fatalities are possible is required.

In the US Bureau of Mines Bulletin 656 *Blasting vibrations and their effects on structures* [26] provide results obtained from blasting undertaken in Sweden. These results were obtained following blasting where the vibrations were attenuated very little with distance since both the charge location and the buildings were set in rock. In order to improve the economy of the blasting, larger charge weights were used that would result in minor damage. The cost of repair of the buildings was considered preferable to the use of smaller charge weights. Hence, there was a large amount of data obtained on damage to buildings from blasting. The results obtained showed that:

Table 7.1 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)
Serious cracking	231 (9.1)

Further information on the damage to buildings is provided by the US Department of Defence Standard DoD 6055.9-STD 2004 DOD Ammunition and explosives safety standards [11] Paragraph C9.7.2.3.1.1 states that for the protection of residential buildings against significant structural damage by ground shock, the maximum particle velocity induced in the ground at the building site shall not exceed 9.0 in/sec or **229 mm/s** for strong rock.

The explosives magazine storage is to be constructed under Mount Davies, which comprises cretaceous volcanic rocks, which are dominantly a coarse ash crystal tuff. Therefore, the ground shock that may result from the accidental initiation of a storage chamber is considered to be transmitted through strong rock. The WIL alignment will also be constructed in strong rock.

The criteria for the damage to inhabited buildings shall be based on the US DoD 6055.9-STD for strong rock. This indicates that a detonation within the explosive magazine does not result in dangerous peak particle velocities at the nearest inhabited building and is unlikely to cause cosmetic damage to the building.

Criteria adopted for building risk assessment were summarized as below:

- **PPV = 229mm/s – Building structural element collapse threshold.** It represents significant structural damage to a building. Note that based on expect judgment [10], PPV at this level is not likely to cause any structural element to collapse.

- **PPV = 100mm/s – Object falling threshold.** Based on the discussion below, it is assumed to represent a 1% fatality level within a building due to vibration causing object falling, but no major building damage is expected at this level.

A peak particle velocity significantly larger than the assumed threshold limit value of 229 mm/s, would be required to fail a typical building in Hong Kong [10]. Hence the above criteria are considered to be conservative.

Building Collapse Models for Explosion/ Earthquake

Estimation of fatalities from falling objects relies on assumptions such as number of objects with the potential to fall, weight and size of those objects, probability of fatality when a person is hit etc. Although the number of fatalities given an object of a given size can be estimated, the probability of objects falling due to ground vibration particularly at a low threshold value of 100mm/s is uncertain. It would depend on the condition of building, presence of temporary or unauthorized structures etc.

For the types of buildings considered in the QRA, objects with the potential to fall are assumed to cover an area of 1 m^2. Based on the maximum pedestrian population density of 0.5 person/m^2 estimated in the QRA, the resulting number of fatalities due to an object falling is one. Even assuming conservatively that one object will fall on each side of a building, the expected number of fatalities will be 2 given a 50% chance of fatality for such an object falling [41].

Since, the assessment of risks due to objects falling due to blast vibrations involve the assessment of unknown factors, the QRA has used building collapse correlations applied to the entire building population (assuming full occupancy) to capture such unknown factors based on the consideration that building collapse will cause more fatalities than object falling. Building vulnerability model have been well established and extensively used to determine the fatality rate due to damage or collapse of buildings caused by explosion or earthquake.

A review of building damage vulnerability models for partial building collapse / damage was carried and summarized in *Table 7.2*.

Table 7.2 Review of Building Vulnerability Models

Source	Model Type	Description	Fatality Rate
Gibert, Lees and Scilly [8]	Explosion model	Housing Damage Category Cb - Houses which are rendered uninhabitable by serious damage and need repairs so extensive that they must be postponed until after the war. Examples of damage resulting from such conditions include partial or total collapse of roof structures, partial demolition of one or two external walls up to 25% of the whole, and severe damage to the load bearing partitions necessitating demolition and replacement	0.009
PEER Survey-based NDCF Fatality model [36]	Earthquake model	Partial collapse includes: 1) Ceiling / roof collapsed 2) Ceiling / roof collapsed + Foundation destroyed 3) Floors collapsed 4) Floors collapsed + Foundation destroyed 5) Ceiling / roof collapsed + Floors collapsed 6) Ceiling / roof collapsed + Floors collapsed + Foundation destroyed	0.015
ATC-13 [37]	Earthquake model	Major damage to building	0.01
HAZUS ® 99SR-2 [38]	Earthquake model	Extensive – 20-50% of building being damaged	0.00001

If it is assumed that every building experiencing the 'fine cracking' or 'object falling' vibration threshold (ie 100mm/s) will result in comparable fatality modes caused by partial collapse due to heavy explosion or earthquake, then the building vulnerability model can be used as a basis for this study.

The fatality modes caused by partial collapse will be mainly due to collapse of roofs, ceilings and walls, which may be considered as the most serious concern of object falling causing fatality (ie more than one or two fatalities).

Since partial collapse/damage of a building defined in those models refer to severe building damage, this approach is deemed to be conservative.

The fatality rates calculated from various models for partial collapse of a building vary from 0.01% to 1.5%. A fatality rate of 1% has therefore been conservatively considered for fatalities resulting from objects falling.

Review of Historical Incidents

UK HSE has carried a survey to collect all the incidents related to object falling at work from 2004-2007 [39] irrelevant of the cause.

The results show that a total of 51,092 object falling incidents impacting persons and 101 fatalities were reported during this period in UK.

Based on these statistics, it can be derived that for a given falling object incident, the chance of killing a person is around 0.1%. This factor can be increased by one or two orders of magnitude to account for potentially higher population density, giving a probability range of 1% to 10%. Assuming conservatively that one object can fall at each side of the building, the number of fatalities expected is one person.

Based on typical building occupancies of 600 to 800 people, the 1% fatality criteria has therefore assessed that there could be 6-8 fatalities per building affected for each blast causing objects to fall. Based on the above discussion, the expected number of fatalities due to object falling does not exceed one or two, therefore the assumption of 1% fatality is deemed conservative.

Effect on slopes

The following approach has been developed specific to this project.

A study was performed to determine the vibration level required to lead to failure of slopes due to earthquakes in Hong Kong [28]. This is based on Sarma 1975 as referred to in GEO Report 15 [12]. The formula for slope movement is given below (based on [28] which made reference to Sarma 1975 work):

$$Xm = 0.25 * C * Am * T^2 * 10^{(1.07-3.83\ Ac\ /\ Am)}$$

where Xm = slope movement
C is a function of the slope geometry and generally has a value near unity
Am is the peak acceleration,
T is the dominant period of the ground motion, and
Ac is the critical acceleration required to cause sliding.

From blast observations, and according to GEO report 15 [12] the dominant period is about 1/30 seconds. Also from blast observation it appears that the peak ground acceleration in mm/s^2 is about 670 times the PPV in mm/s (i.e. for a PPV of 60mm/s the peak acceleration is about 4g or $40,000mm/s^2$ [10]. It follows that X_m, the slope movement

$$X_m = 0.186 x PPV x 10^{\left(1.07-3.83 PPVc/PPV\right)}$$

However, this equation is based on the use of earthquake data, which will comprise several low frequency pulses instead of a singular pulse at higher frequency that would result from explosives detonating. From analysis of data for the El Centro (1940) earthquake [27], it appears that a typical earthquake consists of at least four (4) separate peaks. Since each peak will cause slope movement it is considered appropriate to incorporate a factor of 0.25 in the Sarma equation to allow for the single pulse that would result from explosives detonation within the magazine. Therefore, the modified Sarma equation to estimate slope movement from the detonation of explosives is:-

$$X_m = 0.0465 x PPV x 10^{\left(1.07-3.83 PPVc/PPV\right)}$$

where PPVc is the critical velocity calculated using the equations supplied in GEO Report 15 [12] and knowledge of the slope.

$PPVc = K_c g/(\omega Ka)$

Where
$K_c g$ = the critical acceleration at which the slope has a factor of safety of 1.0 against failure (ms^{-2})
g = the acceleration due to gravity (ms^{-2})
ω = the circular frequency of the ground motion (2πf)
Ka = the magnification factor

The soil strength values used in determining the PPVc values are those recommended by GEO Guidance documents and are generally considered to be a conservative estimate of the actual expected strengths. Additionally while saprolite may experience a post peak drop in strength this strength drop requires a significant movement of the slope and is the main contributory factor leading to the assessment of 100mm being the displacement required to cause ongoing failure of the slope. If there is no post peak drop in strength the Sarma method can be used to assess much larger slope movements that will still cease once the vibration has stopped and therefore not lead to a complete slope failure.

GEO Report 15 [12] publishes a graphical representation of the Critical Peak Particle Velocity, PPVc, and the initial static factor of safety for varying joint displacements at peak stress. This is reproduced in the *Figure 7.1* below.

Based on the modified Sarma equation,

$$X_m = 0.0465 x PPV x 10^{\left(1.07 - 3.83 PPVc/PPV\right)}$$

the peak particle velocity (PPV) required to cause slope movement can be plotted for each critical peak particle velocity value. This is illustrated in the *Figure 7.2* below for the critical peak particle velocities estimated for the slopes 11-SW-A-C292/3, and the retaining wall 11-SW-A-R782 which will be impacted by the detonation of explosives within the magazine (see *Section 7.3.1*) for illustration.

Figure 7.1 Critical Peak Particle Velocity vs Initial Static Factor of Safety

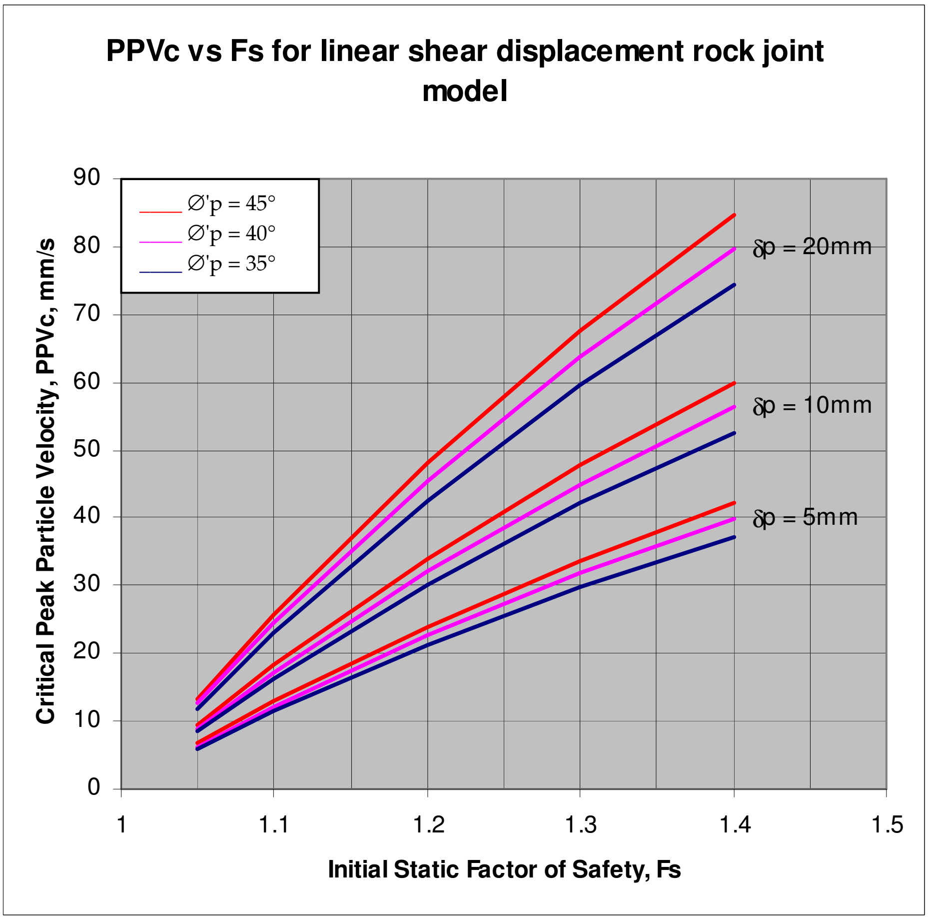
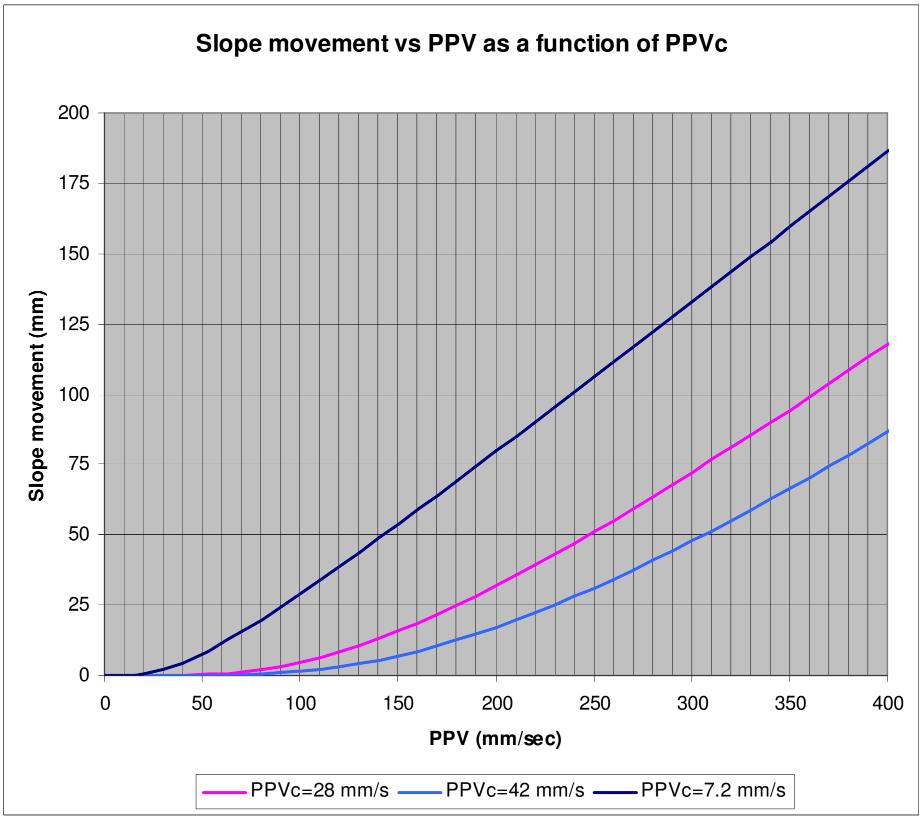


Figure 7.2 Slope Movement for the Slopes Nearest to Magazine



Expert judgement has been used to determine the criteria for the failure of slopes based on the amount of shear displacement or slope movement [10]. The criteria that is appropriate to this study are:

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

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.

In addition, a screening criteria of PPV = 90mm/s was adopted for screening of slopes which are potentially at risk during the construction of WIL alignment and magazine. This PPV level corresponds to 0.01% chance of a slope failure with Factor of Safety (FOS) =1.1. A detailed analysis was then conducted for each of the slopes which exceeded the above criteria.

7.2.7 *Ground Shock Generated by Accidental Explosion in Magazine Niches*

The DoD 6055.9-STD [11] provides equations for establishing the minimum safe distance for inhabited buildings from underground magazines based on the magazine loading density. The magazine loading density is defined as:

Loading density = Q / V_c
Where Q is the explosives mass, kg
V_c is the chamber volume, m^3.

The magazine is to store 300 kg of explosives within a 125 m^3 chamber. Therefore, the loading density is 300 / 125 = 2.4 kg/m^3.

The DoD 6055.9-STD equation C9.7-2 for the inhabited building distance for low loading density storage is:-

$D_{ig} = 2.3\ Q^{1/3}$

For the purpose of this study it is assumed that this distance is the distance at which the ground shock, or Peak Particle Velocity equals 229 mm/sec for strong rock, based on paragraph C9.7.2.3.1.1 of the DoD standard. This represents the limit value for causing significant structural damage to a building [11].

Therefore, for a single chamber explosive quantity of 300 kg, the safe distance, D_{ig} is 15.4m. This information can now be used to estimate a revised rock constant , K, that reflects the increased ‘decoupling’ of the explosives compared to that value used when the explosive is fully ‘coupled’ in the blasthole.

The rock constant, K, that reflects the magazine chamber's level of confinement can now be estimated from:-

$PPV = K (R / Q^{0.5})^{-1.22}$

Re-arranging gives

$K = PPV / (R / Q^{0.5})^{-1.22}$
$K = 229 / (15.4/ 300^{0.5})^{-1.22}$
$K = 200$

Hence, the equation for the estimation of the PPV values that result from an explosion within a storage chamber involving 300kg of explosives is:

$PPV = 200 (R / Q^{0.5})^{-1.22}$

The effects of buildings and slopes are given in *Section 7.2.6*.

7.2.8 Landslide Consequence

A landslide consequence classification system was published in the GEO Report 81 Slope Failures along BRIL Roads: Quantitative Risk Assessment and Ranking [13]. This provides an equation for the estimation of the number of fatalities:

$$N = \frac{\sum WFPEA}{V}$$

Where W is the width of the landslide plus an adjustment for effective stopping distance;
F is the frequency of passing passengers, which may be taken as the product of the Annual Average Daily Traffic (AADT) and the average number of people in a vehicle;
P is the probability of death due to being caught in the landslide;
E is the extent of the landslide equivalent to the number of lanes affected;
A is an adjustment factor for proportion of normal road usage at the time of the landslide; and
V is the speed of vehicles.

The following assumptions have been made in applying this model.

- Average speed of the vehicles is taken to be 30 miles/hr (48 km/h) based on the road conditions at the location of the magazine. It should be noted that the speed of the vehicles is not particularly sensitive to the calculation of N since the effect is largely compensated by the effective stopping distance

- A stopping distance of approximately 23m is assumed based on UK Highway Code data for a vehicle speed of 30 miles/hr (48 km/h) [29]. This stopping distance includes the reaction time. Higher speeds will require greater stopping distances. However, it is considered that the road conditions at the site of the magazine prohibit excessive vehicle speeds.

- The probability of death, P, due to the landslides given in *Table 7.3* is obtained from the GEO Report 81 [13]. GEO has developed the consequence model and has published papers on this subject [34]. The past incidents show that for landslides the assumptions are reasonable. This model has been applied for several studies on landslides in Hong Kong.

Table 7.3 ***Probability of Fatality due to Landslide [13]***

Proximity to Slope	Probability of Death
Lane nearest the slope	0.8
2nd lane away from slope	0.6
3rd lane from slope	0.4

- For the failure of a retaining wall, that causes the collapse of a road, the probability of death is assumed to be 1 for the lanes affected.

- The parameter A can be taken as 0.82 and accounts for the fact that landslides are most likely to occur during heavy rainfall. However, as the possible slope failure is caused by explosives detonating it is assumed that the value for A is unity.

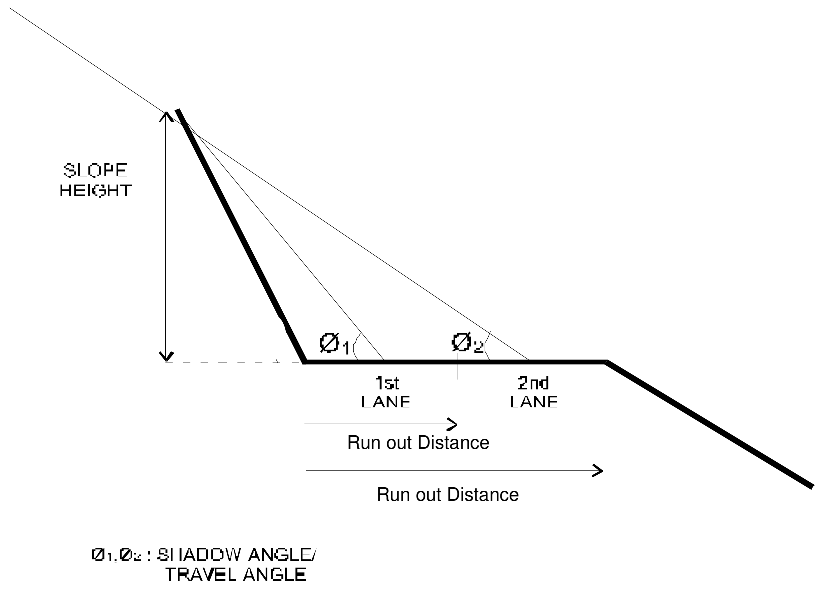
- To allow for the additional risk due to footpaths adjacent to the road, an adjustment factor is applied to the calculated value of N.

- Victoria Road is comparatively remote, and hence a lower factor than that recommended for major transportation routes is considered appropriate. Therefore, to account for pedestrians the calculated N value is increased by 10%.

The travel distance of landslide debris is influenced by the mechanism of its failure. For example, it would be expected that a landslide induced by rainfall will travel further than one caused by blasting as the soil and rock may behave in a more liquid manner. Therefore, the travel distance for rainfall induced landslides that involve liquefaction may be based on an apparent angle of friction of 15 to 30°. This apparent angle of friction or travel angle is defined as the inclination. The GEO Report 81 [13] indicates that a typical rain induced landslide that involves a landslide volume less than 2000m^3 generally ranges from 30 to 40°. For conservatism, it is assumed that a slope failure caused by detonation of explosives will result is a travel angle of 30°.

The relationship of shadow/travel angle and run out distance is illustrated by the following figure.

Figure 7.3 Influence Zone for Slope Failures



Therefore, the run out distance for the landslide, assuming a triangular volume, can be approximated by the equation:

$$L = \sqrt{\frac{2V}{W \tan(30)}}$$

Where L is the run out distance, m;
V is the slip volume, m^3; and
W is the slip width, m.

7.2.9 *Boulder Fall Consequence*

The consequence of a boulder fall is based on the methodology described within the GEO Report 81 [13]. The probability of a falling rock of greater than 150mm diameter hitting a moving vehicle is based on the fraction of the road occupied by the vehicle. This is defined as

P(S:H) = (AADT x Length of the vehicle) / (average vehicle speed x 24,000)

Where AADT is the annual average daily traffic. The average length of a vehicle is assumed to be 5m, whilst the average speed of the vehicles along the stretch of Victoria Road near the magazine is taken to be 30 miles per hour (48 km/hr). The value of 24,000 is a conversation factor for units.

The probability that a rock hits a vehicle is then given by:-

$P(S) = 1 – \{ 1 – P(S:H)\}^{Nrf}$

Where N_{rf} is the frequency of rock fall per year.

The probability of loss of life of an occupant given a vehicle is hit by a rock is assumed to be 0.2 [13]. This probability accounts for the size of the rock, the number of occupants within the vehicle, the construction of the vehicle.

In addition, the consequence of a vehicle hitting the boulder once it has fallen can be estimated based on the stopping distance of the vehicle. The stopping distance can then be substituted as the average length of the vehicle, and a probability of fatality to an occupant is assumed to be 0.1 [13].

With regard to boulders impacting pedestrians, the Territory Wide Quantitative Risk Assessment of Boulder Fall Hazards Stage 1 Final Report [35] has suggested an increase factor of 25% over the fatality estimated based on road vehicles.

Regarding effects on buildings, there are no boulders that were above the buildings as identified in the Blast Assessment Reports [4]-[6].

7.3 *RESULTS OF CONSEQUENCE ASSESSMENT*

7.3.1 *Proposed Magazine*

The slopes nearest to the magazine are 11-SW-A-C292, 11-SW-A-C293 and the retaining wall is 11-SW-A-R782 Data for these slopes has been supplied by MTRC, and is tabulated below:-

Table 7.4 Particulars of the Slopes Nearest to the Magazine

Slope Identification	Static Factor of Safety	Slope length, m	Slope angle	Slope depth, m	Slope material	PPVc, mm/s	Slip Volume, m^3	Location*
11-SW-A-C292	1.22	6.8	55	1.5	Soil & Rock	28	36	Near eastbound lane of Victoria road
11-SW-A-C293	1.2	28	60	4	Soil & Rock	42	1640	Near eastbound lane of Victoria road
11-SW-A-R782	1.27 (overturning 1.46 (sliding)	20	85	5 max	Masonry and concrete wall	7.2	32.7	Near westbound lane of Victoria road

*Refer to Table 4.3 for annual average daily traffic (AADT) data

The peak particle velocity that could possibly arise from an initiation within each magazine chamber has been evaluated for the nearby slopes and occupied buildings. The results are tabulated below. The slope movement is read from the respective PPVc curve for the concerned slope/ retaining wall in *Figure 7.2* based on the calculated PPV value.

Table 7.5 Peak Particle Velocity from Accidental Initiation within Magazine

Peak Particle Velocity at the nearest inhabited building				
Chamber	Charge, TNT Eq., kg	Dist., m	Peak Particle Velocity, PPV, mm/s	Comments
1	300	95	25	PPV value at the limit for cosmetic damage
2	300	109	21	Below the limit for cosmetic damage
3	300	123	18	Below the limit for cosmetic damage
4	300	142	15	Below the limit for cosmetic damage
5	300	156	14	Below the limit for cosmetic damage
6	300	161	13	Below the limit for cosmetic damage
7	300	153	14	Below the limit for cosmetic damage
8	300	140	16	Below the limit for cosmetic damage
9	9	127	2	Below the limit for cosmetic damage
Entrance tunnel	200	57	37	Possible cosmetic damage only

Peak Particle Velocity at the slope 11-SW-A-C292				
Chamber	Charge, TNT Eq., kg	Dist., m	Peak Particle Velocity, PPV, mm/s	Comments
1	300	58	46	PPVc is 28 mm/s, No slope movement
2	300	73	35	PPVc is 28 mm/s, No slope movement
3	300	90	27	PPVc is 28 mm/s, No slope movement
4	300	105	22	PPVc is 28 mm/s, No slope movement
5	300	118	19	PPVc is 28 mm/s, No slope movement
6	300	118	19	PPVc is 28 mm/s, No slope movement
7	300	106	22	PPVc is 28 mm/s, No slope movement
8	300	93	12	PPVc is 28 mm/s, No slope movement
9	9	80	4	PPVc is 28 mm/s, No slope movement
Entrance tunnel	200	11	272	PPVc is 28 mm/s, slope movement is 60 mm

Peak Particle Velocity at the slope 11-SW-A-C293

Chamber	Charge, TNT Eq., kg	Dist., m	Peak Particle Velocity, PPV, mm/s	Comments
1	300	56	48	PPVc is 42 mm/s, No slope movement
2	300	71	36	PPVc is 42 mm/s, No slope movement
3	300	86	28	PPVc is 42 mm/s, No slope movement
4	300	98	24	PPVc is 42 mm/s, No slope movement
5	300	97	24	PPVc is 42 mm/s, No slope movement
6	300	82	30	PPVc is 42 mm/s, No slope movement
7	300	62	42	PPVc is 42 mm/s, No slope movement
8	300	50	55	PPVc is 42 mm/s, No slope movement
9	9	42	8	PPVc is 42 mm/s, No slope movement
Exit tunnel	200	7	472	PPVc is 42 mm/s, Slope movement 118mm

Peak Particle Velocity at the retaining wall 11-SW-A-R782

Chamber	Charge, TNT Eq., kg	Dist., m	Peak Particle Velocity, PPV, mm/s	Comments
1	300	109	21	PPVc = 7.2 mm/s, <1mm movement
2	300	124	18	PPVc = 7.2 mm/s, <1mm movement
3	300	141	15	PPVc = 7.2 mm/s,<1mm movement
4	300	157	14	PPVc = 7.2 mm/s, <1mm movement
5	300	168	13	PPVc = 7.2 mm/s, <1mm movement
6	300	170	12	PPVc = 7.2 mm/s, <1mm movement
7	300	160	13	PPVc = 7.2 mm/s, <1mm movement
8	300	145	15	PPVc = 7.2 mm/s, <1mm movement
9	9	132	2	PPVc = 7.2 mm/s, No movement
Entrance tunnel	200	42	53	PPVc = 7.2 mm/s, 9mm movement

Therefore, based on the above approach the detonation of explosives within an individual magazine chamber will not result in C292/3 or R782 slope failure. However, during the transfer of explosives to or from the magazine chamber there is a risk of slope failure due to detonation of explosives within the tunnel when the vehicle is close to the slope toe.

Based upon *Figure 7.2*, the peak particle velocity that results in a 0.01% chance (i.e. 20 mm slope movement) of slope failure is 165 mm/s, 211 mm/s, and 81 mm/s for slopes C292, C293 and R782 respectively. These values for PPV correspond to a distance of 17m, 14m and 30m for the slopes C292/3 and the retaining wall R782 based on a 200 kg explosive in a truck. Therefore, beyond these distances there is considered to be a negligible chance of failure of the slope or wall due to ground vibration from a blast within the magazine access tunnel. Based on these limiting distances, the approximate length of the magazine tunnel which has the potential to cause a slope failure is approximately 30m for slopes C292 and C293. The access tunnel is over 40m from the retaining wall R782, hence there is already a less than 0.01% chance of the wall failing in the event of an explosion at the magazine adit entrance.

For the slope C293, assuming 16 vehicle movements within magazine access tunnel per day (6 trips for transfer into the niches and 10 trips for taking out from niches to construction site), the frequency of an initiation of explosives on a vehicle within the vulnerable 30m sections of the magazine access tunnel is:-

$3.31 \times 10^{-10} \times 16 \times 365 \times 30 / 1000 = 5.8 \times 10^{-8}$ yr^{-1}

The estimated PPV value caused by a detonation immediately beneath the slope is 117mm/s. Therefore, it is conservatively assumed that for the entire 30m tunnel section that there is a 50% chance of failing slope C293 (see section 7.2.6).

However, for the failure of slope C292, only an initiation within the entrance tunnel will be sufficient to cause possible slope failure, and the frequency of initiation within the entrance tunnel will be 2.1×10^{-8} yr^{-1}.

Slopes 11-SW-A-C292/3

For slope 11-SW-A-C292 the landslide run out distance will be 4.3 m, whereas a slope failure at 11-SW-A-C293 will result in a run out distance of 14.2m. Immediately adjacent to both slopes is a footpath, and allowing 1.5m for the footpath and 3.5m for each lane means that a slope failure of C292 would be expected to affect the Eastbound lane only, whereas a slope failure of C293 would result in both lanes being affected.

For slope 11-SW-A-C292, the number of fatalities is estimated to be:

$$N = \frac{\sum WFPEA}{V}$$

$$N = \frac{(6.8 + 23)(3450x3/24)x0.8x1x1}{48,000} = 0.2$$

Hence, the failure of slope C292 will cause a single fatality.

For slope 11-SW-A-C293, the number of fatalities is estimated to be:-

$$N = \frac{\sum WFPEA}{V}$$

$$N = \frac{(28+23)(3450x3/24)x0.8x2x1}{48{,}000} + \frac{(28+23)(4020x3/24)x0.6x2x1}{48{,}000} = 0.73 + 0.64 = 1.37$$

Allowing for the presence of pedestrians then the calculated value of N is 1.37 x 1.1 = 1.5. Therefore, failure of slope C293 will result in 2 fatalities.

Retaining wall 11-SW-A-R782

For the retaining wall 11-SW-A-R782 the landslide run out distance will be 2.4 m. Above the retaining wall is a footpath, and allowing 1.5m for the footpath, this results in only a partial collapse of the Westbound lane. However, for the purpose of this study it is assumed that the failure of the retaining wall will result in the collapse of the Westbound lane of Victoria Road only.

For failure of the retaining wall 11-SW-A-R782, the number of fatalities is estimated to be:

$$N = \frac{\sum WFPEA}{V}$$

$$N = \frac{(20+23)(4020x3/24)x1x1x1}{48{,}000} = 0.45$$

Allowing for the presence of pedestrians then the calculated value of N is 0.45 x 1.1 = 0.5. Hence, for the purpose of this study, the failure of the retaining wall 11-SW-A-R782 will cause a single fatality.

The above analysis is summarised in the table below.

Table 7.6 ***Summary of Results of Magazine Slope Failure Scenarios***

Event	**Daily vehicle movements**	**Event frequency**	**Probability that C292 fails(1)**	**Probability that C293 fails(1)**	**Probability that R782 fails**	**Number of fatalities**	**Frequency**
Explosion within entrance adit	6	$2.15x10^{-8}$	0.1	0.5	-	3	$1.1x10^{-9}$
			-	0.5	-	2	$9.9x10^{-9}$
			0.1	-	-	1	$1.1x10^{-9}$
Explosion within exit adit	10	$3.6x10^{-8}$	-	0.5	-	2	$1.8x10^{-8}$
Explosion at the entrance portal	6	-(2)	-	-	0.0		

Notes:

(1) Refer to *Section 7.2.6* and *Figure 7.2* for the relationship between slope displacement and slope failure probability

(2) Not evaluated since explosion at entrance portal do not lead to any consequence, ie less than 0.01% chance of failure of R782

Boulder fall

Boulders were identified from the magazine blast assessment report at the vicinity of the magazine. The types 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, eg. degree of embedment, local slope angle etc.

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.

The boulders with the potential to fall have been tabulated below:

Table 7.7 Boulders at the Vicinity of the Magazine

Boulder	Comments from inspection			Easting	Northing	Level (mPD)
	Condition	Potential failure mode	Travel path			
B1	Base of boulder well embedded	None. Base of boulder well embedded	Densely vegetated with trees	830168	815413	63.5
B2	Erosion of soil at base of boulder	None. Boulder is generally tabular and resting on flat side	Densely vegetated with trees	830189	815404	75.5
B3	Base of boulder reasonably well embedded	None. Base of boulder reasonably well embedded	Densely vegetated with trees	830173	815406	68.5
B4	-	Rolling	Densely vegetated with trees	830180	815389	77.5
B5	Rock outcrop	None. No obvious unstable blocks	Densely vegetated with trees	830194	815382	85
B6	Rock exposures nearby so soil thickness likely to be thin	None. Boulder generally tabular and resting on flat side	Densely vegetated with trees	830225	815387	99.5
B7	-	None. Boulder tabulated and resting on flat side	Densely vegetated with trees	830207	815356	99.5
B8	-	Sliding - Boulder resting at crown of landslide scar Other - Retrogressive slope	Densely vegetated with trees	830236	815353	114.5

Boulder	Comments from inspection			Easting	Northing	Level (mPD)
	Condition	Potential failure mode	Travel path			
		failure results in dislodgement				
B9	Loose boulder resting within landslide debris	Erosion of foundation - Boulder resting within landslide debris Other - Reactivation of debris results in further movement	Densely vegetated with trees	830223	815360	105.5
B10	-	Rolling and Erosion of foundation	Densely vegetated with trees	830154	815308	75
B11	Existing dentition at base of boulder	None. Existing dentition at base of boulder	Open flat platform	830191	815447	66.5
B12	Boulders appears reasonable well embedded at base	None. Boulder appears well embedded	Densely vegetated with trees	830203	815470	69.5
B13	Boulder almost entirely embedded within soil	None. Boulder almost entirely embedded within soil	Densely vegetated with trees	830229	815478	78.5
B14	Boulder resting on other boulders	Topping - Stability dependent on other boulders	Densely vegetated with trees	830210	815511	60.5
B15	-	None. Tabular boulder resting on flat side	Densely vegetated with trees	830226	815537	66
B16	-	Rolling	Densely vegetated with trees	830156	815431	52.5
B17	Base of boulder well embedded	None. Mostly interlocked and well embedded	Densely vegetated with trees	830202	815413	77
B18	Boulder almost embedded within soil	None. Boulder almost embedded within soil	Densely vegetated with trees	830191	815387	82
B19	Base of boulder well embedded	None. Base of boulder well embedded	Densely vegetated with trees	830200	815370	91
B20	Base of boulder well embedded	None. Base of boulder well embedded	Densely vegetated with trees	830212	815406	84
B21	Base of boulder well embedded	None. Base of boulder well embedded	Densely vegetated with trees	830183	815466	60.5
B22	-	None. Boulder is generally tabular and resting on flat side	Densely vegetated with trees	830225	815436	83.5
B23	Rock outcrop	None. No obvious unstable block	Densely vegetated with trees	830221	815434	82.5
B24	Rock outcrop	None. No obvious unstable block	Densely vegetated with trees	830234	815428	90

From the boulder survey, all the boulders are observed to be reasonably well embedded and travel path of the boulder are all densely vegetated with trees. Referring to the GEO Report 80, vegetation will help in stopping most boulders and will limit the rundown distance in the event of boulder fall.

Boulder falling due to accidental initiation of explosives within magazine niches

Considering a detonation of 300kg of explosives within a niche, the impact distance to 90mm/s (screening criteria) is 33.3m. Base on this, no boulder was found to be affected as all the boulders are elevated with at least 40m distance away from magazine niches.

Boulder falling due to accidental initiation of explosives during transfer of explosives

Considering the maximum load of a delivery truck of 200kg of explosives, the impact distance to 90mm/s (screening criteria) is 27m. Base on this criterion and the geometric separation of the boulders from the magazine tunnel, only boulder B16 may have the potential to be dislodged. This potential exists only for a 30m section of tunnel near the entrance portal and a 20m section of tunnel near the exit based on separation distances.

Boulder fall frequency:

No. of vehicle movement per day (/day) x Concerned section of the tunnel (km) x Frequency of explosives initiation (/km) x 365 (day/year) x chance of boulder failure

= [(6 x 0.03 x 3.31E-10) + (10 x 0.02 x 3.31E-10)] x 365 x 1% = 4.59E-10 per year

Probability of a falling boulder strikes a vehicle:

$P(S) = 1 - [\, 1 - (4020 + 3450) \times 5 \,/\, (48 \times 24{,}000)\,]^{4.59E-10} = 1.51E-11$ per year

Probability of a vehicle hitting the boulder once it has fallen, assuming stopping distance of 23m [29]:

$P(S) = 1 - [\, 1 - (4020 + 3450) \times 23 \,/\, (48 \times 24{,}000)\,]^{4.59E-10} = 7.41E-11$ per year

Probability of a falling boulder strikes a person, assuming conservatively a 50% presence factor and avoidance factor:

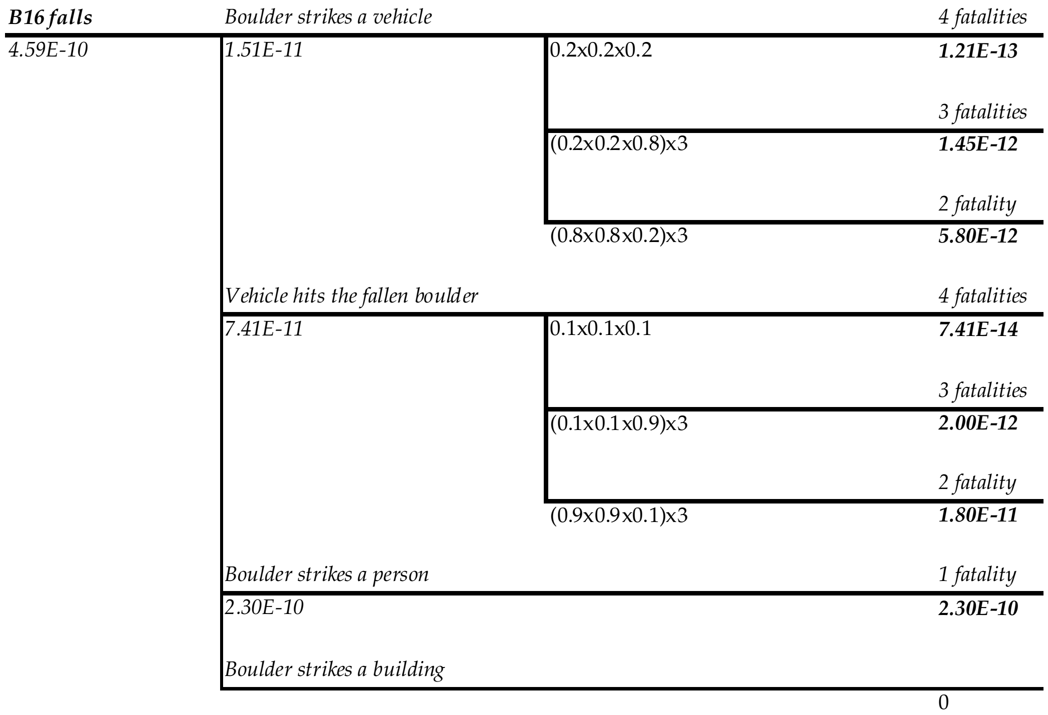
P(S) = 4.59E-10 x 0.5 = 2.30E-10 per year

Probabilities of fatality to an occupant were assumed to be 20% and 10% for "boulder strikes a vehicle" and "Vehicle hits the fallen boulder" respectively based on GEO Report 81. One hundred percent (100%) fatality was assumed for a boulder hitting a person.

For the boulder B16 of concern, there is no impact to building. Hence, fatality due to a boulder hitting a building not was considered further.

The event tree below summarized the frequencies and number of fatalities due to boulder B16 fall:

Figure 7.4 Event Tree of a Boulder Fall Scenario



Note: A vehicle has assumed to carry no less than 3 passengers and 25% increase in fatality has been accounted to incorporate additional pedestrian fatality

7.3.2 *Transport of Explosives*

The results for each transport scenario are summarized in *Table 7.8*.

Table 7.8 Summary of Results for Transport Scenarios

Scenario	Description	TNT eqv. (kg)	Length. of the Road (km)	Total Freq in AM or PM (/yr)	*Indoor* Harm Prob.	Impact distance (m)	*Outdoor* Harm Prob.	Impact distance (m)
R01	Initiation of explosives during transport of explosives from magazine to delivery point 01 via route 01	77	1.5	1.81E-07	90% 50% 1%	13 15 36	90% 50% 1%	11 11 14
R02	Initiation of explosives during transport of explosives from magazine to delivery point 02 via route 02	77	1.6	1.93E-07	90% 50% 1%	13 15 36	90% 50% 1%	11 11 14
R03	Initiation of explosives during transport of explosives from magazine to delivery point 03 via route 03	120	2	4.83E-07	90% 50% 1%	15 18 42	90% 50% 1%	12 13 16
R04	Initiation of explosives during transport of explosives from magazine to delivery point 04 via route 04	77	3.3	3.98E-07	90% 50% 1%	13 15 36	90% 50% 1%	11 11 14
R07	Initiation of explosives during transport of explosives from magazine to delivery point 07 via route 07	77	5.7	6.88E-07	90% 50% 1%	13 15 36	90% 50% 1%	11 11 14

7.3.3 *Use of Explosives*

3-D Review of Features

The ground vibration levels at a given receptor will depend on the distance between the receptor and the blasting point. The location of the blast site will move forward every time the proceeding blast completes and the rock spoil is removed. Therefore, the distance between the features and the blasting site will vary for each and every blast.

In order to consider the dynamic characteristic of the blasting work, a 3-dimenional review was carried out to assess the nearest features to the blasting site. The graphical representation is shown in *Figure 4.2* and *Figure 4.3* for the WIL alignment and magazine store respectively.

Screening of Features for Consequence Assessment

During the review, every feature was represented by one or more coordinates in a 3-dimensional plane (Northing, Easting, and Elevation) based on data given in the Blast Assessment Report. Similarly, every 10m-chainage interval of the alignment and magazine was represented by a single point. The nearest feature for every 10m-chainge section was then identified.

The vibration level for the nearest feature for every 10m chainage was assessed for a charge weight equivalent to 2 to 6 times of the base MIC. A sample calculation is shown in *Table 7.9*. The charge weight of more than 6 MIC was not considered for a credible case for consequence assessment as the occurrence frequency is lower than 10^{-9} for the WIL project (see *Appendix 10, Annex E*).

The results show that the PPV value for all building or other features will not exceed 140mm/s for a charge weight of 6 MIC or less. Therefore, no building will be subject to failure due to the use of explosive for rock excavation, based on the limit of 229mm/s required to cause significant structural damage.

It was also found that some buildings or features (excluding slopes and boulders) will exceed 100 mm/s and some slopes and boulders will exceed 90 mm/s for a charge weight of 4 to 6 MIC. The 90mm/s for the slopes and boulders was chosen for screening out the relevant slopes and boulders for further analysis, as mentioned previously. Therefore, each of the concerned slopes and boulders were further assessed to determine if a failure will occur at a charge weight of 4 to 6 MIC.

Consequence Assessment for Specific Features

If a feature is susceptible to a vibration level higher than 90 or 100 mm/s from the nearest chainage, it may also be affected by the adjacent chainage. Therefore, the effects from the adjacent chainage were also assessed.

With respect to slopes and boulders, the minimum vibration level that will initiate a slope / boulder failure was assessed for each of them based on their individual characteristic.

The hazard footprints in terms of PPV were then established for each particular feature, with respect to a range of chainage that may establish a footprint of 100 mm/s for buildings or that of the specific minimum vibration level for failure for slopes and boulders. The chainage was studied at 10-m interval and those that can establish a hazard footprint on these criteria were identified.

Table 7.9 Sample Calculation of PPV Level for each Feature at 1 or more MIC detonated at the same time

Feature Description	Allowable PPV	Min Distance from closest chainage (m)	Closest Blast Chainage	Explosive charge used (kg)	PPV expected (mm/s) - Two charges per delay	PPV expected (mm/s) - Three charges per delay	PPV expected (mm/s) - Four charges per delay	PPV expected (mm/s) - Five charges per delay	PPV expected (mm/s) - Six charges per delay
Building 1	25	33	SYPSHW_EB_100010	4.14	60.72	77.76	92.67	106.19	118.68
Building 2	25	29	SYPSHW_WB_100013	3.55	66.17	84.74	100.99	115.72	129.33

Notes: The PPV level is estimated using K = 1200

Risk Summation of Use of Explosives

Although the whole WIL will be constructed in 3 years, it was conservatively assumed that all the scenarios leading to failure would occur in the same year. All the buildings that can experience more than 100mm/s and slopes and boulders that will subject to more than the minimum vibration level assessed for each individual slope or boulder, were considered as scenarios leading to failure.

The frequency of occurrence of more than 4, 5 and 6 MIC detonated at the same time has been derived on a per 10-m basis (see *Table 6.5*). The relevant length of the chainage that impact the feature as identified in the consequence assessment was then used to obtain the frequency of the hazard footprints.

The hazard footprints at each 10m interval of the relevant chainage were then overlaid on each particular feature to estimate the number of fatalities due to falling objects in buildings, or failure of slopes/ boulders.

The resulting risk for every 10m interval of the relevant chainage was summed over to determine the overall risk for a feature and the risks of all concerned features are summed over to give the overall risk due to blasting operation for the WIL.

Conservatism in the Consequence Assessment

Due to delay scatter within the realms of manufacturing tolerance, additive effects can be considered for short time delays.

The combined additive effect based on experience is presented below [32]:

- Instantaneous detonation: 100% PPV Level
- Short Time Delay Detonators (25ms interval): 70% PPV Level
- Long Time Delay Detonators (500ms interval): 30% PPV Level

This is generally applicable to more than 3 MIC detonated at the same time. However, the reduced additive effects have not been considered in the consequence assessment for conservatism.

Consequence Assessment Results for Construction of Magazine

Ground Vibration Effect on Buildings or Slopes due to Errors in Blasting Face

It was found that a series of unregistered retaining walls, boulder area and an empty building could be potentially affected due to an incident during magazine construction.

Following similar approach described in *Section 7.3.1* for slope assessment, the results of the analysis were summarized as *Table 7.10* and *Table 7.11* below.

Table 7.10 Analysis of Slopes Exceeding Peak Particle Velocity of 90 mm/s due to Accidental Initiation during the Construction of Magazine

Mapsheet	**Type**	**No.**	**Static F.O.S**	**Slope length (m)** [1]	**Slope depth (m)** [2]	**Slope Material**	**PPVc (mm/s)**	**Slip Volume (m)**[3]	**PPV correspond to 90% slope failure (mm/s)**	**PPV correspond to 50% slope failure (mm/s)**	**PPV correspond to 10% slope failure (mm/s)**	**PPV correspond to 0.01% slope failure (mm/s)**
Unregistered	Retaining wall		1		1.5	Fill	23.2	84	-[4]	330	230	160

Notes:

(1) Slope length along its own slope

(2) Slope depth measured as a perpendicular distance below the slope surface

(3) It is assumed that the slope failure width is equal to the length and that the volume = π*length^2*depth/6.

(4) PPV >400mm/s which is unachievable based on the assessment

Table 7.11 ***Features Affected by Higher Vibration Generated by Accidental Initiation During the Construction of Magazine***

Scenario	Chainage	Features Affected	Scenario Frequency (yr)(6)	Expected Fatality (N)(1)	Remarks
Slope					
5MIC detonated at the same time	#338	Series of Unregistered RW	4.72E-09	-	(3)
6MIC detonated at the same time	#338	Series of Unregistered RW	4.72E-09	-	(3)
6MIC detonated at the same time	#238	Boulder area	4.72E-09	- (2)	(4)
Building					
6MIC detonated at the same time	#0	Empty building (830135, 815468)	4.72E-09	0	(5)

Notes:

(1) Expected fatality = Population x Fatality rate

(2) No further analysis was made since the slope failing event frequency was low, 3.78E-11 << 1e-9. In addition, the majority of the boulders observed during the walkover were reasonably well embedded and all appeared to be stable enough to resist the ground vibrations produced by the adit blasting.

(3) Although 90mm/s threshold reached, no fatality expected since the observed vibration level is well below actual 0.01% slope failing threshold 160mm/s

(4) 90mm/s (0.01% chance slope failure) threshold reached

(5) 1% fatality threshold reached

(6) This value is obtained from *Table 6.5*.

No fatality is expected due to higher vibration generated by the blast face due to human errors and other reasons such as manufacturing defects causing deviation from the confirmed design.

Ground Vibration and Air Overpressure Effect due to Detonation of Full Load during Transferring Explosives within Magazine Adit

The operation of magazine will be commenced following the completion of the construction work. It is not possible to consider the risk associated with the operation and construction of magazine to happen simultaneously, rather they should be one after another.

Since the societal risk is assessed on a per annum basis, the risk derived for the operational phase for the magazine (see *Section 7.3.1*) has therefore well covered the risk associated with the construction phase, since the frequency for transportation within the access tunnel during the operation of the magazine has covered that for the construction phase as far as a duration of a year is concerned.

<u>*Ground Vibration Effect on Buildings due to Errors in Blasting Face*</u>

No building was found exceeding PPV of 140mm/s and thus the building structural element collapse threshold (PPV = 229mm/s) considering accidental explosion up to 6MIC is not applicable.

It was found that 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 7.12 Features Affected by Higher Vibration Generated by Accidental Initiation during the Construction of Tunnels and Adits Blasting

Scenario/ Chainage	Features Affected	Scenario Frequency (yr)[1]	Expected Fatality (N)[2,3]
4MIC detonated at the same time			
SYPSHW_WB_100013	Building No. 426 (833026 ,816513)	7.38E-09	2
	General Utilities	7.38E-09	1
SYPSHW_EB_100010	General Utilities	7.38E-09	1
UNVADIT_const_0	Elevated Road	7.38E-09	2
UNVADIT_const_10	Elevated Road	7.38E-09	2
UNVADIT_EnB2_10	Elevated Road	7.38E-09	2
UNVADIT_EnB2_20	Elevated Road	7.38E-09	2
UNVADIT_EnC2_160	Building No. 131 (831833 ,816190)	7.38E-09	7
5MIC detonated at the same time			
SYPSHW_WB_100023	Building No. 426 (833026 ,816513)	7.38E-09	2
SYPSHW_WB_100013	Building No. 426 (833026 ,816513)	7.38E-09	2
	General Utilities	7.38E-09	1
UNVKET_UP_98128	Building No. 143 (831362 ,815859)	7.38E-09	2
UNVKET_UP_98126	Building No. 143 (831362 ,815859)	1.48E-09	2
SYPSHW_EB_100000	General Utilities	7.38E-09	1
SYPSHW_EB_100010	Building No. 427 (833013 ,816537)	7.38E-09	1
SYPSHW_EB_100020	Building No. 427 (833013 ,816537)	7.38E-09	1
	Building No. 426 (833026 ,816513)		2
	General Utilities		1
	General Utilities		1
UNVADIT_const_0	Elevated Road	7.38E-09	2
UNVADIT_const_10	Elevated Road	7.38E-09	2
UNVADIT_const_20	Elevated Road	7.38E-09	2
UNVADIT_const_30	Elevated Road	7.38E-09	2
UNVADIT_EnB2_10	Elevated Road	7.38E-09	2
UNVADIT_EnB2_20	Elevated Road	7.38E-09	2
UNVADIT_EnC2_150	Building No. 131 (831833 ,816190)	7.38E-09	7

Scenario/ Chainage	Features Affected	Scenario Frequency (yr)(1)	Expected Fatality (N)(2,3)
UNVADIT_EnC2_160	Building No. 131 (831833 ,816190)	7.38E-09	7
6MIC detonated at the same time			
SYPSHW_WB_100023	Building No. 426 (833026 ,816513)	7.38E-09	2
	General Utilities		1
SYPSHW_WB_100013	Building (833013 ,816537)	7.38E-09	1
	Building No. 426 (833026 ,816513)		2
	General Utilities		1
SYPSHW_WB_100003	Building No. 426 (833026 ,816513)	7.38E-09	2
	General Utilities		1
UNVKET_UP_98128	Building No. 143 (831362 ,815859)	7.38E-09	2
UNVKET_UP_98126	Building No. 143 (831362 ,815859)	1.48E-09	2
SYPSHW_EB_100000	Building No. 427 (833013 ,816537)	7.38E-09	1
	General Utilities		1
SYPSHW_EB_100010	Building No. 427 (833013 ,816537)	7.38E-09	1
	Building No. 426 (833026 ,816513)		2
	General Utilities		1
SYPSHW_EB_100020	Building No. 427 (833013 ,816537)	7.38E-09	1
	Building No. 426 (833026 ,816513)	7.38E-09	2
	General Utilities	7.38E-09	1
UNVKET_DOW_98131	Building No. 143 (831362 ,815859)	4.43E-09	2
UNVADIT_const_0	Elevated Road	7.38E-09	2
UNVADIT_const_10	Elevated Road	7.38E-09	2
UNVADIT_const_20	Elevated Road	7.38E-09	2
UNVADIT_const_20	Building No. 103 (832047 ,816283)	7.38E-09	3
UNVADIT_const_30	Elevated Road	7.38E-09	2
UNVADIT_EnB2_10	Elevated Road	7.38E-09	2
UNVADIT_EnB2_10	Elevated Road	7.38E-09	2
UNVADIT_EnB2_20	Elevated Road	7.38E-09	2
UNVADIT_EnB2_30	Elevated Road	7.38E-09	2
UNVADIT_EnC2_150	Building No. 131 (831833 ,816190)	7.38E-09	7
UNVADIT_EnC2_160	Building No. 131 (831833 ,816190)	7.38E-09	7

Note:

(1) This value is obtained from *Table 6.5*. For the concern section which is less than 10 m, the frequency will be adjusted accordingly

(2) Expected fatality = Population x Fatality rate

(3) 1% fatality threshold reached

Ground Vibration Effect on Slopes due to Errors in Blasting Face

Three slopes 11SW-A/C370, 11SW-A/C110011SW-A/R940 has been screened out for further assessment, based on the screening criteria of the 90 mm/s.

The similar approach described in *Section 7.3.1* was applied for assessing these three slopes, the results of the analysis were summarized as *Table 7.13* and *Table 7.14*.

Table 7.13 Analysis of Slopes Exceeding Peak Particle Velocity of 90 mm/s due to Accidental Initiation during the Construction of Tunnels and Adits

Mapsheet	**Type[1]**	**No.**	**Static F.O.S**	**Slope length (m) [2]**	**Slope depth (m) [3]**	**Slope Material**	**PPVc (mm/s)**	**Slip Volume (m3) [4]**	**PPV correspond to 90% slope failure (mm/s)**	**PPV correspond to 50% slope failure (mm/s)**	**PPV correspond to 10% slope failure (mm/s)**	**PPV correspond to 0.01% slope failure (mm/s)**
11SW-A	C	370	1.4	30	4.5	Soil	82	2120	- [5]	- [5]	- [5]	330
11SW-A	C	1100	1.394	32.5	3	Soil & Rock	51.1	1660	- [5]	- [5]	340	240
11SW-A	R	940	1.493	10	3.5	-	29.8	185	- [5]	370	250	170

Note:

(1) C-Cut Slope, F-Fill Slope, CR/FR – Slope & Retaining Wall, R-Retaining Wall

(2) Slope length along its own slope

(3) Slope depth measured as a perpendicular distance below the slope surface

(4) It is assumed that the slope failure width is equal to the length and that the volume = π*length^2*depth/6.

(5) PPV >400mm/s which is unachievable based on the assessment

Table 7.14 Slopes Exceeding Peak Particle Velocity of 90 mm/s due to Accidental Initiation during the Construction of Tunnels and Adits

Scenario/ Chainage	Features Affected	Scenario Frequency (yr)(4)	Expected Fatality (N)(5)	Remarks
4MIC Detonated at the same time				
UNVKET_DOW_98147	11SW-A/C370	7.38E-09	-	(1)
UNVADIT_EnC2_50	11SW-A/C1100	7.38E-09	-	(2)
5MIC Detonated at the same time				
UNVKET_UP_98148	11SW-A/C370	7.38E-09	-	(1)
UNVKET_UP_98138	11SW-A/C370	7.38E-09	-	(1)
UNVKET_UP_98128	11SW-A/C370	7.38E-09	-	(1)
UNVKET_UP_98126	11SW-A/C370	1.48E-09	-	(1)
UNVKET_DOW_98157	11SW-A/C370	7.38E-09	-	(1)
UNVKET_DOW_98147	11SW-A/C370	7.38E-09	-	(1)
UNVKET_DOW_98137	11SW-A/C370	7.38E-09	-	(1)
UNVKET_DOW_98131	11SW-A/C370	4.43E-09	-	(1)
UNVADIT_EnC2_40	11SW-A/C1100	7.38E-09	-	(2)
UNVADIT_EnC2_50	11SW-A/C1100	7.38E-09	-	(2)
UNVADIT_const_30	11SW-A/R940	7.38E-09	-	(3)
6MIC Detonated at the same time				
UNVKET_UP_98148	11SW-A/C370	7.38E-09	-	(1)
UNVKET_UP_98138	11SW-A/C370	7.38E-09	-	(1)
UNVKET_UP_98128	11SW-A/C370	7.38E-09	-	(1)
UNVKET_UP_98126	11SW-A/C370	1.48E-09	-	(1)
UNVKET_DOW_98157	11SW-A/C370	7.38E-09	-	(1)
UNVKET_DOW_98147	11SW-A/C370	7.38E-09	-	(1)
UNVKET_DOW_98137	11SW-A/C370	7.38E-09	-	(1)
UNVKET_DOW_98131	11SW-A/C370	4.43E-09	-	(1)
UNVADIT_EnC2_40	11SW-A/C1100	7.38E-09	-	(2)
UNVADIT_EnC2_50	11SW-A/C1100	7.38E-09	-	(2)
UNVADIT_EnC2_60	11SW-A/C1100	7.38E-09	-	(2)
UNVADIT_const_30	11SW-A/R940	7.38E-09	-	(3)
UNVADIT_const_40	11SW-A/R940	7.38E-09	-	(3)

Note:

(1) Although 90mm/s threshold reached, no fatality expected since the observed vibration level is well below actual 0.01% slope failing threshold 330mm/s

(2) Although 90mm/s threshold reached, no fatality expected since the observed vibration level is well below actual 0.01% slope failing threshold 240mm/s

(3) Although 90mm/s threshold reached, no fatality expected since the observed vibration level is well below actual 0.01% slope failing threshold 170mm/s

(4) This value is obtained from *Table 6.5*. For the concern section which is less than 10 m, the frequency will be adjusted accordingly

(5) Expected fatality = Population x Fatality rate

Ground Vibration Effect due to Detonation of Full Load during Transferring Explosives within Tunnel

For the accidental detonation of full load, 125 kg, of explosives within the tunnel whilst transferring explosives to the appropriate blast site, neither buildings will be experienced a PPV of 100 mm/s (threshold of 1% fatality), nor slopes will be susceptible to a PPV of 90 mm/s (screening criteria).

Air Overpressure Effect due to Detonation of Full Load during Transferring Explosives within Tunnel

Air overpressure effect due to detonation of full load during transferring explosives within tunnel are summarised in *Table 7.15*.

Table 7.15 Summary of Air Overpressure Effects associated with Transport of Explosives within Tunnel

				Indoor		***Outdoor***	
Scenario	**Description**	**TNT eqv. (kg)**	**Freq. (/yr)**	**Harm Prob.**	**Impact distance (m)**	**Harm Prob.**	**Impact distance (m)**
S01	Initiation of explosives at delivery point 01	77	6.04E-08	90%	13	90%	11
				50%	15	50%	11
				1%	36	1%	14
S02	Initiation of explosives at delivery point 02	77	6.04E-08	90%	13	90%	11
				50%	15	50%	11
				1%	36	1%	14
S03	Initiation of explosives at delivery point 03	120	1.21E-07	90%	15	90%	12
				50%	18	50%	13
				1%	42	1%	16
S04	Initiation of explosives at delivery point 04	77	6.04E-08	90%	13	90%	11
				50%	15	50%	11
				1%	36	1%	14
S07	Initiation of explosives at delivery point 07	77	6.04E-08	90%	13	90%	11
				50%	15	50%	11
				1%	36	1%	14

8 RISK SUMMATION

8.1 OVERVIEW

Risk summation combines the estimates of the consequences of an event with the event probabilities to give an estimate of the resulting frequency of varying levels of fatalities. The Consultants in-house software RISKPLOT™ has been used for risk summation.

RISKPLOT™ calculates the number of fatalities from each event with a given probability of occurrence. The number of fatalities are based upon the proportion of each population area overlapped by the hazard effect, taking into account protection factors. Unlike the grid system, which assumes all occupants of a given grid sector suffer the same degree of impact, RISKPLOT™ assumes only that proportion of the population with a polygonal area equivalent to that covered by the hazard effect are affected, with an accuracy level to the nearest metre. Hence, the modelling exercise is as realistic as reasonably possible.

8.2 RISK MEASURES

The two types of risk measures considered are societal and individual risks.

8.2.1 Societal Risk

Societal risk is defined as the risk to a group of people due to all hazards arising from a hazardous installation or activity. The simplest measure of societal risk is the Rate of Death or Potential Loss of Life (PLL), which represents the predicted equivalent fatalities per year.

The frequency (f) and fatalities (N) associated with each outcome event are derived as described in earlier sections. Based on this, the Potential Loss of Life is calculated as follows:

$PLL = f_1N_1 + f_2N_2 + f_3N_3 + + f_nN_n$

Societal risk can also be expressed in the form of an F-N curve, which represents the cumulative frequency (F) of all event outcomes leading to N or more fatalities. This representation of societal risk highlights the potential for accidents involving large numbers of fatalities.

8.2.2 Individual Risk

Individual risk may be defined as the frequency of fatality per individual per year due to the realisation of specified hazards. Individual Risk may be derived for a hypothetical individual present at a location 100% of time or a named individual considering the probability of his presence etc. (the latter case is known as Personal Individual Risk).

8.3 SOCIETAL RISK

8.3.1 *Potential Loss of Life*

Table 8.1 below shows the overall Potential Loss of Life (PLL) values for the transport of explosives to the blasting sites.

Table 8.1 Potential Loss of Life Value for WIL Project

Case	PLL (Per year)	Percentage Contribution (%)
Storage of Explosives		
Proposed magazine, , including transport within the adits	9.04E-08	0.26%
Transport of Explosives		
Delivery of explosives from magazine to delivery point 1	1.26E-06	3.66%
Delivery of explosives from magazine to delivery point 2	1.68E-06	4.89%
Delivery of explosives from magazine to delivery point 3	9.39E-06	27.29%
Delivery of explosives from magazine to delivery point 4	6.04E-06	17.57%
Delivery of explosives from magazine to delivery point 7	8.80E-06	25.57%
Use of Explosives		
Construction of magazine	1.13E-08	0.03%
Construction of WIL alignment	1.26E-06	3.67%
Detonation of explosives within the tunnel whilst transferring explosives to the blast site at delivery point 1	8.99E-08	0.26%
Detonation of explosives within the tunnel whilst transferring explosives to the blast site at delivery point 2	1.74E-07	0.51%
Detonation of explosives within the tunnel whilst transferring explosives to the blast site at delivery point 3	1.82E-06	5.29%
Detonation of explosives within the tunnel whilst transferring explosives to the blast site at delivery point 4	3.35E-06	9.73%
Detonation of explosives within the tunnel whilst transferring explosives to the blast site at delivery point 7	4.28E-07	1.25%
Total	3.44E-05	100.00%

8.3.2 *F-N Curves*

The WIL project will last for about 2 to 3 years. The risks during the project have been estimated based on the following:

a) for transport, the total number of deliveries by truck in one year has been considered. The deliveries were calculated based on maximum daily peak which is conservative. Since risks are expressed on an annualised basis, deliveries for one year period have been considered.

b) storage has been considered at full storage capacity 100% of the time in a year. There may be variations in storage levels but this has been ignored. The storage requirements may also vary depending on the amount of cartridged explosives used but it has been used that the entire blasting will be based on the use of cartridged explosives instead of a higher mix of bulk emulsion.

c) risks from use have been estimated considering that all blasting activities will occur in one year period. Since only some buildings and some sections along the alignment are affected by greater than 100mm/s PPV, and given the likelihood that the work on these sections may be completed in a one year time span, this assumption may be reasonable.

Figure 8.1 shows the overall risk due to transport, storage and use of explosives. During phase 1 of the construction, there is an option to deliver explosives to point 7 at AM or PM time, whereas deliveries to other points will be as per the timing indicated (see *Table 2.4*). The FN curve has been presented for delivery to point 7 am and pm case separately and it includes delivery to other points, storage and use as well.

Figure 8.2 and *Figure 8.3* show the contribution of transport, storage and use of explosives to the overall risk individually. The FN curve for transport has been presented for delivery to pt 7 am and pm case separately and it includes delivery to other points as well. The FN curve for use of explosives covers construction of the WIL alignment and the magazine store.

The assessed risks to public due to construction of WIL, as shown in *Figure 8.1, Figure 8.2 and Figure 8.3* are within acceptable region of the HKRG for societal risk.

It can be seen that transport risk dominates the WIL Project. The reason for the societal risk lying close to the ALARP at low N range is the risk to the on-road population, ie people within vehicles in the immediate vicinity of the incident.

Figure 8.1 F-N Curve - Storage, Use and Transport of Explosives from Magazine to Point 1, 2, 3, 4 & 7

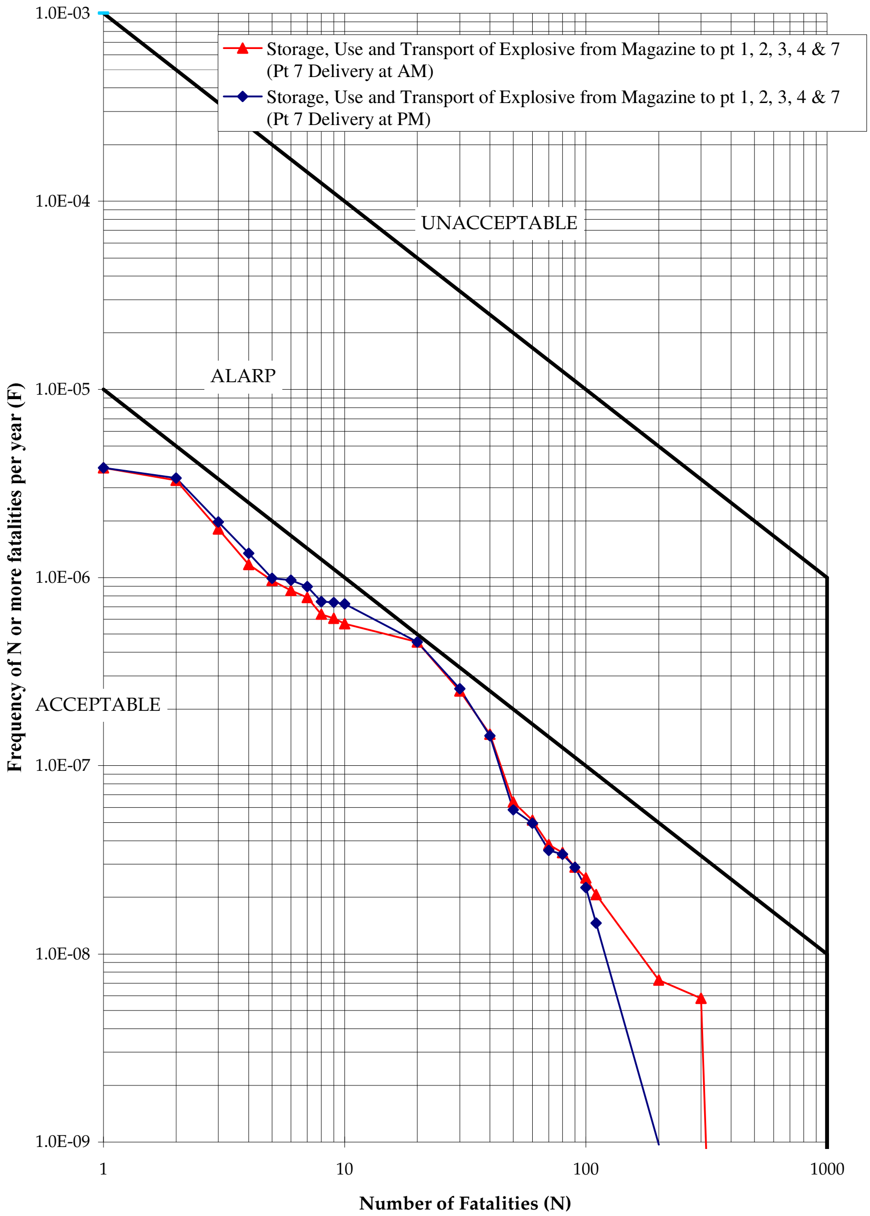


Figure 8.2 F-N Curve - Storage, Use and Transport of Explosives from Magazine to Point 1, 2, 3, 4 & 7 (Point 7 delivery at PM)

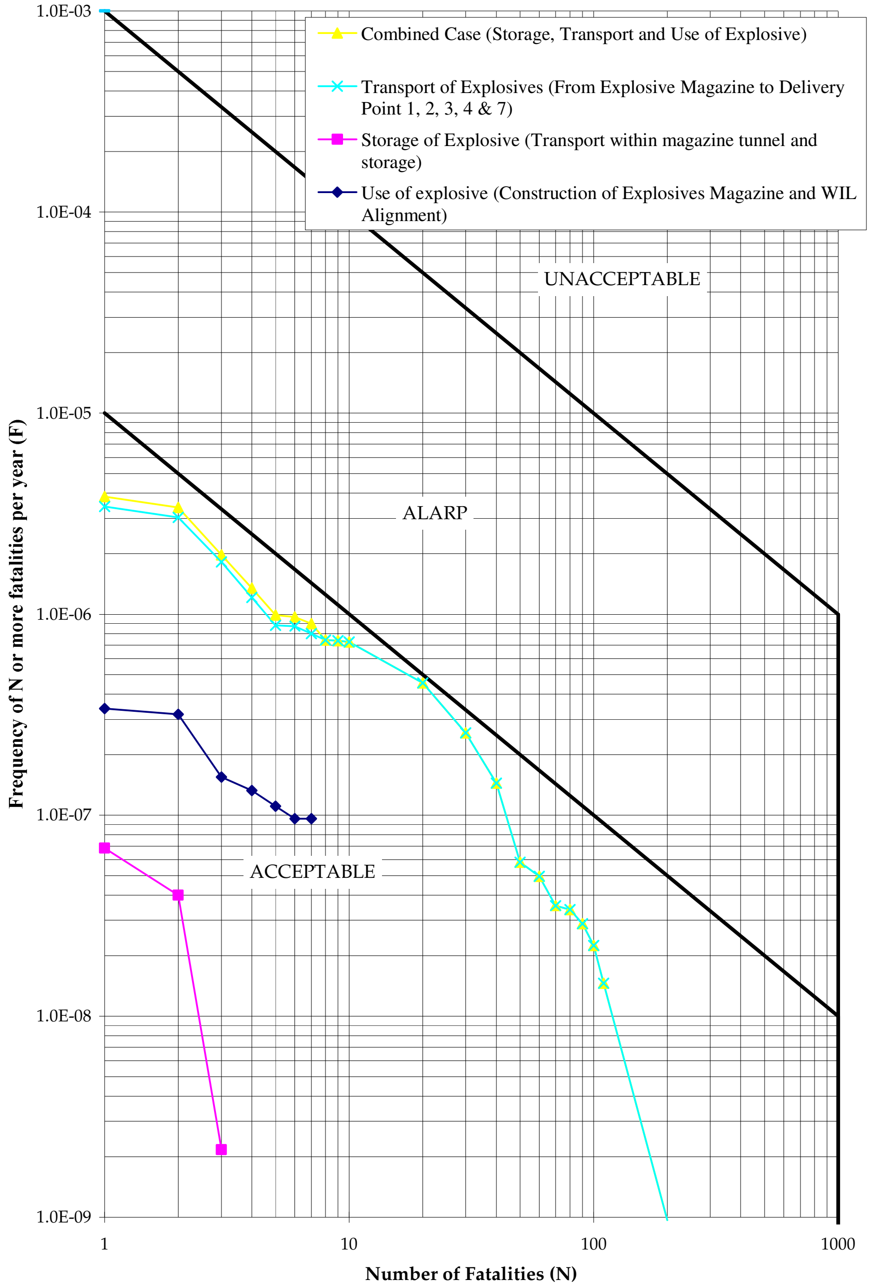
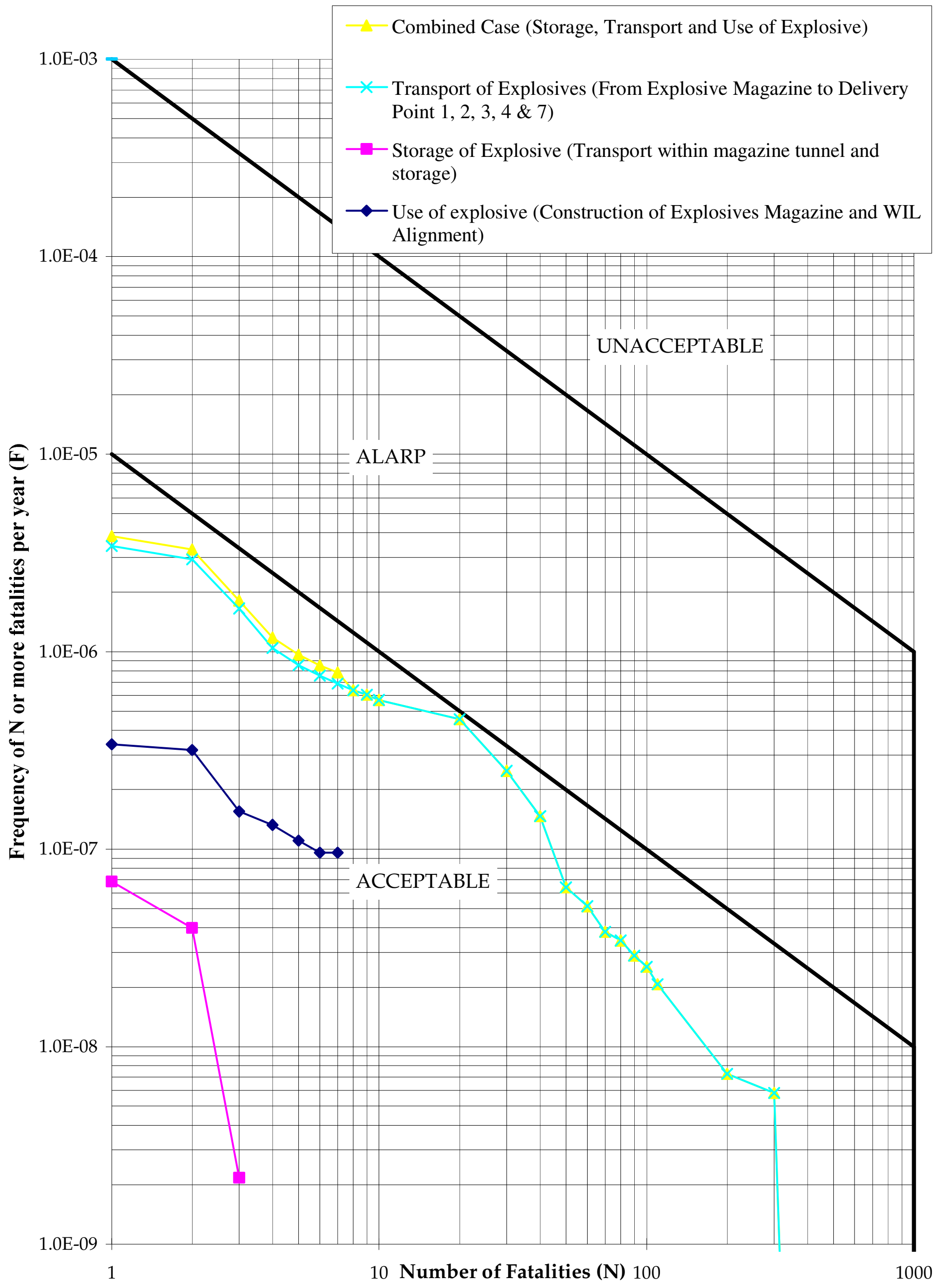


Figure 8.3 F-N Curve - Storage, Use and Transport of Explosives from Magazine to Point 1, 2, 3, 4 & 7 (Point 7 delivery at AM)



8.4 *INDIVIDUAL RISK*

The assessed individual risks for transport and use of explosives were expressed in terms of outdoor exposure and indoor exposure. The results are shown in *Figure 8.4, Figure 8.5, Figure 8.6* and *Figure 8.7*. In these figures, 'indoor' refers to the population located inside buildings, and 'outdoor' refers to the population located outside buildings ie in open area.

The IR contours for 'indoor' and 'outdoor' have been presented separately as the fatality probability is different for indoor and outdoor population. The current version of the Riskplot model enables to present indoor and outdoor fatality iso-risk contours separately. This approach is more rigorous than the equivalent fatality model since the effect distances for indoor and outdoor fatality could be quite different.

For the delivery routes, it is observed that no section of routes has an IR exceeding 5×10^{-8} per year. The highest risk contour of 1×10^{-7} contour (in red colour on *Figure 8.4,* and *Figure 8.5*) represents the scenario of detonation of a full load of explosives within the tunnel whilst transferring explosives to the blast site. Although this scenario is part of 'use', it has been drawn in the figure as it affects the same location.

The IR contour for magazine is a 2 dimensional representation and hence does not account for relative elevation of the magazine with respect to the receivers. Hence risk to the user on Victoria Road is slightly conservative. Moreover, a presence factor of 10% should be applied to calculate the individual risk from the magazine to account for the time of the most exposed individual to the risks from the explosives storage. The most exposed population are Victoria road users which are considered as mobile population. There is no permanent population in the vicinity. For the most exposed pedestrian walking along Victoria road, based on a conservative walking speed of 1km/hr for a 300m section of Victoria road near the magazine 4 times a day, the presence factor was calculated as 5%. Similarly, for a vehicle travelling at 30km/hr passing by the section of the road 20 times a day, the presence factor was around 4% (this includes an idle time of 2min per trip). Therefore, considering a 10% presence factor, the individual risk from magazine is acceptable.

For rock excavation using explosives, features at risk due to ground vibration were identified and the maximum risk of fatality to any individual is estimated as 4.428×10^{-10} per year (See *Table 8.2*). This is much lower than the Individual Risk Criteria of 1×10^{-5} per year.

Table 8.2 Individual Risk for Ground Vibration generated by Rock Excavation Using Explosives

Features	**Total Impact Frequency (/yr)**	**Harm Probability**	**Individual Risk (per year)**
Building No. 426 (833026 ,816513)	4.43E-08	0.01	4.43E-10
Building No.427 (833013 ,816537)	4.43E-08	0.01	4.43E-10
Building No. 103 (832047 ,816283)	7.38E-09	0.01	7.38E-11
Building No.143 (831362 ,815859)	2.22E-08	0.01	2.22E-10
Building No. 131 (831833 ,816190)	3.69E-08	0.01	3.69E-10

Figure 8.4   IR of Delivery Route for Indoor Population

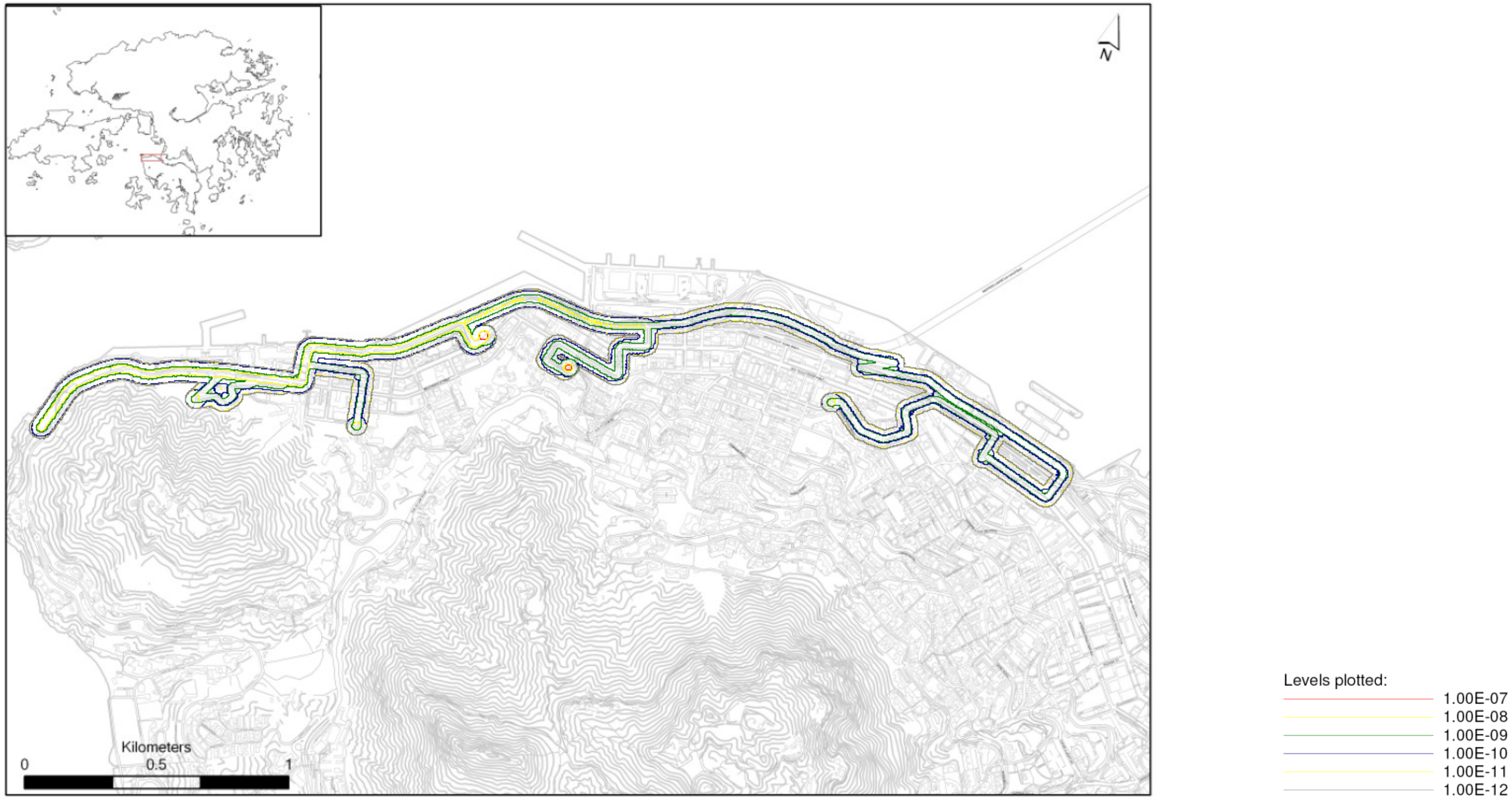


Figure 8.5 IR of Delivery Route for Outdoor Population

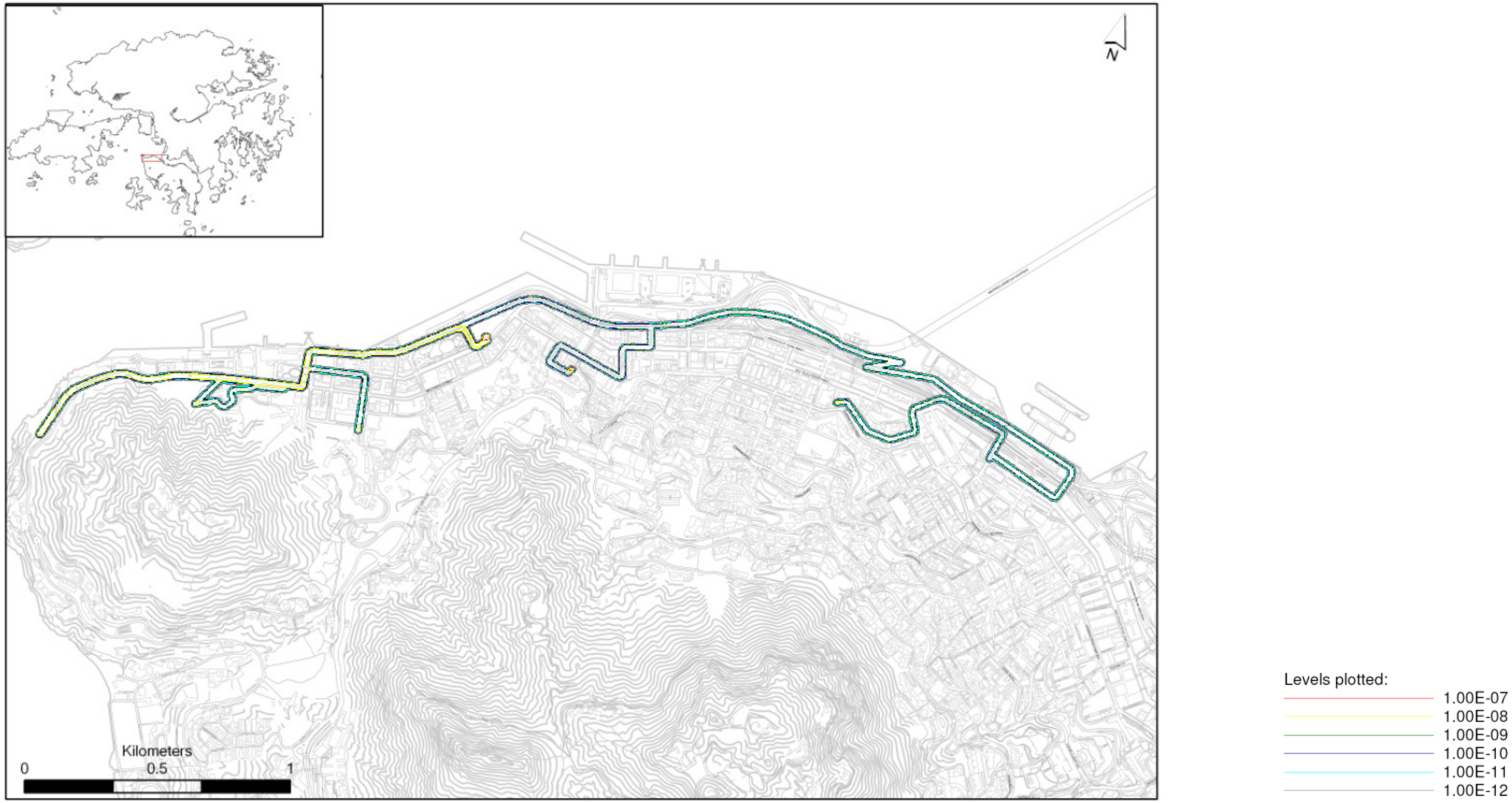


Figure 8.6 IR of the Proposed Magazine for Indoor Population

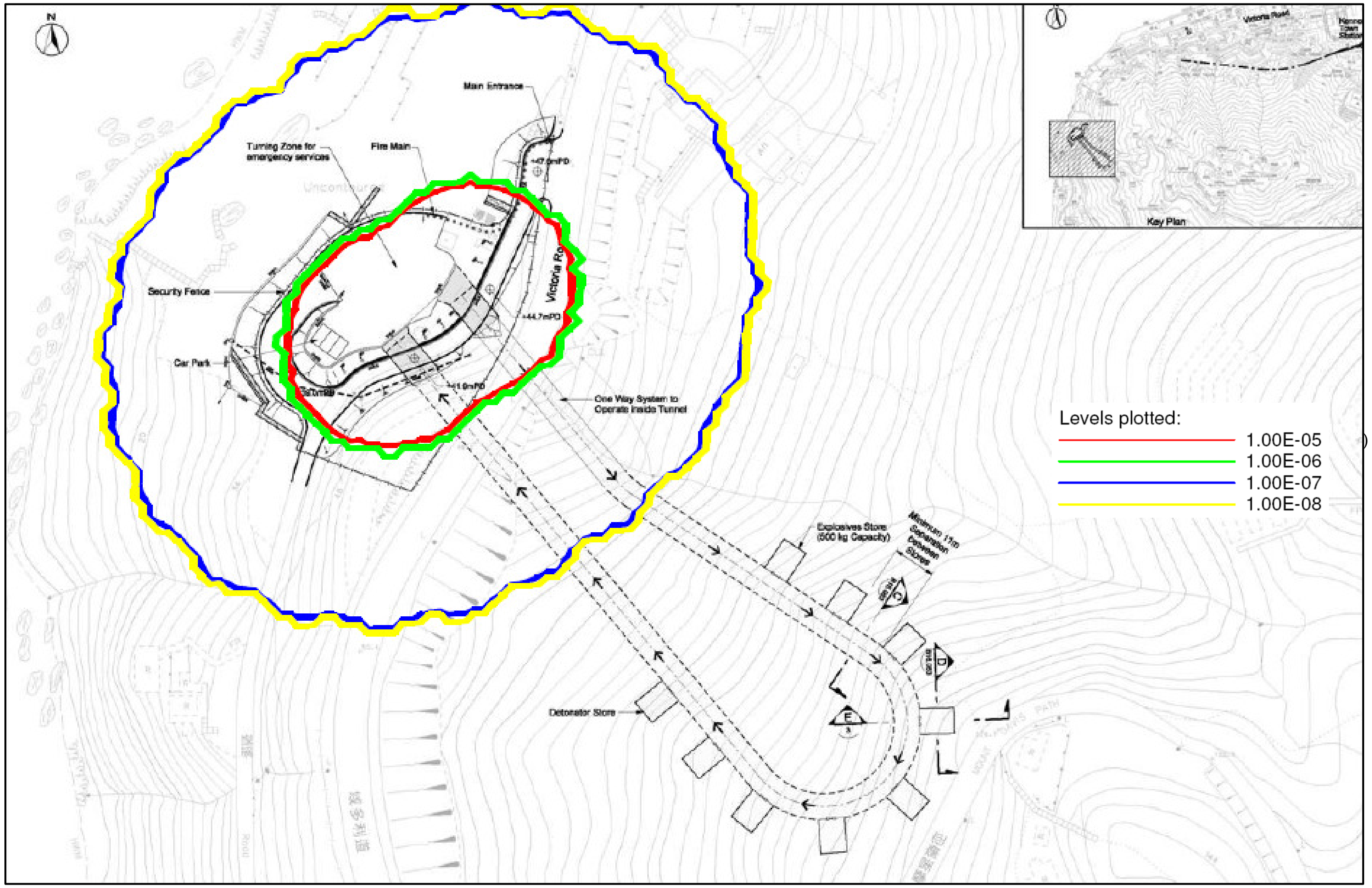
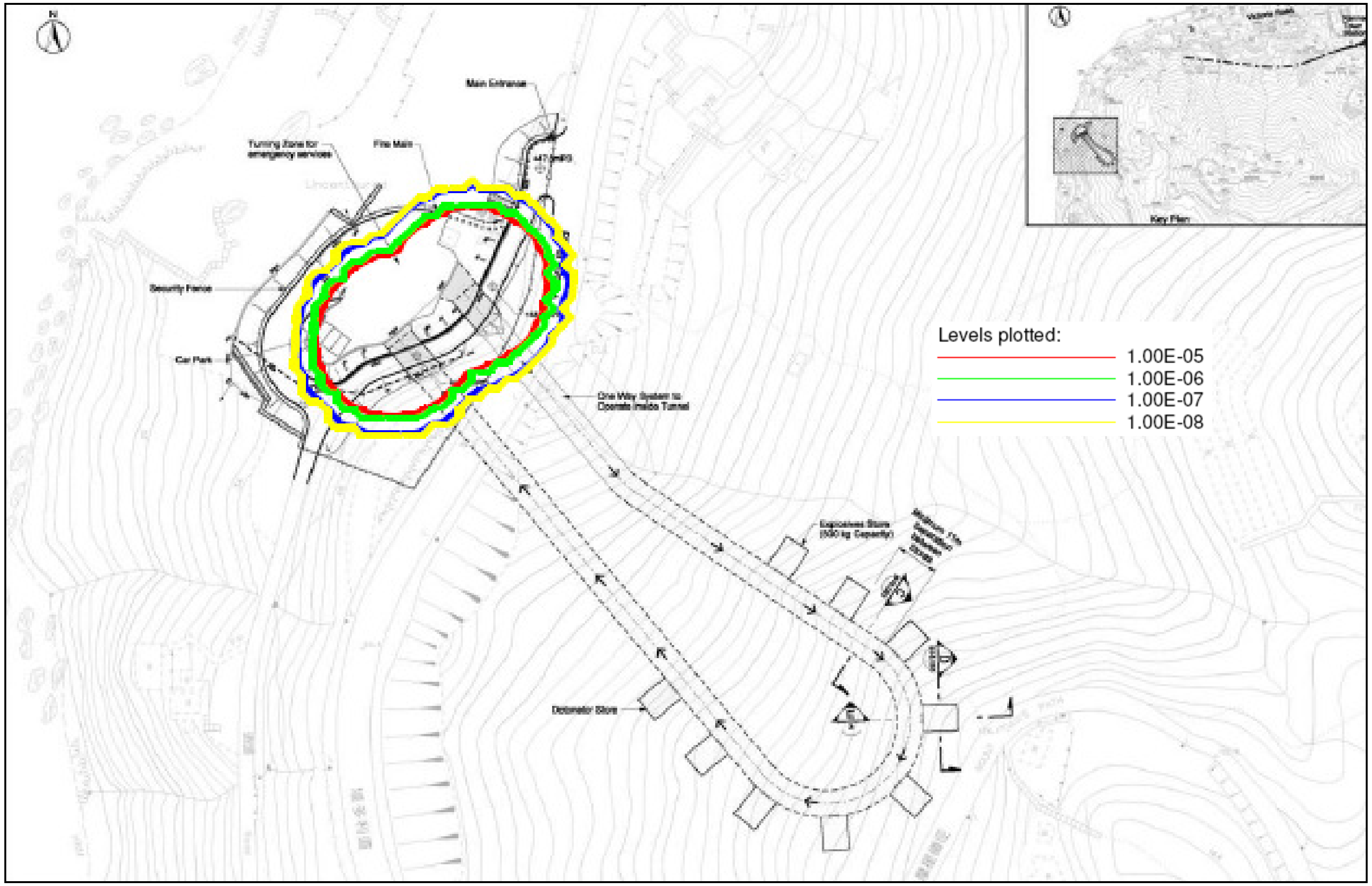


Figure 8.7 IR of the Proposed Magazine for Outdoor Population



8.5 *OPTION ANALYSIS*

As per the latest explosives consumption program (as of this study) for WIL / magazine construction activities, the access shaft at Site at Kennedy Town Praya (point 3) will have the highest consumption rate of 250kg explosives per AM or PM. Although the current explosives delivery plan indicates that it will be done in 2 trips of 125kg loaded truck per AM/PM (base case of this QRA), the possibility of using a higher load of 250kg per truck has also been explored in this QRA as an optimized case.

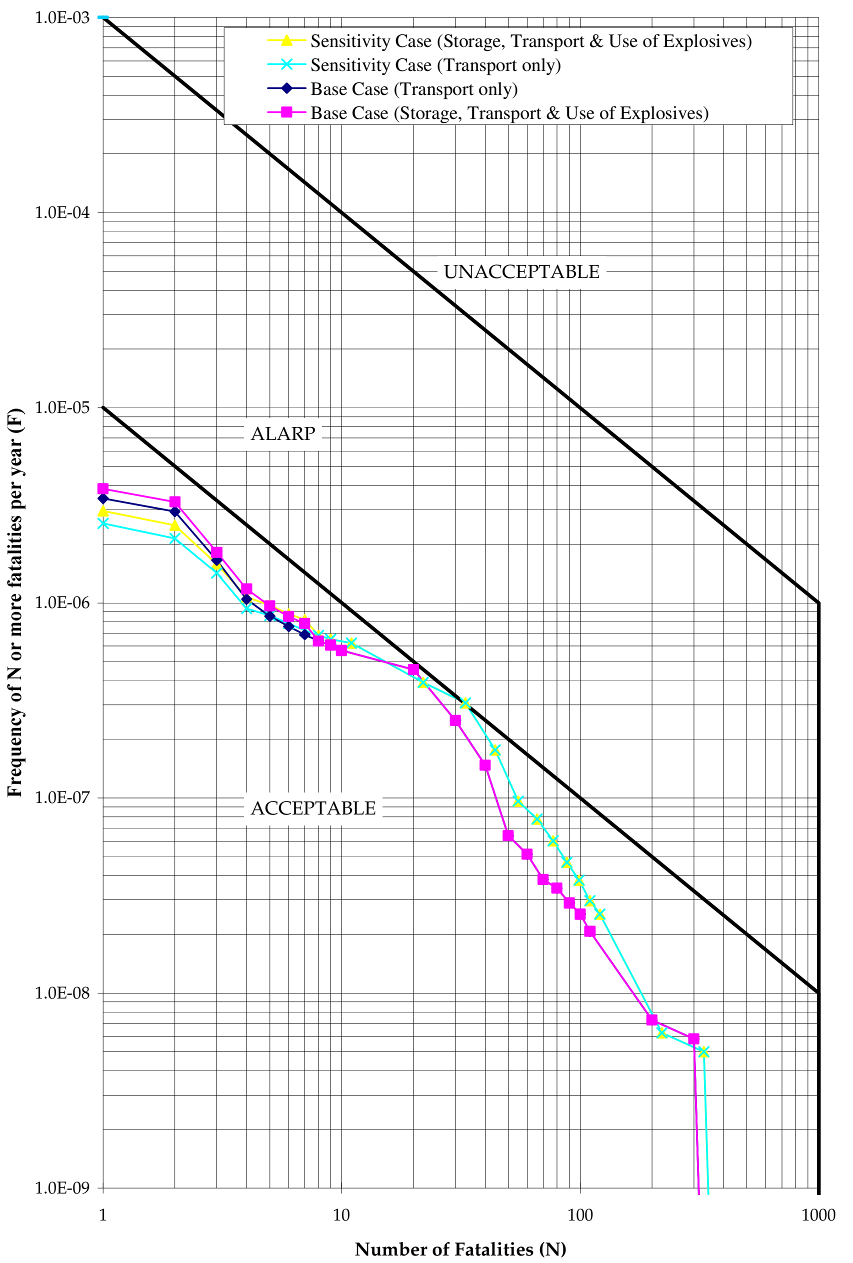
The same input as the base case has been used for the optimized case except for delivery point 3:

- Consequence distances of 90%, 50% and 1% fatality zone are 19, 22 and 55m respectively for indoor population and 15, 16 and 20m respectively for outdoor population calculated by ESTC model based on 250kg explosives.

- Explosive delivery to point 3 reduced from 4 trips per day to 2 trips per day for 6 days a week.

Figure 8.1 shows that the societal risk of the optimized case. It can be seen that the societal risk for the optimized case is higher than the base case in the high fatality region of the curve due to the larger impact zone from the 250kg load of explosives. The FN curve for the optimized case is close to the ALARP region.

Figure 8.1 F-N Curve (Sensitivity Case)



8.6 *UNCERTAINTY ANALYSIS AND SENSITIVITY TESTS*

The study is based on a number of assumptions as previously highlighted in various sections of this report.

A discussion on the uncertainties and sensitivity of the results is given below.

8.6.1 *Transport of Explosives*

Explosion Consequence Model

The employed ESTC model, or any other established TNT explosion model, tends to overpredict the number of fatalities (or, probability of fatality for an individual) when compared to the actual fatalities in past incidents related to explosives (See *Annex C*). It can be seen that no recorded incident involving road transport had resulted in more than 12 fatalities even in urban location, while from the assessment, the maximum fatalities due to road transport is estimated as about 100. There is some conservatism in the model although it is acknowledged that given the dense urban environment in Hong Kong, the fatalities estimated during transport of explosives may not be too conservative.

Escape and Evacuation

In certain circumstance it may be possible for people to escape from the scene of an accident before the occurrence of an explosion event. This is particularly true in the case of a fire accident, for example fire on a truck in which explosives cargo is not initially involved but is only affected after a period of gradual escalation. However, for the purpose of this study, no credit was given for people to escape as a conservative assumption.

Accident Frequency for Underground Tunnel Transport

Initiation of explosives during transport includes initiation due to crash fire, non-crash fire and crash impact. It is should be noted that the crash frequency used for road transport was derived based on data on public roads, and the same has been applied for transport within the underground access tunnel, ie access tunnel to the storage magazine and the blast face. The crash frequency for transport within the tunnel is however, expected to be much lower due to speed restrictions inside the tunnel and the absence of other vehicle movements.

Actual Consumption of Explosives

The WIL construction is likely to use significant quantity of bulk emulsion instead of cartridge explosives. However, for the risk calculations, only cartridge explosives have been considered to assess the maximum risks during transport. The maximum peak daily consumption rate of cartridged explosives during the project has been applied for all days in a year (to estimate the annual risks from transport). The total quantity of cartridged explosives that will be used based on this assumption is approximately equal to the total explosives required for the WIL construction, while in reality, the amount of cartridged explosives that will be used is expected to be between 25 to 50%, with the remaining being made up by bulk emulsion. Note that bulk emulsion is not considered hazardous until it gets sensitized at the blast face, ie posing negligible risks during road transport. Therefore, the risk estimated by this study should be regarded as upper bound and the actual risks will be lower.

8.6.2 Use of Explosives

Ground Vibration Model

In the study, it has been assumed that when more than one blasthole charge is detonated at the same time, the vibration effect will be equivalent to the summation of all charge weight detonated at the same (ie. the effect will be additive). However, due to delay scatter within the realms of manufacturing tolerance, direct summation of charge weight would lead to significant overestimation of the predicted vibration. Based on experience, this could lead to an over-prediction of 30% for long time delay detonator and 70% for short time delay detonator. However, the consequence assessment has considered the effects to be additive which is conservative.

Impact on Buildings and other Features due to Ground Vibration

It has been conservatively assumed that any building subject to vibration of more than 100mm/s PPV will experience some damage to non-structural elements such as brick walls or lead to objects falling off the building including advertisement signboards, any unauthorised features etc leading to a fatality. A fatality level of about 1% of the total population inside the building has been assumed. The maximum PPV affecting any building due to six MIC charge weight is about 110 to 140mm/s. This assumption of 1% fatality level for vibration effects of more than 100mm/s PPV is also expected to account for any impacts on other minor features along the tunnel alignment including advertising sign, scaffolding etc.

During the analysis, it was noted that the PPV levels for the majority of buildings and slopes along the alignment are much less than 100mm/s (only about 5 to 10 buildings/ slopes are subject to more than 100mm/s as against the more than 1000 buildings and slopes along the WIL alignment, identified in the Blast Assessment Report). This was because the design charge weight (MIC) determined for blasting along the route was governed by other sensitive features, example, historical buildings have a limit of 5 mm/s, some cables have a limit of 13 mm/s etc. These limits are lower than 25mm/s for buildings and hence the design provides some implicit safety margin for the buildings on account of other factors.

Frequency of Blast involving more than one MIC

The frequency of blasts involving more than one MIC has been estimated from failure mode analysis, fault trees, expert judgement and human error analysis. There is not sufficient data to compare with the past underground blasting experience given that the amount of explosives that will be used for the WIL project is approximately equal to the total quantity of explosives that has been used for all tunnel blasting to date in Hong Kong. Also, the WIL project will involve blasting in close proximity to buildings and slopes, more than ever as compared to previous blasting projects in Hong Kong, with the exception of blasting undertaken near Quarry Bay. A broad comparison with data on all of the blasting operations in Hong Kong including surface blasting shows the results estimated by fault tree analysis is reasonable.

The frequency of 5MIC and 6MIN detonation occurring simultaneously has been conservatively assumed to be same as 4 MIC. Hence the FN curve for 'use' does not extend below a frequency of 9E-8 per year. The frequency of more than 6MIC is negligible, ie. below 1E-9 per year.

8.6.3 *Storage of Explosives*

Frequency of Explosion

The frequency of explosion has been assumed as 1×10^{-4} per year based on the data from the UK HSE. Given that it is an underground storage and the level of security is higher. The frequency of explosion due to arson or other causes is expected to be lower than the value assumed.

9 CONCLUSION & RECOMMENDATIONS

9.1 CONCLUSIONS

A QRA has been carried out to assess the hazard to life issues arising from the storage, transport and use of explosives during construction of WIL Project.

Assessment results indicated that the individual and societal risk is within the acceptable limit of the Risk Guidelines specified in EIAO-TM Criteria.

Nevertheless some general recommendations have been made to minimise risks further and in accordance with best practices (see *Section 9.2*).

9.2 RECOMMENDATIONS

9.2.1 *General Recommendations*

Blasting activities regarding storage, use and transport of explosives should be supervised and audited by competent site staff to ensure strict compliance with the blasting permit conditions.

The following general recommendation should also be considered for the use, storage and transport of explosives:

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

2. Emergency plan shall be developed to address uncontrolled fire in magazine area and tunnel. The case of fire near to truck in jammed traffic should also be covered. Drill of the emergency plan should be carried out at regular intervals.

3. Adverse weather working guideline should be developed to clearly define procedure for transport and use of explosives during thunderstorm.

4. Contingency plans for misfires and delayed blasts should be developed and form part of the Method Statement.

Specific recommendations for each of use, transport or storage of explosives are given below.

9.2.2 *Storage of Explosives in Magazine Store*

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

1. Only one contractor's vehicle should be allowed within the magazine at any one time.

2. A speed limit within the magazine access tunnels should be enforced to reduce the risk of a vehicle impact or incident within the magazine.

3. A suitable work control system should be introduced, such as a Permit-to-Work system, to ensure that work activities undertaken during the operation of the magazine are properly controlled.

4. There should be good house-keeping within the magazine to ensure that combustible materials are not allowed to accumulate.

5. The magazine shall be without open drains, traps, pits or pockets into which any molten ammonium nitrate could flow and be confined in the event of a fire.

6. The magazine shall be regularly checked for water seepage through the roof, walls or floor.

7. Caked explosives shall be disposed of in an appropriate manner.

8. Delivery vehicles shall not be permitted to remain unattended within the magazine. In addition they shall not be allowed to park overnight or when not required within the magazine or its adits.

9.2.3 Transport of Explosives

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

1. Detonators shall not be transported in the same vehicle with other Class 1 explosives. Separation of vehicles should be maintained during the whole trip.

2. Location for stopping and unloading from truck to be provided as close as possible to shaft, free from dropped loads, hot work, etc. during time of unloading.

3. Develop procedure to ensure that parking space on the site is available for the explosive truck. Confirmation of parking space should be communicated to truck driver before delivery. If parking space on site could not be secure, delivery should not commence.

4. During transport of the explosives within the tunnel, hot work or other activities should not be permitted

5. Ensure lining is provided within the transportation box on the vehicle and in good condition before transportation.

6. Ensure that UN 1.4B packaging of detonators remains intact until handed over at blasting site.

7. Emergency plan to include activation of fuel isolation switch on vehicle when fire breaks out to prevent fire spreading and reducing likelihood of prolonged fire leading to explosion,.

8. Use only experienced driver(s) with good safety record for explosive vehicle(s).

9. Ensure that cartridged emulsion packages are damage free before and after every trip.

9.2.4 Use of Explosives

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

1. Blast charge weight (MIC) should be limited to a maximum of 5kg per delay for each blast.

2. Temporary mitigation measures such as blast doors or heavy duty blast curtains should be installed at the access adits, shafts and at suitable locations underground to prevent flyrock and control the air overpressure.

3. Blasting from multiple faces as well as different locations will be carried out for this project. Good communication and control will need to be adopted in ensuring that the works are carried out safely.

4. It is intended that complete evacuation of the underground tunnels need not be carried out and secure refuge areas should be identified workers in the area.

5. A Chief Shotfirer and a Blasting Coordinator shall be employed in addition to the normal blasting personnel to ensure that the works are coordinated between blasting areas and between adjacent contracts.

6. Shotfirer to be provided with a lightning detector, and appropriate control measures should be in place.

7. Speed limit for the diesel vehicle truck and bulk emulsion truck in the tunnel should be enforced. The truck may be escorted while underground to ensure route is clear from hazards and obstructions.

8. Hot work should be suspended during passage of the diesel vehicle truck and bulk emulsion truck in tunnel.

9. Prior to construction of the magazine, a survey of boulders should be undertaken based on the likely PPV values that would result from the initiation of the entire quantity stored in a magazine niche. Boulders identified within this limit should be numbered and assessed, if required they should either be strengthened or removed. The remaining boulders

identified should then be monitored during the blasting of the magazine adits and chambers.

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Annex A

Blasting Process

CONTENTS

A1 OVERVIEW OF BLASTING PROCESS

A1.1 BLASTING FUNCTION

The objective of underground blasting is to excavate a void by fragmenting and ejecting rock. The size of the fragmentation is an important factor and impacts on efficient removal of the blasted material, the smaller the rock fragments, the faster the material can be handled by excavation equipment and the faster it can be removed enabling the drill and blast cycle to progress.

To blast rock a pre-determined quantity of explosives are placed in holes which have been drilled on a pre-determined pattern. The explosives are initiated by either a detonator for cartridged emulsion or a small booster attached to a detonator for bulk emulsion.

The following elements are important functions within the blasting process.

A1.2 SENSITIVE VIBRATION RECEIVERS AND MAXIMUM INSTANTANEOUS CHARGE (MIC)

Each and every blast is directly influenced by a controlling sensitive receiver which can be a building, slope or utilities. This controlling sensitive receiver will have a pre-determined maximum allowable critical peak particle velocity (PPVc), otherwise known as a maximum allowable ground vibration expressed in mm/second. This maximum PPV value dictates the amount of explosives that can be detonated at once i.e. per delay detonator, and is known as the maximum instantaneous charge (MIC).

A1.3 DETONATION SEQUENCE

The order in which the detonators are initiated is a key component of the blasting process. Blasts are designed so that no two detonators will initiate at the same instant in time resulting in a doubling of the MIC. To achieve this sequential initiation detonators are selected which have different delay periods (eg. 300, 350,400, 450 milliseconds etc).

All underground tunnel/adit blasts start with a 'cut' area which is usually positioned at the centre lower portion of the face to be blasted. This area is characterised by 2 or more large diameter drill holes which are not loaded with explosives. Their purpose of these 'relief' holes is to provide a void area which allows the ejection of the blasted rock, creating a larger void. This provides the space for the rocks from outer sectors of the blast face to collapse into following detonation of the explosives within the production holes.

Detonators of different delays are positioned starting from the ' cut ' area and their delay time increases radially outwards towards the tunnel/adit perimeter allowing the face to be blasted in ring like sections.

In larger tunnels/adits the face is divided into 4 or more sections, with at least two sections having similar delay detonator times. However, the sectors are separated by further 'delays' achieved by the use of bunch blocks (ie 0 ms surface connectors) and time delay surface connectors (ie 9 ms, 17 ms, etc). Other than the delay time, difference between the bunch block and time delay surface connectors is essentially the explosive mass that it contains. A bunch block contains approximately 0.3 grams of high explosive, which is sufficient to set off detonating cord. Whereas a time delay surface delay detonator contains only 0.11 grams of explosives and whilst it is insufficient to initiate detonating cord, it is sufficient to ignite shock tubes.

All the shock tube tails of the down-the-hole detonators within an individual sector are 'bunched' together and secured with at least two strands of 5 gms/m detonating cord. The detonating cord is connected to a bunch block having a 0ms delay (no delay element). This ensures the ignition of the bunched shock tubes that are wrapped by the detonating cord.

The shock tube tail from the bunch block may itself be ignited by a surface connector, which will typically have a delay time of 9ms or 17ms (i.e. 9 or 17ms delay element). In addition, two or more time delay surface connector may be linked in series, with their connected bunch blocks in parallel. This ensures that no two detonations in adjoining sectors will simultaneously fire with detonations across the entire blast face starting at 0ms and continuing at 9, 17, 26, 34 and 43ms dependant on the number of sectors.

A1.4 EXPLOSIVES TYPES AND CHARGING OF BLASTHOLES

Blastholes may be charged (loaded) with the following explosives types:

- Cartridged emulsion explosives (UN Category 1.1D)
- Bulk emulsion explosives (UN Cat egory1.5D)

A1.4.1 Cartridged Emulsion Explosives

Cartridged Emulsion explosives typically contain:

- 80-85% ammonium/sodium nitrate solution (oxidizer)
- 6-8% fuel or mineral oil (fuel)
- 0.7 – 1.0% surfactant (also a fuel)
- 13.3-6.0% water
- The percentage of fuels can be varied if aluminium powder is added; the aluminium being used to raise the explosion temperature.

Cartridged Emulsion explosives are packaged in either plastic film (valeron) or paper wrapped. They have a semi-soft consistency, the softness being controlled by their water content. Cartridged Emulsions have the appearance of slightly yellow viscous cream or silver when aluminium is added to the formulation.

Cartridged Emulsions do not completely fill the blasthole and result in various degrees of 'decoupling' depending on the diameter of the cartridge stick and the blast hole into which it is placed. This 'decoupling' reduces the overall effectiveness of the explosive as the explosive cartridge is not in total contact with the blasthole wall, being separated by an air annulus.

Cartridged Emulsion explosives usually have the following technical parameters:

- Density 1.20 – 1.25 gms/cc
- Velocity of Detonation 4,300-4,500 m/sec
- Detonation Pressure 55.7 – 63.5 kBar
- Sensitivity No. 8 detonator

A1.4.2 Bulk Emulsion Precursor

Bulk Emulsion Precursor has a similar composition to Cartridged Emulsion, however, these are usually manufactured using mineral oil as the fuel phase and do not contain aluminium. The bulk emulsion precursor has a density of 1.38-1.40 gms/cc and is an oxidising agent. It is not considered an explosive and is classified as UN 5.1 and DG Category 7 Strong Supporters of Combustion.

Bulk Emulsion explosives have the appearance of viscous cream and are frequently slightly yellow in colour.

A1.4.3 Bulk Emulsion

Bulk Emulsion precursor is sensitised at the blast face where a gassing solution (usually Acetic/Citric acid) is added to the charging hose downstream from delivery pump. This gassing solution mixes with the emulsion precursor, aided by a 'static mixer' positioned near the outlet end of the delivery hose and produces nitrogen bubbles, which in turn results in a final product density of 0.80-1.10 gms/cc. At this density the Bulk Emulsion precursor becomes a booster sensitive explosive. Bulk Emulsion will not reliably detonate if primed only with a No. 8 detonator.

Bulk Emulsion explosives which are pumped into blastholes completely fill the blasthole and thus are 'fully coupled' to the blasthole. This results in improved explosive performance and enables Bulk Emulsion explosives of lower power (cf. Cartridged Emulsions) to be utilized, resulting in equal or better performance over Cartridged Emulsions.

Bulk Emulsion explosives usually have the following technical parameters:

- Density 0.80 – 1.10 gms/cc

- Velocity of Detonation 4,500-4,800 m/sec
- Detonation Pressure 40.7 – 63.6 kBar
- Sensitivity 12 gram cast booster

A1.5 *NON-ELECTRIC DETONATORS*

The ignition of a non-electric detonator, or blasting cap, is achieved by the use of a shock tube, which is a small diameter plastic tube that has a light dusting of combustible explosive powder to the inside surface along its length. When ignited by a hot, high pressure impulse the explosive powder combusts at a rate of 2,000 - 2,200 m/s, and causes ignition of the detonator pyrotechnic delay mixture.

The delay time of a detonator is controlled by the burning time of a pyrotechnic ignition mixture pressed into a 6.5mm diameter steel tube, which is the delay element. This element causes the primary explosive, which is typically a small amount of lead azide, to detonate. This in turn, causes the secondary, or output, explosive to detonate, which is usually PETN (Pentaerythrite tetranitrate). The quantity of PETN within each detonator is approximately 0.8 gram.

Each detonator has a delay time that is based upon the length of steel tube and the compaction of the pyrotechnic mixture within it.

These type of detonators are insensitive to static electricity, stray currents and have a higher safety threshold than electric type to being initiated by electrical impulses resulting from lightning strikes on nearby structures or the ground.

A1.6 *CAST BOOSTERS*

These devices are only required if bulk emulsion is to be used instead of cartridged emulsion. They are small devices, usually containing 12 grams in weight of high explosive into which a detonator is inserted and the whole assembly is then placed in the end of the blasthole, and once assembled is called a primer.

Cast Boosters are usually manufactured from a 50/50% mixture of TNT and PETN, termed Pentolite. Cast Boosters detonate at speeds of 6,000 m/sec and provide sufficient 'shock' energy to reliably detonate the Bulk Emulsion, after firstly being initiated by the delay detonator.

A1.7 *DETONATING CORD – PERIMETER BLASTHOLES*

The perimeter blastholes are drilled at 600 mm intervals around the circumference of the adit/tunnel profile. These blastholes are not loaded with the equivalent MIC for the blast as this would lead to a substantial amount of 'overbreak' of the tunnel profile.

Perimeter blast holes are instead loaded with 80 gms/m of detonating cord (2 x 40 gms/m), and a single stick of cartridged emulsion is placed in the 'toe' (bottom) of the blasthole. When these blastholes are initiated the high Velocity of Detonation (VOD) of the detonating cord (about 7,000 m/sec), and the gas produced by the single cartridge of emulsion is sufficient to crack the rock between adjoining blastholes resulting in a smooth tunnel profile. It is not unusual to see half blastholes around the adit/tunnel perimeter after a blast indicating a perfect pre-split.

A1.8 *PERSONNEL – ROLES & RESPONSIBILITIES*

Under current Hong Kong Law a Shotfirer is legally responsible for collecting the explosives, loading the blast holes, ensuring a blast site has been evacuated, detonating the blast and for the consequential outcome of that blast.

The legislation states that the Shotfirer is the only individual that can make up primer charges and load blastholes and as such, is in control of the physical blast preparation at the working face.

The Blasting Engineer is responsible for the blast design and for obtaining endorsements/approvals from the Resident Engineer (RE) and Mines for all blasts. The blasting engineer's duties include calculating the required volume of explosives and initiating systems for the blast, maintaining safety, ensuring that the monitoring plan is implemented and for supervising the work of the Shotfirer(s).

A2 *BLASTING CYCLE*

The following sections describe the complete blasting cycle and the responsible person(s) for each step.

A2.1 *BLAST PLANNING & DOCUMENTATION*

Underground adit/tunnel blasts are planned two days in advance. This allows sufficient time for the Contractors' Blasting Engineer to submit blast documentation to the RE and Mines for endorsement. Blast documentation should be submitted to the RE and Mines by 5:00pm two days before the intended blast. The RE and Mines will confirm their endorsement by 11:00am one day before the planned blast.

The required blast documentation comprises the following information, which is signed by both the Blasting Engineer and the Registered Shotfirer:

- Plan view of the blast face detailing the diameter and position of all blastholes, the delay detonators to be used within each blasthole in each face sector, and the surface delays to be used between sectors;
- The total required number of detonators tabulated by delay number and length;
- The quantity of cartridged or bulk emulsion explosives to be used within the blast;
- The quantity of mini cast boosters or cartridged emulsion boosters required;
- The quantity of detonating cord to be used in perimeter blast holes;
- The MIC for the blast;
- The predicted Peak Particle Velocity (PPV) (vibration) and Air Overpressure (AOP) at the nominated sensitive receivers; and
- Date and estimated time of the subject blast.

A2.2 *ORDERING OF EXPLOSIVES & INITIATION SYSTEMS*

The detailed blast documentation also forms the explosives and initiating systems order from the explosives magazine.

When the explosives are required the Registered Shotfirer along with nominated representatives from the Contractor and the RE will go to the explosives magazine with the endorsed blast documentation which is presented to the security chief.

The security chief will check the identity of all personnel against a photo ID list held at the magazine before allowing the individuals access to the magazine complex.

The Registered Shotfirer, the representative from the Contractor, and the RE will then proceed to, and unlock the niche(s), to withdraw the endorsed quantity of explosives and initiating systems for the blast.

After securing the various niches of the magazine, the party will return to the security office and update and sign the Explosives Register.

The Registered Shotfirer, his helpers and an armed security guard will then transport the explosives and initiating systems (separately), to the nominated delivery/access shaft. Upon arrival, the explosives and initiating systems will be transported down the shaft in separate lots to a diesel powered vehicle for transportation to the working blast face.

A2.3 BLASTHOLE CLEANING

While the Registered Shotfirer is collecting the explosives and initiating systems from the explosives magazine, the Assistant Shotfirer will supervise the blast crew workers while they clean all blastholes to remove rock chips that may cause a blockage during loading of the blastholes.

Any blastholes which cannot be cleaned due to severe blockages will be deleted from the blast and marked with a spray painted red cross.

A2.4 BLASTHOLE MARKING

After the blastholes have been cleaned the Registered and Assistant Shotfirer will consult the blasting plan and mark each blasthole (using spray paint) with the required delay detonator number. Every delay detonator number is unique to a particular delay time.

A2.5 DELAY DETONATOR PLACEMENT

The Registered Shotfirer and the Assistant Shotfirer will then study the blast plan and insert the required delay detonator (with its shock tube coiled) in its planned blasthole, in doing so they will check the delay time printed on the detonator shell and printed on the shock tube tag, to ensure the correct detonator has been placed into the correct blast hole.

A2.6 PRIMING CUT, LIFTER & PRODUCTION BLASTHOLES

The Registered Shotfirer and the Assistant Shotfirer will remove the coiled detonator from the blasthole and check the shock tube tag on the detonator against the required delay number for the blasthole. If bulk emulsion is to be used, then the detonator will be inserted into the mini cast booster or the cartridged emulsion primer and the assembly gently pushed to the back of the cut, lifter or production blasthols. The primer is always positioned so that the detonator is pointing towards the blasthole collar (i.e. the face of the blast).

A2.7 *LOADING CARTRIDGED EMULSION EXPLOSIVES*

After priming all the cut, lifter and production blastholes the Registered Shotfirer and the Assistant Shotfirer will load the blastholes with the required MIC of cartridged emulsion sticks.

In the case of cartridged emulsion explosives, this will be a pre-calculated number of 'sticks' of the explosive; eg. if the MIC is 1.0 kg and 32 mm x 200 mm cartridged emulsion (.208 kg / stick) is being used, then 5 x cartridges will be inserted into each blasthole.

A2.8 *LOADING BULK EMULSION EXPLOSIVES*

When bulk emulsion explosives are utilized, the blast plan will have determined the required emulsion density. This will be communicated to the bulk emulsion pump / truck operator. The operator will consult calibration charts and set the flow rate of the gassing solution chemicals to provide the correct final bulk emulsion density.

Before pumping bulk emulsion into the blastholes, the pump truck operator will pump the gassed bulk emulsion into a beaker of known size and weight (usually 1 litre capacity). The operator will wait for about 5 minutes to allow the gassing phase to be completed and using a spatula, will wipe the top of the beaker to remove any excess material. The beaker and its gassed bulk emulsion contents are then weighed on calibrated laboratory scales to confirm the final product density.

Should the density require further adjustment, the above process is repeated until such time as the final product density is achieved.

Once the density is correct the Registered Shotfirer and his Assistant Shotfirer shall instruct the pump truck operator to provide the required MIC in each blasthole.

As an added checking method the Blasting Engineer knowing the final bulk emulsion density and the blasthole diameter, will calculate the length of the blasthole that will be filled with the MIC. For example, an MIC of 1.43 kg in a 45 mm blasthole at 0.90 gms/cc explosive density, the explosive column will be 1.0 m long). Typically, the Registered and Assistant Shotfirer will place a highly visible mark at the required distance from the end of the bulk emulsion loading hose. When the bulk emulsion is being pumped into the blasthole and the loading hose slowly withdrawn, the visible mark will appear at the blast hole collar indicating that the MIC has been loaded. The bulk emulsion pump should automatically shut down once it has delivered the pre-determined quantity.

When all blastholes have been loaded the pump truck operator will check the 'totalizer' and print out two copies of a certificate detailing the total volume of bulk emulsion used/loaded for the particular blast. The Blasting Engineer will sign both copies and will return one copy to the pump truck operator.

A2.9 *LOADING PERIMETER BLASTHOLES*

The detonating cord and cartridged emulsion booster for the perimeter blastholes are usually made up along a length of split bamboo, the explosive components being taped to the bamboo.

After preparation the lengths of bamboo are pushed to the back of the blastholes. Depending on the MIC for the blast groups of perimeter blastholes are linked together by 2 x 5 gms/m detonating cord and the 'group' of blastholes are fired by a single delay detonator; eg. for blastholes of 4.2 m in length with 2 x 40 gms/m detonating cords and a 0.208 kg cartridge emulsion booster, the charge per blasthole would be 0.544 kg ((4.2 x 40 x 2) + 0.208 kg = 0.544 kg). If the MIC for the blast was 1.7 kg, then three perimeter blastholes can be detonated at the same time instant (0.544 x 3 = 1.632 kg).

A2.10 *DETONATOR HOOK-UP*

After all blastholes have been loaded with the required explosive charge (MIC) the Registered and Assistant Shotfirer proceed to 'bunch' together all the shock tube tails of the down-the-hole detonators within a particular face sector. The tails are lashed together with 2 x strands of 5 gms/m detonating cord and tied with a slip proof knot.

A Bunch Block (0 ms delay) is attached to the detonating cord and the required time delay surface connector (9 or 17 ms) is attached to the shock tube tail of the Bunch Block.

This process continues until each face sector (4 – 6) is 'bunched' with its accompanying Bunch Block and surface connector. Thereafter the Registered and Assistant Shotfirer will connect the shock tube tail of the surface connector to the 'bunch' of shock tubes in the sector that is designed to initiate immediately beforehand.

Sectors will then initiate at times [0, 9, 17 and 26 ms] for a four sector face and [0 , 9, 17, 26, 34 and 43 ms] if there are six sectors in the face.

A2.11 *FINAL CHECKS*

The Registered and Assistant Shotfirer, together with the Blasting Engineer will stand back from the face and visually check for the following:

- That there are no shock tube tails from one sector connected into the 'bunch' of another sector;

- That there are no shock tube tails from down-the-hole detonators left unattached;
- That each sector has a Bunch Block attached to the detonating cord securing the 'bunch' of shock tube tails in a sector;
- That a surface connector is connected to each bunch blokc except in the 0 ms firing sector.
- That the shock tube tail of each surface connector is connected to the 'bunch' of shock tube tails of the sector initiating immediately before that particularly sector;
- That the 9 ms surface connector is connected from the 0 ms firing sector (bottom left sector) to the bottom right sector and that all other surface connectors are 17 ms and connected vertically upwards between sectors;
- That all perimeter blastholes are connected in the intended 'groups', the delay detonators are attached to the first blasthole in every group, and that the shock tube tail of these detonators are connected into the correct sector 'bunch'; and
- That the sector initiating at 0 ms has a bunch block attached to the detonating cord.

A2.12 *MONITORING PLAN*

About 1 hour before the blast is to be initiated the Blasting Engineer will instruct the Instrument Engineer to commence deploying the monitoring equipment to record vibration (PPV) and air overpressure (AOP) at the designated monitoring locations for the subject blast.

Once completed the Instrument Engineer will confirm that all instruments have been deployed and are active.

A2.13 *BLAST SITE EVACUATION*

At this time the Blasting Engineer will instruct all the Shotfirers' helpers to evacuate the blast site and to proceed to their predetermined sentry positions and to await further instructions.

Once all final checks have been completed the Blasting Engineer shall instruct the Registered Shotfirer to attach the electric detonator to the shock tube tail of the Bunch Block in the sector firing at 0 ms. After doing so, the Registered Shotfirer will attach a reel of firing line wire to the electric detonator and the face will be evacuated. The Blasting Engineer, the Registered and Assistant Shotfirer will then retreat to the nominated 'firing point' which would normally be at least 200 m from the blast face.

At this time the Blasting Engineer will give instructions for the blast door(s) to be closed.

A2.14 *BLAST INITIATION*

The Blasting Engineer will check that all 'Gongmen' (sentries) are at their designated location and that all affected areas of the underground excavation have been cleared of personnel.

At this time the Blasting Engineer will ask the Registered Shotfirer to check the resistance of the electrical circuit connected to the electric detonator and to verify he is ready to initiate the blast.

The Blasting Engineer will contact each Gongman to verify that their area of responsibility is secure. When satisfied that the evacuation procedure is complete and that the safety of all personnel has been secured, the Blasting Engineer shall instruct the Gongmen to commence beating a 'slow gong' and to wave their red flags.

After a period of about 20 seconds, the Blasting Engineer shall instruct the Gongmen to beat a 'fast gong' and instruct the Registered Shotfirer to connect the electrical circuit to his exploder (electric detonator initiator).

The Blasting Engineer will then reconfirm that all sentry points are secure and instruct the Assistant Shotfirer to count down from 10 to 0.

The Registered Shotfirer will then charge the capacitor in his exploder and when the 'count' reaches 0, he will initiate the blast.

A2.15 *POST BLAST INSPECTION*

After the blast has been initiated, and after the post blast dust and fumes have diminished, the Registered and Assistant Shotfirer, along with the Blasting Engineer will inspect the blast site for any 'misfired' blastholes.

If no misfires are detected the Blasting Engineer shall give the 'all clear' and the sentries will leave their designated locations and other site personnel will return to their place of work.

Should a misfire be detected, the Registered Shotfirer will make sure the misfire is made safe and shall connect an electric detonator to the detonating cord or shock tube tail. The standard evacuation procedure will again been completed and the misfire shall be initiated and a further post blast inspection made.

A2.16 *VENTILATION AND RETURN TO WORKING FACE*

Once the all clear has been given the ventilation fans will be turned on and the broken rock from the blast will be watered down to reduce dust emissions.

Once the area is safe to resume work the following activities are sequentially commenced:

- Scaling down the walls, backs and face (removing loose rock)
- Removal of the broken rock from the blast site
- Inspection by a geologist to determine the required rock stabilization/support
- Installation of the recommended rock support mechanisms (rock bolts, wire mesh and/or shotcrete)
- Drilling of a horizontal forward probe hole to determine rock quality in advance of the blast face (usually up to 20 m in length)
- Drilling of the blastholes for the next blast

The 'ideal' cycle time for blasting is about 12 hours allowing 2 blasts per 24 hour period however, this is dependant on several factors such as the time taken to stabilize the excavation and equipment breakdown.

A2.17 POST BLAST SENSITIVE RECEIVER INSPECTION & MONITORING REPORT

After the all clear has been given, the Instrument Engineer will inspect the sensitive receivers (particularly slopes) for any sign of distress/damage.

He will then recover all the monitoring instruments used for the blast and return them to the site office for the downloading of their recordings.

Initially the Instrument Engineer will check to ensure that none of the Alert-Alarm-Action (A-A-A) levels have been exceeded and advise the Blasting Engineer and the RE accordingly.

Thereafter the Instrument Engineer will download the recordings from each monitoring device and produce a Monitoring Report detailing the following information:

- The sensitive receivers for the subject blast
- Their radial distance from the blast
- The MIC for the blast
- Their A-A-A levels
- The predicted PPV and AOP levels, and
- The actual PPV and AOP (recorded) levels.

This report is copied to the RE and Mines, and sometimes to the project owner/sponsor if requested.

Annex B

Accident Review

B1 ACCIDENT REVIEW

This section presents a review of reported safety incidents involving the use of explosives (industrial applications). Records were retrieved mainly from the UK Health and Safety Executive (UK HSE)'s Explosives Incidents Database Advisory Service (EIDAS), US Mine Safety and Health Administration (MHSA) and Western Australia's Department of Consumer and Employment Protection (DOCEP). The records provided are also supplemented with information obtained from various sources.

Incidents were sorted according to the following categories to highlight causative factors to the incidents:

- Incidents involving storage of explosives
- Explosive transport incidents
- Explosive Use Incidents

The *Tables 1.1, 1.2 and 1.3* of this Annex provide a summary of relevant incidents for each of the categories above.

Table 1.1 Explosives Storage Related Incidents

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
1944	Detonators	Explosion	Storage	Explosive Factory, UK	Fatalities: 0 Injuries: 0	Two wooden carrying boxes containing detonators exploded in an unoccupied varnishing shop of an explosives factory. It is believed that a badly fixed notice board simply fell off the wall onto some detonators causing an explosion. No fatalities/injuries recorded in this incident	UK HSE	
1949	Blasting cartridges / detonators	Explosion	Storage	Demolition/ Construction Site, UK	Fatalities: 0 Injuries: 1	Blasting cartridges and detonators were left in a shed at a sand pit. There was a lighted slow combustion stove in the building. After a time the explosives ignited and detonated and one person was injured.	EIDAS, UK	N1
1949	Blasting cartridges / detonators	Explosion	Handling	Quarry (UK)	Fatalities: 1 Injuries: 0	A fatal accident occurred at a Division B Store. A shotfirer may possibly have dropped a box of explosives onto some detonators. The whole brick and reinforced concrete store was disintegrated. Minor damage occurred to property up to 1000 yards away.	EIDAS, UK	N1
1956	Detonators	Explosion	Storage	Storage Area, UK	Fatalities: 0 Injuries: 1	A boy aged 11 broke into an explosive store which had last been used in 1923, and the axe he was using struck a detonator which exploded causing minor injuries. A number of other detonators found after this accident were still quite serviceable.	EIDAS, UK	N2

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
1957	Detonators; Gelignite	Explosion	Storage	Quarry site, UK	Fatalities: 0 Injuries: 2	A fire occurred at a County Council hut in a quarry. Two detonators and 2 lbs. of gelignite, contained in a locked metal box, were in the hut. The explosives were initiated by the heat & 2 men who were endeavouring to extinguish the fire received injuries	EIDAS, UK	N1
1961	Detonators	Explosion	Storage	Mine site, UK	Fatalities: 0 Injuries: 0	A fire followed by an explosion occurred in an iron shed used as a store near the entrance of a small mine. The shed contained hay, a metal box of detonators and a "Tortoise" stove. The stove ignited the combustibles causing the detonators to explode.	EIDAS, UK	N1
07 Feb 19 69	Gelignite; Detonators	Explosion	Storage	Demolition/ Construction Site, UK	Fatalities: 0 Injuries: 0	Explosives had been stored in a workmen's hut on a construction site. A gas ring in the hut had been left burning overnight to dry damp clothing. The clothing was ignited by the gas-ring and in the resultant fire the detonators and gelignite exploded.	EIDAS, UK	N1
05 Feb 19 70	Detonators	Explosion	Storage	Quarry site, UK	Fatalities: 1 Injuries: 0	Explosion in a store at a quarry. Corroded detonators were recovered from the remains of the demolished building.	EIDAS, UK	
21 May 19 70	Detonators	Explosion	Storage	Not Known	Fatalities: 0 Injuries: 1	Electric detonators in draw came into contact with a 6 volt battery	EIDAS, UK	
07 May 1986	High Explosive	Explosion	Storage	Manufacturin g Site, UK	Fatalities: 0 Injuries: 1	An operation personnel of an explosive factory suffered burns to his hand after inadvertently dropping a tool into a can containing phials of tantallium pressed powder	UK HSE	N2

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
16 May 1995	Detonators	Explosion	Storage	Workshop, Australia	Fatalities: 0 Injuries: 1	A man received shrapnel injuries to his chest and lost an eye when detonators located on a work bench were accidentally initiated. The man was repairing a seeding machine when a spark from a grinder ignited two cardboard boxes containing detonators. The man had used the detonators a few weeks earlier and subsequently placed them on the work bench rather than where they were normally stored.	DOCEP, Western Australia	N3

Notes:

1. This involves nitroglycerin based explosives
2. This involves manufacture of non-commercial explosives
3. This is a farming incident.

Table 1.2 Transport Related Incidents

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
1952	High explosive	Fire	Transport	Road (UK)	Fatalities: Unknown Injuries: Unknown	Fire broke out on non-regulation van carrying 6000lb of blasting explosives. A tarpaulin between the cab and van body was ignited by hot exhaust. There was no fire screen in front of the van body. Only two boxes of explosives were consumed in the fire.	EIDAS, UK	N1
1953	Unspecified explosives	No Ignition	Transport	Mine (UK)	Fatalities: 0 Injuries: 3	Local train hit lorry containing explosives, scattering a large quantity of the explosive along the line. There was no ignition. Three men were injured by the collision.	EIDAS, UK	N1
1957	High explosives	No Ignition	Transport	Road (UK)	Fatalities: 0 Injuries: 0	A road vehicle carrying a full load of blasting explosives was found to be on fire at the rear - presumably due to a puncture in one of the rear tyres.	EIDAS, UK	N1
1958	High explosive	No Ignition	Transport	Road (UK)	Fatalities: 0 Injuries: 0	Fire broke out in engine of truck carrying 7700 lb of blasting explosive. The fire was confined to the front of the fire screen but was not extinguished before severe damage had been caused to the engine and cab.	EIDAS, UK	N1
1959	Safety fuse	Fire	Transport	Road (UK)	Fatalities: 0 Injuries: 0	A vehicle carrying 400 cases of safety fuse caught fire. The fire started in a rear twin tyred wheel. Possible cause was a deflated tyre or brake drum heat. Eighty two of the cases were salvaged	EIDAS, UK	

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
19 Oct 1973	Unspecified	Fire/ Explosion	Transport	Demolition/ Construction Site (UK)	Fatalities: 0 Injuries: 0	An unattended Landrover containing detonators and explosives caught fire on a construction site and exploded. It is thought that the fire was started by a discarded cigarette.	EIDAS, UK	N1
16 Aug 1985	Slurry	No Ignition	Transport	Manufacturing Site (UK)	Fatalities: 0 Injuries: 0	Fork lift truck driven over case of slurry explosive. Case ruptured but there was no initiation.	EIDAS, UK	
22 Mar 1989	Fuseheads, Slurry	Fire/ Explosion	Transport	Road (UK)	Fatalities: 1 Injuries: 107	Van carrying Powergel, Magna Primers, Ammon Gellit, detonators and fuseheads exploded in an industrial estate. Unsafely packaged fuseheads ignited by impact/friction when van went over ramp. Fire broke out and load exploded 10mins later killing fireman.	EIDAS, UK	
07 Jul 1989	Slurry	No Ignition	Transport	Road (UK)	Fatalities: 0 Injuries: 0	SGV carrying 3000 detonators and 260 kg of Powergel E80 crashed head on with another HGV. Major incident procedure implemented - local residents evacuated and roads closed. However on examination, load was found to be intact.	EIDAS, UK	
29 Aug 1989	Detonators	No Ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: Unknown	Explosives vehicle leaving reserve collided with passenger which had cut corner. Explosives unaffected	DOCEP, Western Australia	
25 Aug 1989	ANFO-P	No Ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: 2	Explosives vehicle ran off bitumen into culvert injuring driver and co-driver and causing major vehicle damage. Explosives unaffected	DOCEP, Western Australia	

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
20 Jan 1990	Ammonium Nitrate and Emulsion	No Ignition	Transport	Mine site (Australia)	Fatalities: 0 Injuries: 0	Blasting agent mixing vehicle self-propelled over bench face on mine site spilling ingredients	DOCEP, Western Australia	
20 May 1990	Emulite 1210	No ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: 0	15 tonnes of emulsion explosives conveyed on a dog trailer was spilt when the trailer overturned and the container ruptured	DOCEP, Western Australia	
10 Aug 1990	Explosives, low sensitivity	No ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: 0	Bulk explosives vehicle collided with roadside tree-explosives not involved	DOCEP, Western Australia	
18 Aug 1990	Detonators	No ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: 1	A station wagon conveying detonators rolled over as the driver negotiated a compound curve. Detonators remained intact	DOCEP, Western Australia	
7 Sep 1990	Powergel 2500 (emulsion)	Fire	Loading/ Un-loading	Mine site (Australia)	Fatalities: 0 Injuries: 0	A fire occurred on a mobile bulk explosives pumping unit due to an electrical short circuit. Examination of the unit revealed that the throttle cable had worn through the plastic battery cover and shorted out on the positive terminal causing overheating and resultant fire. The fire damage was limited to the battery, cables, alternator and isolation switch and fortunately did not spread to the load	DOCEP, Western Australia	

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
07 Jan 1991	High explosive	No Ignition	Transport	Road (UK)	Fatalities: 0 Injuries: 0	Lorry carrying one ton of explosives to an open cast coal site was involved in a collision with another lorry. Neither driver was injured. Accident occurred on the Guyzance bridge over the River Coquet, near Amble, which was blocked for almost an hour.	EIDAS, UK	
23 Sep 1991	Ammonium Nitrate	Fire	Transport	Mine site (Australia)	Fatalities: 0 Injuries: 0	Exhaust leakage caused fire to cladding in the engine compartment under the cabin of a blasting agent mixing vehicle. The fire was quickly extinguished by hose and caused no damage to the vehicle beyond the insulation	DOCEP, Western Australia	
22 May 1992	Low sensitivity explosives	No ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: 0	Tank seam failure due to poor road conditions resulted in spillage of bulk emulsion explosives	DOCEP, Western Australia	
06 June 1992	Low sensitivity explosives	Fire	Loading/ Un-loading	Mine site (Australia)	Fatalities: 0 Injuries: 0	Smouldering and small flames were noticed from a mono pump on an explosives mixing vehicle while it was being use to load explosives. The vehicle was being used to self load product, with the mono pump in reverse mode as the static ground pump had broken down. Fire extinguishers were used to extinguish the flames prior to the vehicle being driven away from the loading area to an isolated location. The cause of this incident is believed to be a valve being left open, allowing the mono pump to draw air which resulted in it not being lubricated by the product and thereby overheating	DOCEP, Western Australia	

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
21 Jan 1994	Bulk emulsion	No ignition	Transport	Mine site (Australia)	Fatalities: 0 Injuries: 0	Brake failure on an explosives mixing vehicle allowed it to roll backwards and roll over when it rolled up a windrow. The impact caused a tear on emulsion tank which led to loss of some emulsion product	DOCEP, Western Australia	
18 May 1994	Bulk emulsion	No ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: 1	An explosives mixing vehicle rolled over when it failed to negotiate a bend on a gravel road. Approximately 4 tonnes of unsensitised emulsion was spilt due to damage to the top hatch	DOCEP, Western Australia	N2
04 May 1995	Non-sensitised emulsion product	No ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: 0	The driver of an explosives mixing vehicles failed to negotiate a corner resulting in the vehicle rolling over and spilling bulk emulsion product	DOCEP, Western Australia	N2
16 Oct 1996	Ammonium Nitrate	Fire	Loading/ Un-loading	Mine Site (Australia)	Fatalities: 0 Injuries: 0	An ANFO mixing vehicle with a leaking fuel oil tank was used in charging operation at a surface mine. The vehicle caught fire halfway through loading a shot. The operators were not injured and mine personnel were evacuated to a distance of 1000 metres. The fire subsided to the area under the fuel oil tank, but continued to burn for 48 hrs, at which time the fire crew extinguished the fire	DOCEP, Western Australia	N2
06 Oct 199 7	Unspecified explosives	Fire	Transport	Quarry (UK)	Fatalities: 0 Injuries: 0	A truck carrying 100kg of explosives caught fire in a quarry near Dunbar. A container packed with 1te of ammonium nitrate was located nearby. Firemen tackled the blaze and no explosion was reported.	EIDAS, UK	

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
08 Aug 1998	Unspecified explosives	Explosion	Transport	Road (Canada)	Fatalities: 0 Injuries: 0	A truck carrying 18,000 kg of blasting explosives caught fire. People were immediately evacuated from the site. The truck exploded about 32 to 37 minutes later, causing minor injuries and throwing debris 2.5km away.	NIOSH (2008 study)	
Sep 2004	Ammonium Nitrate, detonators, and blasting boosters	No ignition	Transport	Road (US)	Fatalities: 0 Injuries: 0	A truck carrying ammonium nitrate and detonators overturned in I-85. Except for minor spill, the cargo was unaffected	NIOSH (2008 study)	
13 May 2004	Ammonium Nitrate-based liquid and detonators	No ignition	Transport	Road (US)	Fatalities: 0 Injuries: 0	A truck carrying 1,360 kg of ammonium nitrate based liquid and detonators overturned. Nearby homes and business evacuated	NIOSH (2008 study)	
12 Sep 2005	Ammonium nitrate	Explosion	Transport	Road (US)	Fatalities: 12 Injuries: 43	A large explosion occurred in the village of Shengangzhai, China. It is unclear what caused the truck carrying 18MT of ammonium nitrate to explode	NIOSH (2008 study)	N3
31 May 2006	Ammonium Nitrate, other explosives	No ignition	Transport	Road (US)	Fatalities: 0 Injuries: 0	A truck carrying 18.2MT of ammonium nitrate , 10,000 blasting caps and several dynamites overturned in a highway traversing a sparsely populated area in Utah. Authorities evacuated homes within 3.3-km (2-mile) radius from the crash site	NIOSH (2008 study)	

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
16 June 2006	Ammonium Nitrate, other explosives	Fire	Transport	Road (US)	Fatalities: 0 Injuries: 0	Electric short-circuit caused fire on a truck carrying 10 MT of ammonium nitrate, 8 cases of dynamite and 1,466 blasting caps. The fire was extinguished and the cargo is unaffected. Authorities closed the interstate and evacuated a 1-mile radius area	NIOSH (2008 study)	
1 Feb 2007	Ammonium Nitrate	No Ignition	Transport	Road (Australia)	Fatalities: 0 Injuries: 0	Truck carrying ammonium nitrate rolled over into creek	NIOSH (2008 study)	N3

Notes:

1. This involves nitroglycerin based explosives
2. This involves emulsion mixing vehicle, not an explosives vehicle
3. This involves ammonium nitrate only, not explosives
4. Some accidents from the NIOSH database have been included even though the reports were about dynamite explosives. It is most likely that the USA reporters have used old terminology referring to cartridged emulsion based explosives as dynamite.

Table 1.3 Explosives Use Related Incidents

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
1946	Detonators	Explosion	End Use	Not Specified (UK)	Fatalities: 0 Injuries: 1	Safety Fuse was being crimped onto a Detonator when the latter fired and communicated to other Detonators in a box, causing injuries to the operator.	EIDAS	N1
1953	Detonator	Explosion	Handling	Demolition/ Construction Site (UK)	Fatalities: 0 Injuries: 1	While a workman was handling a detonator during an excavation for a water supply scheme, it exploded, injuring 2 of his fingers and one eye.	EIDAS	N1
1961	Capped fuse; Detonator	Explosion	Handling	Demolition/ Construction Site (UK)	Fatalities: 0 Injuries: 1	A land clearance contractor charged a bore hole with explosive under a tree stump and then lit a capped fuse which he dropped on to a plain detonator lying on the ground. The explosion of the detonator fired the main charge.	EIDAS	N1
1964	Detonator	Explosion	End Use	Demolition/ Construction Site (UK)	Fatalities: 0 Injuries: 1	A man was using a piece of safety fuse as a slow match unaware that the end he was holding had a detonator attached. As the fuse burned down the detonator exploded in his hand.	EIDAS	N1
6 Jul 1984	Not known	Flyrock	End Use	Drainage trench (Australia)	Fatalities: 0 Injuries: 0	Flyrock damaged several vehicles in central Bunbury when blast mats moved during delayed firing in a drainage trench	DOCEP, Western Australia	N2
2 Sep 1984	Detonator	Explosion	End Use	Not Specified (Australia)	Fatalities: 0 Injuries: 1	A Quininup resident received a severe hand injury when he found a short length of fuse with a crimped detonator at the local tip. He decided to light the fuse and the detonator exploded in his hand	DOCEP, Western Australia	N1
13 Mar 1985	Not known	Flyrock	End Use	Demolition/ Construction Site (Australia)	Fatalities: 0 Injuries: 0	Overcharging with explosives whilst attempting to break up a concrete slab located within a prefabricated aluminum shed resulted in the destruction of the shed. The resultant flying debris subsequently damaged windows and asbestos panels on two adjoining holiday homes.	DOCEP, Western Australia	N2

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
3 Dec 1985	Not known	Explosion	Drilling	Not Specified (Australia)	Fatalities: 0 Injuries: 1	An Albany man sustained severe lacerations and shock when an unexploded portion of a charge exploded as he was drilling into an old drill hole	DOCEP, Western Australia	
16 May 1989	ANFO	Flyrock	End Use	Mine site (Australia)	Fatalities: 0 Injuries: 1	Flyrock damage and injury resulted from overcharging of a blast pattern, believed to have been caused by a lack of supervision	DOCEP, Western Australia	N2
5 Jul 1990	Unspecified	Flyrock	End Use	Mine Site (US)	Fatalities: 1 Injuries: 0	A blaster standing on the top of a 200-ft highwall about 505 ft from the blast site was fatally injured by flyrock [MSHA, 1990a]. The highwall could not shield him from flyrock. The employee suffered a massive head injury. The flyrock originated from a toe blast. The toe round consisted of 23 holes ranging in depth from 3 to 5 ft. The holes were loaded with 2-1/2-in diameter packaged explosive product The blaster failed to perceive that flyrock could strike him on the top of a highwall. This accident could have been prevented by using a proper blasting shelter or "matting" the holes.	US MSHA	N2
12 Oct 1990	Unspecified	Flyrock	End Use	Mine Site (US)	Fatalities: 1 Injuries: 0	A visitor sustained severe injuries and a miner was fatally injured by flyrock in a surface silica flux mine. The mining company used a blasting contractor for loading and firing the shots. The visitor and the miner were about 150 ft from the edge of the blast. Upon firing the shot, the miner was fatally struck on the back of his head.	US MSHA	N2
1 Feb 1992	Unspecified	Flyrock	End Use	Mine Site (US)	Fatalities: 1 Injuries: 0	A blaster was fatally injured in a surface coal mine. The blaster positioned himself under a Ford 9000, 2-1/2-ton truck while firing the shot. Flyrock traveled 750 ft and fatally injured the blaster.	US MSHA	N2

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
24 Mar 1992	Unspecified	Flyrock	End Use	Construction Site (US)	Fatalities: 1 Injuries: 0	An employee was standing next to a front-end loader when a blast was detonated. The blast consisted of 68 holes loaded with 2-in diameter by 16-in long cartridges of explosives. A dirt cover of 4- to 5-ft was used to confine the blast. The employee suffered trauma to his neck and lacerations to his face.	US OSHA	N2
25 Apr 1994	Unspecified	Flyrock	End Use	Mine Site (US)	Fatalities: 1 Injuries: 0	A driller/loader was fatally injured by flyrock in a surface coal mine [MSHA, 1994]. The blaster notified the superintendent of an impending blast and cleared other employees from the pit area. The victim and another employee working under the direction of the blaster were about 236 ft from the nearest blasthole. Upon firing the blast, the driller/loader was fatally injured by flyrock.	US MSHA	N2
13 Apr 1995	Unspecified	Flyrock	End Use	Construction Site (US)	Fatalities: 1 Injuries: 0	A blaster having 16 years experience was fatally injured by flyrock. He loaded the blastholes and took shelter behind a magazine of approximate size 4-ft high by 4-ft wide by 6-ft depth. Upon firing the shot, a single piece of rock struck the blaster on the head. He was about 150 ft from the blast site.	US OSHA	N2
29 June 1995	Unspecified	Flyrock	End Use	Mine Site (Australia)	Fatalities: 0 Injuries: 2	A receptionist received a scalp laceration and a supervisor bruised ribs when flyrock from a blast struck them. The rock passed through a window, across an empty room then through a closed door before striking the occupants of the office.	DOCEP, Western Australia	N2
31 Jan 1998	Unspecified	Explosion	End Use	Mine Site (Australia)	Fatalities: 0 Injuries: 1	A two metre length of safety fuse burnt in less than five seconds resulting in a premature blast.	DOCEP, Western Australia	N1

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
19 Mar 1998	Detonator	Air Blast	End Use	Mine Site (Australia)	Fatalities: 1 Injuries: 0	A leading hand of the scaling crew was fatally injured when he was struck on the head by either the ventilation doors or a ventilation regulator. The deceased had been assisting in charging a long hole raise and had retired behind the ventilation doors in the decline prior to firing. It is believed the air blast associated with the detonation caused the doors to swing and strike him.	DOCEP, Western Australia	
28 Mar 1998	Detonator	Explosion	End Use	Unspecified (Australia)	Fatalities: 0 Injuries: 1	A teenage boy sustained superficial injuries to his hand and face when he accidentally initiated a detonator.	DOCEP, Western Australia	
11 Dec 1998	Unspecified	Flyrock	End Use	Unspecified (Australia)	Fatalities: 0 Injuries: 0	Flyrock from a blast landed on occupied residential properties however there were no injuries.	DOCEP, Western Australia	N2
21 Dec 1999	Unspecified	Flyrock	End Use	Unspecified (US)	Fatalities1 Injuries: 0	An equipment operator in a pickup truck was guarding an access road to the blast site. The pickup truck was about 800 ft from the blast site. Flyrock entered the cab through the windshield and fatally struck the employee. The highwall face was about 50 ft high and the depth of holes ranged between 49 and 54 ft. The blast round consisted of 22 holes drilled on a 16- by 16-ft pattern. Some of the holes were angled up to 25° toward the highwall to compensate for irregularities in the highwall face. At least one of the holes blew out causing flyrock.	USMSHA	N2

Incident Date	Explosive Type	Event	Activity	Location	Casualties	Summary	Source	Notes
15 Aug 2003	Unspecified	Explosion	End Use	Unspecified (Australia)	Fatalities: 0 Injuries: 1	A shot-firer received a flash burn to his hand when he initiated a blast using a Cobra non-electric initiator. It is believed that the shot-firer had failed to ensure that the signal tube was fully engaged on the initiator before firing the shot. The unit was tested and returned to service.	DOCEP, Western Australia	

Notes:

1. This involves plain detonators and safety fuse or crimping, which are not relevant to this operation
2. This involves surface blasting and flyrock, not relevant to this operation

Annex C

Population Data

C1 ROAD POPULATION

C1.1 CALCULATION OF ROAD POPULATION DENSITY

Traffic density information was peak 2006 traffic flows obtained from the 2000 – Based District Traffic Model (BDTM). A growth factor of 1% per year to the construction year has been included. As the morning delivery will be carried out before 6:30 am, the AM road population has been reduced to 30% (to 50% for market area) to account for the light traffic at that time. Road population density was then calculated using the formula

Population Density = P x N / (W x V x 1000)
Where:
Average number of persons per vehicle, P = 3.
W is the road width (m)
V is the vehicle speed in km/hr
N is the number of vehicles counted.

The following table lists the road population density used in the model. Location of the roads and the passenger car unit (PCU) figures are shown in *Figure 1.1* and *Figure 1.2*. An asterisk (*) before the reference no. indicates that the road's population has been updated according to the traffic survey result (see *Appendix 10, Annex D*).

Table 1.1 Road Population Data

Ref.	Road Name	Road Population Density (persons / m^2) AM	PM
R1	Sai Ning St.	0.003882	0.010236
R2	Victoria Rd - North of Magazine	0.007125	0.0193
R3	Cadogan Street & Kennedy Town New Praya	0.005888	0.013838
R4	Shing Sai Road 1	0.011838	0.032563
R5	Sai Cheong Street North	0.000875	0.002713
R6	Shing Sai Road 2	0.015891	0.025127
R7	Elevated Road 1	0.003455	0.013491
R8	Ka On Street	0.004288	0.0057
*R9	Des Voeux Road West	0.002517	0.0068
R10	Whitty Street	0.001825	0.00285
R11	Queen's Road West	0.00476	0.0102
R12	Woo Hop Street	0.004533	0.012883
R13	Elevated Road 2	0.013075	0.036788
R14	Connaught Road Central	0.004065	0.0118
R15	Rumsey Street	0.0035	0.0154
R16	Wing Lok Street	0.00075	0.0041
R17	Connaught Road W	0.006982	0.020891
R18	Queen's Street 1	0.00082	0.00211
R19	Queen's Street 2	0.00326	0.01151
*R20	Queen's Road West	0.00345	0.01175
R21	Victoria Road - Kennedy Town	0.007125	0.0193

Ref.	Road Name	Road Population Density (persons / m²)	
		AM	PM
R22	Victoria Road – South of Magazine	0.005075	0.013575
R23	Mount Davis Road	0.001667	0.005083
R24	Pok Fu Lam Road 1 – from Mount Davis Road	0.008471	0.0226
R25	Pok Fu Lam Road 2 – from bus terminal to point 5	0.008893	0.02415
R26	Pok Fu Lam Rosd - West of Bonham Road	0.003643	0.00985
R27	Bonham Road - West of Western St	0.007013	0.023188
R28	Bonham Road - East of Western St	0.005713	0.011338
R29	Western St	0.012567	0.016017
R30	High St	0.00165	0.004617
R31	Second St	0.0065	0.006017
R32	Eastern St	0.0059	0.0073
R33	Ka Wai Man Road	0.002063	0.010838
*R34	Catchick St	0.00225	0.006367
R35	Smithfield Rd	0.000917	0.001167

Figure 1.1 PCU Figures on Delivery Routes (1)

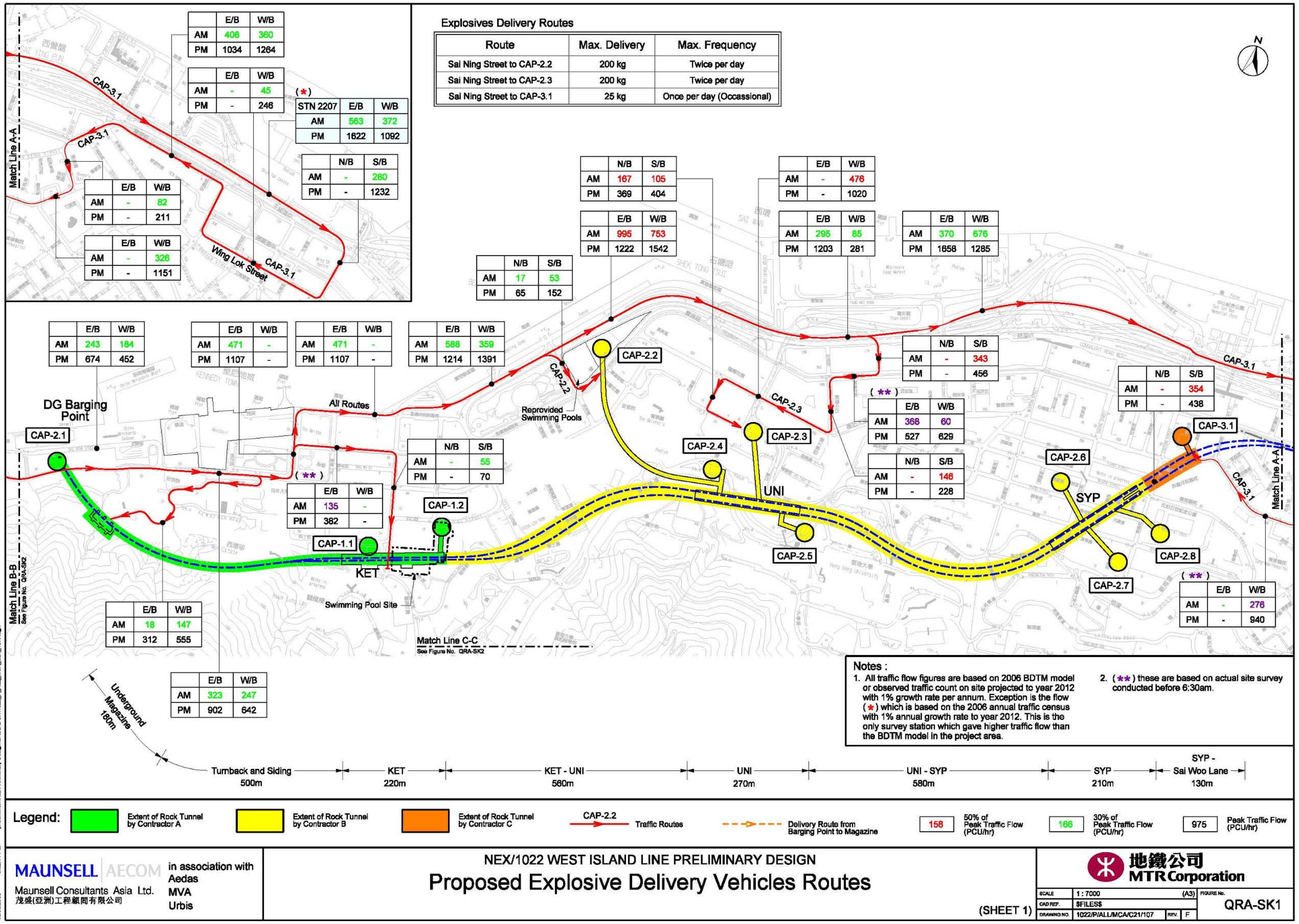
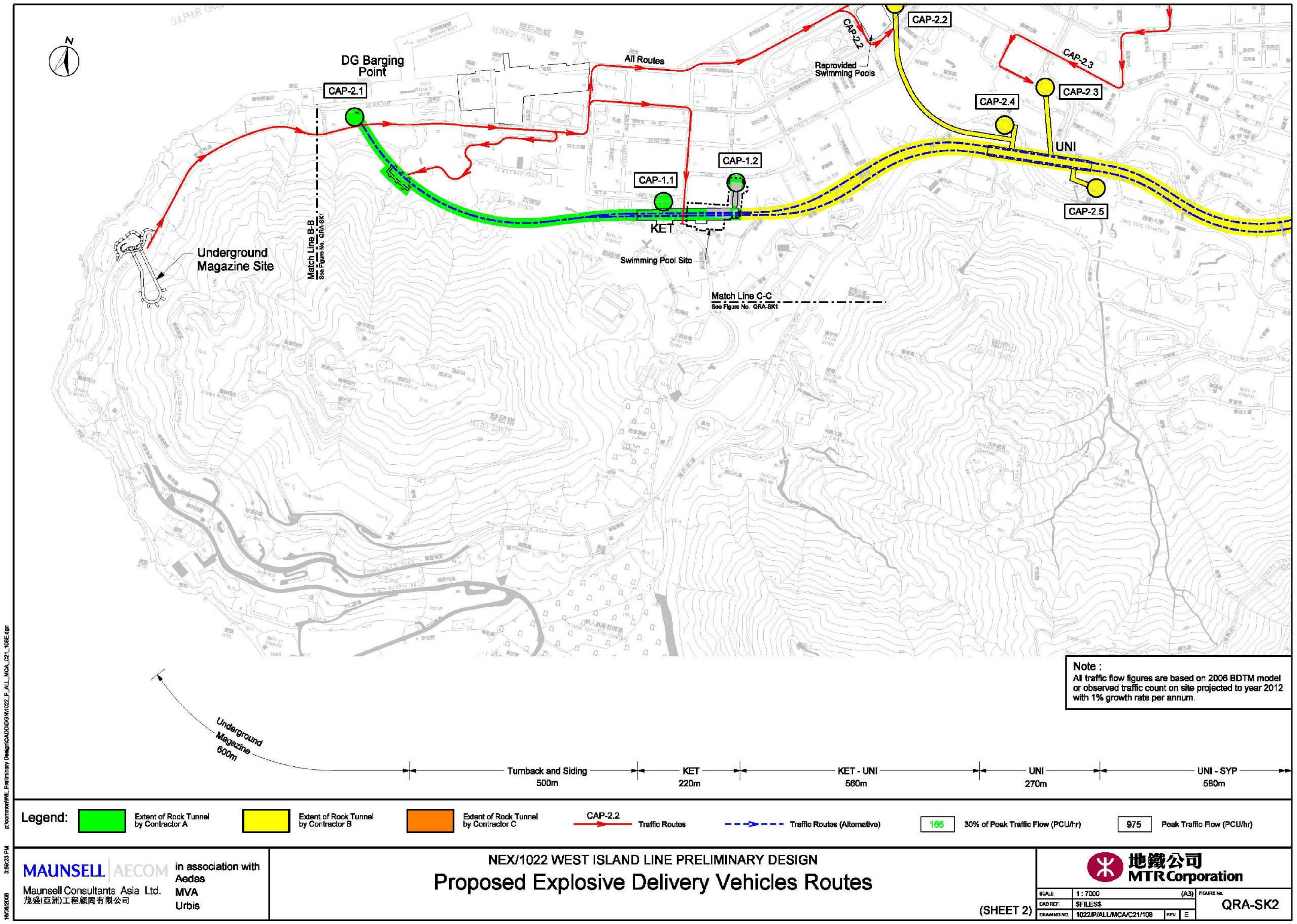


Figure 1.2 PCU Figures on Delivery Routes (2)



C2 BUILDING POPULATION

C2.1 OVERVIEW

Population data has been collected by a combination of survey, the Code of Practice for the Provision of Means of Escape in Case of Fire, Planning Department Zoning Plans, the census, and Centamap. Assumptions in estimating building population are:

- Residential building: 3 persons per flat
- Commercial building: 9 m^2/person with reference to the minimum requirement as stated in Code of Practice for the Provision of Means of Escape in Case of Fire.
- Footpath: 0.5 persons / m^2 with reference to the above Code of Practice.
- Educational Institution: 500 persons per hall.

Unless it is marked as commercial, industrial, institutional, community use, a building is assumed to be residential building.

For residential bldg, the AM population is assumed to be 100% occupancy; for PM it is assumed to be 50% occupancy. For industrial, commercial and community uses, the AM population is assumed to be 10% of the maximum occupancy; for PM it is assumed to be 100% occupancy. The percentage of occupancy at different time period assumed in the study is consistent or more conservative than the CLP LNG receiving terminal EIA. (1)

For multi-storeys building, where information on the number of floors is available, the population in 10 storeys of the building has been used in the modelling for delivery points 1, 2, 4 and 7, and the population in 12 storeys of the building has been used for delivery point 3, with the AM and PM effect considered as above. If there is no information on the number of floors, it is assumed that 100% population is exposed. The 'Adjustment Population' in *Table 2.1* indicates the population for 10 stories. A factor of 1.2 was applied to obtain the population for 12 stories during the assessment.

The following table lists the building population in the vicinity of the delivery routes. Locations of the buildings are shown *Figure 2.1* to *Figure 2.6*. The colour of the blocks in the figures has no physical significance.

(1) Castle Peak Power Company Limited (CLP), Liquefied Natural Gas (LNG) Receiving Terminal and Associated Facilities, EIA Study Report No. EIA-125/2006, 2006

Table 2.1 *Building Population*

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
1	Abandoned building	410 Victoria Road	Population estimate based on site visit	0	0	0
2	Caritas Jockey Club Hostel Mount Davis	405 Mount Davis Cottage Area	Population estimate based on site visit, information on building size and facility use	200	200	200
3	Chee Sing Kok Social Centre Of The Humanity Life	404 Mount Davis Cottage Area	Population estimate based on site visit, information on building size and facility use	200	200	200
4	Serene Court	84 Victoria Road	232	696	696	348
5	Regent Height	80 Victoria Road	63	189	189	95
6	Huncliff Court	70 Victoria Road	38	114	114	57
7	Petrol Station	Victoria Road	Population estimate based on site visit, information on building size and facility use	10	1	10
8	Kwong Ga Factory Building	64 Victoria Road	Industrial (20 Storey and area = 30x20m)	2667	133	1333
9	Yiuga Factory Building	62 Victoria Road	Industrial (24 Storey and area = 15x20m)	1600	67	667
10	Bus Station	Victoria Road	Population estimate based on site visit, information on building size and facility use	10	1	10
11	Workshop	30 Victoria Road	Population estimate based on site visit, information on building size and facility use	10	1	10
12	Carpark	Sai See Street	Population estimate based on site visit, information on building size and facility use	10	1	3
13	Centenary Mansion Block 1 & 2	9 - 15 Victoria Road	608	1824	1824	912

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
14	Ka Wai Man Road Garden	Ka Wai Man Road	Population estimate based on site visit, information on building size and facility use	50	50	25
14A	Cadogan Street Tempoary Garden	Ka Wai Man Road	Population estimate based on site visit, information on building size and facility use	100	100	50
15	Block 1, Cayman Rise	29 Ka Wai Man Road	Population estimate based on site visit, information on building size and facility use	100	100	50
16	Block 2, Cayman Rise	29 Ka Wai Man Road	Population estimate based on site visit, information on building size and facility use	100	100	50
17	Skh Lui Ming Choi Memory Primary School	31 Ka Wai Man Road	Population estimate based on site visit, information on building size and facility use	1242	124	1242
18	Kennedy Town Jockey Club Clinic	45 Victoria Road	Population estimate based on site visit, information on building size and facility use	500	50	500
19	St Luke's Settlement	47 Victoria Road	Population estimate based on site visit, information on building size and facility use	300	300	150
20	Bayanihan Kennedy Town Centre	55 Victoria Road	Population estimate based on site visit, information on building size and facility use	300	300	150
21	(Hong Kong Institute of Vocation Education (Morrison Hill) Kennedy Town Centre)	12 Ka Wai Man Road	Population estimate based on site visit, information on building size and facility use	500	50	500

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
22	Sai Wan New Apartments	177 - 185 Belchers Street	109	327	327	164
23	Kai Yuen Lau	158 Belchers Street	15	45	45	23
24	Kwan Yick Building	150 - 156 Belchers Street	28	84	84	42
25	Catrick Street Garden	Catrick Street	Population estimate based on site visit, information on building size and facility use	20	2	20
26	Cheong Kat Mansion	98-100 Catrick Street	66	198	198	99
27	Merton Block 3	Catrick Street	Population estimate based on site visit, information on building size and facility use	120	120	60
28	Yue On Building	78 - 86 Catrick Street	40	120	120	60
29	Shing Tai Building	70-76 Catrick Street	28	84	84	42
30	Kam Fu Mansion	66-68 Kam Fu Mansion	10	30	30	15
31	Chi Fung Building	62-64 Catrick Street	10	30	30	15
32	Kuk Fung Building	46-60 Catrick Street	36	108	108	54
33	44 Catrick Street	44 Catrick Street	5	15	15	8
34	42 Catrick Street	42 Catrick Street	5	15	15	8
35	Kam Fai House	38-40 Catrick Street	16	48	48	24
36	Shun Hing Building	22-34 Catrick Street	88	264	264	132
37	Tai Tak House	19 Smithfield	7	21	21	11
38	2 Hau Wo Street	2 Hau Wo Street	3	9	9	5
39	4 Hau Wo Street	4 Hau Wo Street	2	6	6	3
40	Nam Shan House	113-119 Belcher's Street	10	30	30	15
41	Carpark	Belcher's Street	Population estimate based on site visit, information on building size and facility use	10	1	10
42	Smithfield Court Block 1	43 Smithfield	258	774	774	387
43	Luen Tak Apartments	45 Smithfield	147	441	441	221

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
44	Smithfield Complex (Cooked Food Centre)	12K Smithfield	Population estimate based on site visit, information on building size and facility use	500	50	500
45	Man Kwong Court	12 Smithfield	110	330	330	165
46	Nan Sang Building	86 Belcher's Street	54	162	162	81
47	107-111 Belcher's Street	Belcher's Street	19	57	57	29
48	Markfield Building	8 Smithfield	150	450	450	225
49	Shanghai Commerical Building	47 Catrick Street	Population estimate based on site visit, information on building size and facility use	500	50	500
50	May Sun Building	55-57 Catrick Street	21	63	63	32
51	Hing Wong Building	61 Catrick Street	Population estimate based on site visit, information on building size and facility use	150	150	75
52	Ka Fu Building Block B	63 Catrick Street	46	138	138	69
53	Ka On Building Block A	65 Catrick Street	48	144	144	72
54	Catrick Street	93 Catrick Street	5	15	15	8
55	Catrick Street	95 Catrick Street	5	15	15	8
56	Timely Court	99 Catrick Street	Population estimate based on site visit, information on building size and facility use	300	300	150
57	The Merton Block 1 & 2	38 New Praya Kennedy Town	Population estimate based on site visit, information on building size and facility use	300	300	150
58	Grand Fortune Mansion	1-1A Davis Street	92	276	276	138

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
59	Manhattan Heights	71-91 Catchick Street / 31 Kennedy Town New Praya	Population estimate based on site visit, information on building size and facility use	300	300	150
60	Ka On Building Block B	27 New Praya, Kennedy Town	48	144	144	72
61	Ka On Building Block A	25 New Praya, Kennedy Town	46	138	138	69
62	Hing Wong Building	23 New Praya, Kennedy Town	116	348	348	174
63	May Sun Building	7-8 New Praya, Kennedy Town	22	66	66	33
64	Kennedy Town Fire Station	6 Kennedy Town Praya	Population estimate based on site visit, information on building size and facility use	300	300	300
65	Bus Terminus	Shing Sai Road	Population estimate based on site visit, information on building size and facility use	30	3	30
66	Western District Public Cargo Working Area	Shing Sai Road	Population estimate based on site visit, information on building size and facility use	50	5	50
67	Lung Cheung Garden	26 New Praya, Kennedy Town	128	384	384	192
68	Block B Belcher Court	2 Sai Cheung Street	120	360	360	180
69	Namhung Mansion Block A & B	5-5H Belcher's Street	379	1137	1137	569
70	Yick Fung Garden Block A	20 Praya, Kennedy Town	120	360	360	180
71	Sun Court	3-3A Belcher's Street	92	276	276	138
72	Carpark	Praya, Kennedy Town	Population estimate based on site visit, information on building size and facility use	10	1	5

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
73	Electricial Sub-Station	Fung Mat Road	Population estimate based on site visit, information on building size and facility use	1	0	1
74	Tram Depot	Fung Mat Road	Population estimate based on site visit, information on building size and facility use	10	1	10
75	WSD - Sai Ying Pun Fresh Water Pumping Station	Fung Mat Road	Population estimate based on site visit, information on building size and facility use	2	0	2
76	LPG Filling Station	Fung Mat Road	Population estimate based on site visit, information on building size and facility use	3	0	3
77	Kwan Yick Building Phase 2 Block A	343 Des Voeux Road West	240	720	720	360
78	Cheung Ka Industrial Building	179-180 Connaught Road West	Industrial (19 Storey and area = 27x40m)	4560	240	2400
79	Fung Yip Building	347-349 Des Voeux Road West	132	396	396	198
80	Kong Chian Tower Block 1	351 Des Voeux Road West	92	276	276	138
81	Lun Fung Court	363 Des Voeux Road West	122	366	366	183
82	Des Voeux Road West Building	406, 406 A & B Des Voeux Road West	104	312	312	156
83	Whitty Building	22-44 Whitty Street	168	504	504	252
84	Chong Yip Centre Block A	402-404 Des Voeux Road	184	552	552	276
85	Chong Yip Centre Block B	11-21 Whitty Street	265	795	795	398
86	Chong Yip Centre Block C	423-425 Queen's Road West	184	552	552	276

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
87	Whitty Street Substation	Whitty Street	Population estimate based on site visit, information on building size and facility use	2	0	2
88	Wing Wah Mansion Block G-Z	425G-425K Queen's Road West	445	1335	1335	668
89	Sang Cheong Building	427-437 Queen's Road West	64	192	192	96
90	Hang Lung Bank Western Branch	15 Hill Road	52	156	156	78
91	Yip Cheong Building	4-16 Hill Road	374	1122	1122	561
92	Dragonfair Garden Block 1	455 Queen's Road West	112	336	336	168
93	Dragonfair Garden Block 2	485 Queen's Road West	108	324	324	162
94	Po Tak Building	540-546 Queen's Road West	53	159	159	80
95	Kwok Ga Building	6-12 Woo Hop Street	88	264	264	132
96	Green View Court	14-20 Woo Hop Street	60	180	180	90
97	Kam Ling Count Block A & B	1-3 Woo Hop Street	220	660	660	330
98	Joy Fat Mansion	522-530 Queen's Road West	119	357	357	179
99	Luen Wah Mansion	518-520 Queen's Road West	55	165	165	83
100	Centuary Harbour View Hotel	508 Queen's Road West	Population estimate based on site visit, information on building size and facility use	300	300	150
101	Sun On Building	484-496 Queen's Road West	194	582	582	291
102	Wing Hing House	476-482 Queen's Road West	81	243	243	122
103	Shek Tong Tsui Complex	470 Queen's Road West	Population estimate based on site visit, information on building size and facility use	300	30	300
104	Western Court	454-456G Queen's Road West	160	480	480	240
105	Western Court	450-452G Queen's Road West	160	480	480	240

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
106	Wah Ming Centre Block C	394-400 Des Voeux Road West	84	252	252	126
107	Tung Tat Building	390-392 Des Voeux Road West	39	117	117	59
108	Kam Wa Building	382-388 Des Voeux Road West	84	252	252	126
109	380 Des Voeux Road West	380 Des Voeux Road West	4	12	12	6
110	Grace Mansion	374-376 Des Voeux Road West	69	207	207	104
111	Lucky Building	370-372 Des Voeux Road West	32	96	96	48
112	Chung Ah Mansion	352-366 Des Voeux Road West	139	417	417	209
113	South Lane	14 - 4 South Lane	35	105	105	53
114	Hill Court	28 Hill Road	138	414	414	207
115	11-25 South Lane	11-25 South Lane	75	225	225	113
116	Nam Wah Mansion	5-9 South Lane	52	156	156	78
117	1-3 South Lane & 34 Hill Road	South Lane	22	66	66	33
118	Jadeview Court	38 Hill Road	152	456	456	228
119	Nam Cheong Building	48-52 Hill Road	92	276	276	138
120	Sik On House	54-66 Hill Road	79	237	237	119
121	Graceful Court	27-37 Hill Road	48	144	144	72
122	Fu Yin Court	39 Hill Road	Population estimate based on site visit, information on building size and facility use	200	200	100
123	Petrol Station	Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	10	1	10
124	Petrol Station	Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	10	1	10

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
125	Bus Terminus	Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	30	3	30
126	Academic Terrace Block 1	101 Pok Fu Lam Road	216	648	648	324
127	Switching Station	97 Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	2	0	2
128	Pok Fu Lam Zone Substation	95 Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	2	0	2
129	Starr Hall, The University of Hong Kong	91B Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	300	300	150
130	Lady Ho Tung Hall, The University of Hong Kong	91A Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	300	300	150
131	Tower 3, The Belcher's	89 Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	700	700	350
132	University of Hong Kong - Yam Pak Building	79C Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	300	300	150
133	Chiu Sheung School, Hong Kong	79B Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	300	30	300
134	Bauhnia	79 Pok Fu Lam Road	9	27	27	14
135	Bowie Court	77 Pok Fu Lam Road	27	81	81	41
136	Fairview Court	75 Pok Fu Lam Road	48	144	144	72

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
137	Charmview Court	73 Pok Fu Lam Road	48	144	144	72
138	Tsui On Court	71 Pok Fu Lam Road	48	144	144	72
139	93-99 Hill Road	93-99 Hill Road	10	30	30	15
140	Good Luck Mansion	10 Hill Road	6	18	18	9
141	Salesians Of Don Bosco Provincial Office / St. Anthony's House	69B Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	200	20	200
142	University of Hong Kong - Hsu Long Sing Amenities Centre	Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	200	20	200
143	Podium	Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	150	15	150
144	University of Hong Kong - The Kadoorie Biological Science Building	Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	200	20	200
145	University of Hong Kong - Pao Siu Loong Building	Bonham Road	Population estimate based on site visit, information on building size and facility use	200	20	200
146	University of Hong Kong - Hung Hing Ying Building	Bonham Road	Population estimate based on site visit, information on building size and facility use	200	20	200
147	Kingsfield Tower Block A & B	64-68 Bonham Road	Population estimate based on site visit, information on building size and facility use	1000	1000	500
148	St Stephen's Church Primary School	71 Bonham Road	Population estimate based on site visit, information on building size and facility use	500	50	500

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
149	St. Paul College	67-69 Bonham Road	Population estimate based on site visit, information on building size and facility use	500	50	500
150	Lim Kai Bit Yip	65A-65B Bonham Road	19	57	57	29
151	Mai Hing House	3-4 Hing Hon Road	26	78	78	39
152	Smiling Court	65 Bonham Road	23	69	69	35
153	Hing Yip Building	7-8 Hing Hon Road	20	60	60	30
154	Hilary Court	63G Bonham Road	Population estimate based on site visit, information on building size and facility use	300	300	150
155	Hing Hon Building	15 Hing Hon Road	92	276	276	138
156	King's College	63A Bonham Road	Population estimate based on site visit, information on building size and facility use	1000	100	1000
157	University of Hong Kong - Fung Ping Shan Building	94 Bonham Road	Population estimate based on site visit, information on building size and facility use	500	50	500
158	University of Hong Kong - Tsui Tsin Tong Building	Bonham Road	Population estimate based on site visit, information on building size and facility use	500	50	500
159	Bonham Towers	88 Bonham Road / 1-2 Prospect Place	Population estimate based on site visit, information on building size and facility use	500	500	250
160	Chinese Rhenish Church, Hong Kong	86A Bonham Road	Population estimate based on site visit, information on building size and facility use	500	50	500
161	Rhenish Mansion	84 Bonham Road	60	180	180	90
162	Ning Yeung Terrace Block A & B	78A-78B Bonham Road	180	540	540	270

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
163	Ihong Mansion	7 St. Stephen's Lane	7	21	21	11
164	Hansen Court	3 St. Stephen's Lane	24	72	72	36
165	Golden Phoenix Court	1-2 St. Stephen's Lane	114	342	342	171
166	Wilton Place	68 Bonham Road	134	402	402	201
167	Ever Rise Mansion	63 Bonham Road	100	300	300	150
168	Ying Yin Mansion	50-52 Western Street	22	66	66	33
169	42-48A Western Street	Western Street	35	105	105	53
170	Scholar Court	38-40 Western Street	24	72	72	36
171	Kam Fung Mansion	59-61 Bonham Road	69	207	207	104
172	55-57 Bonham Road	Bonham Road	24	72	72	36
173	Good View Court	51-53 Bonham Road	20	60	60	30
174	88-90 High Street	High Street	15	45	45	23
175	Lai Yin Court	80-86 High Street	50	150	150	75
176	49 Bonham Road	Bonham Road	10	30	30	15
177	Hang Sing Mansion	48-78 High Street	251	753	753	377
178	Aspen Court	46 High Street	72	216	216	108
179	Wing Cheung Court	37-47 Bonham Road	101	303	303	152
180	62-64 Centre Street	Centre Street	20	60	60	30
181	35 Bonham Road	Bonham Road	4	12	12	6
182	33 Bonham Road	Bonham Road	7	21	21	11
183	Sun Luen Building	29-31 Bonham Road	44	132	132	66
184	Ka Fu Building	19-27 Bonham Road	72	216	216	108
185	Cheong King Court	26-38 High Street	84	252	252	126
186	16-24 High Street	High Street	19	57	57	29
187	Ko Wang Court	31-33 High Street	24	72	72	36
188	35-37 High Street	High Street	11	33	33	17
189	Kam Lun Mansion	39-41 High Street	10	30	30	15

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
190	43-49 High Street	High Street	20	60	60	30
191	Wealth Building	53-65 High Street	90	270	270	135
192	Yin Tak Building	69-73 High Street	18	54	54	27
193	Highlight House	75-79 High Street	15	45	45	23
194	Lechler Court	97 High Street	80	240	240	120
195	Zion Court	95A-95B High Street	10	30	30	15
196	81-95 High Street	High Street	15	45	45	23
197	Kau Yan Tsung Tsin Church	97A High Street	Population estimate based on site visit, information on building size and facility use	100	10	100
198	Western District Community Centre	105 Third Street / 36A Western Street	Population estimate based on site visit, information on building size and facility use	100	10	100
199	Yee Fung Court	101 Third Street	200	600	600	300
200	Yue Sun Mansion	89-99 Third Street	98	294	294	147
201	Yee Sun Mansion	58-66 Second Street	66	198	198	99
202	48-58 Second Street	Second Street	19	57	57	29
203	1-7 Tak Sing Lane	Tak Sing Lane	18	54	54	27
204	1-2, 7-21 Yu Lok Lane	Yu Lok Lane	32	96	96	48
205	Rest Area	Second Street	Population estimate based on site visit, information on building size and facility use	10	1	10
206	Sui Wah House	92-98 High Street & 39-45 Western Street	52	156	156	78
207	31-37 Western Street	Western Street	20	60	60	30
208	Wing Cheung Building	19-29 Western Street	90	270	270	135
209	5-17 Western Street	Western Street	36	108	108	54
210	96-100 Second Street	Second Street	13	39	39	20
211	102-108 Second Street	Second Street	20	60	60	30

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
212	Wing Fong Mansion	107-117 Second Street	49	147	147	74
213	30-36 Western Street	Western Street	20	60	60	30
214	Western Garden Evergreen Tower	83 Second Street	216	648	648	324
215	Western Garden Ivy Tower	83 Second Street	216	648	648	324
216	Centre Street Market	44 Centre Street	Population estimate based on site visit, information on building size and facility use	100	10	100
217	Sai Ying Pun Market	43-47 Centre Street	Population estimate based on site visit, information on building size and facility use	100	10	100
218	14-32 Second Street	Second Street	31	93	93	47
219	Tong Nam Mansion	43-47 Third Street	120	360	360	180
220	2-10 Second Street	Second Street	37	111	111	56
221	25-31 Eastern Street	Eastern Street	20	60	60	30
222	Elite Court	33 Centre Street	Population estimate based on site visit, information on building size and facility use	350	350	175
223	Tung Cheung Building	1-11 Second Street	104	312	312	156
224	Hing Yip Building	5-23 First Street	44	132	132	66
225	Good Times Building	230-236 Queen's Road West	46	138	138	69
226	226-228 Queen's Road West	Queen's Road West	15	45	45	23
227	Wing Yin Building	245-247 Queen's Road West	Commercial - No info on no. of storey (Area =10 x 18m)	1000	100	1000
228	Nil	239-243 Queen's Road West	15	45	45	23
229	Nil	235-237 Queen's Road West	9	27	27	14
230	Nil	227-233 Queen's Road West	15	45	45	23

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
231	Nil	219-223 Queen's Road West	Population estimate based on site visit, information on building size and facility use	85	85	43
232	Rich Court	213 Queen's Road West	21	63	63	32
233	Tai Shing House	203-209 Queen's Road West	28	84	84	42
234	Wah Ying Commerical Building	197-201 Queen's Road West	Commercial - No info on no. of storey (Area =12 x 10m)	1000	100	1000
235	191-195 Queen's Road West	Queen's Road West	6	18	18	9
236	Wai Lee Building	2 Wilmer Street	12	36	36	18
237	The Prince Philip Dental Hospital	34 Hospital Road	Population estimate based on site visit, information on building size and facility use	1000	100	1000
238	Kam Shek House	38-42 Eastern Street	10	30	30	15
239	36 Eastern Street	Eastern Street	3	9	9	5
240	Nil	220-224 Queen's Road West	15	45	45	23
241	Wah Lee Building	210-218 Queen's Road West	130	390	390	195
242	Nil	204-208 Queen's Road West	13	39	39	20
243	Nil	200-202 Queen's Road West	10	30	30	15
244	Fulfil Building	196-198 Queen's Road West	8	24	24	12
245	Nil	192- 194 Queen's Road West	7	21	21	11
246	Nil	188-190 Queen's Road West	11	33	33	17
247	Tat Hing Building	182-186 Queen's Road West	15	45	45	23
248	Kin Hing Building	172-180 Queen's Road West	15	45	45	23
249	Nil	150-170 Queen's Road West	70	210	210	105
250	Teen Wo Building	146-148 Queen's Road West	15	45	45	23
251	Nil	142-144 Queen's Road West	15	45	45	23
252	Fu Tai Mansion	138-140 Queen's Road West	15	45	45	23

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
253	Nil	136 Queen's Road West	5	15	15	8
254	Nil	183-189A Queen's Road West	23	69	69	35
255	Nil	167-181 Queen's Road West	38	114	114	57
256	Nil	163-165 Queen's Road West	10	30	30	15
257	Wo Fu Building	159-161 Queen's Road West	10	30	30	15
258	Nil	153-157 Queen's Road West	8	24	24	12
259	Wing Cheung Building	141-151 Queen's Road West	30	90	90	45
260	Nil	135-139 Queen's Road West	15	45	45	23
261	Nil	129-133 Queen's Road West	10	30	30	15
262	Hua Chang Commercial Building	123 Queen's Road West	Commercial (G/F to 22/F and area = 15x10m)	367	17	167
263	Kam Yu Mansion	8 Kom U Street	108	324	324	162
264	Kiu Fat Building	117 Queen's Road West	Commercial (No info on No. of Storey and area = 20x60m)	1000	100	1000
265	Hua Fu Commercial Building	111 Queen's Road West	Commercial (upto 16/F and area = 22x15m)	587	37	367
266	Hollywood Centre	77-91 Queen's Road West	Commercial (G/F to 20/F and area = 25x15m)	833	42	417
267	Marco Garden	128 Queen's Road West	96	288	288	144
268	Construction works in Progress	118-122 Queen's Road West	Population estimate based on site visit, information on building size and facility use	50	5	50
269	Nil	108-116 Queen's Road West	21	63	63	32
270	Chartered Bank Building	102-106 Queen's Road West	Commercial (upto 12/F and area = 12x15m)	240	20	200
271	Nil	94-100 Queen's Road West	20	60	60	30
272	Tung Hing Court	88 Queen's Road West	Commercial (upto 22/F and area = 26x15m)	953	43	433
273	Nil	250-258 Hollywood Road	20	60	60	30

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
274	Nil	248 Hollywood Road	Commercial (upto 4/F and area = 20x15m)	133	13	133
275	Nil	236-244 Hollywood Road	25	75	75	38
276	Ko Shing Building	265-267 Hollywood Road / 78-80 Queen's Road West	29	87	87	44
277	Nil	58-76 Queen's Road West	43	129	129	65
278	Lai Yan Lau	42-56 Queen's Road West	100	300	300	150
279	Tower 3, The Belcher's	Queen Road	Population estimate based on site visit, information on building size and facility use	700	700	350
280	Tower 1, The Belcher's	Queen Road	Population estimate based on site visit, information on building size and facility use	700	700	350
281	Cooked Food Market	Queen Road	Population estimate based on site visit, information on building size and facility use	300	300	150
282	Yien Yieh Bank Western Branch	32-36 Des Voeux Road West	Commercial (upto 14/F and area = 16x20m)	498	36	356
283	Wong House	26-30 Des Voeux Road West	Commercial (upto 13/F and area = 14x25m)	506	39	389
284	Western Centre	48 Des Voeux Road West	Commercial (upto 21/F and area = 30x30/2m)	1050	50	500
285	Nil	22-24 Des Voeux Road West	6	18	18	9
286	Golden Crown Building	18-20 Des Voeux Road West	Commercial (upto 15/F and area = 12x10m)	200	13	133
287	Hang Wo Building	72-74 Bonham Strand West	Commercial (upto 9/F and area = 25x12m)	300	33	333
288	Shun Kwong Commercial Building	8 Des Voeux Road West	Commercial (upto 17/F and area = 30x10m)	567	33	333
289	Nil	25 Des Voeux Building	31	93	93	47

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
290	King Kong Commercial Centre	9 Des Voeux Road West	Commercial (upto 29/F and area = 25x30m)	2417	83	833
291	Wui Tat Centre	55 Connaught Road West	Commercial (upto 18/F and area = 10x20m)	400	22	222
292	Nil	1 Des Voeux Road West	Commercial (No info on No. of storey and area = 20x10/2m)	1000	100	1000
293	Kian Nan Mansion	81-85 Bonham Strand West	38	114	114	57
294	Nil	243-245 Wing Lok Street	6	18	18	9
295	Fui Nam Building	48 Connaught Road West	Commercial (upto 18/F and area = 14x10m)	280	16	156
296	Kai Fat Building	45 Connaught Road West	Commercial (upto 15/F and area = 20x25m)	833	56	556
297	Goldfield building	42-44 Connaught Road West / 200-202 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	300	300	150
298	Tung Kwong Building	40-41 Connaught Road West	Population estimate based on site visit, information on building size and facility use	300	300	150
299	Talon Tower	38 Connaught Road West	Population estimate based on site visit, information on building size and facility use	300	300	150
300	B2B Center	35-36 Connaught Road West	Commercial (No info on No. of storey and area = 8x20m)	2100	210	2100
301	Wayson Commercial Building	28 Connaught Road West	Commercial (upto 24/F and area = 35x22m)	2053	86	856
302	Seaview Commercial Building	21-24 Connaught Road West	Commercial (upto 22/F and area = 25x25m)	1528	69	694
303	Chung Ying Building	20-20A Connaught Road West	Commercial (upto 15/F and area = 10x30m)	500	33	333
304	Uwa Building	18-19 Connaught Road West	Commercial (upto 9/F and area = 9x25m)	225	23	225

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
305	Nil	17 Connaught Road West/ 33 New Market Street	Population estimate based on site visit, information on building size and facility use	300	300	150
306	China Merchants Commercial Building	15-16 Connaught Road West / 29-31 New Market Street	Commercial (No info on No. of Storey and area = 10x25m)	1000	100	1000
307	Ka On Building	8-14 Connaught Road West	89	267	267	134
308	Nil	7 Connaught Road West	Population estimate based on site visit, information on building size and facility use	300	300	150
309	Yardley Commercial Building	3 Connaught Road West	Commercial (upto 23/F and area = 25x30m)	1917	83	833
310	Western Market	323 Des Voeux Road Central	Commercial (No info on No. of Storey and area = 25x45m)	1000	100	1000
311	Kai Tak Commercial Building	317-319 Des Voeux Road Central	Commercial (upto 21/F and area = 14x25m)	817	39	389
312	Hoi Kiu Commercial Building	158 Connaught Road Central	Commercial (upto 18/F and area = 16x25m)	800	44	444
313	Ing Tower	308-320 Des Voeux Road Central	Commercial (upto 28/F and area = 24x30m)	2240	80	800
314	Hong Kong Telcom CSL Tower	322 Des Voeux Road Central	Population estimate based on site visit, information on building size and facility use	300	30	300
315	Yue's House	304-306 Des Voeux Road Central	Commercial (upto 9/F and area = 10x30m)	300	30	300
316	Wah Kit Commercial Centre	302 Des Voeux Road Central	Commercial (upto 20/F and area = 10x30m)	667	33	333
317	Chun Yin House	298 Des Voeux Road Central	Commercial (No info on No. of Storey and area = 8x30m)	950	95	950
318	Eton Building	288 Des Voeux Road Central	Commercial (upto 24/F and area = 26x14m)	971	40	404
319	Foo Cheong Building	82-86 Wing Lok Street	Commercial (upto 10/F and area = 12x14m)	187	19	187

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
320	Nil	78-80 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	300	300	150
321	Winning House	72-76 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	300	300	150
322	Hing Yip Commercial Building	280 Des Voeux Road Central	Commercial (upto 23/F and area = 26x11m)	731	32	318
323	Central Pointa	68-70 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	300	300	150
324	Cheong Tai Commercial Building	60-66 Wing Lok Street	Commercial (upto 12/F and area = 16x14m)	299	25	249
325	Cheong Fat House	56-58 Wing Lok Street	Commercial (upto 4/F and area = 8x12m)	43	4	43
326	Nil	52-54 Wing Lok Street	8	24	24	12
327	Nil	46-50 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	450	450	225
328	Hillier Commercial Building	89-91 Wing Lok Street	Commercial (1 to 19/F)	422	22	222
329	Nil	69 Bonham Strand	Population estimate based on site visit, information on building size and facility use	550	550	275
330	New Victory House	93-103 Wing Lok Street	Commercial (2 to 18/F)	576	34	339
331	Nil	77 Bonham Strand West	Commercial (1 to 5/F)	53	5	53
332	Travel Way Building	105-107 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	500	500	250
333	Bonham Centre	79-85 Bonham Strand	Commercial (4 to 17/F)	604	43	432

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
334	Nil	109-111 Wing Lok Street	4	12	12	6
335	Nil	113-119 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	300	300	150
336	Nil	87 Bonham Strand East	Population estimate based on site visit, information on building size and facility use	300	300	150
337	Man Lok Building	89 Bonham Strand East	Commercial (2 to 13/F)	243	20	202
338	North East Commercial Building	95 Bonham Strand East	Commercial (1 to 5/F)	33	3	33
339	Wing Tat Commercial Building	121 Wing Lok Street	Commercial (2 to 14/F)	261	20	201
340	Nil	97 99 Bonham Strand	Population estimate based on site visit, information on building size and facility use	300	300	150
341	Lee Man Commercial Building	105 Bonham Strand East	Commercial (Ground to 12/F)	187	16	156
342	Fu Lok Building	131-133 Wing Lok Street	Commercial (upto 6/F only)	75	7	75
343	Kai Wah Building	135-137 Wing Lok Street	1	3	3	2
344	Wing Hing Commercial Building	139 Wing Lok Street	Commercial (1/F to 25/F)	467	19	187
345	Nil	145 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	450	450	225
346	Harmony Court	127 Bonham Strand	50	150	150	75
347	Nil	113-123 Bonham Strand	26	78	78	39
348	Tung Hip Commercial Building	244-248 Des Voeux Road Central	Commercial Area = 462sqm (No info on no. of floor)	300	300	150
349	Tung Shing Commercial Building	34 Wing Lok Street	Commercial (2/F to 20/F)	560	29	295

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
350	Yien Yieh Bank Building	238-242 Des Voeux Road Central	Commercial (8/F to 14/F)	448	45	448
351	Charles L Corn Building	26 Wing Lok Street	3	9	9	5
352	Tak Cheung Building	22-24 Wing Lok Street	Commercial (3/F)	47	5	47
353	Nim Chi Lau	18-20 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	450	450	225
354	Wing Sing Commercial Centre	12-16 Wing Lok Street	Commercial (2/F to 23/F)	457	21	208
355	Lloyds Commercial Centre	8-10 Wing Lok Street	Commercial (2/F to 23/F)	327	15	148
356	Hing Loong Building	6A-8A Wng Lok Street	Commercial Area = 140sqm (No info on no. of floor)	450	450	225
357	Kwong Fat Hong Building	1 Rumsey Street	Commercial (6/F to 23/F)	423	24	235
358	Ngan House	210 Des Voeux Road Central	Commercial (upto 19/F and area = 12x12m)	304	16	160
359	Des Voeux Commercial Centre	212-214 Des Voeux Road Central	Commercial (upto 21/F and area = 8x14m)	261	12	124
360	Sam Cheong Building	216-220 Des Voeux Road Central	Commercial (upto 14/F and area = 13x14m)	283	20	202
361	Willie Building	222-224 Des Voeux Road Central	Commercial (upto 6/F and area = 8x14m)	75	7	75
362	Ka Wah Bank Centre	232 Des Voeux Road Central	Commercial (upto 10/F and area = 29x14m)	451	45	451
363	Shum Tower	268 Des Voeux Road Central	Commercial (upto 21/F and area = 16x12m)	448	21	213
364	Yat Chau Building	262 Des Voeux Road Central	Commercial (upto 21/F and area = 12x14m)	392	19	187
365	Finance Building	254 Des Voeux Road Central	Commercial (upto 14/F and area = 8x14m)	174	12	124
366	Teda Building	87 Wing Lok Street	Commercial (upto 22/F and area = 8x24m)	469	21	213
367	On Wing Building	51-59 Bonham Strand	88	264	264	132

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
368	Skyline Commercial Centre	77 Wing Lok Street	Commercial (upto 25/F and area = 18x16m)	800	32	320
369	The Strand	47-49 Bonham Strand East	Commercial (upto 20/F and area = 10x15m)	333	17	167
370	Foo Sang Building	67-69 Wing Lok Street	Commercial (upto 5/F and area = 10x17m)	94	9	94
371	Nil	63-65 Wing Lok Street	7	21	21	11
372	Nil	59-61 Wing Lok Street	Population estimate based on site visit, information on building size and facility use	300	300	150
373	Mandarin Building	35-43 Bonham Road	90	270	270	135
374	Cosco Tower	183 Queen's Road Central	Commercial (upto 55/F and area = 50x32m)	9778	178	1778
375	Golden Centre	188 Des Voeux Road Central	Commercial (upto 27/F and area = 26x12m)	936	35	347
376	Vicwood Plaza	199 Des Voeux Road Central	Commercial (upto 38/F and area = 40x45m)	7600	200	2000
377	Wing On Centre	111 Connaught Road Central	Commercial (upto 29/F and area = 70x48m)	10827	373	3733
378	Rumsey Street Multi-Storey Car Park	2 Rumsey Street	Population estimate based on site visit, information on building size and facility use	500	50	125
379	Shun Tak Centre China Merchants Tower	168 Connaught Road Central	Commercial (upto 40/F and area = 40x50m)	8889	222	2222
380	Shun Tak Centre and West Tower	168-200 Connaught Road Central	Commercial (upto 39/F and area = 118x30m and 50x40m)	24007	616	6156
381	Recreational Area and bus terminus	Connaught Road Central	Population estimate based on site visit, information on building size and facility use	300	30	300
382	Waterfront Division Police Station	2 Chung Kong Road	Population estimate based on site visit, information on building size and facility use	500	500	500

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	Adjusted Population PM
383	Sheung Wan Fire Station	2 Western Fire Services Street	Population estimate based on site visit, information on building size and facility use	500	500	500
384	Islands & Marine Fire Command Headquarters	Western Fire Service Street	Population estimate based on site visit, information on building size and facility use	500	500	500
385	Jade Court	8 High Street	48	144	144	72
386	Nil	6A,6& 4B High Street	Population estimate based on site visit, information on building size and facility use	200	200	100
387	Nil	4 High Street	20	60	60	30
388	Nil	2B-2C High Street	10	30	30	15
389	Eastern Street Methadone Clinic	45 Eastern Street	Population estimate based on site visit, information on building size and facility use	200	20	200
390	Sai Ying Pun Community Complex	2 High Street	Population estimate based on site visit, information on building size and facility use	200	20	200
391	Not used				0	0
392	Nil	21-27A High Street	63	189	189	95
393	Nil	1-3 Leung I Fong	6	18	18	9
394	Nil	15-17 High Street	10	30	30	15
395	Ko Chun Court	11 High Street	26	78	78	39
396	Ko Nga Court	9 High Street	226	678	678	339
397	High House	19A-19B High Street	46	138	138	69
398	Villas Sorrento	64-64A Mount Davis Road	Population estimate based on site visit, information on building size and facility use	100	100	50

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
399	Villa Primavera	188 Victoria Road	Population estimate based on site visit, information on building size and facility use	50	50	25
400	Villa D'Ora	63 Mount Davis Road	1	10	10	5
401	Block 1 - 8 Felix Villas	61 Mount Davis Road	Population estimate based on site visit, information on building size and facility use	80	80	40
402	Cape Mansions Block A	60-62 Mount Davis Road	33	99	99	50
403	Cape Mansions Block B	56-58 Mount Davis Road	40	120	120	60
404	Canossian Retreat House HoneyVille	57 Mount Davis Road	Population estimate based on site visit, information on building size and facility use	100	100	50
405	Vista Mount Davis	52-54 Mount Davis Road	40	120	120	60
406	Bayview Court	49 Mount Davis Road	12	36	36	18
407	Ocean View	37 Mount Davis Road	Population estimate based on site visit, information on building size and facility use	36	36	18
408	Greenvale Block 1	15 Mount Davis Road	5	15	15	8
409	Greenvale Block 2	17 Mount Davis Road	6	18	18	9
410	Greenvale Block 3	19 Mount Davis Road	6	18	18	9
411	Greenvale Block 4	21 Mount Davis Road	6	18	18	9
412	Greenvale Block 5	23 Mount Davis Road	4	12	12	6
413	House A1 to A7	6 Mount Davis Road	7	35	35	18
414	Four Winds	4 Mount Davis Road	49	147	147	74
415	Nil	7 Mount Davis Road	6	18	18	9
416	Mount Davis Garden	5 Mount Davis Road	24	72	72	36
417	Greenery Garden Block A to D	2A Mount Davis Road	112	336	336	168

No.	Building Name	Street Name	Flat No.	Maximum Population	Adjusted Population AM	PM
418	Pok Fu Lam Road Playground	Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	50	5	50
419	Football Field	Pok Fu Lam Road	Population estimate based on site visit, information on building size and facility use	30	3	30
420	Tennis Court	University of Hong Kong	Population estimate based on site visit, information on building size and facility use	20	2	20
421	Flora Ho Sports Centre	University of Hong Kong	Population estimate based on site visit, information on building size and facility use	200	20	200
422	The Lindsay Ride Sports Centre	University of Hong Kong	Population estimate based on site visit, information on building size and facility use	200	20	200
423	St. John's College AW Boon Haw Wing	University of Hong Kong	Population estimate based on site visit, information on building size and facility use	300	30	300
424	St. John's College Marden Wing	University of Hong Kong	Population estimate based on site visit, information on building size and facility use	300	30	300
425	KET Swimming Pool	Sai Cheung Street North	Population estimate based on site visit, information on building size and facility use	1000	100	1000
426	Nil	Ko Shing Street 84-86	Commercial (up to 10/F and area = 160m^2)	184	184	184
427	Nil	Des Voeux Road West 114	Commercial (up to 12/F and area = 60m^2)	75	75	75

Figure 2.1 Population Distribution (1)

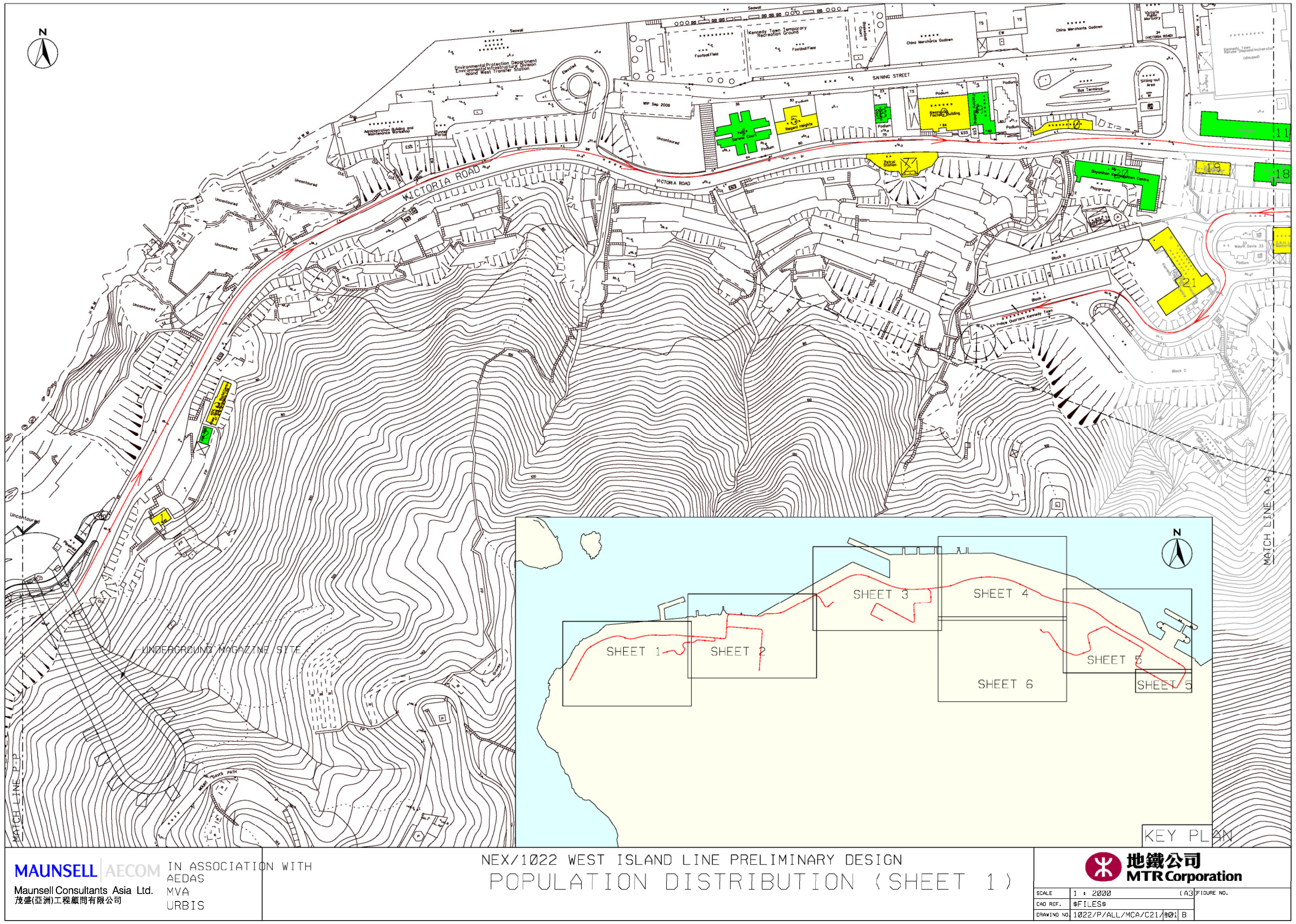


Figure 2.2 Population Distribution (2)

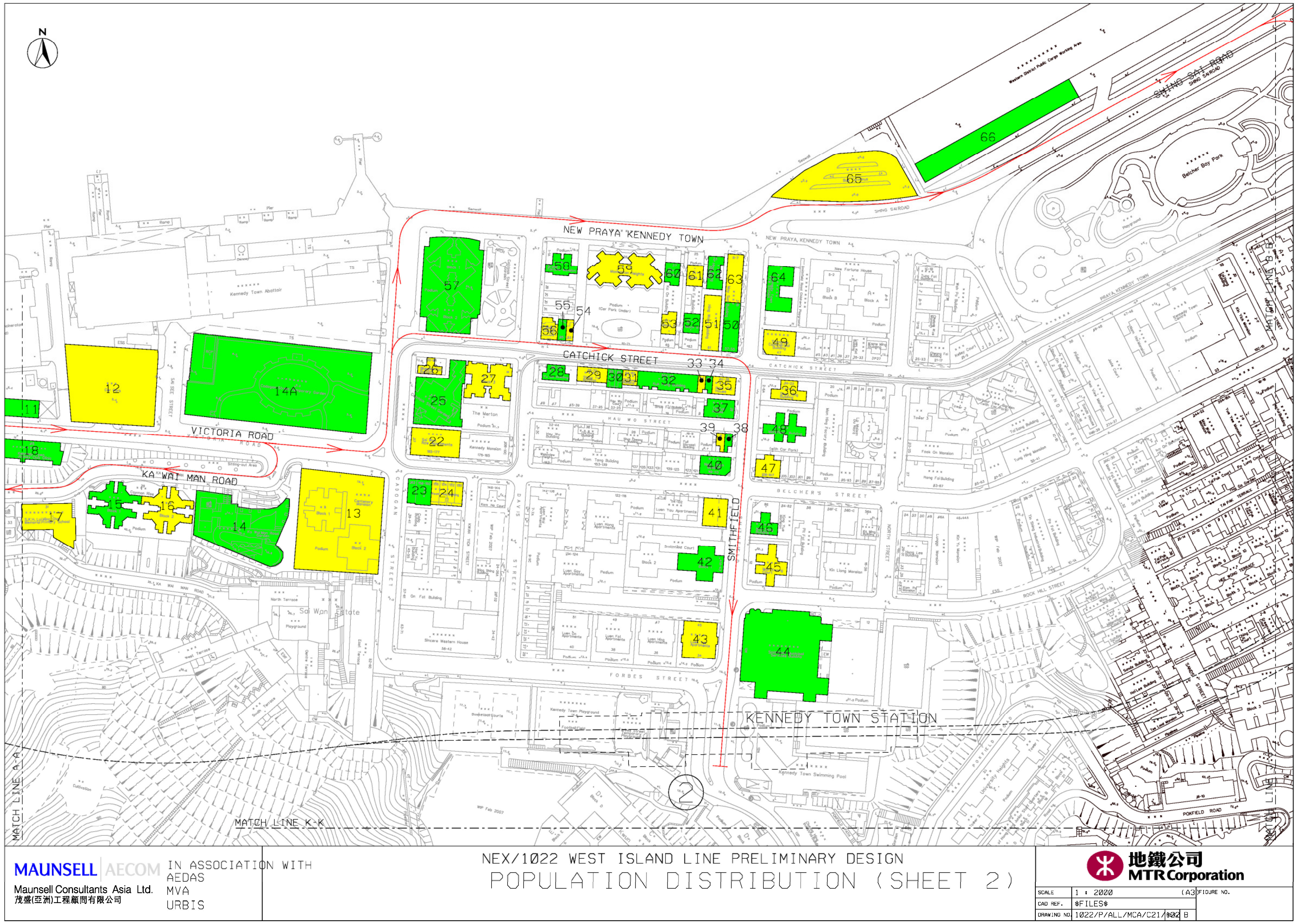


Figure 2.3 Population Distribution (3)

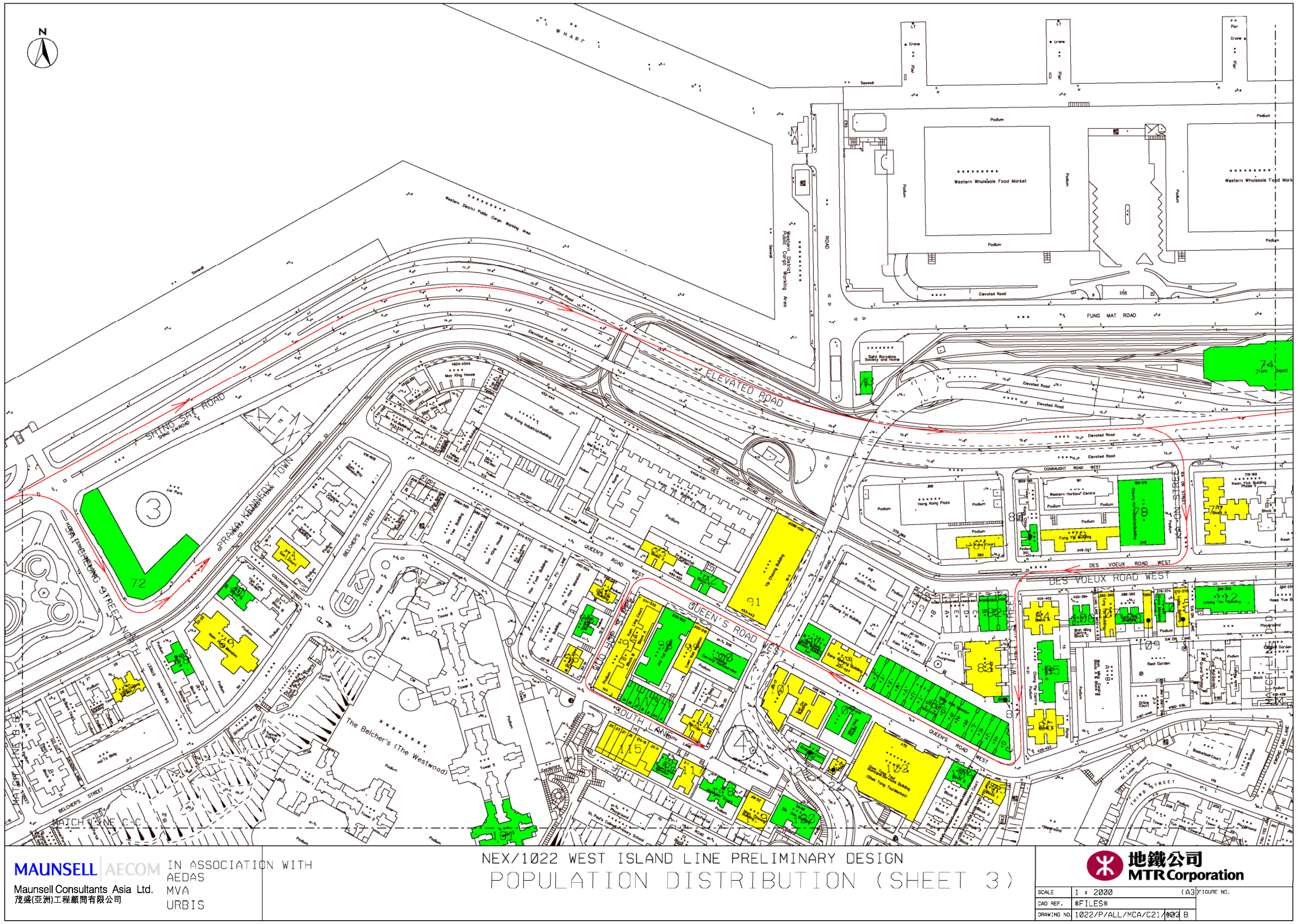


Figure 2.4 Population Distribution (4)

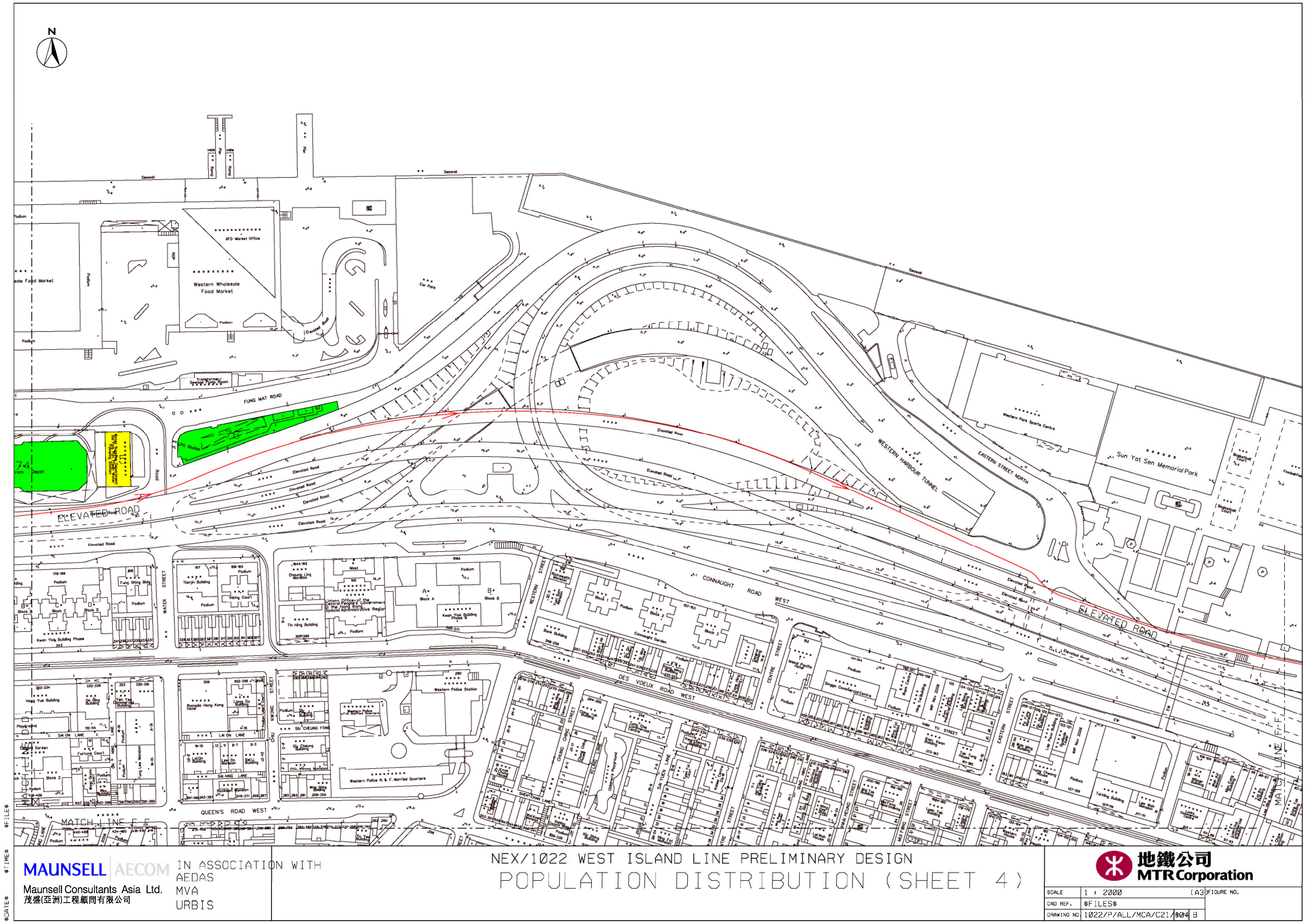


Figure 2.5 Population Distribution (5)

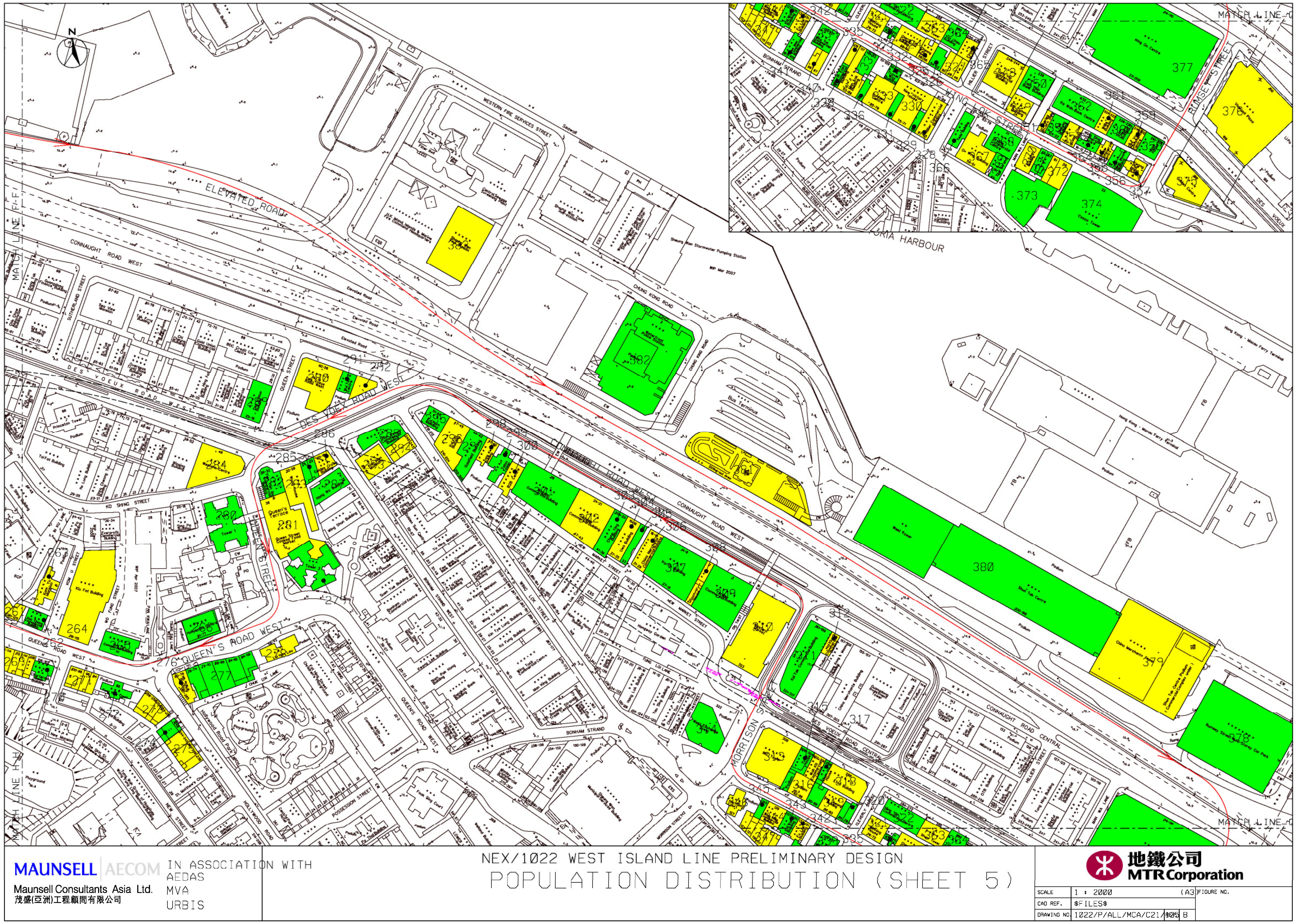


Figure 2.6 *Population Distribution (6)*

Annex D

Traffic Survey Report

D1 OVERVIEW

Maunsell Consultants Asia Ltd. (MCAL) was commissioned by MTR Corporation Limited (MTRCL) in early April 2008 to undertake a traffic survey on 8 key road links for the transport of explosives in the areas of Sheung Wan, Sai Ying Pun and Kennedy Town. The eight road links are listed below:

1. Victoria Road near Ka Wai Man Road;
2. Catchick Street between Smithfield Road and Davis Street;
3. Shing Sai Road between Sai Cheung Street North and Sands Street;
4. Queen's Road West between Hill Road and Wo Hop Street;
5. Des Voeux Road West between Water Street and Whitty Street;
6. Second Street between Eastern Street and Centre Street;
7. Queen's Road West between New Street and Eastern Street; and
8. Rumsey Street between Connaught Road Centre and Des Voeux Road West.

The aim of the traffic survey is to collect observed traffic data to compare with those previously adopted for the Quantitative Risk Assessment (QRA) to see whether the assumed traffic figures for QRA are reasonable.

Traffic survey was carried out on 8th April 2008 (Tuesday) during 03:30 and 06:30 in the early morning.

The results of the traffic survey are summarized and presented in *Table 1.1* below.

Table 1.1 Summary of Traffic Survey Results

Location	Road Name	Direction	Observed Traffic Flows (pcu/hr)		
			03:30 to 04:30	**04:30 to 05:30**	**05:30 to 06:30**
1	Victoria Road near Ka Wai Man Road	Eastbound	11	15	136
		Westbound	27	37	140
2	Catchick Street between Smithfield Road and Davis Street	Eastbound	59	107	135
3	Shing Sai Road between Sai Cheung Street North and Sands Street	Eastbound	55	69	141
		Westbound	128	144	255
4	Queen's Road West between Hill Road and Wo Hop Street	Westbound	101	118	265
5	Des Voeux Road West between Water Street and Whitty Street	Eastbound	134	169	368
		Westbound	20	22	60
6	Second Street between Eastern Street and Centre Street	Westbound	35	45	89
7	Queen's Road West between New Street and Eastern Street	Westbound	129	160	276
8	Rumsey Street between Connaught Road Centre and Des Voeux Road West	Southbound	141	149	172
Total			**840**	**1035**	**2037**

From *Table 1.2*, it can be seen that the traffic flows in the hour 05:30 to 06:30 (2037 pcus) were observed to be the peak hourly traffic flows during the period between 03:30 and 06:30. Therefore the peak hourly traffic flows observed during 05:30 and 06:30 were selected and presented for the comparison.

Table 1.2 shows the comparison of the observed traffic flows during 05:30 and 06:30 and the assumed traffic flows for QRA.

Table 1.2 Comparison of Observed Traffic Flows and Assumed Traffic Flows for QRA

Location	Road Name	Direction	Observed Traffic Flows (pcu/hr)	Traffic Flows based on BDTM Model (pcu/hr)
			05:30 to 06:30	05:30 to 06:30
1	Victoria Road near Ka Wai Man Road	Eastbound	136	323
		Westbound	140	247
2	Catchick Street between Smithfield Road and Davis Street	Eastbound	135	118
3	Shing Sai Road between Sai Cheung Street North and Sands Street	Eastbound	141	588
		Westbound	255	359
4	Queen's Road West between Hill Road and Wo Hop Street	Westbound	265	476
5	Des Voeux Road West between Water Street and Whitty Street	Eastbound	368	188
		Westbound	60	268
6	Second Street between Eastern Street and Centre Street	Westbound	89	390
7	Queen's Road West between New Street and Eastern Street	Westbound	276	243
8	Rumsey Street between Connaught Road Centre and Des Voeux Road West	Southbound	172	280

As seen from *Table 2.2*, most of the observed traffic data is smaller than or within ± 10% of the assumed traffic data adopted in the QRA except for the traffic flows at Location 5 - Des Voeux Road West between Water Street and Whitty Street. It is possibly due to the unexpected high and frequent red minibus westbound trips on Des Voeux West during early morning.

In view of the findings of the traffic survey, the observed traffic data for the following locations were used for the study:

- Location 2: Catchick Street between Smithfield Road and Davis Street;
- Location 5: Des Voeux Road West between Water Street and Whitty Street for refinement of the QRA;
- Location 7: Queen's Road West between New Street and Eastern Street.

Annex E

Use of Explosives - Frequency Assessment Details

CONTENTS

E1 ESTIMATION OF NUMBER OF BLASTS FOR WIL

A total of about 5,660 blasts has been estimated for the West Island Line (WIL) project, based on a review of the Maximum Instant Charge (MIC) profile and layout design for the alignment. The breakdown along the WIL sections is summarized as below.

Table 1.1 Numbers of Blasts for the West Island Line

Section of Alignment	No. of sector per face	No. of Blasts
Sai Ying Pun (SYP) Station & Adits	6 sectors	811
	4 sectors	186
	1 sector	372
University (UNV) Station & Adits	6 sectors	868
	4 sectors	505
	1 sector	493
Running Tunnels	6 sectors	90
	4 sectors	2,184
	Total for WIL Alignment	**5,509**
Mass Transit Railway Corporation (MTRC) Explosives Magazine	6 sectors	113
	1 sector	36
	Total for WIL Project Magazine	**149**
	Total for WIL Project	**5,658**

E2 FREQUENCY ASSESSMENT OF SCENARIOS LEADING TO HIGHER GROUND VIBRATION AT A BLAST FACE

E2.1 HIGH-LEVEL FAILURE MODE ANALYSIS FOR USE OF EXPLOSIVES

A high-level failure mode effect analysis was carried out to systematically identify failure scenarios associated with use of explosives for the construction of the tunnel and adits. The analysis focused on those failure modes that could lead to potential increase in ground vibration, given consideration of human errors and other causes. The worksheets are enclosed in *Attachment F1*.

The following failure modes were identified and further investigated in the subsequent sections.

1. Face freeze caused by cut failure

2. Two MIC detonated at the same time at a blast face

3. Multiple MIC detonated at the same time at a blast face

4. More cartridged sticks/ bulk emulsion explosives loaded into a production hole than required

5. Unforeseen ground condition

Fault tree analysis was then carried out, as described in *Section E2.3* to assess the casual relationship amongst the failure modes and causes, and evaluate the probability of occurrence for each failure scenario that could lead to higher ground vibration.

E2.2 ASSUMPTIONS FOR FREQUENCY ASSESSMENT

The following assumptions were made for assessing the probability of occurrence for the failure scenarios associated with the use of explosives:

- An analysis of cross section areas for typical section for station caverns, tunnels and rock adits was carried out to determine the typical design of the blast faces to facilitate the frequency assessment (see *Section E1*). Typical faces of 6 sectors, 4 sectors and 1 sector (bench blasting) were analysed.

  No more than 4 numbers of same time delay detonators for production holes have been imposed as a design constraint for a blast face having more than 1 sector. It is not possible to have more than one time delay detonators with the same delay time within production holes located in the same sector unless there has been an erroneous permutation, connection or manufacturer defects. It is therefore not consider possible to get more than 4 MIC in any blast with 4 or 6 sectors due to erroneous permutation or connection because of the design constraint.

- Delay surface connectors will be used to provide external time delay to different sectors so that each sector will be detonated in sequence. If an external surface connector fails completely, the explosion sequence will stop onwards.

- There are two connection arrangements from detonators to bunch blocks (ie 0 ms surface connector). One of them is to use detonating cord to bundle all detonators in a sector and then connect the detonating cord to a surface connector. Another arrangement is to connect detonators to a ring of detonating cord which will connect to the surface connectors. It was assumed that ring firing will not be permitted as a restriction.

- No failure modes of detonator will result in significant change in time delay with the exception of manufacture scatter out of tolerance. In case of failure modes other than manufacture defect, detonation is not expected.

- Perimeter holes are designed such that each of them will be loaded with a charge less than a MIC and multiple perimeter holes will be detonated at the same time. Long time delay detonators will be installed at the perimeter holes.

  In case there is a swap of detonators between a perimeter hole and a production hole, the perimeter hole will be blasted out earlier than expected but will have minimal effect on vibration as the charge load is lower than a MIC. For the production hole loaded with a longer time delay detonator, it will be blasted out when the outer ring comes off and no significant effect is expected.

  A minimum of two permutations are required to put two or more perimeter detonators of same time delay into the production holes of same sector, leading to multiple MIC going off together. Perimeter hole detonators require one further level of error or permutation than production hole detonators to cause multiple MIC detonated at the same time, and therefore, perimeter holes were not considered further in the frequency assessment.

E2.2.1 Face freeze caused by cut failure due to either wrong hole diameter for relief holes at cut or wrong time delay at cut

A cut is provided for each blast face to provide a void/ relief before other production holes are blasted, allowing the rock to be blasted out in a ring like sequence. Three relief holes are provided at the centre of the cut to provide relief when the 6 cut holes blast out in sequence.

In case the size or location of relief holes is not correctly drilled to an extent significantly enough to hinder sufficient relief, possible freeze of blast face may result. The reason for incorrect size or location of relief holes could be either design or drilling errors. A probability of 0.5 was assumed for such error significantly enough to cause a face freeze.

A minimum of 4 out of 6 cut holes should be blasted out in order to achieve sufficient relief for other production holes. If more than 2 cut holes cannot beblasted out due to design error, installation error, or manufacturer defect, the cut cannot be ejected to provide a void of sufficient relief before the production holes blast out. Possible freeze of blast face will result.

In the event of a face freeze, the vibration will increase by about 30% to 40% than the expected vibration for a given MIC with sufficient relief. Since the PPV correlation has considered blast under confined condition, the face freeze caused by cut failure will not contribute further increase in PPV value.

The human error probabilities associated with the face freeze caused by cut failure were calculated in *Annex F* and summarized in *Table 2.1* below. It is noted that the probabilities were derived for each occasion that the task is undertaken. Therefore, the number of cut holes in a face (ie 6 numbers) needs to be considered for deriving the human error probability for wrong installation of detonator (ie Event 1.3.1) per face.

Table 2.1 Human Error Probabilities for Cut Hole Error

Event/ task no.	Description	Human Error Probability for a face
1.1	**Wrong design of hole diameter/location for cut**	
1.1.1	Design error by Blasting Engineer and failure of design check	1.92e-02
1.1.2	Failure to detect and correct error by Resident Engineer, Mines Division and Shotfirers	2.76e-05
1.2	**Wrong location of drilling or incorrect drill size used**	
1.2.1	Operator fails to drill correctly	2.26e-02
1.2.2	Failure to detect and correct error by Blasting Engineer and Shotfirer	1.72e-03
1.3	**Detonator is installed incorrectly**	
1.3.1	Wrong installation of one detonator by the Shotfirer	3.01E-06
1.3.2	Shotfirer fails to detect and correct that there are holes without detonators left in the face	2.79e-02

The probability of manufacture defect of detonators leading to wrong time delay or no detonation is discussed in *Section E2.2.2 Bullet c*.

E2.2.2 Two MIC detonated at the same time at a blast face

More than one MIC detonated at the same time in a face will result in higher vibration than the design limit. A total of 6 failure modes leading to two MIC detonated at the same time were identified in the high-level failure modes analysis. They were analysed as below.

a) Wrong design of time delay

The cross-sections for station caverns, tunnels and adits are typically the same amongst each of them. A standard and typical blast plan can therefore be developed for each cross-section layout.

The typical blast plan will contain those information that are applicable for all blast faces of same layout and dimension, these include layout and dimension of the blast face, number of production holes, demarcation of sectors, location of cut, type and number of delay detonators. The typical blast plan can then be customized to accommodate face-specific details such as the co-ordinates of the holes, loading of each perimeter hole, MIC for holes, and sensitive receiver, to meet the location specific blasting constraints.

As mentioned previously, the detonators in the same sector will have different time delay while the delay surface connectors will provide external time delay for different sectors to ensure no 2 detonators will set off at the same instant of time in a face. For a design error such that two same time delay detonators are provided in the same sector or incorrect time delay surface connector are specified, two MIC may detonate at the same time.

The human error probabilities associated with the wrong design of time delay were calculated in *Annex F* and summarized in *Table 2.2* below.

Table 2.2 ***Human Error Probabilities for Wrong Design of Time Delay***

Event/ task no.	**Description**	**Human Error Probability for a face**
2.1	**Wrong design of time delay for a face**	
2.1.1	Design error by Blasting Engineer and failure of design check	1.92e-02
2.1.2	Failure to detect and correct error by Resident Engineer, Mines Division and Shotfirers	2.76e-05

b) One detonator wrongly put into one sector which contains the same time delay detonator

The detonators of same time delay will be installed in separate sectors to ensure no 2 detonators will set off at the same time in a face. In case 1 detonator is wrongly put into a sector which contains the same time delay detonator during the blast face set up, 2 MIC will be set off at the same time.

The potential causes that will lead to wrong detonator put into one sector which contains the same time delay detonator are listed below:

- Incorrect detonators are delivered to site and Shotfirer fails to detect during the label check before and after the installation
- The Shotfirer marks the delay number of holes at the face incorrectly
- Shotfirer fails to check the detonator labels before and after installation
- Shotfirer picks up the right detonator but incorrectly puts in an adjacent sector

For most of these errors, they can easily be detected later in the installing process since a detonator which supposes to go into the sector will be found left over and there is an empty hole in other sector which still needs to be installed with a detonator, given that exact amount of detonators needed for a blast will be delivered to site.

The human error probabilities associated with putting a detonator into a wrong sector were calculated in *Annex F*. However the probabilities were derived for the occasion that the task is undertaken. In order to derive the human error probabilities per face, the number of production holes in a face needs to be considered for those action tasks detailed in *Annex F*.

Generally about 70% of the holes at a typical blast face with 4 or 6 sectors are production holes while the rest are perimeter holes. It was therefore assumed 90 production holes for a blast face with 6 sectors and 60 production holes for a face with 4 sectors. For a blast face with 1 sector (bench), 40 production holes were assumed. The details are summarized in *Table 2.3* below.

Table 2.3 Number of Holes per a Blast Face

Sectors per Blast Face	No. of Holes in Face	Number of Production Holes for Frequency Assessment
6	80-130	90
4	65-80	60
1	30-35	40

The human error probabilities associated with putting a detonator into a wrong sector on a per face basis is presented in *Table 2.4* below.

Table 2.4 Human Error Probabilities for Wrong Design of Time Delay

Event/ task no.	Description	Human Error Probability for a face		
		6-Sector face	4 sector face	1-sector face
2.2	**Detonator put into wrong hole**			
2.2.1	Delivery of incorrect detonators from the magazine to the blast site	2.10E-06	2.10E-06	2.10E-06
2.2.2	Installation of one detonator by Shotfirer into a sector already containing a detonator of that delay period	4.91E-05	3.27E-05	2.18E-05
2.2.3	Shotfirer fails to check and correct installation error	2.79E-02	2.79E-02	2.79E-02

The human error probability for delivering incorrect detonators from the magazine to the blast site (Event 2.2.1) without notice by Shotfirers on site, ie failure of label check before and after installation of detonator at the same time (task step no. 2.2.2-5 and 7 in *Annex F*), was estimated as 1.14E-12. This is comparatively negligible to Event No. 2.2.2 and hence delivery error was not considered further in the frequency assessment of this failure mode.

For a 6-sector blast face, the 5th and 6th sector will start with a longer time delay, ie even though a detonator is installed in a wrong sector, it may go to a 'safe' sector which does not contain the same time delay detonator. A probability of unsafe sector was assumed as 0.5 (ie 3 out of 6 sectors).

For a 4-sector blast face, all wrong sectors will contain the same time delay detonator, the probability of unsafe sector is 0.75 (ie 3 out of 6 sectors).

For a 1-sector (bench) blast face, only one type of time delay detonators (usually 500 ms) will be used. This failure mode is therefore not applicable for 1-sector blast face.

c) Incorrect timer default of detonators due to manufacture defect

The detonators of different time delay are produced in batches. Systematic errors, such as wrong labeling of detonators and chemical scatter out of tolerances, affecting whole batch of detonators will be readily detected by the destructive product sample tests.

However, random failure for individual off-spec detonator exceeding chemical delay tolerance or wrong labelling of individual detonator may not be detected by the sample tests. The manufacture defect for detonators was therefore considered as one of the potential cause leading to 2 MIC detonated at the same time.

A manufacturer who produces about 50 millions detonators/ surface connectors in a year has confidentially reported a failure probability of 1 in a 100,000 detonators/ surface connectors. Most of them relate to the distortion of the aluminum shell tube which can be detected by visual inspection. It was assumed that 1% of the failure mode is incorrect timer default or wrong labeling such that it will coincide with one another in the same sector. It is noted that this 1% factor will not be applied to the manufacturer defect causing wrong time delay in cut since no detonation could also cause cut error.

The probability of manufacturer defect of one detonator for a blast face is presented in *Table 2.5* below.

Table 2.5 Probability of Manufacturer Defect of One Detonator for a Blast Face

Sectors per Blast Face	Probability of Manufacturer Defect of One Detonator for a Blast Face
6	9E-06
4	6E-06
1	4E-06

The probability of manufacturer defect was assumed as 0.01 for each additional defective detonator to consider potential common cause for conservative purpose.

d) Surface connector fails to provide necessary delay

Surface connectors of 0ms, 9 ms and 17 ms will be used for a face with 4 and 6 sectors, 0 ms, 17 ms and 42 ms will be used for 1 sector. The numbers required are summarized below.

Table 2.6 Number of Surface Connector per Face

Time Delay of Surface Connector	Sectors per Face		
	6 Sectors	4 Sectors	1 Sector
0 ms	6	4	1
9 ms	1	1	-
17 ms	4	2	n/2 (Note 1)
42 ms	-	-	n/2 – 1 (Note 1)
Note 1: Where n is the number of blast holes in a face			

In order to assess potential failure modes of manufacturing defects leading to multiple MIC going off at the same time, the design for surface connectors was examined as below.

A surface connector consists of an aluminum shell, a neoprene sealing plug, shock tube, a pre-case tube of chemical delay element, primary explosive, secondary explosive and a moulded plastic outer body.

The dimensions and appearance of the aluminum shell, neoprene sealing plug, primary explosive and shock tube are the same for all types of time delay surface connectors. The differences amongst different types of time delay surface connectors are listed:

- The delay elements are contained in pre-cast tube, which will be assembled into the aluminum shell at the production line for all time delay surface connectors except 0 ms. The length of delay elements and compression/ compaction ratio of the delay elements within the cast tube will vary depending on the necessary time delay to be achieved. The same type of surface connectors will have the same length and compression/ compaction ratio but these parameters are within tolerance level due to the inherent scatter in delay elements.

  The delay chemical is a medium to propagate the shock from the shock tube through to the primary and secondary explosives in a pre-determined time period (delay) within the surface connectors. In case the chemical delay is empty in the pre-cast tube, the shock will not propagate to set off the detonators/ surface connectors connected to it. Hence, no failure modes of 9 ms, 17 ms or other time delay surface connectors will lead to detonation at 0 ms time delay.

- The secondary explosive charge for 0ms surface connectors is about 0.300 grams which is strong enough to set off detonating cord. The secondary explosive charge for other time delay surface connector is about 0.1 grams which can only set off a maximum of 8 shock tubes from detonators at the same time. Even when the chemical delay tube is put into a 0 ms surface connector by error, the neoprene sealing plug cannot be securely installed. Hence, no failure modes of 0 ms surface connector will lead to detonation at certain time delay.

Potential manufacturer defects that could lead to multiple MIC going off at the same time could therefore be incorrect labeling of a 0 ms detonator as 9 ms, 17 ms or other time delay, or chemical scatter out of tolerance for surface connectors other than 0 ms. Systematic errors, such as wrong colour coding of surface connectors and chemical scatter out of tolerances, affecting whole batch of surface connectors are expected to be detected by the destructive product sample tests. However, random failure for an individual off-spec surface connector or wrong colour coding of an individual surface connector could be possible given the sampling nature of the destructive tests.

Similar to the discussion under *Bullet c)* of this *Section E2.2.2*, the probability of manufacturer defect of one surface connector was assumed as 1% of a base probability of 1 in a 100,000.

The probability of manufacturer defect of one surface connector for a blast face is presented in *Table 2.7* below.

Table 2.7 Probability of Manufacturer Defect of One Surface Connector for a Blast Face

Sectors per Blast Face	No. of Time Delay (excluding 0 ms) used per face	Probability of Manufacturer Defect of One Surface Connector for a Blast Face
6	5	5E-07
4	3	3E-07
1	39 (assuming 40 production hole on a face)	3.9E-06

The probability of manufacturer defect was assumed as 0.01 for each additional defective surface connector to consider potential common cause for conservative purpose.

e) One detonator of a sector connected wrongly to a surface connector of another sector (mis-wiring)

The detonators of a sector will be bundled by a detonating cord which will then be connected to a 0ms surface time delay surface connector. In case one detonator of a sector is bundled wrongly to another sector which contains the same time delay detonator, 2 MIC will detonate at the same time.

Considering the possibility that the detonator tube may be incorrectly connected to either 0 ms or 9/17 ms time delay surface connectors of another sectors directly, the probability of 'safe' sector was not applied.

The human error probabilities associated with detonator of one sector wrongly connected to a surface connector of a different sector were calculated in *Annex F*. As mentioned before, the probabilities were derived for each occasion that the task is undertaken. In order to derive the human error probabilities per face, the number of production holes in a face needs to be considered for those action tasks detailed in *Annex F*.

The human error probabilities associated with the connecting a detonator into to a wrong sector on a per face basis is summarized in *Table 2.8* below.

Table 2.8 Human Error Probabilities for Connection of a Detonator to a Wrong Surface

Event/ task no.	Description	Human Error Probability for a face		
		6-Sector face	4 sector face	1-sector face
2. 3	**Detonator of one sector wrongly connected to a surface connector of a different sector**			
2.3.1	Shotfirer misconnects one detonator to the wrong surface connector	7.25E-01	4.85E-01	3.25E-01
2.3.2	Failure to detect and correct connection error	1.44E-04	1.44E-04	1.44E-04

For a 6-sector blast face, the 5th and 6th sector will start with a longer time delay, ie even though a detonator is connected to a wrong sector, it may connect to a 'safe' sector which does not contain the same time delay detonator. A probability of unsafe sector was assumed as 0.6 (ie 3 out of 5 wrong sectors).

For a 4-sector blast face, all wrong sectors will contain the same time delay detonator, hence the probability of unsafe sector is 1.

For a 1-sector (bench) blast face, misconnection of several detonators to one surface connector leading to more than 1 MIC detonated at the same time is possible, since a surface connector can connect upto a maximum of 8 detonators. This failure mode is therefore considered applicable for blast faces with 1 sector.

f) Use of a wrong surface connector

Different time delay surface connectors are provided with unique colour coding. The colour coding system (see *Table 2.9*) is universal amongst all manufactures in the world. The permutation of surface connection error of surface connectors can be easily spotted during the final hook up check.

Table 2.9 Colour Coding of Surface Connectors

Time Delay of Surface Connector	Colour
0 ms	Dark green/ purple
9 ms	Brown
17 ms	Yellow
42 ms	White

A number of failure modes were analysed as below with regard to use of a wrong surface connector, these include

- Blast faces with 4 or 6 sectors
  - Not all permutation cases between 9 ms and 17 ms will lead to 2 MIC detonated at the same time. 3 permutation cases are anticipated for blast face with 6 sectors, and 1 permutation case is anticipated for blast face with 4 sectors that will lead to 2 MIC detonated at the same time.
  - Permutation between 0 ms and 9 ms within a sector or 0 ms and 17 ms within a sector will not able to set off the sector in concern and other

sectors in subsequent sequence. However, in case three 0 ms are connected to each other sequentially (ie 0ms from other sector swap with 9/17 ms of another sector), 2 MIC will detonate at the same time. 5 permutation cases are anticipated for blast face with 6 sectors, 3 permutation cases for blast face with 4 sectors, 1 permutation case for blast face with 1 sector, that will lead to 2 MIC detonated at the same time.

- Connection of 0ms surface connector to 0ms or 9/17 ms surface connectors of other sectors additionally to the one it supposed to connect to, will also lead to 2 MIC detonated at the same time. This failure mode does not deal with permutation of surface connectors. Even single connection error will lead to 2 MIC detonated at the same time. However, this is the most obvious error which is easily detected during final hook up check.

- Similar to the discussion under *Bullet b)* of this *Section E2.2.2*, the human probability for delivery of wrong surface connectors are not a significant issue as color coding check will be carried out prior to installation. The human error probability for delivering incorrect surface connectors from the magazine to the blast site (Event 2.2.1) without notice by Shotfirers on site, ie failure of color coding check before installation and correction before final hook-up check (task step no. 2.4.1-1and 2.4.2-2 in *Annex F*), was estimated as 1.32E-08. This is comparatively negligible to Event No. 2.4.1 and hence delivery error was not considered further in the frequency assessment of this failure mode for blast faces with 4 or 6 sectors.

- The human error probabilities associated with the use of wrong surface connector on a per occasion basis were calculated in *Annex F.* The number of surface connector in a face was considered for those action tasks detailed in *Annex F* to derive the human error probabilities on a per face basis, see *Table 2.10* below.

Table 2.10 Human Error Probabilities for Use of a Wrong Surface Connector (4/6-Sector Faces)

Event/ task no.	Description	Human Error Probability for a face	
		6-Sector face	4 sector face
2.4	**Shot Firer uses a wrong surface connector**		
2.4.1	Wrong installation of surface connector	1.62E-02	1.03E-02
2.4.2	Shot firer fails to detect and respond	4.24E-02	4.24E-02
2.4.3	Failure to detect and respond during final hook-up check	1.19E-04	1.19E-04

- Blast faces with 1 sector
  - Any permutation between 0, 17 and 42 ms surface connectors will not lead to two MIC detonated at the same time. However, if a 0 ms surface connector is delivered instead of a 17/42 ms and this error is not detected and then the 0ms is used in the installation, 2 MIC detonated at the same time will occur. The delivery errors are required to be considered instead of Event 2.4.1 and 2.4.2 for blast face with 1 sector. The human error probabilities on a per face basis are shown in *Table 2.11* below.

Table 2.11 Human Error Probabilities for Use of a Wrong Surface Connector (1-sector Faces)

Event/ task no.	Description	Human Error Probability for a face
2.4	**Shot Firer uses a wrong surface connector**	
2.2.1	Wrong delivery of surface connector	2.10E-06
2.4.1-1	Shot firer fails to check surface connector colour before use	2.95E-02
2.4.2-2	Shot firer fails to correct wrong connection	5.54E-03
2.4.3	Failure to detect and respond during final hook-up check	1.19E-04

E2.2.3 Multiple MIC detonated at the same time at a blast face

As discussed above, no more than 4 numbers of same time delay detonators will be put into a face as a design constraint. Hence, maximum 4 holes detonated at the same time are considered for face with 4 or 6 sectors.

The failure mode analysis considers simply the multiple failures of the same types of failure modes identified for 2 MIC detonated at the same time above, for example, 3 detonators wrongly put into one sector which contains the same time delay detonator. In actual, combinations of these failure modes will also lead to 4 MIC detonated at the same time. These were analysed further with the assistance of fault tree analysis detailed in *Section E2.3*.

Nevertheless, in case there are design errors not readily detected by the robust design check or more number detonators which have time delay coinciding with the ones already in the face due to manufacturer defect, it is possible to have more than 4 MIC detonated at the same time. See *E2.3.3* for further discussion.

E2.2.4 More bulk emulsion explosives loaded into a production hole than required

There are three causes that will lead to more bulk emulsion explosives loaded into a production hole than required:

- Wrong density check of bulk emulsion
  - Density checks will be carried out by the truck operator, with results verified by Chief Shotfirer and Blasting Engineer, prior to loading of bulk emulsion into holes, in the middle of loading and towards end of

loading. In case the results read low density but the density is actually high due to human error or mechanical failure of instruments, more than required bulk emulsion will be loaded into the holes. Considering the MIC profile of WIL, the density of the bulk emulsion and pull length of blasts, the holes will be overloaded with double MIC in worst case.

The gassing flow meter and scales used for the density checks will be calibrated by certified bodies once every year. The failure rate of erratic output for flow meter is 2.78E-06 per hour based on OREDA [1]. It was assumed that the usage of the truck (which can act as proof tests of the flow meter) is at least once every week. The probability of failure of the flow meter was evaluated to be 2.4E-04 (ie 2.78E-6 x 168 hours/2). No reported failure data for scales are available in generic datasource. The probability of failure of the scales was assumed to be the same as flow meter. This value is considered conservative based on the engineering judgment by the Blast Expert who did not observe such failures in his past experience (ie more than 12,000 blasts).

- Truck operator, Shotfirer, Blasting Engineer do not realise holes are overloaded
  - In case the truck operator inputs incorrect revolutions of bulk emulsion loading pump (note that each revolution of pump will deliver a certain amount of bulk emulsion) into PLC or Shotfirer puts mark on hose in the wrong place, holes overload could be possible. However, a totaliser is provided on the truck to indicate the total amount of bulk emulsion delivered for a blast and the reading will be checked by Truck operator and verified by Blasting Engineer at the end of loading.
- Wrong design of MIC
  - The MIC profile has been defined for the WIL in the Blast Assessment Reports [1]-[3]. The MIC along the alignment varies with respect to the type and maximum design PPV of sensitive receivers and distance to the sensitive receivers from the alignment. Actual site blast trials will be carried out prior to full scale blasts for the whole alignment to obtain site specific details for refining the MIC values.
  - In case there are any errors in the MIC calculation, a higher charge load may be defined upto 5 kg which is the maximum MIC specified for the WIL. However, the MIC profile along the alignment basically changes gradually (the change of charge load is generally less than one charge load of the preceding location) and any sudden spike will be obviously spotted. It was therefore assumed that design error will lead to no more than double charge.

The human error probabilities associated with more bulk emulsion explosives loaded into a production hole than required were calculated in *Annex F* and summarized in *Table 2.12* below.

Table 2.12 Human Error Probabilities for Excess Emulsion Loaded into a Hole

Event/ task no.	Description	Human Error Probability for a face
3.1	**Excess emulsion is loaded into a hole**	
3.1.1	Excess emulsion is loaded due to wrong density	7.95E-11
3.1.2	Shotfirer does not realise hole is overloaded	1.09E-06
3.2	**Wrong design of MIC**	
3.2.1	Design error by Blasting Engineer	8.52E-05
3.2.2	Failure to detect and correct design error	1.06E-03

E2.2.5 More cartridged sticks loaded into a production hole than required

There are four causes that will lead to more cartridged stick loaded into a production hole than required:

- Shotfirer does not count number of cartridges he has picked up and loads too many into a hole. This will be detected towards end of the loading process as the exact amount of cartridges required for a blast will be delivered to site.

- Cartridges left over from blocked holes may be disposed of incorrectly. The Shotfirer may load additional cartridges into the lifter holes to ensure a good blast. This can be seen as a violation of procedure, although the Shotfirer will be well aware of the risks he is taking. However, the other Shotfirer and Blasting Engineer will check the cartridges leftover due to presence of blocked holes at the end of the loading process. The probability of presence of blocked holes was assumed as once every week, two blasts every day.

- The Shotfirers may not realize holes are overloaded in case there are excess amount of cartridges delivered to site, failure to check for remaining detonator bundles by Shotfirer and Blasting Engineer towards end of loading process.

  It is noted that each storage box will contain 25 kg cartridges ie 120 sticks at about 0.208 kg per stick. Generally, several full un-open boxes as a multiple of 25 kg plus loose sticks (for the balance less than 25 kg) will be delivered to site depending on the necessary amount for a face. For example, if a blast requires say 215 kg, there would be 8 full un-open box and 72 sticks to be delivered to site. In the worst case, an additional full box delivered instead of loose sticks, the overload per hole is expected to be less than 2 MIC due to the physical limitation by the hole length and diameter, and not all holes at a face will be overloaded.

- Wrong design of MIC, as discussed in *Section E2.2.5*

The human error probabilities associated with more cartridged sticks loaded into a production hole than required were calculated in *Annex F* and summarized in *Table 2.13* below.

Table 2.13 Human Error Probabilities for Excess Emulsion Loaded into a Hole

Event/ task no.	Description	Human Error Probability for a face		
		6-Sector face	4 sector face	1-sector face
4.1	**Too many cartridges are inserted in holes**			
4.1.1	SF does not count correctly and load excess cartridges into holes	6.64E-02	4.43E-02	2.95E-02
4.1.2	Cartridges from blocked holes are not disposed of correctly	8.13E-03	8.13E-03	8.13E-03
4.1.3	Shotfirers/Blasting Engineer do not realise holes are overloaded	1.69E-05	1.69E-05	1.69E-05
4.1.4	Shotfirers/Blasting Engineer do not realise blocked holes are not disposed of	1.21E-03	1.21E-03	1.21E-03
4.2	**Wrong design of MIC**			
4.2.1	Design error by Blasting Engineer	8.52E-05	8.52E-05	8.52E-05
4.2.2	Failure to detect and correct design error	1.06E-03	1.06E-03	1.06E-03

5. Unforeseen ground conditions

The MIC values derived in the Blast Assessment Reports [1]-[3] are based on site surveys carried out for sensitive receivers and will be refined using the trial blast results prior to the full scale blast process of the WIL project. A 3As (Alert-Alarm-Action) monitoring programme will also be implemented to continuously monitor any potential exceedance of 25 mm/s for every blast. All potential causes leading to increase in ground vibration level (such as deviation of geological condition from the base design) will be investigated and the root cause will be identified. It was assumed that the unforeseen ground conditions between the blast faces and the sensitive receivers will be detected by the 3As programme.

As an additional check on forward ground conditions, the geologist will drill a horizontal forward probe hole to determine rock quality in advance of the blast face (usually up to 20m in length). This will help to determine the geographical condition prior to the actual blast.

E2.3 FAULT TREE ANALYSIS

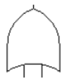
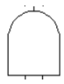
E2.3.1 Overview

Fault Tree Analysis (FTA) was used to estimate the probability of occurrence for each failure scenario identified in *Section E2.1*.

FTA is a technique widely applied to estimate the probability of unwanted events. It is a technique by which the logical relationships between the circumstances, equipment failure and human error are examined. The software package, FaultTree+, was used to construct fault trees for the estimation of probability of occurrence. FaultTree+ calculated the probability of occurrence using cutset to model multiple levels of protections, checking and review process.

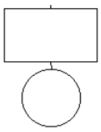
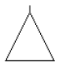
The gate symbols are listed in *Table 2.14* together with their causal relations.

Table 2.14 ***Gate Symbols for Fault Tree Models***

Gate Symbol	**Name**	**Causal Relation**	**Valid No. of Inputs**
	*OR*	Output event occurs if any one of the input events occur	≥ 2
	*AND*	Output event occurs if all input events occur	≥ 2

The event symbols used in fault tree models are illustrated in *Table 2.15* together with their meanings.

Table 2.15 ***Event Symbols for Fault Tree Models***

Event Symbol	**Name**	**Meaning**
	*BASIC*	System or component event description Basic event for which failure and repair data is available
	*TRANSFER*	Indicates that this part of the fault tree is developed in a different part of the diagram or on a different page

E2.3.2 *Fault Tree Models*

The fault tree models (see *Attachment F2*) were developed for each of the following failure scenarios associated with the use of explosives.

- Higher vibration due to cut hole error (not applicable for blast faces with 1 sector)
- 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

Modelling of Overcharge of Emulsion more than Required

Fault tree models were also developed for the following two failure scenarios. Since either bulk or cartridged emulsion will be used for a blast face, the one with higher failure probability was considered as an integral part of the above models. The overload was considered as one of the causes leading to a maximum of 2 MIC detonated at the same time as mentioned in the previous section.

- More cartridged sticks loaded into a production hole than required

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

Since the overload could be a maximum of 1 MIC or less than that, it has been considered that

- For 3 MIC case, charge overload with one error other than overload (ie 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) will lead to 3 MIC detonated at the same time.

- For 4 MIC case, either charge overload with one error other than overload, or charge overload with two errors other than overload will lead to 4 MIC detonated at the same time.

Configuration of Fault Tree Models

For the construction of the fault tree models, the number of the errors (failure modes) required and their combinations need to be considered, as shown bellow.

- One error leading to 2 MIC detonation at the same time

- Two errors leading to 3 MIC detonation at the same time

- Three errors leading to 4 MIC detonation at the same time

Therefore, the trees have been constructed in such a way that:

- For 3 MIC case, the two errors could be of the same type or different types.

- For 4 MIC case, the three errors could be 3 of same types, or 2 of same type + 1 different type, or 3 of different types. In addition, it has been assumed that "Overcharge of emulsion more than required" plus 1 error other than overcharge will lead to 4 MIC detonation at the same time, as discussed above.

Potential Dependency of Human Errors

In order to consider potential dependency of human errors, the probability of the second human error of the same type was conservatively assumed as 0.01. Taking Event 2.2 for example, if the human error probability for installation of a detonator into a wrong hole is 2.10E-06 for a 6-Sector face, the human error probability for installation of another one detonator into a wrong hole will be 0.01.

E2.3.3 *Modelling Results*

The modelling results are summarised in *Table 2.16*.

Table 2.16 Probability of Occurrence per Face

Scenarios	Probability of Occurrence Per Face 6 Sectors	4 Sectors	1 Sector
Higher vibration due to cut hole error	1.97E-05	1.97E-05	-
Higher vibration due to 2 MIC detonated at the same time	7.53E-05	7.89E-05	5.65E-05
Higher vibration due to 3 MIC detonated at the same time	2.10E-07	2.46E-07	9.95E-08
Higher vibration due to 4 MIC detonated at the same time	1.34E-09	1.25E-09	1.04E-09
Others			
More cartridged sticks loaded into a production hole than required	1.91E-06	1.54e-06	7.89E-07
More bulk emulsion explosives loaded into a production hole than required	1.24E-06	1.24E-06	1.24E-06

As shown in *Table 2.16*, the probability of occurrence for overload of bulk emulsion into holes is higher than that for overload of cartridged sticks into holes. The overload of bulk emulsion was therefore considered in the models for the failure scenarios of more than 1 MIC detonated at the same time.

Table 2.16 shows that the probability of occurrence of multiple MIC detonated at the same time will generally reduce as additional error is required to result in one more MIC going off together.

As mentioned in *Section E2.2.3* above, if there are design errors not readily detected by the robust design check or more number detonators which have time delay coinciding with the ones already in the face due to manufacturer defect, it is possible to have more than 4 MIC detonated at the same time. Considering the probability of each additional error for either design or manufacturing of detonator is 0.01, the occurrence probability for each additional MIC detonated at the same time will be roughly 2 order of magnitude lower each time, ie the occurrence probability for 5 MIC detonated at the same of 10^{-11} per face, that for 6 MIC detonated at the same time will be in the order of magnitude of 10^{-13} per face, that for 7 MIC will be in the order of magnitude of 10^{-15} per face.

It was conservatively assumed that the occurrence probability of 5 and 6 MIC detonated at the same time will be the same as that for 4 MIC detonated at the same time for hazard assessment purpose. For detonation of more than 6 MIC at the same time, the derived frequencies are very low, ie negligible and hence will not be considered further.

E2.4 *OVERALL FREQUENCY FOR FAILURE SCENARIOS*

The overall frequency of failure scenarios leading to higher vibration for the whole WIL project are summarised as below. It may be noted that blasting will be spread over a few years.

Table 2.17 Overall Frequency for Failure Scenarios leading to Higher Vibration for the Whole Project

Sections	Blast Linear Length	Occurrence Frequency for multiple MIC detonated at the same time per Section (Occurrence per project)				
		2MIC	**3MIC**	**4MIC**	**5MIC**	**6MIC**
WIL Alignment	9.3 km	4.09E-01	1.16E-03	6.86E-06	6.86E-06	6.86E-06
WIL Magazine Store	0.4 km	1.05E-02	2.73E-05	1.89E-07	1.89E-07	1.89E-07
Overall for WIL project	**9.7 km**	**4.19E-01**	**1.19E-03**	**7.05E-06**	**7.05E-06**	**7.05E-06**

Notes: The Blast Linear Length refers to the total pull length by the drill and blast operation. For the WIL alignment, the blast linear length includes the two running tunnels, two station blocks and associated adits. For the WIL Magazine Store, the blast linear length covers the access tunnel and 9 niches.

E2.5 CONSERVATISM BUILT INTO THE FAULT TREE ANALYSIS

The following conservatism have been built into the models, these include:

- The probability of 5 or 6 MIC detonated at the same time was assumed to be the same as that of 4 MIC detonated at the same time.

- The estimation of the probability of the overload of cartridges into holes does not take credit that the amount of over-delivery or number of blocked holes in a face is limited. In addition ,the probability of a hole being overloaded and at the same time it has a detonator of same time delay being misplaced have not been taken into consideration. The maximum overload of a hole could be 1 MIC or less depending on the charge length and load. It was however conservatively considered both cases in the fault models.

- A surface connector once connected to appropriate detonators/ surface connectors, it will be wrapped by tapes to prevent accidental connection with other detonators/ surface connectors. It is therefore seldom to have multiple wrong connections to a surface connector at a time. This has not been taken into consideration into the fault tree models.

- The blast faces were categorised into 6-sector, 4 sector or 1-sector faces in the study, however the number of the production holes varies depending on the cross-sectional area of a face. The biggest cross-section, ie the maximum number of production holes, of the same face category was assumed for the study.

E3.1 *INCIDENT DATA IN HONG KONG*

E3.1.1 *Territory-wide Data*

According to the Hong Kong SAR Government's Annual Controlling Officers Report, there were 36,062 blasts carried out between 1997 and 2007 (see *Table 3.1*).

Table 3.1 ***Tonnes of Explosives Consumed and Number of Blasting Activities (1997-2007)***

Year	Tonnes of Explosives Consumed	No. of Blast Faces
1997	4,172	2,493
1998	3,600	4,865
1999	2,790	8,350
2000	3,250	6,880
2001	2,120	2,164
2002	1,792	1,770
2003	2,083	1,503
2004	2,339	3,409
2005	2,627	3,053
2006	876	711
2007	943	864
Total	**26,592**	**36,062**

A summary of the incidents that had taken place during these 36,062 blasts is presented in *Table 3.2*. It can be seen that 6 incidents are associated with flyrock, while one incident relates to blast induced slope failure. All these incidents had occurred from surface blasting and hence not applicable to this study.

Table 3.2 ***Summary of Blasting Incidents (1997 - 2007) [Note 1]***

Year	Date	Site	Incident type / Probable Causes [Note 2]	Consequence
1997	4-Dec-97	Sau Mau Ping, Kowloon	Blast induced slope failure	No injury or damage. Road blocked.
1999	9-Jul-99	Sau Mau Ping, Kowloon	Flyrock (250m)	Injury to 1 person
	14-Sep-99	Sau Mau Ping, Kowloon	Flyrock (260m)	Injury to 3 persons and damage to properties
2001	19-May-01	Sau Mau Ping, Kowloon	Flyrock (250m)	No injury or damage
2003	17-Feb-03	Jordan Valley, Kowloon	Flyrock (115m)	Damage to properties
	6-Jun-03	Jordan Valley, Kowloon	Flyrock (230m)	Injury to 9 persons and damage to properties
	26-Jun-03	Penny's Bay, Lantau Island	Flyrock (150m)	No injury or damage

Notes:

[1] Blasting incidents are considered as cases of serious consequence such as flyrock or blast induced slope failure causing potential injuries, fatality, damage to structures, vehicles etc.

[2] Figure given within bracket is the approximate maximum flyrock distance from the blast location

All blasts for the WIL will be carried out underground, therefore, flyrock incidents are not relevant to WIL as blast doors are provided and kept closed during blasting.

The blast induced slope failure was the result of vibration impacting a water lubricated sheeting joint above Sau Mau Ping Road, which collapsed on the road. This incident may be considered as relevant to the WIL, as it was caused by ground vibration.

The probability of a blast induced slope failure can be estimated as 2.8E-05 per blast (ie once every 36,062 blasts) based on the above data. However, it is important to note that the total number of blasts in the last 10 years is only 6 times the number of blasts that will be carried out for the WIL, and therefore it is not sufficiently large enough to verify the results from the fault tree analysis.

Details of near miss incidents eg of the type discussed above, are not available, hence it is not possible to verify the assumptions here. Also details of the incident that cause slope failure is not available, hence it is not possible to determine the root cause that led to the blast induced slope failure.

If it is assumed that any failure scenario on a blast face as investigated in *Section E2* lead to this failure, then the probability of a failure will be 5.7E-05 per face assuming benching (1-sector face) blasting, based on the probability give in *Table 2.16*. The value predicted by the fault tree analysis is similar to the historical data.

E3.1.2 Tunnel Blasting Projects in Hong Kong

The territory-wide data presented in *Section E3.1* above consist of all types of blasting activities carried out in Hong Kong. Therefore, specific data for tunnel projects using drill-and-blast construction method in Hong Kong since 1995 have been scrutinised and detailed in *Table 3.3*.

It can be seen that more than 8,600 blasts has been carried out for the tunnel projects in Hong Kong, without any reported cases for vibration induced damage to buildings or slopes. Since the number of blasts are not significantly higher than the estimated number of blasts in WIL (ie about 5,660), these data are not sufficient large enough to draw any conclusion on the occurrence probability for accident scenarios for blasting.

Table 3.3 Tunnel Projects in Hong Kong since 1995

Project	Drill & Blast Tunnel Lengths (m)	Rock Blasting Quantities (m³)	From	To	No of Blasts / Rounds	No of Holes Fired	Explosives Quantities Used			Charge Weights		Blast Damage-related complaints
							High Explosives (Kgs)	Emulsion (Kgs)	Detonators (nos)	Aver (kg/delay)	Max (kg/delay)	
MTR Projects												
Airport Railway, East Lantau Tunnels	1,940	61,123	Apr-95	Feb-96	552							[Note 2]
Airport Railway, Tsing Yi Tunnels	3,550											[Note 2]
Airport Railway, Lai King Station & Tunnels												[Note 2]
QBR, North Point Station Modification & Tunnels	1,525	170,000	Jun-99	Oct-99	2,997	209,790	126,200		229,634	2.47	6.67	[Note 2]
Tseung Kwan O, Black Hill Tunnels	7,200	1,440,000	Apr-99	May-00	1,200	96,000						None
Tseung Kwan O, Pak Shing Kok Tunnels	7,200	1,440,000	Jul-99	May-00	1,200	96,000						None
Disneyland, Penny's Bay Line Tunnel	800	160,000	Jul-99	May-00	240	19,200	6,000	38,000	17,000	4.35	5.00	None
Queensway Subway at 3PP	300	65,400	Apr-04	Sep-05	300	24,000	16,438	0	72,228	0.35	0.90	None
Former KCRC Projects												
West Rail, DB-350	2,555	279,950	Nov-99	Feb-01	548	85,790	43,444	397,755	93,977	5.03	15.05	None
Highways Dept Projects												
Route 9, Eagles Nest Tunnels												[Note 2]
Route 9, Shatin Heights Tunnels	1,765	322,381	Oct-03	Jun-05	534	92,916	217,665	84,650	102,208	1.43	3.84	2 (unproven) [Note 1]
R3 Country Park (Tai Lam) Tunnels – South drive												[Note 2]
R3 Country Park (Tai Lam) Tunnels - North drive	3,700	490,000	Jun-95	Jul-98	740	134,680	26,000	715,000	135,000	30.00	55.00	None
Others												
Ocean Park	1,120	73,610	Oct-07	May-08	290	34,220	13,385	91,249	34,358	3.60	6.40	None
Total	**31,655**	**4,502,464**			**8,601**	**792,596**	**449,132**	**1,326,654**	**684,405**			

Notes:

[1] The two cases are unproven to be blast-related.

[2] No blast induced damage is considered since the reported case in *Table 3.2* is not relevant to this project.

[3] No data is available at the time this report is compiled for those entries highlighted in yellow.

E4 REFERENCES

[1] SINTEF Industrial Management, Offshore Reliability Data, 4th edition, 2002.

[2] MTR, West Island Line, Consultancy Agreement C703, SYP and UNV Stations, and SHW to KET Tunnel, Blast Assessment Report, Volume 1-8, June 2008

[3] MTR, West Island Line, Consultancy Agreement C704, KET Station and Overrun Tunnel, Modifications to SHW Station, Blast Assessment Report, Volume 1-3, July 2008

[4] MTR, West Island Line, Consultancy Agreement C703, SYP and UNV Stations, and SHW to KET Tunnel, Explosives Magazine at Victoria Road Controlling Blast Report, June 2008

Attachment E1

High-Level Failure Mode Analysis

E1 High-Level Failure Mode Analysis

No.	Failure Modes	Cause	Consequence	Detection	Potential Mitigation Measures	Remarks
1.1	Wrong hole diameter for relief holes at cut	1. Wrong design	1. Insufficient relief. Possible freeze of blast face. Increase vibration (about 30% to 40% increase in vibration than the expected vibration for a given MIC, in addition, the vibration at perimeter of a face will also increase)	1. The blasting plan is checked by blast engineer/ RE and Mines Division		
		2. Wrong location of drilling or incorrect drill size being used due to human error	1. Same as consequence for cause 1	1. Only two diameters of holes will be used. The size of relief hole is larger than cut and production holes. Hole position and diameter checked against blast plan and actual blast requirements by blast engineer/ RE and Mines Division. Obvious situation easy to detect	1. For those critical faces which have potential exceedance of acceptable PPV value in case of face freeze, consider independent check of the size of relief holes	1. Diameter of relief holes is 127mm while that for production and perimeter holes is 45mm
1.2	Wrong time delay at cut	1. Wrong design	1. The cut holes do not detonate at correct sequence and the cut cannot be ejected to provide a void for relief before the production holes detonate. Insufficient relief. Possible freeze of blast face. Increase vibration (about 30% to 40% increase in vibration than the expected vibration for a given MIC, in addition, the vibration at perimeter of a face will also increase)	1. The blasting plan is checked by blast engineer/ RE and Mines Division		
		2. Wrong installation (one detonator of longer time delay from other sector put into the cut due to human error)	1. The cut will be ejected if only one or two detonators do not detonate as required.	1. The detonator delay tag number will be checked before and after loading by Shot-Firer	1. Unfolding of the coil of detonators will be done at the late stage so label of detonator can be checked for any incorrect placement if necessary	
		3. Manufacture defect of detonators	1. Detonators does not fire or fire at a wrong time (The cut will be ejected if only one or two detonators do not detonate as required). If the wrong time delay coincides with the time delay of another detonators (ie two MIC going off together), vibration will increase	1. QA/ QC by manufacturer with certificate provided		

No.	Failure Modes	Cause	Consequence	Detection	Potential Mitigation Measures	Remarks
2.1	Two MIC detonated in phase	1. 1 detonator wrongly put into one sector which contains the same time delay detonator	1. Increased vibration due to two MIC going off together (if a shorter time delay detonator put into an outer hole ie longer time delay hole, about 30% increase in vibration)	1. The detonator delay tag number will be checked before and after loading by Shot-Firer	1. Unfolding of the coil of detonators will be done at the late stage so label of detonator can be checked for any incorrect placement if necessary	1. Due to inherent manufacture scatter, 50% chance assumed for MIC of same time delay detonated at the same time
		2. Incorrect timer default of detonators due to manufacture defect	1. Increased vibration due to two MIC going off together	1. QA/ QC by manufacturer with certificate provided		1. Same remarks for cause 1 above
						2. In addition, the defect must be such as it coincides with another detonator
		3. Surface connector fails to provide necessary delay	1. Increased vibration due to two MIC going off together.	1. QA/ QC by manufacturer with certificate provided		1. Same remarks for cause 1 above
		4. One detonator of a sector connected wrongly to a surface connector of another sector (mis-wiring)	1. Increased vibration due to two MIC going off together	1. Final hook-up check will be carried out by Blast Engineer, two Shot-Firers and Mines Department/ER after loading of emulsion. Obvious situation easy to detect	1. Unfolding of the coil of detonators will be done at the late stage so label of detonator can be checked for any incorrect placement if necessary	1. Same remarks for cause 1 above
		5. Use of a wrong surface connector	1. Increased vibration due to two MIC going off together	1. Colour coding and labelling of time delay of surface connector. Obvious situation easy to detect		1. For a face with 3 sectors, if a 17 ms is wrongly connected from 1st to 3rd sector instead from 2nd to 3rd sector, two MIC will go off together. For a face with 4 sectors, if the 9 ms is wrongly connected from 2nd to 4th sector, two MIC will go off together. For a face with 4 sectors, if the 9 ms is wrongly connected from 2nd to 4th sector, 3rd to 5th sector, or 4th to 6th sector, then two MIC will go off together.
				2. The surface connectors will be activated sequentially		
				3. Final hook-up check will be carried out by Blast Engineer, two Shot-Firers and Mines Division/ER after loading of emulsion.		
		6. Wrong design in time delay	1. Increased vibration due to two MIC going off together	1. The blasting plan is checked by blast engineer/ RE and Mines Division		

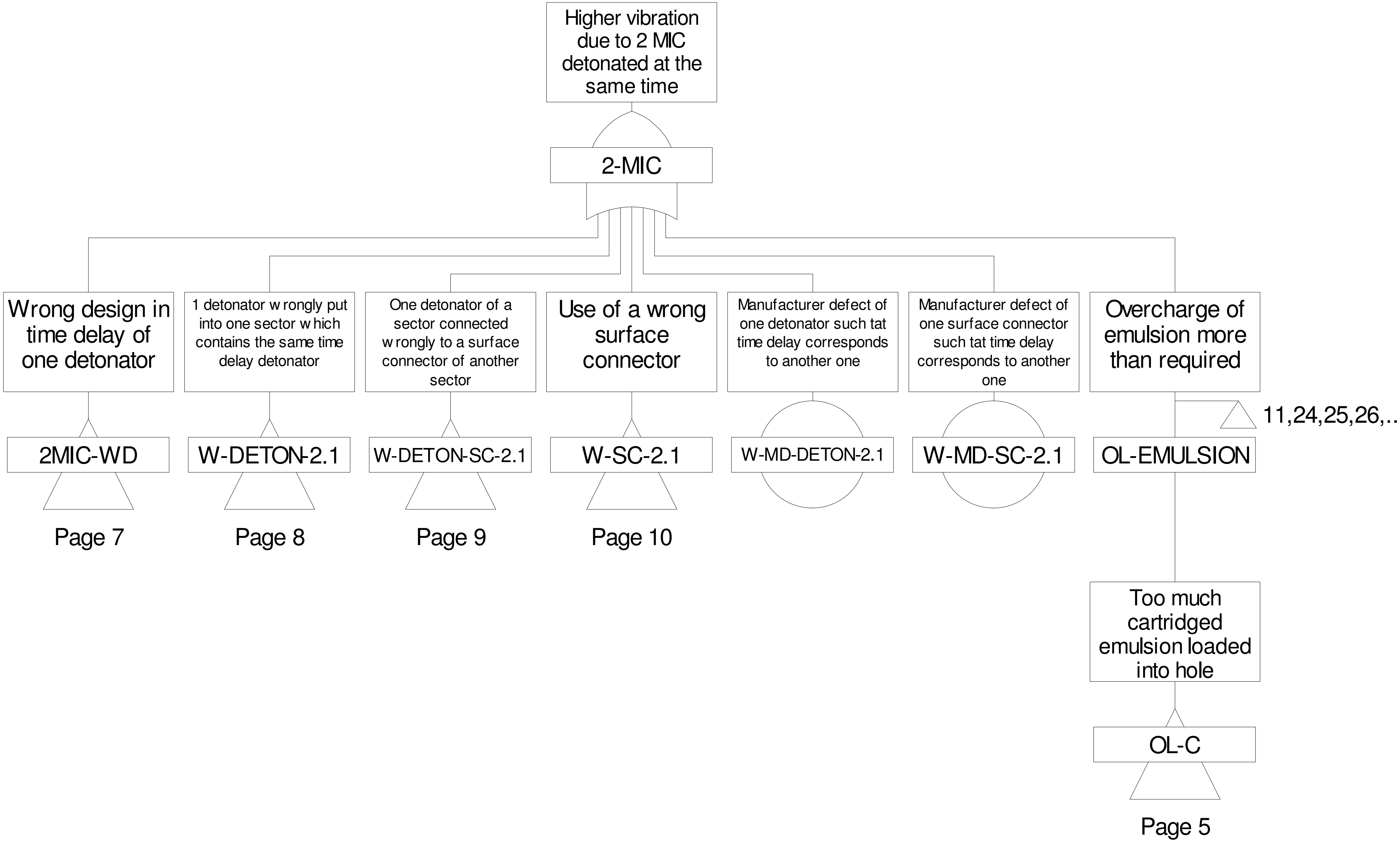
No.	Failure Modes	Cause	Consequence	Detection	Potential Mitigation Measures	Remarks
3.1	Maximum 4 holes detonated in phase (for face with 4 or 6 sectors)	1. 3 detonators wrongly put into one sector which contains the same time delay detonator	1. Increased vibration due to four MIC going off together. (if a shorter time delay detonator put into an outer hole ie longer time delay hole, about 30% increase in vibration)	1. The detonator delay tag number will be checked before and after loading by Shot-Firer	1. Unfolding of the coil of detonators will be done at the late stage so label of detonator can be checked for any incorrect placement if necessary	1. The detonator for the first blast hole in the 5th and 6th sectors has a longer time delay than other sectors. It is expected that a maximum 4 MIC of same time delay will be used for a face of tunnel
						2. Due to inherent manufacture scatter, 50% chance assumed for MIC of same time delay detonated at the same time
		2. Incorrect timer default of detonators due to manufacturer defect	1. Increased vibration due to four MIC going off together	1. QA/ QC by manufacturer with certificate provided		1. Same remarks for cause 1 above
						2. In addition, the defect must be such as it coincides with another detonator
		3. Surface connector fails to provide necessary delay	1. Increased vibration due to four MIC going off together.	1. QA/ QC by manufacturer with certificate provided		1. Same remarks for cause 1 above
		4. Same time delay detonator of other 3 sectors connected wrongly to a surface connector of a sector (mis-wiring)	1. Increased vibration due to four MIC going off together	1. Final hook-up check will be carried out by Blast Engineer, two Shot-Firers and Mines Division/ER after loading of emulsion. Obvious situation easy to detect	1. Unfolding of the coil of detonators will be done at the late stage so label of detonator can be checked for any incorrect placement if necessary	1. Same remarks for cause 1 above
		5. Use of 3 wrong surface connectors	1. Increased vibration due to four MIC going off together	1. Colour coding and labelling of time delay of surface connector. Obvious situation easy to detect		1. Not a credible case unless incorrect surface connector collected from Magazine store
				2. The surface connectors will be activated sequentially		

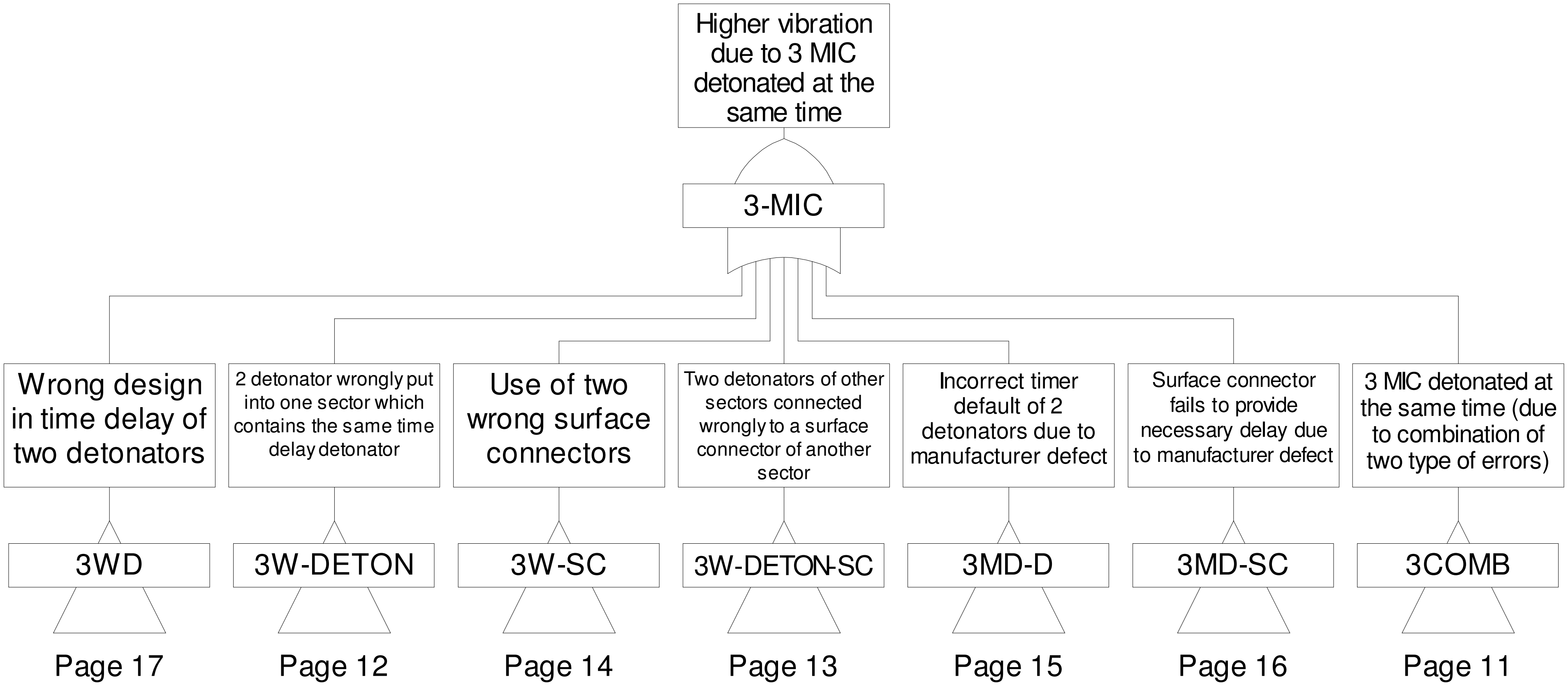
No.	Failure Modes	Cause	Consequence	Detection	Potential Mitigation Measures	Remarks
				3. Final hook-up check will be carried out by Blast Engineer, two Shot-Firers and Mines Division/ER after loading of emulsion. Obvious situation easy to detect		
		6. Wrong design in time delay	1. Increased vibration due to two MIC going off together	1. The blasting plan is checked by blast engineer/RE and Mines Division		
4.1	More cartridged sticks loaded into a production hole than required	1. Cartridges left unused since a hole cannot be loaded due to unforeseen ground condition. The cartridges are loaded into another hole due to human error	1. Increased vibration due to increase in MIC	1. Blast Engineer, Shot-Firer and Mines Division/ER will be aware that a hole cannot be loaded due to unforeseen rock condition during placement of detonators. Cartridge leftover are expected at the end of charging process. They will be removed from blast face before firing and destroyed by burning at site		1. It is unable to load more cartridge than the hole design. The maximum amount of emulsion to be loaded will be less than 33% MIC for a hole
		2. Human error in counting sticks during loading and leading to more than required cartridged sticks in a hole	1. Increased vibration due to increase in MIC	1. Total number of cartridges for a face is determined, based on design		1. Remarks same as Cause 1 above
				2. Precise number of cartridges to be used for a face will be delivered to site. Insufficient number of cartridge will be obvious towards end of loading process	1. In case excess cartridges in a hole is identified, it will be removed	
		6. Wrong MIC calculation in design	1. The calculated charge may be higher than the acceptable level that the sensitive receiver can take	1. The blast assessment report is checked by blast engineer/ RE and Mines Division		
4.2	More bulk emulsion explosives loaded into a production hole than required	1. Malfunction of totalizer on the bulk emulsion truck to check the amount of gassed bulk emulsion to a hole and the total amount to a face	1. Increased vibration due to increase in MIC	1. Loading hose of bulk emulsion will be marked for charge length prior to start of the charging process. The charge process will be ceased when mark appears out of hole	1. In case excess bulk emulsion in a hole is identified, it can be washed out. The hole will be recharged correctly	1. It is unable to load bulk emulsion than the hole design. The maximum amount of emulsion to be loaded will be less than 2 MIC for a hole

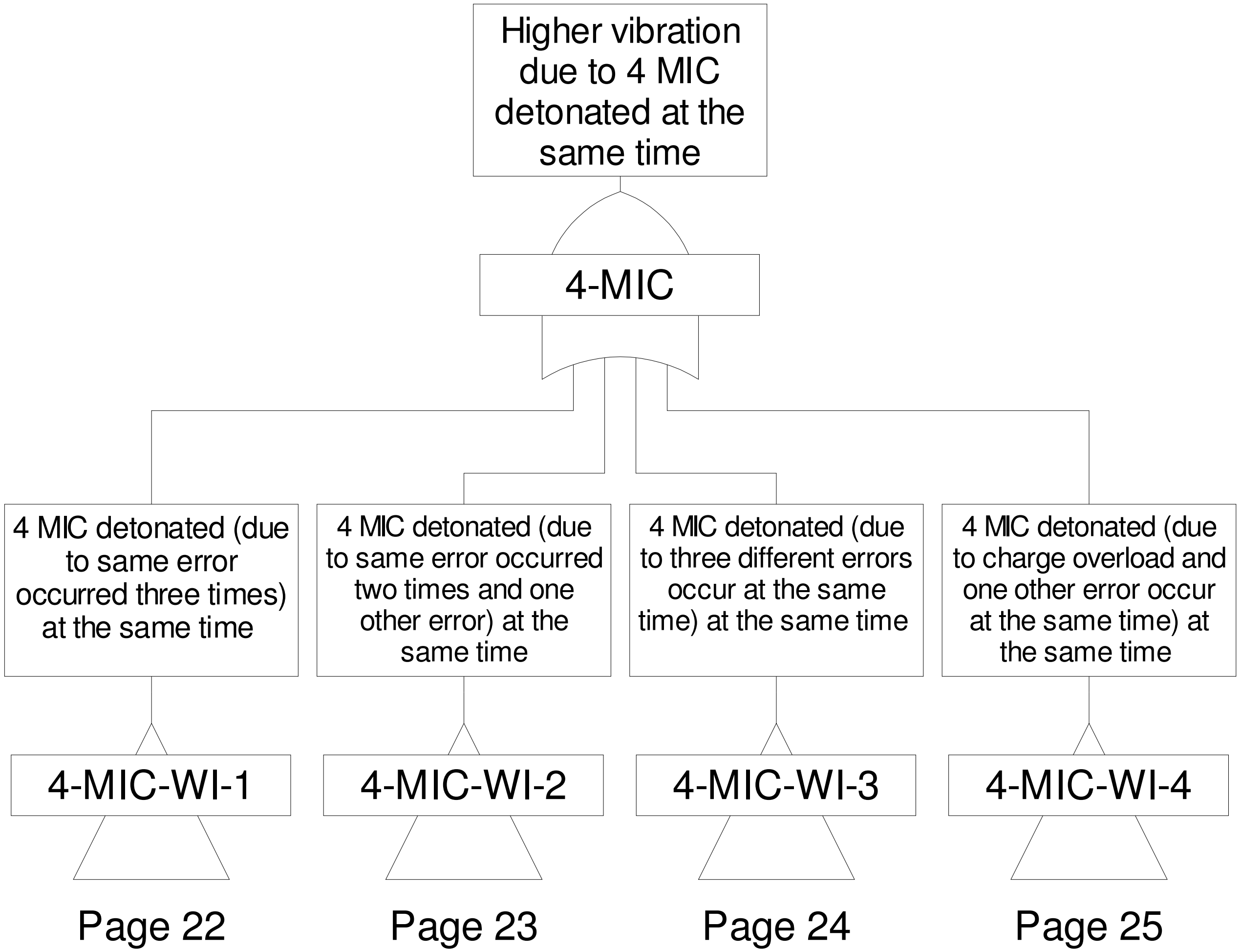
No.	Failure Modes	Cause	Consequence	Detection	Potential Mitigation Measures	Remarks
		2. Incorrect marking of the charge length on the loading hose	1. Increased vibration due to increase in MIC	2. Totalizer on the bulk emulsion truck to check the amount of gassed bulk emulsion to a hole and the total amount to a face. The density of the bulk emulsion will also be checked by the blast engineer at the start, halfway and end of the loading process to holes	1. Same mitigation measure as per Cause 1	1. Remarks same as Cause 1 above
		6. Wrong MIC calculation in design	1. The calculated charge may be higher than the acceptable level that the sensitive receiver can take	1. The blast assessment report is checked by blast engineer/ RE and Mines Division		
5	Unforeseen ground conditions	1. Inadequate site survey for the preparation of Blast Assessment Report	1. Vibration level exceed the design PPV limit for certain sensitive receiver	1. Trial blast results will be carried out prior to the full scale blast process of the WIL project to determine the blasting constant		
				2. A 3As (Alert-Alarm-Action) monitoring programme will be implemented to continuously monitor any potential exceedance of 25 mm/s for every blast. All potential causes leading to increase in ground vibration level (such as deviation of geological condition from the base design) will be investigated and the root cause will be identified. It is considered that the unforeseen ground conditions between the blast faces and the sensitive receivers will be detected by the 3As programme.		
				3. The geologist will drill a horizontal forward probe hole to determine rock quality in advance of the blast face (usually upto 20m in length). This will help to determine the geographical condition prior to actual blast.		

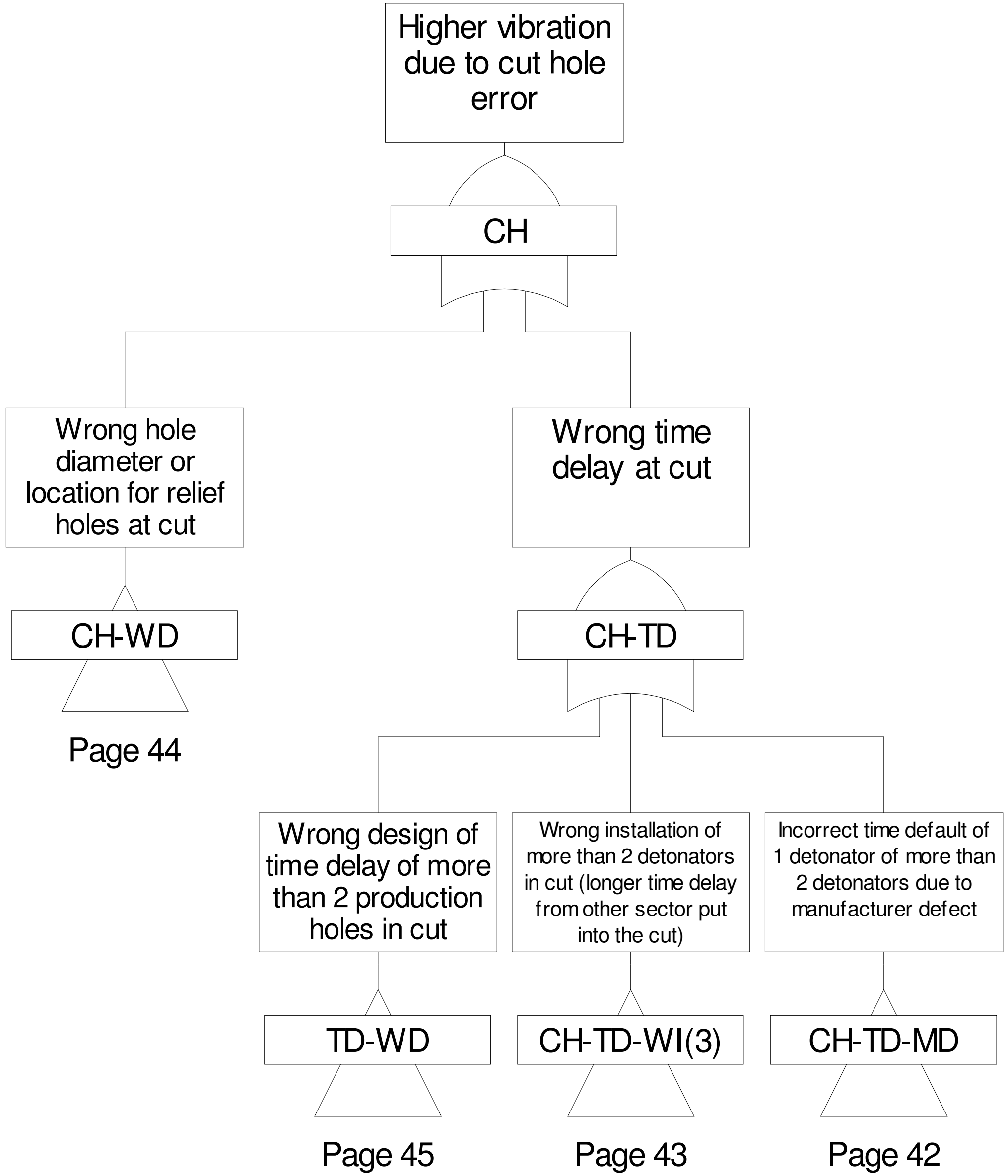
Attachment E2

Fault Tree Models for Use of Explosives

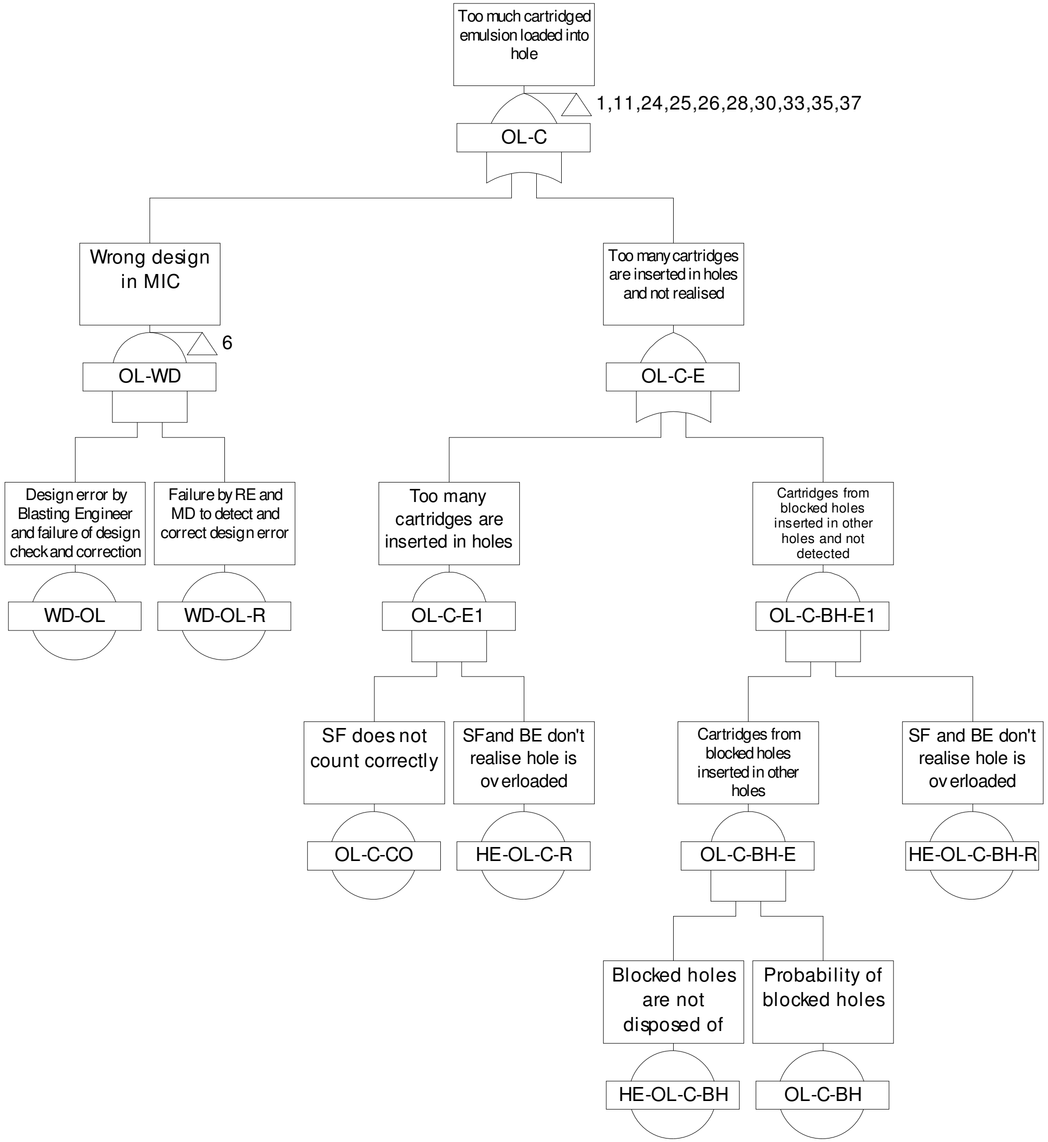

Higher vibration due to 2 MIC detonated at the same time
2-MIC
Wrong design in time delay of one detonator
1 detonator wrongly put into one sector which contains the same time delay detonator
One detonator of a sector connected wrongly to a surface connector of another sector
Use of a wrong surface connector
Manufacturer defect of one detonator such tat time delay corresponds to another one
Manufacturer defect of one surface connector such tat time delay corresponds to another one
Overcharge of emulsion more than required
11,24,25,26,..
2MIC-WD
W-DETON-2.1
W-DETON-SC-2.1
W-SC-2.1
W-MD-DETON-2.1
W-MD-SC-2.1
OL-EMULSION
Page 7
Page 8
Page 9
Page 10
Too much cartridged emulsion loaded into hole
OL-C
Page 5

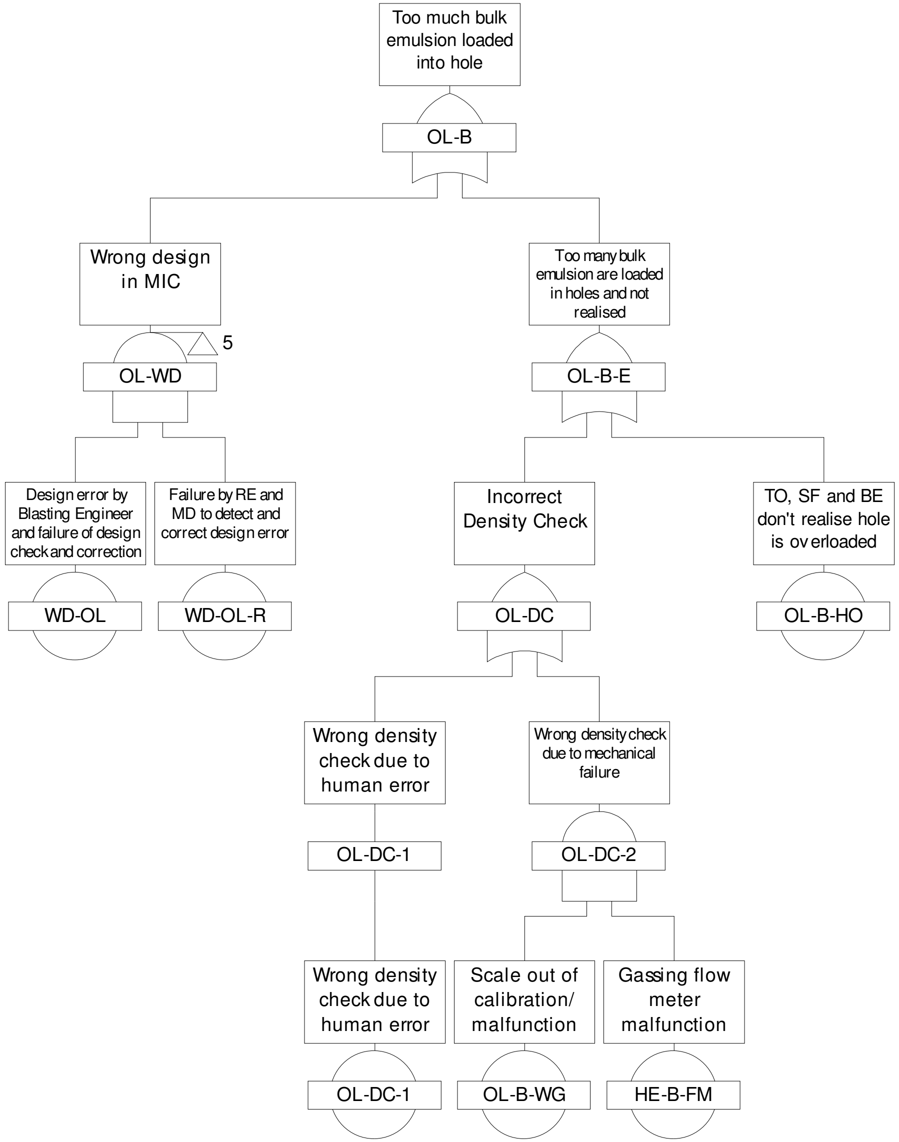

Higher vibration due to 3 MIC detonated at the same time
3-MIC
Wrong design in time delay of two detonators
2 detonator wrongly put into one sector which contains the same time delay detonator
Use of two wrong surface connectors
Two detonators of other sectors connected wrongly to a surface connector of another sector
Incorrect timer default of 2 detonators due to manufacturer defect
Surface connector fails to provide necessary delay due to manufacturer defect
3 MIC detonated at the same time (due to combination of two type of errors)
3WD
3W-DETON
3W-SC
3W-DETON-SC
3MD-D
3MD-SC
3COMB
Page 17
Page 12
Page 14
Page 13
Page 15
Page 16
Page 11

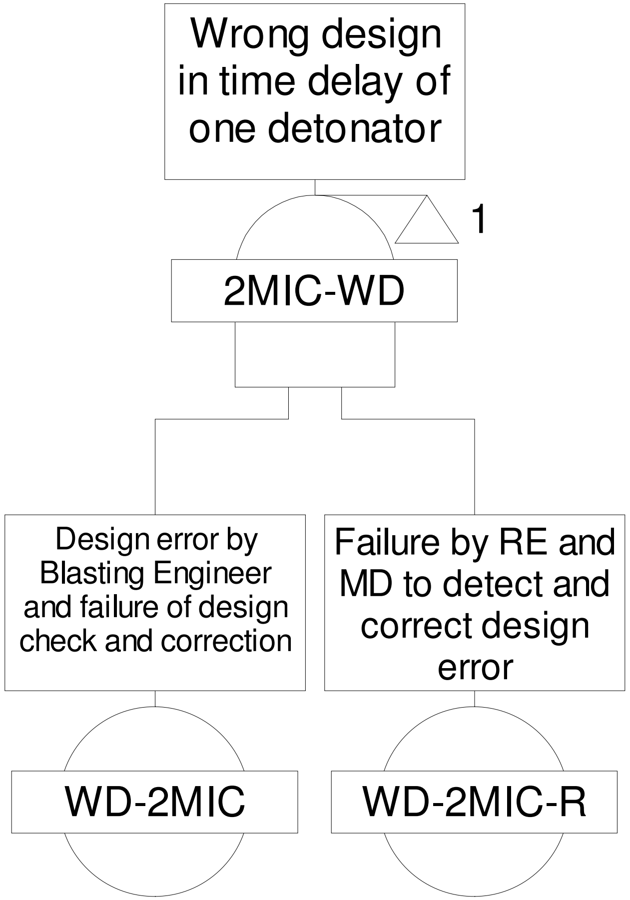

Higher vibration due to 4 MIC detonated at the same time
4-MIC
4 MIC detonated (due to same error occurred three times) at the same time
4 MIC detonated (due to same error occurred two times and one other error) at the same time
4 MIC detonated (due to three different errors occur at the same time) at the same time
4 MIC detonated (due to charge overload and one other error occur at the same time) at the same time
4-MIC-WI-1
4-MIC-WI-2
4-MIC-WI-3
4-MIC-WI-4
Page 22
Page 23
Page 24
Page 25

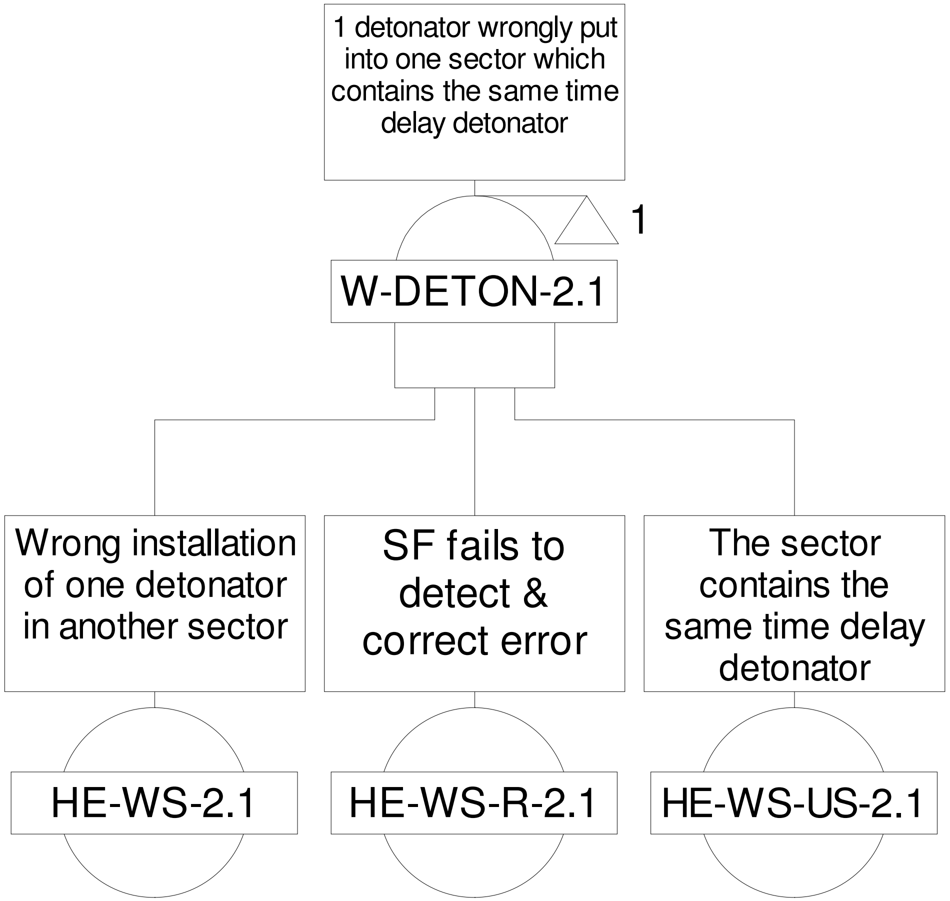


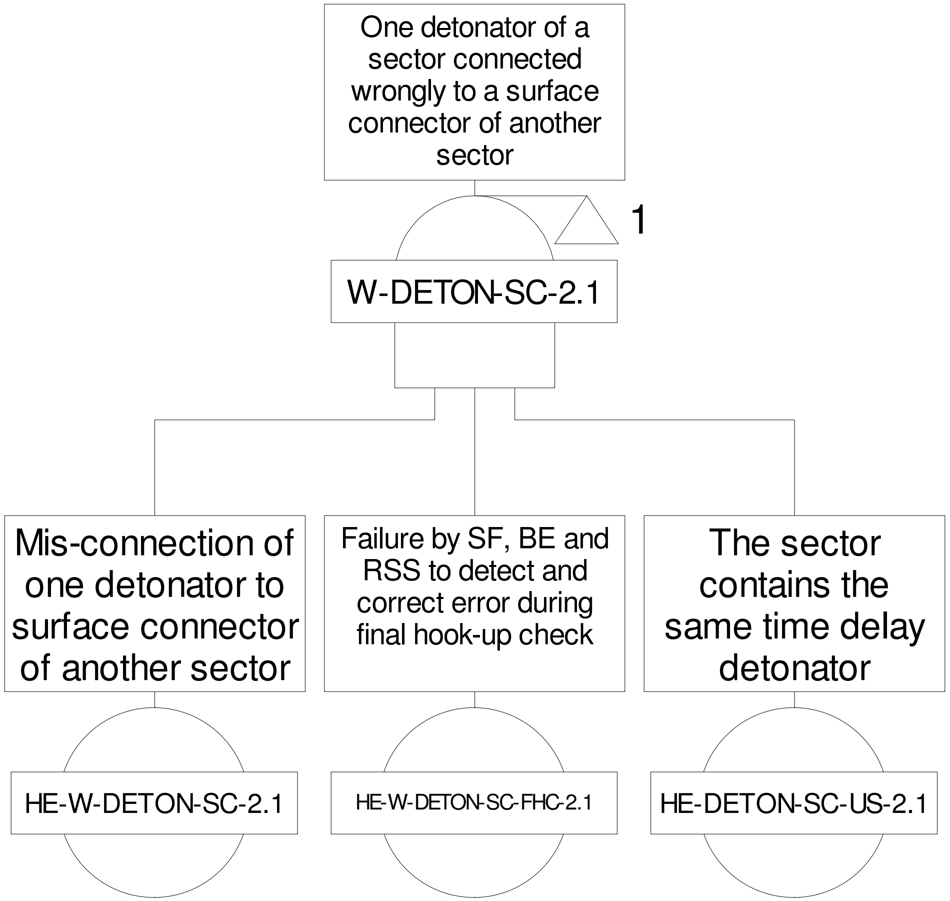
Higher vibration due to cut hole error
CH
Wrong hole diameter or location for relief holes at cut
Wrong time delay at cut
CH-WD
CH-TD
Page 44
Wrong design of time delay of more than 2 production holes in cut
Wrong installation of more than 2 detonators in cut (longer time delay from other sector put into the cut)
Incorrect time default of 1 detonator of more than 2 detonators due to manufacturer defect
TD-WD
CH-TD-WI(3)
CH-TD-MD
Page 45
Page 43
Page 42

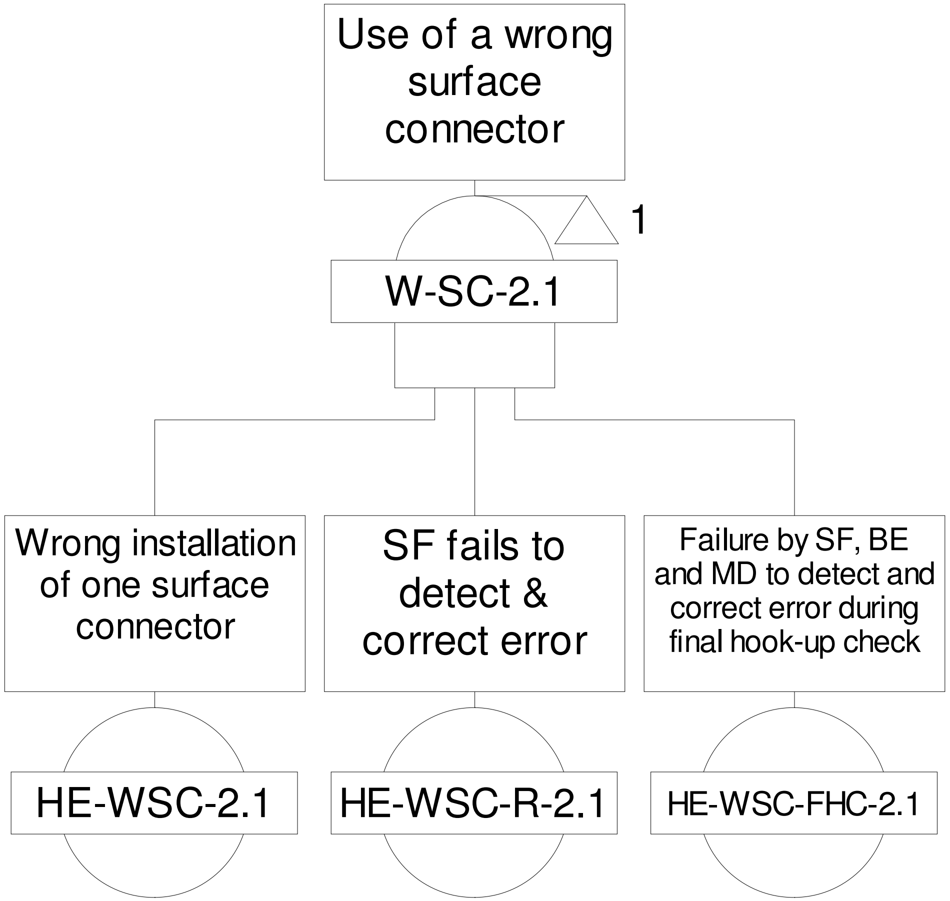

Too much cartridged emulsion loaded into hole
1,11,24,25,26,28,30,33,35,37
OL-C
Wrong design in MIC
6
OL-WD
Too many cartridges are inserted in holes and not realised
OL-C-E
Design error by Blasting Engineer and failure of design check and correction
WD-OL
Failure by RE and MD to detect and correct design error
WD-OL-R
Too many cartridges are inserted in holes
OL-C-E1
Cartridges from blocked holes inserted in other holes and not detected
OL-C-BH-E1
SF does not count correctly
OL-C-CO
SFand BE don't realise hole is ov erloaded
HE-OL-C-R
Cartridges from blocked holes inserted in other holes
OL-C-BH-E
SF and BE don't realise hole is ov erloaded
HE-OL-C-BH-R
Blocked holes are not disposed of
HE-OL-C-BH
Probability of blocked holes
OL-C-BH


Too much bulk emulsion loaded into hole
OL-B
Wrong design in MIC
5
OL-WD
Too many bulk emulsion are loaded in holes and not realised
OL-B-E
Design error by Blasting Engineer and failure of design check and correction
WD-OL
Failure by RE and MD to detect and correct design error
WD-OL-R
Incorrect Density Check
OL-DC
TO, SF and BE don't realise hole is overloaded
OL-B-HO
Wrong density check due to human error
OL-DC-1
Wrong density check due to mechanical failure
OL-DC-2
Wrong density check due to human error
OL-DC-1
Scale out of calibration/ malfunction
OL-B-WG
Gassing flow meter malfunction
HE-B-FM

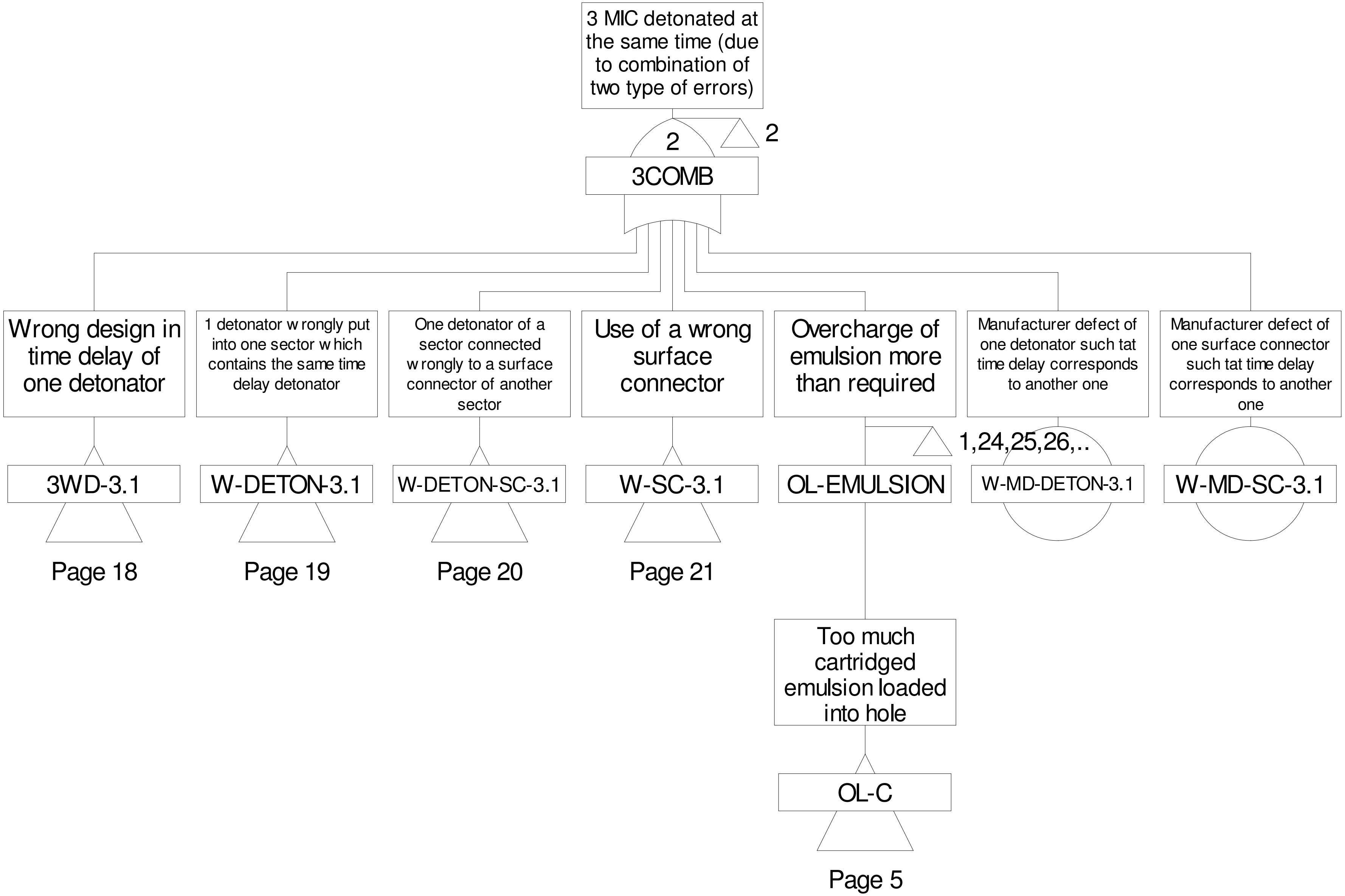

Wrong design in time delay of one detonator
1
2MIC-WD
Design error by Blasting Engineer and failure of design check and correction
Failure by RE and MD to detect and correct design error
WD-2MIC
WD-2MIC-R


1 detonator wrongly put into one sector which contains the same time delay detonator
1
W-DETON-2.1
Wrong installation of one detonator in another sector
SF fails to detect & correct error
The sector contains the same time delay detonator
HE-WS-2.1
HE-WS-R-2.1
HE-WS-US-2.1

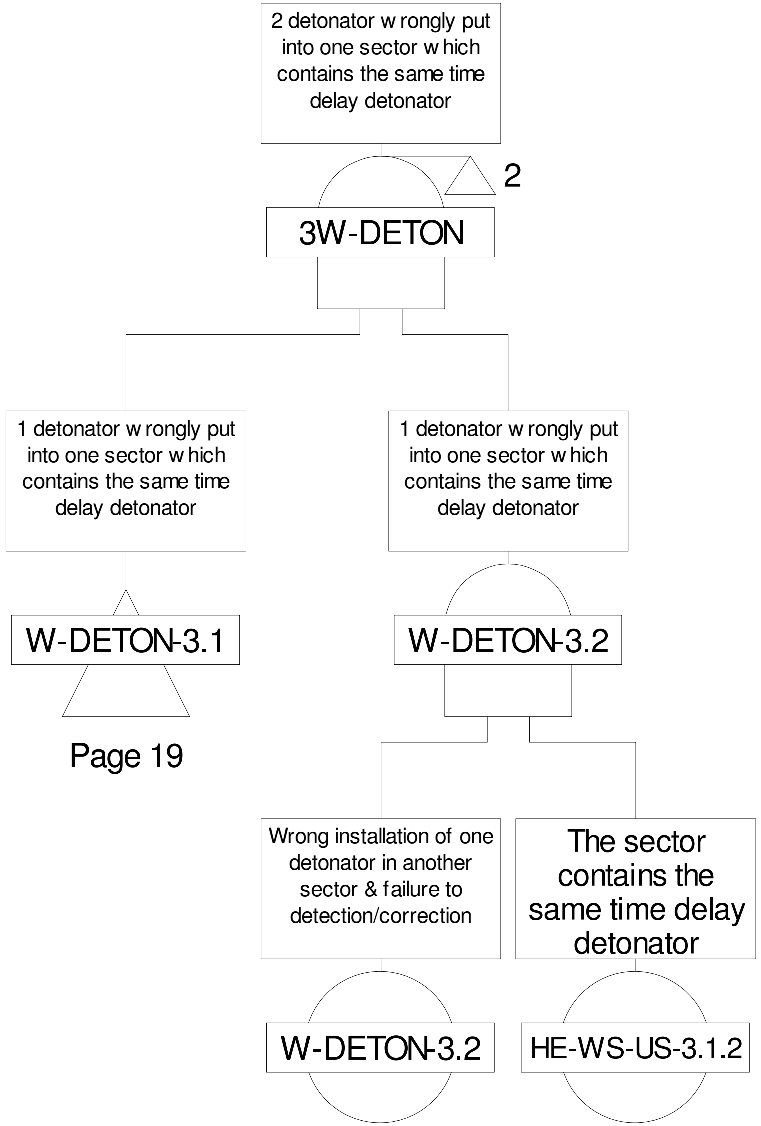

One detonator of a sector connected wrongly to a surface connector of another sector
1
W-DETON-SC-2.1
Mis-connection of one detonator to surface connector of another sector
Failure by SF, BE and RSS to detect and correct error during final hook-up check
The sector contains the same time delay detonator
HE-W-DETON-SC-2.1
HE-W-DETON-SC-FHC-2.1
HE-DETON-SC-US-2.1

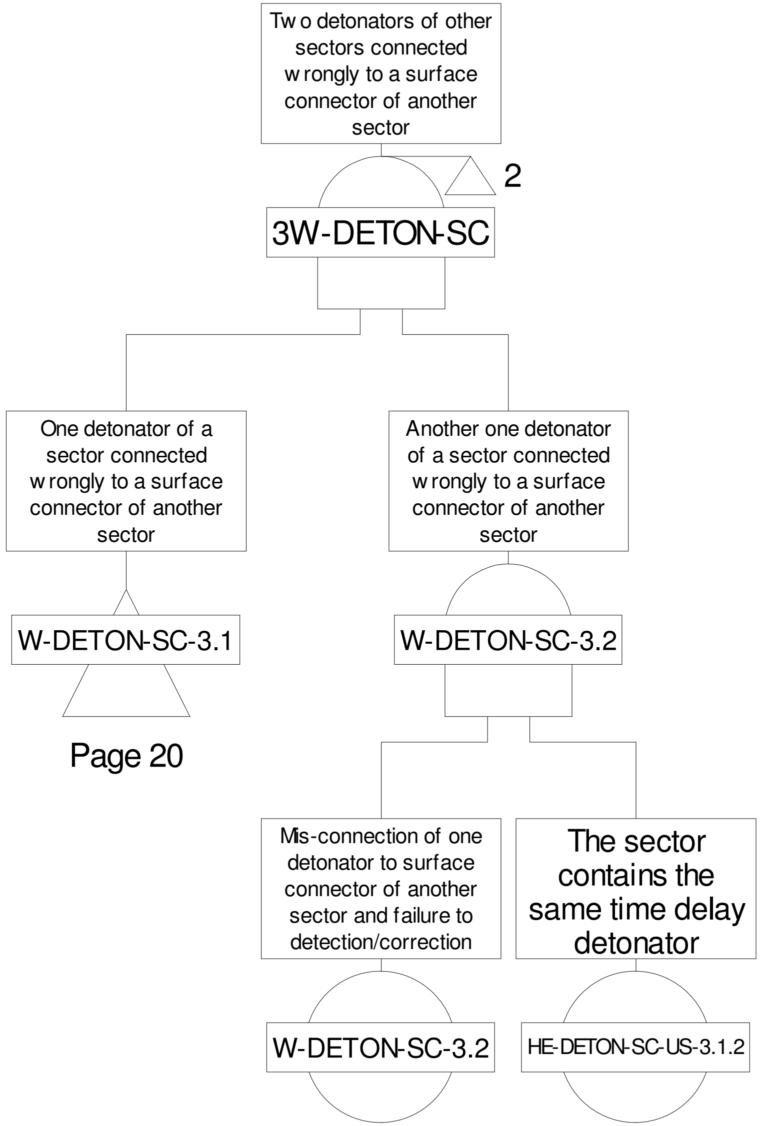


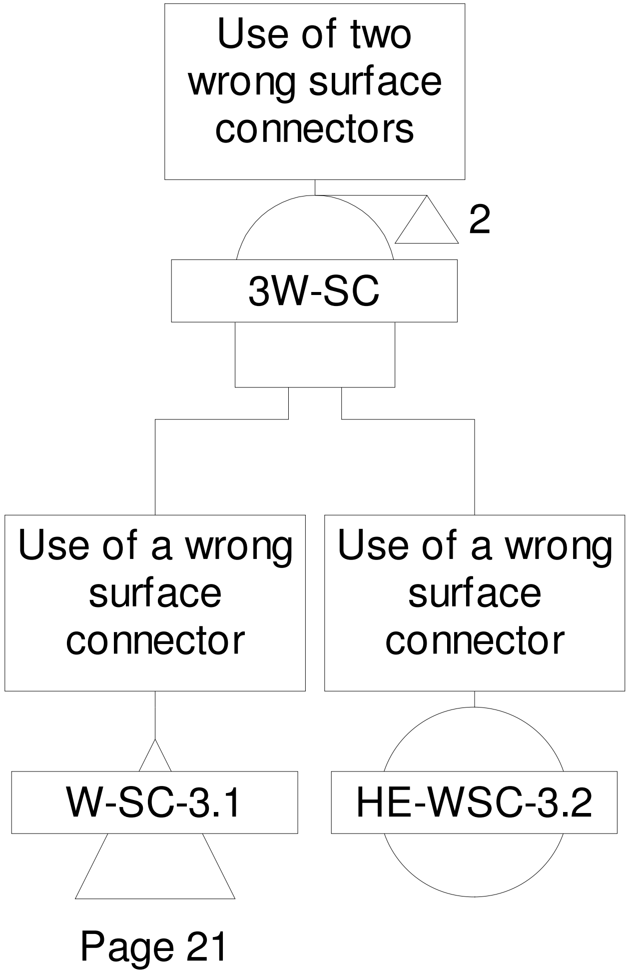
Use of a wrong surface connector
1
W-SC-2.1
Wrong installation of one surface connector
SF fails to detect & correct error
Failure by SF, BE and MD to detect and correct error during final hook-up check
HE-WSC-2.1
HE-WSC-R-2.1
HE-WSC-FHC-2.1

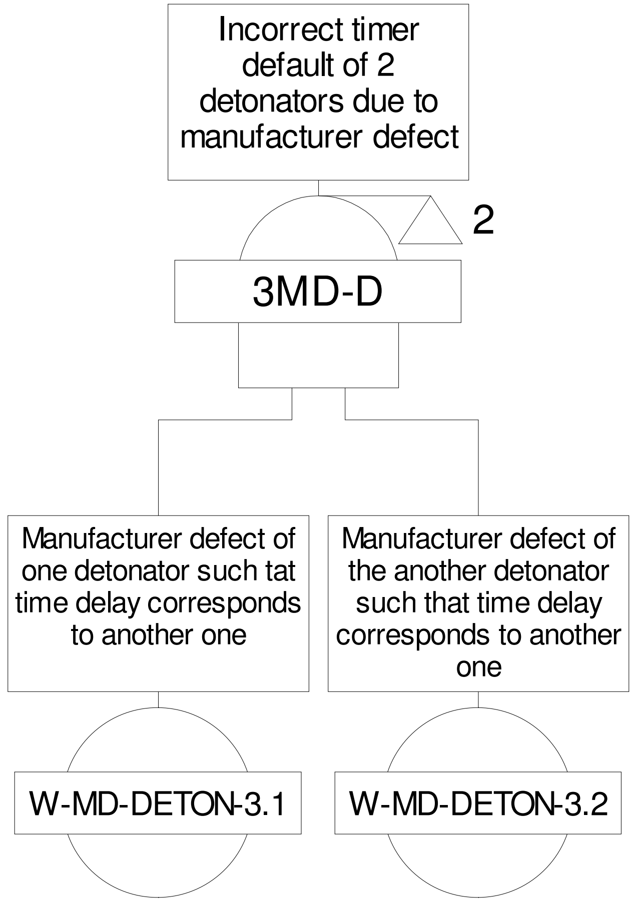


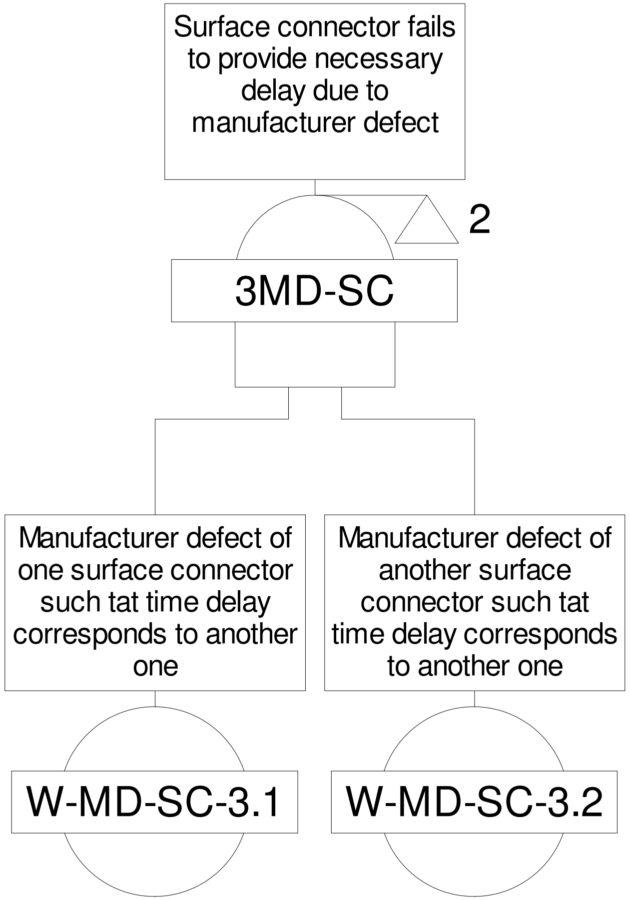
3 MIC detonated at the same time (due to combination of two type of errors)
2
2
3COMB
Wrong design in time delay of one detonator
1 detonator w rongly put into one sector w hich contains the same time delay detonator
One detonator of a sector connected w rongly to a surface connector of another sector
Use of a wrong surface connector
Overcharge of emulsion more than required
Manufacturer defect of one detonator such tat time delay corresponds to another one
Manufacturer defect of one surface connector such tat time delay corresponds to another one
3WD-3.1
W-DETON-3.1
W-DETON-SC-3.1
W-SC-3.1
OL-EMULSION
1,24,25,26,..
W-MD-DETON-3.1
W-MD-SC-3.1
Page 18
Page 19
Page 20
Page 21
Too much cartridged emulsion loaded into hole
OL-C
Page 5

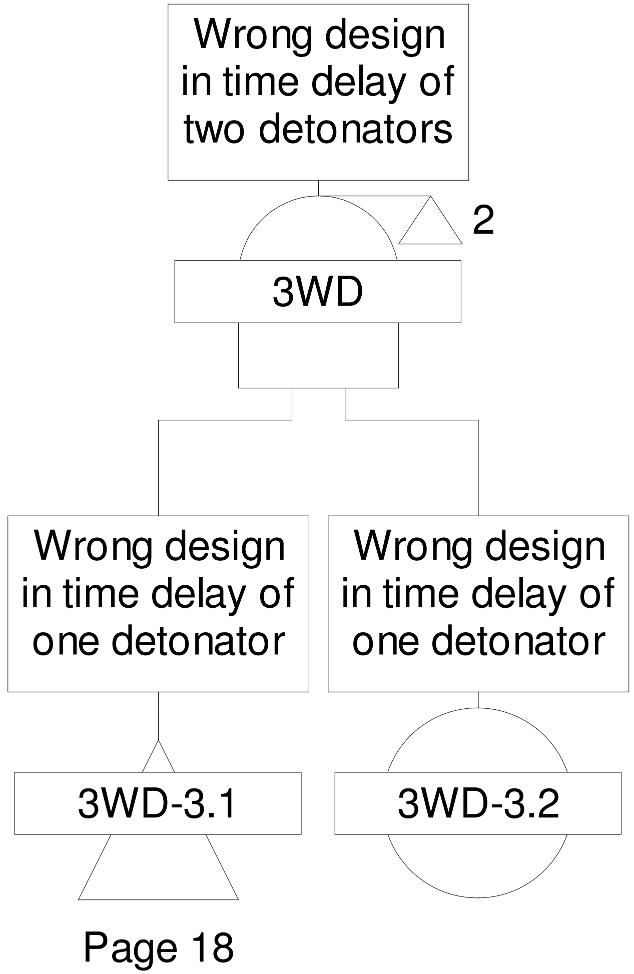

2 detonator w rongly put into one sector w hich contains the same time delay detonator
2
3W-DETON
1 detonator w rongly put into one sector w hich contains the same time delay detonator
1 detonator w rongly put into one sector w hich contains the same time delay detonator
W-DETON-3.1
W-DETON-3.2
Page 19
Wrong installation of one detonator in another sector & failure to detection/correction
The sector contains the same time delay detonator
W-DETON-3.2
HE-WS-US-3.1.2

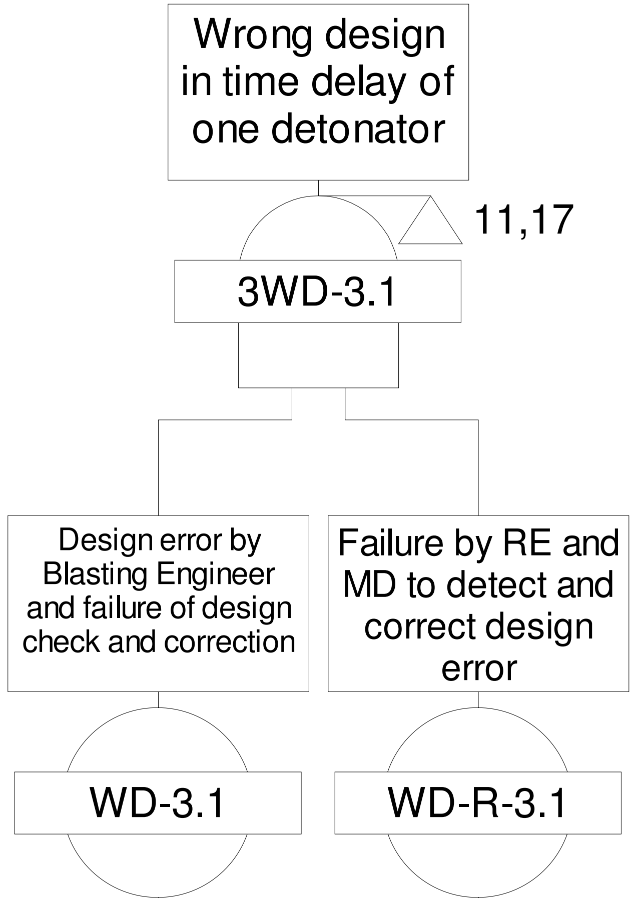

Tw o detonators of other sectors connected w rongly to a surface connector of another sector
2
3W-DETON-SC
One detonator of a sector connected w rongly to a surface connector of another sector
W-DETON-SC-3.1
Page 20
Another one detonator of a sector connected w rongly to a surface connector of another sector
W-DETON-SC-3.2
Mis-connection of one detonator to surface connector of another sector and failure to detection/correction
W-DETON-SC-3.2
The sector contains the same time delay detonator
HE-DETON-SC-US-3.1.2

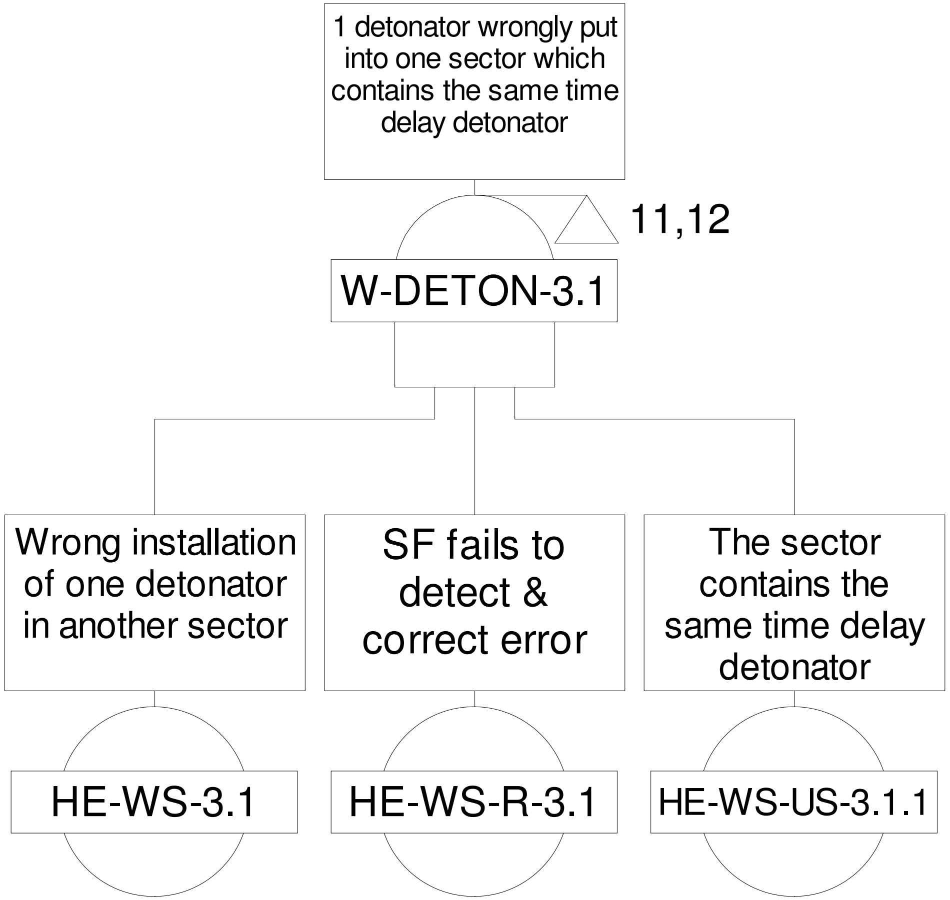

Use of two wrong surface connectors
2
3W-SC
Use of a wrong surface connector
Use of a wrong surface connector
W-SC-3.1
HE-WSC-3.2
Page 21

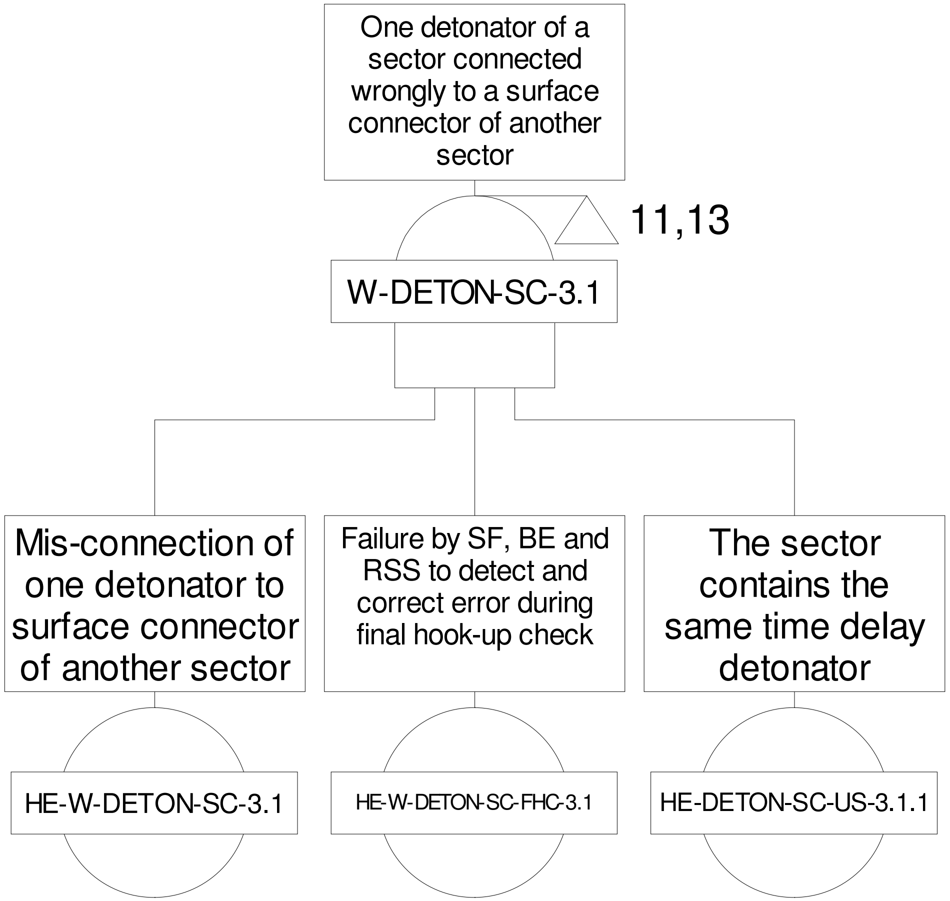

Incorrect timer default of 2 detonators due to manufacturer defect
2
3MD-D
Manufacturer defect of one detonator such tat time delay corresponds to another one
Manufacturer defect of the another detonator such that time delay corresponds to another one
W-MD-DETON-3.1
W-MD-DETON-3.2

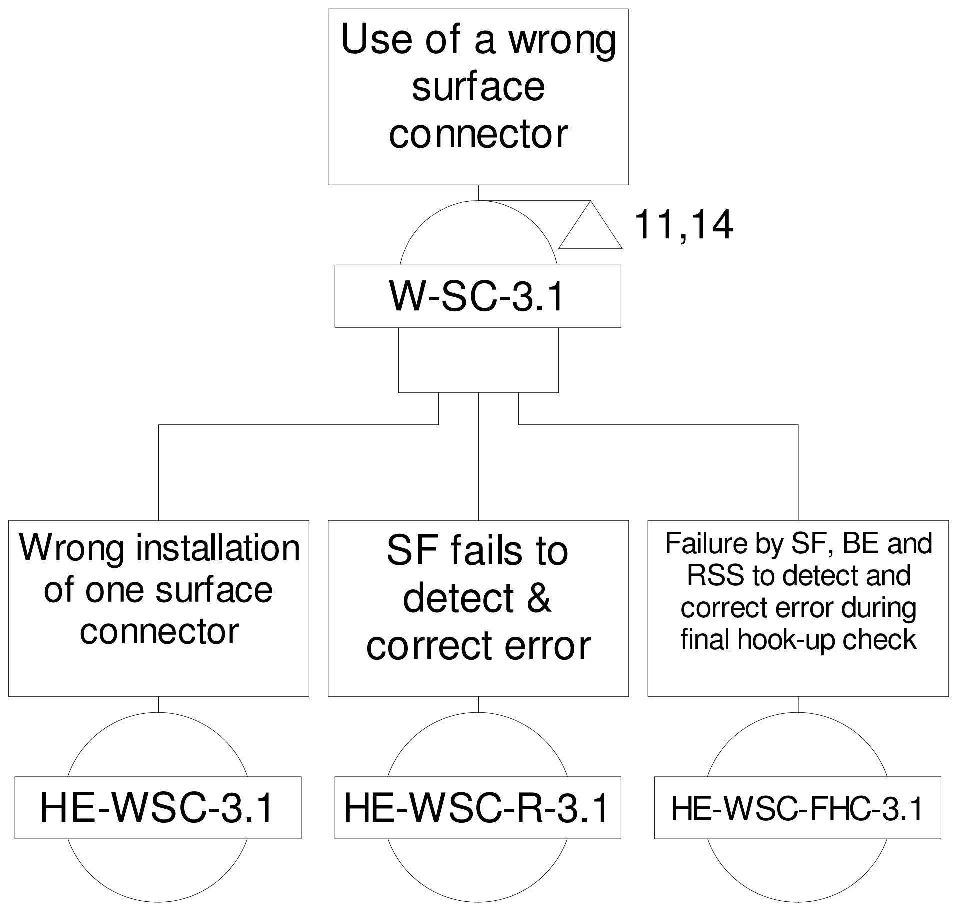

Surface connector fails to provide necessary delay due to manufacturer defect
2
3MD-SC
Manufacturer defect of one surface connector such tat time delay corresponds to another one
Manufacturer defect of another surface connector such tat time delay corresponds to another one
W-MD-SC-3.1
W-MD-SC-3.2

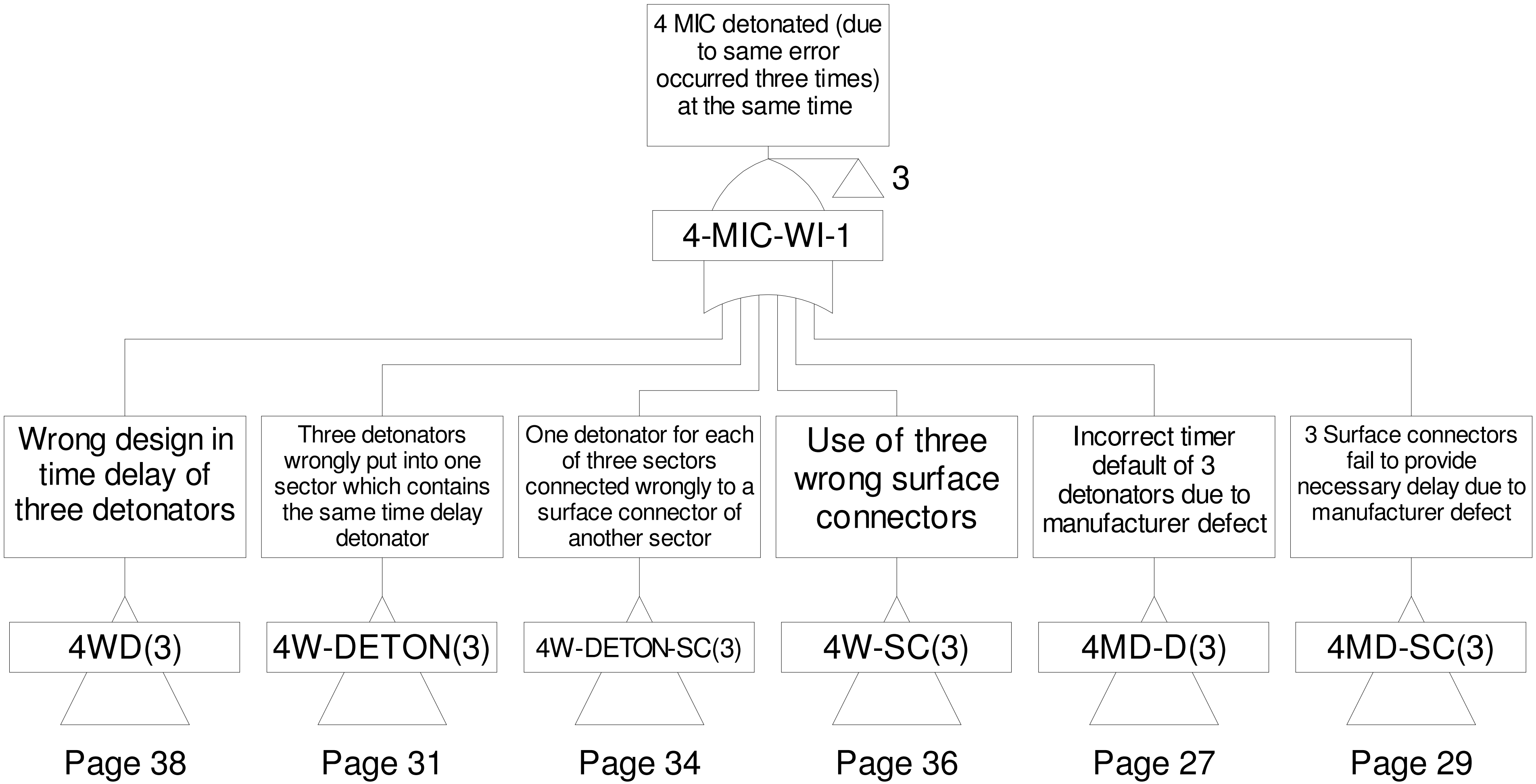

Wrong design in time delay of two detonators
2
3WD
Wrong design in time delay of one detonator
Wrong design in time delay of one detonator
3WD-3.1
3WD-3.2
Page 18

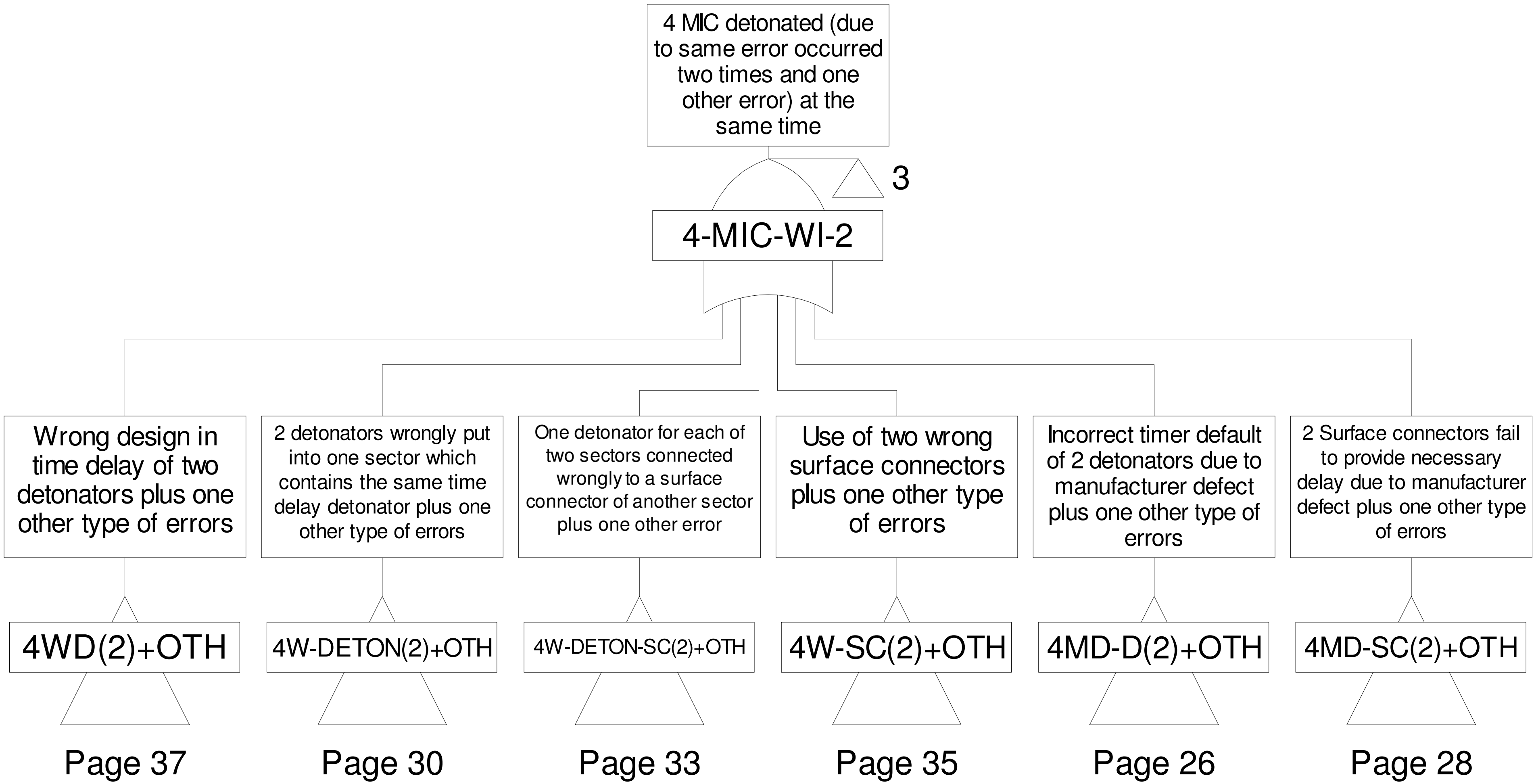

Wrong design in time delay of one detonator
11,17
3WD-3.1
Design error by Blasting Engineer and failure of design check and correction
Failure by RE and MD to detect and correct design error
WD-3.1
WD-R-3.1

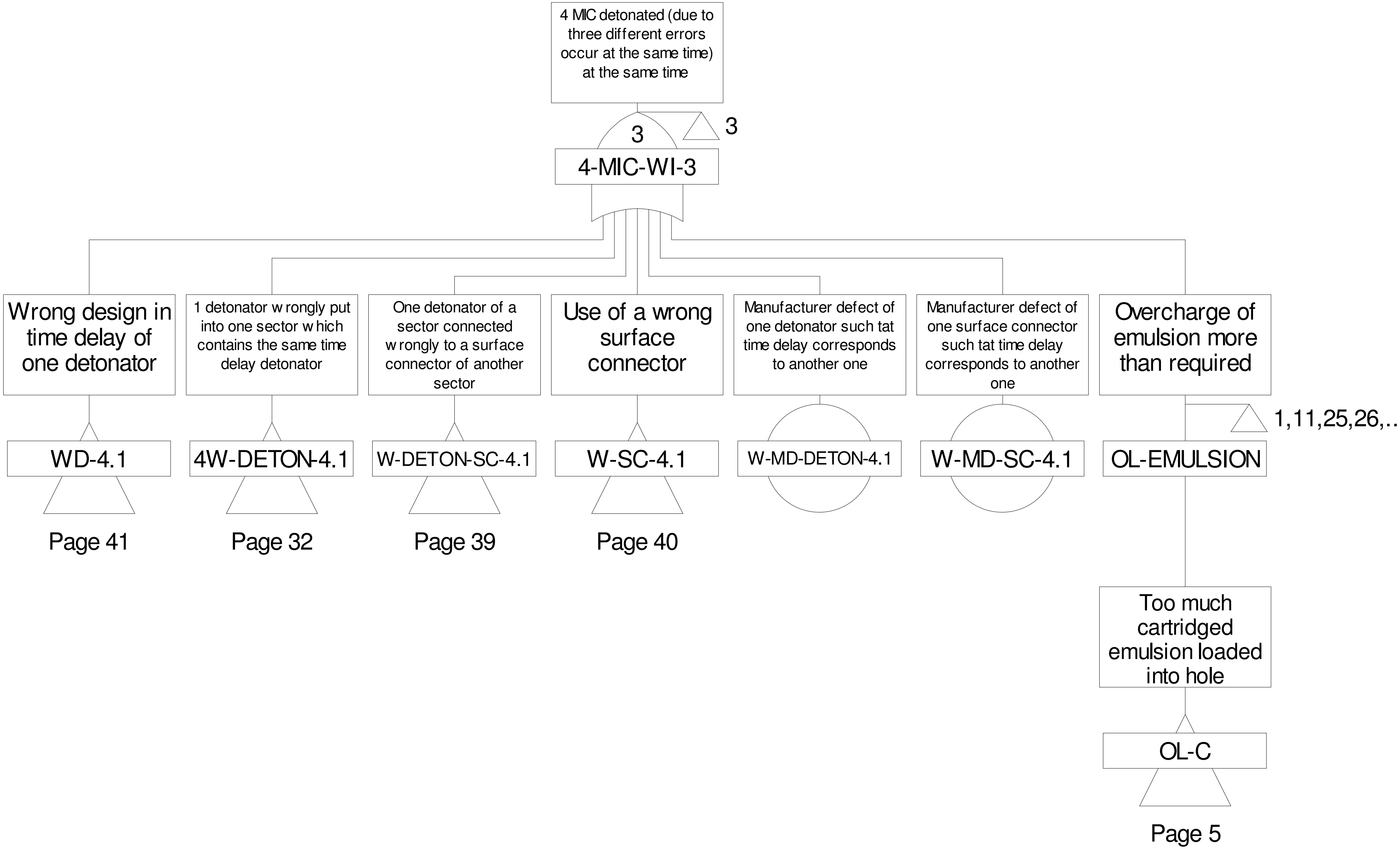

1 detonator wrongly put into one sector which contains the same time delay detonator
11,12
W-DETON-3.1
Wrong installation of one detonator in another sector
SF fails to detect & correct error
The sector contains the same time delay detonator
HE-WS-3.1
HE-WS-R-3.1
HE-WS-US-3.1.1


One detonator of a sector connected wrongly to a surface connector of another sector
11,13
W-DETON-SC-3.1
Mis-connection of one detonator to surface connector of another sector
Failure by SF, BE and RSS to detect and correct error during final hook-up check
The sector contains the same time delay detonator
HE-W-DETON-SC-3.1
HE-W-DETON-SC-FHC-3.1
HE-DETON-SC-US-3.1.1

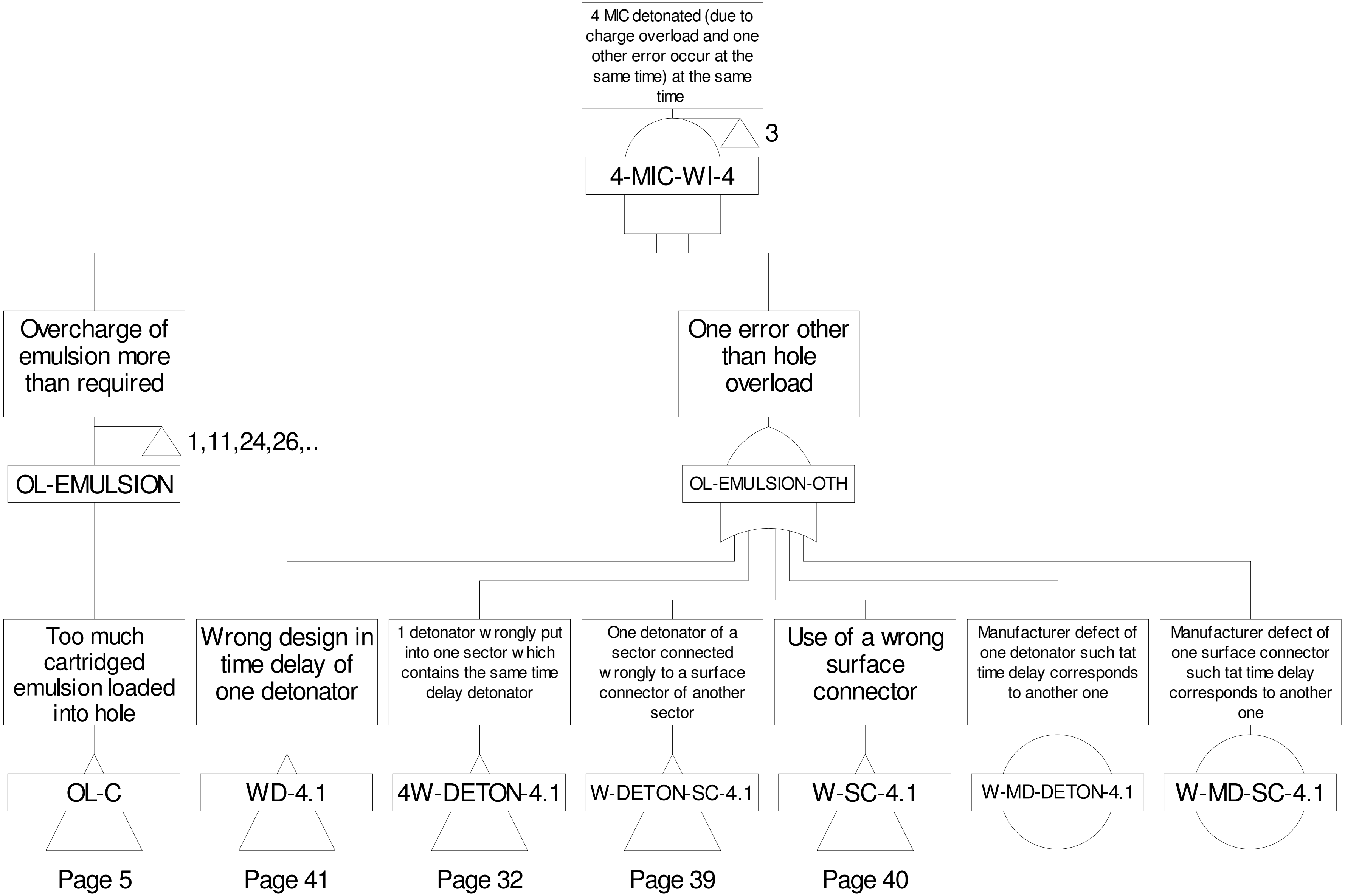

Use of a wrong surface connector
11,14
W-SC-3.1
Wrong installation of one surface connector
SF fails to detect & correct error
Failure by SF, BE and RSS to detect and correct error during final hook-up check
HE-WSC-3.1
HE-WSC-R-3.1
HE-WSC-FHC-3.1


4 MIC detonated (due to same error occurred three times) at the same time
3
4-MIC-WI-1
Wrong design in time delay of three detonators
Three detonators wrongly put into one sector which contains the same time delay detonator
One detonator for each of three sectors connected wrongly to a surface connector of another sector
Use of three wrong surface connectors
Incorrect timer default of 3 detonators due to manufacturer defect
3 Surface connectors fail to provide necessary delay due to manufacturer defect
4WD(3)
4W-DETON(3)
4W-DETON-SC(3)
4W-SC(3)
4MD-D(3)
4MD-SC(3)
Page 38
Page 31
Page 34
Page 36
Page 27
Page 29

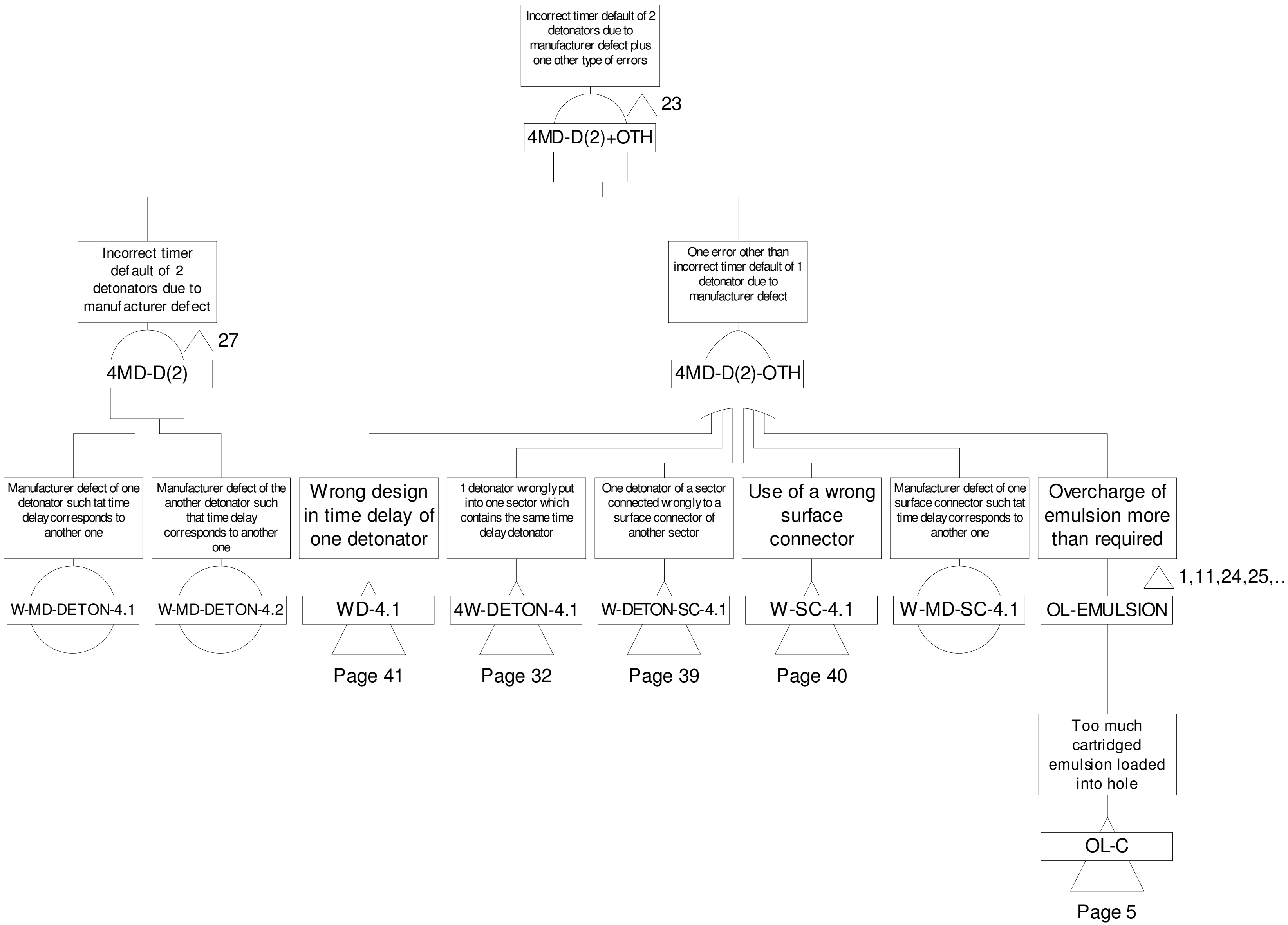

4 MIC detonated (due to same error occurred two times and one other error) at the same time
3
4-MIC-WI-2
Wrong design in time delay of two detonators plus one other type of errors
2 detonators wrongly put into one sector which contains the same time delay detonator plus one other type of errors
One detonator for each of two sectors connected wrongly to a surface connector of another sector plus one other error
Use of two wrong surface connectors plus one other type of errors
Incorrect timer default of 2 detonators due to manufacturer defect plus one other type of errors
2 Surface connectors fail to provide necessary delay due to manufacturer defect plus one other type of errors
4WD(2)+OTH
4W-DETON(2)+OTH
4W-DETON-SC(2)+OTH
4W-SC(2)+OTH
4MD-D(2)+OTH
4MD-SC(2)+OTH
Page 37
Page 30
Page 33
Page 35
Page 26
Page 28

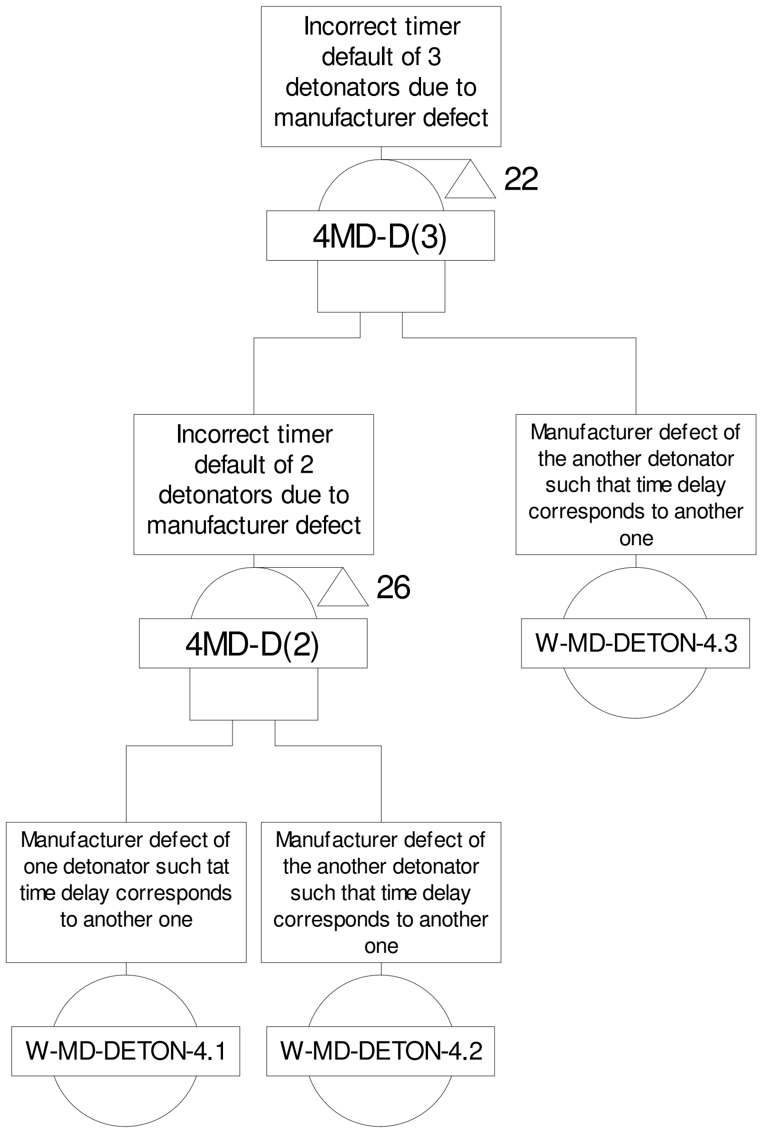


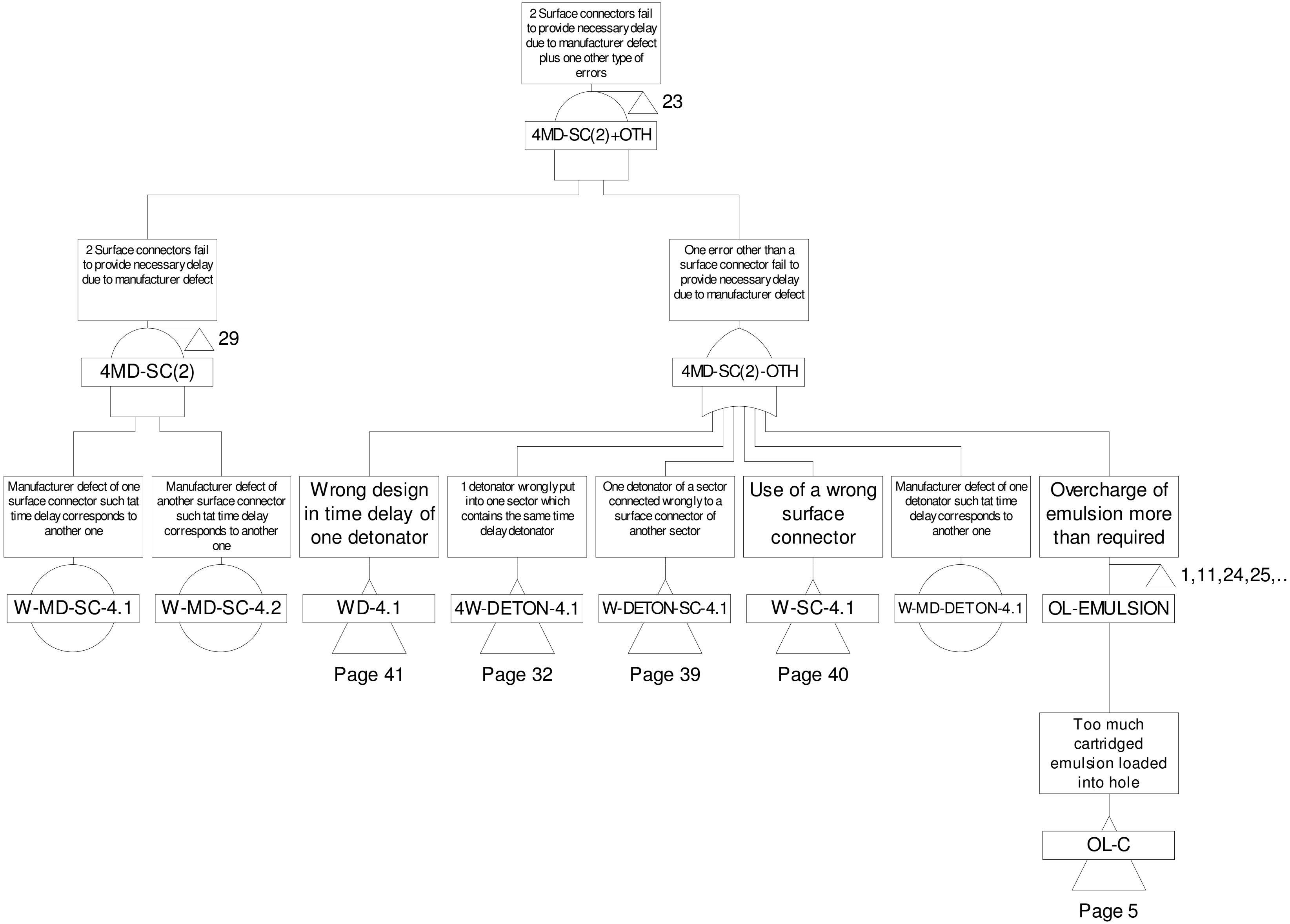
4 MIC detonated (due to three different errors occur at the same time) at the same time
3
3
4-MIC-WI-3
Wrong design in time delay of one detonator
WD-4.1
Page 41
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
Use of a wrong surface connector
W-SC-4.1
Page 40
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1
Overcharge of emulsion more than required
1,11,25,26,..
OL-EMULSION
Too much cartridged emulsion loaded into hole
OL-C
Page 5



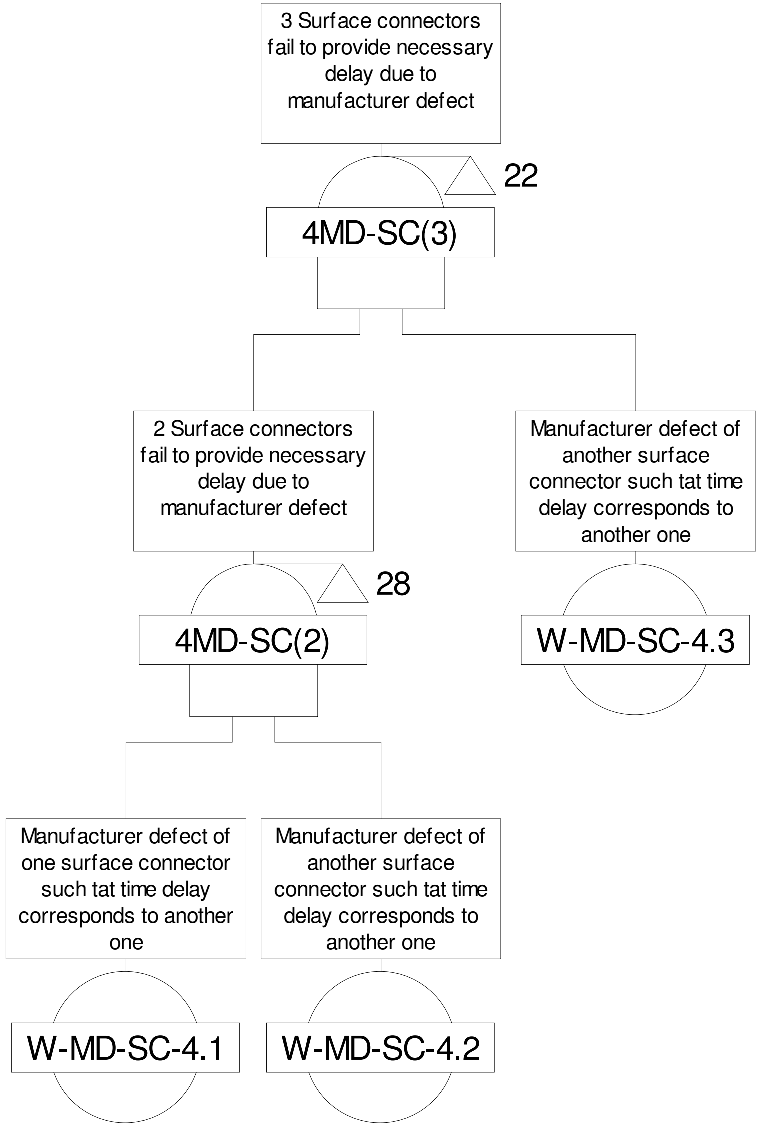
4 MIC detonated (due to charge overload and one other error occur at the same time) at the same time
3
4-MIC-WI-4
Overcharge of emulsion more than required
1,11,24,26,..
OL-EMULSION
One error other than hole overload
OL-EMULSION-OTH
Too much cartridged emulsion loaded into hole
OL-C
Page 5
Wrong design in time delay of one detonator
WD-4.1
Page 41
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
Use of a wrong surface connector
W-SC-4.1
Page 40
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1

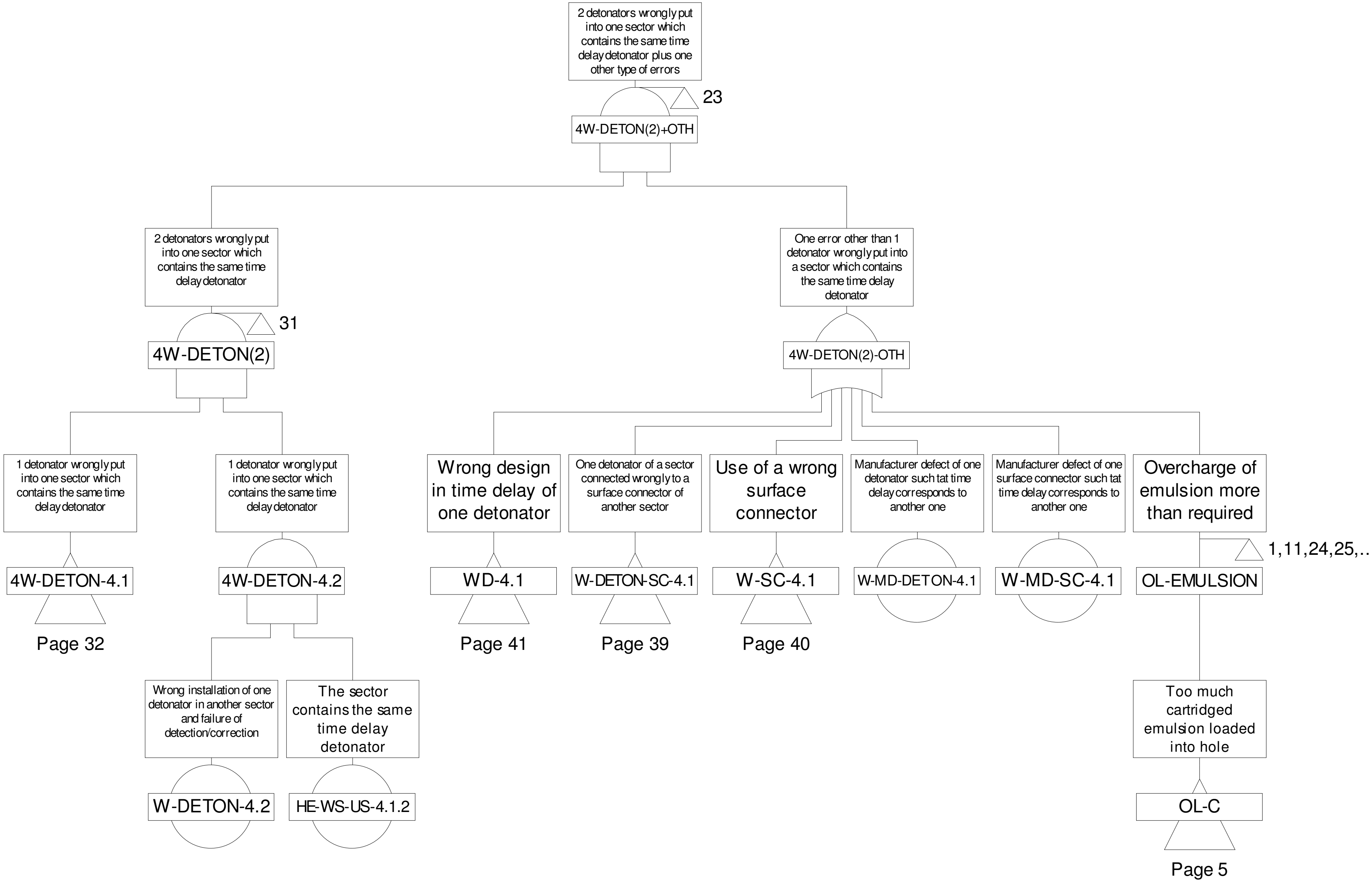

Incorrect timer default of 2 detonators due to manufacturer defect plus one other type of errors
23
4MD-D(2)+OTH
Incorrect timer default of 2 detonators due to manufacturer defect
27
4MD-D(2)
One error other than incorrect timer default of 1 detonator due to manufacturer defect
4MD-D(2)-OTH
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Manufacturer defect of the another detonator such that time delay corresponds to another one
W-MD-DETON-4.2
Wrong design in time delay of one detonator
WD-4.1
Page 41
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
Use of a wrong surface connector
W-SC-4.1
Page 40
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1
Overcharge of emulsion more than required
1,11,24,25,..
OL-EMULSION
Too much cartridged emulsion loaded into hole
OL-C
Page 5

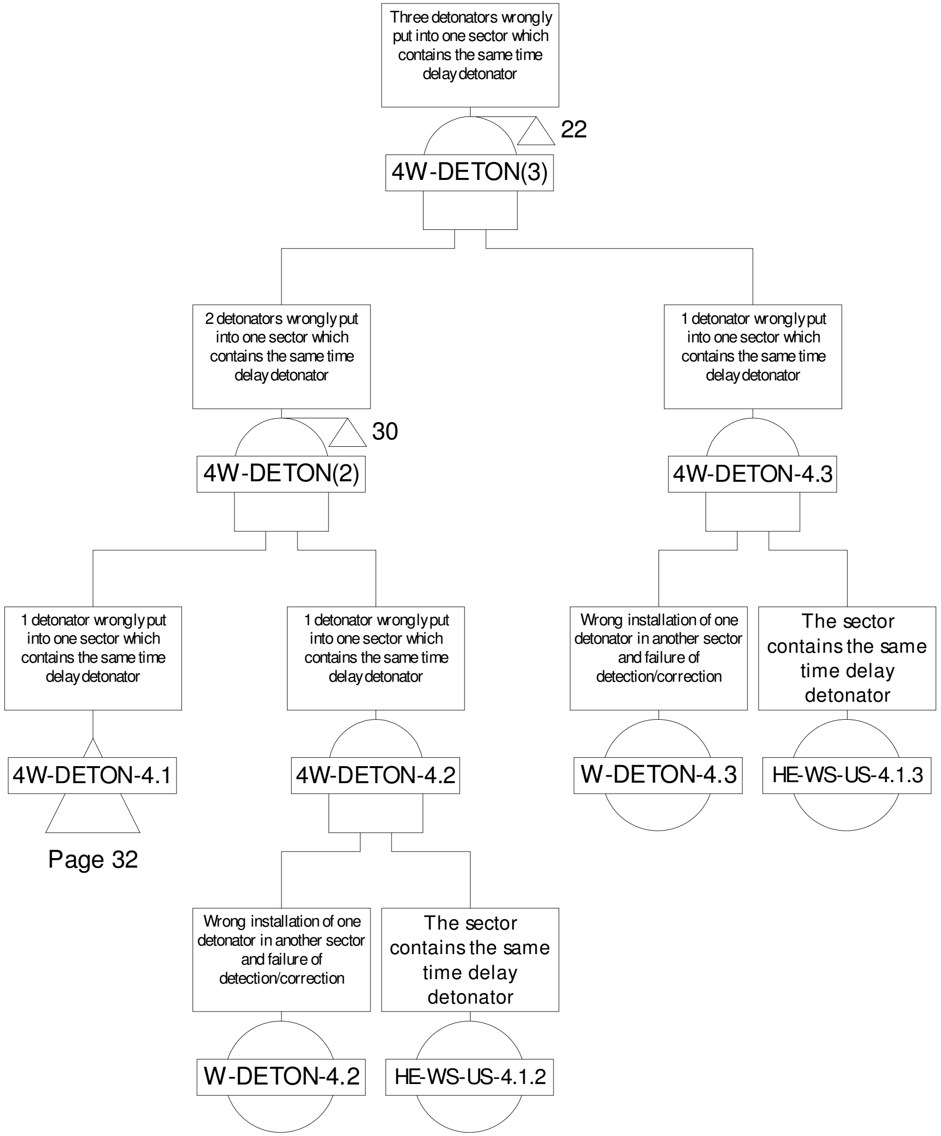

Incorrect timer default of 3 detonators due to manufacturer defect
22
4MD-D(3)
Incorrect timer default of 2 detonators due to manufacturer defect
26
4MD-D(2)
Manufacturer defect of the another detonator such that time delay corresponds to another one
W-MD-DETON-4.3
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Manufacturer defect of the another detonator such that time delay corresponds to another one
W-MD-DETON-4.2



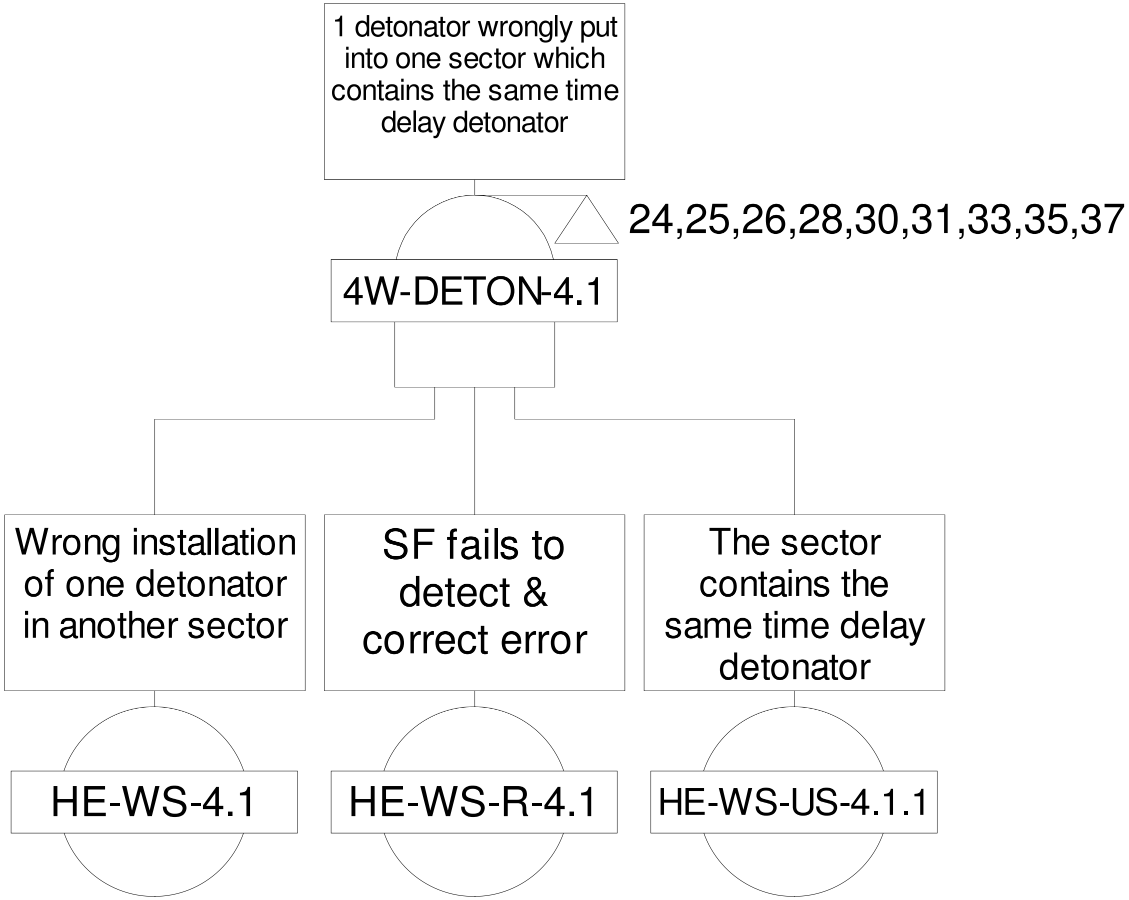
2 Surface connectors fail to provide necessary delay due to manufacturer defect plus one other type of errors
23
4MD-SC(2)+OTH
2 Surface connectors fail to provide necessary delay due to manufacturer defect
29
4MD-SC(2)
One error other than a surface connector fail to provide necessary delay due to manufacturer defect
4MD-SC(2)-OTH
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1
Manufacturer defect of another surface connector such tat time delay corresponds to another one
W-MD-SC-4.2
Wrong design in time delay of one detonator
WD-4.1
Page 41
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
Use of a wrong surface connector
W-SC-4.1
Page 40
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Overcharge of emulsion more than required
1,11,24,25,..
OL-EMULSION
Too much cartridged emulsion loaded into hole
OL-C
Page 5

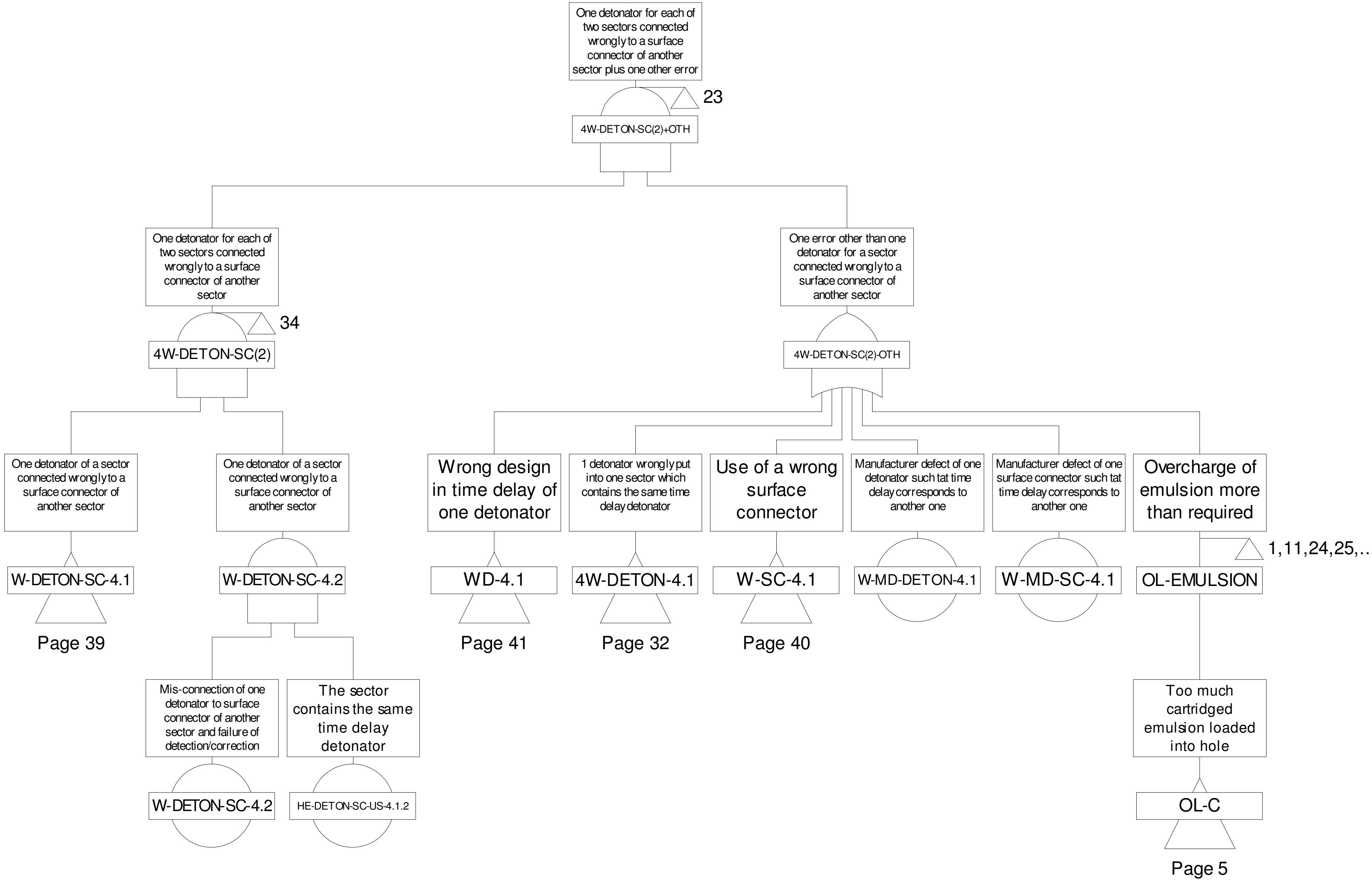

3 Surface connectors fail to provide necessary delay due to manufacturer defect
22
4MD-SC(3)
2 Surface connectors fail to provide necessary delay due to manufacturer defect
28
4MD-SC(2)
Manufacturer defect of another surface connector such tat time delay corresponds to another one
W-MD-SC-4.3
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1
Manufacturer defect of another surface connector such tat time delay corresponds to another one
W-MD-SC-4.2


2 detonators wrongly put into one sector which contains the same time delay detonator plus one other type of errors
23
4W-DETON(2)+OTH
2 detonators wrongly put into one sector which contains the same time delay detonator
31
4W-DETON(2)
One error other than 1 detonator wrongly put into a sector which contains the same time delay detonator
4W-DETON(2)-OTH
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.2
Wrong installation of one detonator in another sector and failure of detection/correction
W-DETON-4.2
The sector contains the same time delay detonator
HE-WS-US-4.1.2
Wrong design in time delay of one detonator
WD-4.1
Page 41
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
Use of a wrong surface connector
W-SC-4.1
Page 40
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1
Overcharge of emulsion more than required
1,11,24,25,..
OL-EMULSION
Too much cartridged emulsion loaded into hole
OL-C
Page 5

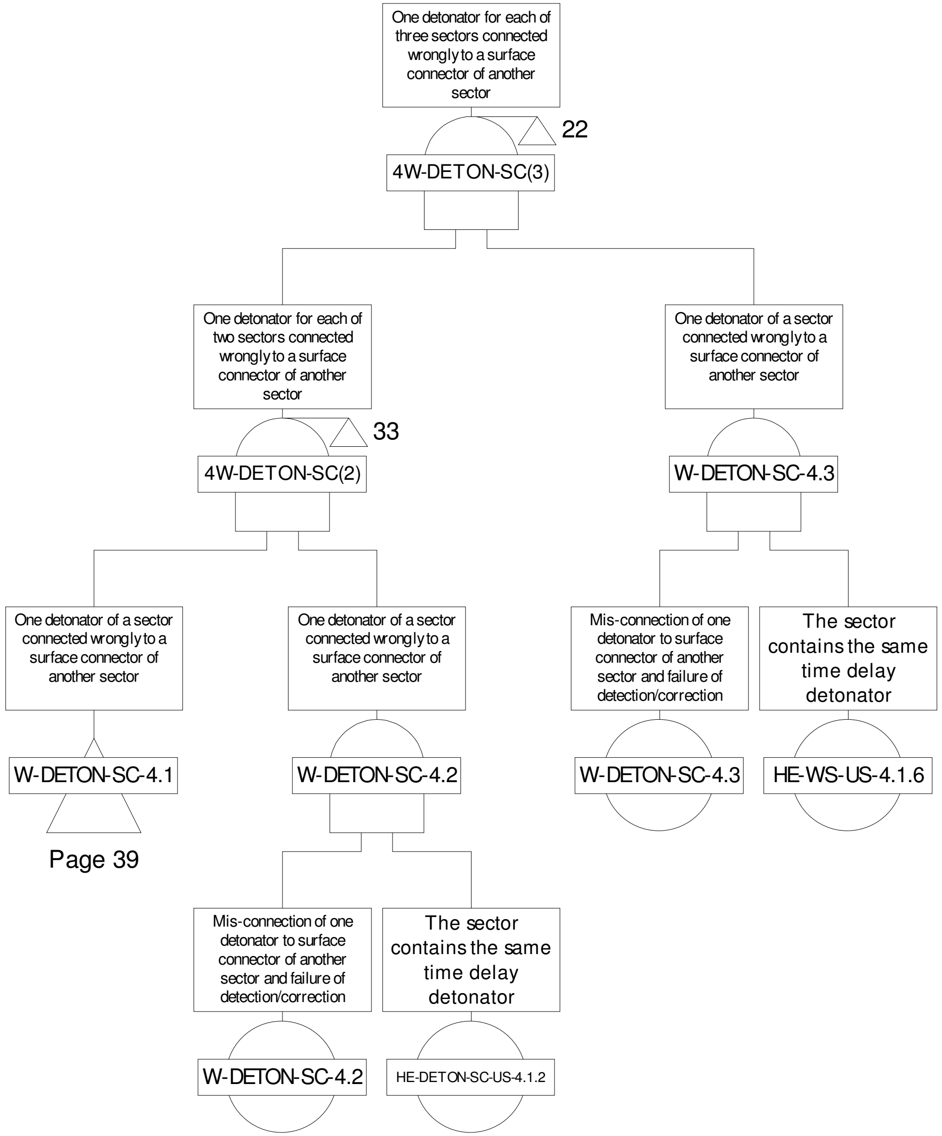


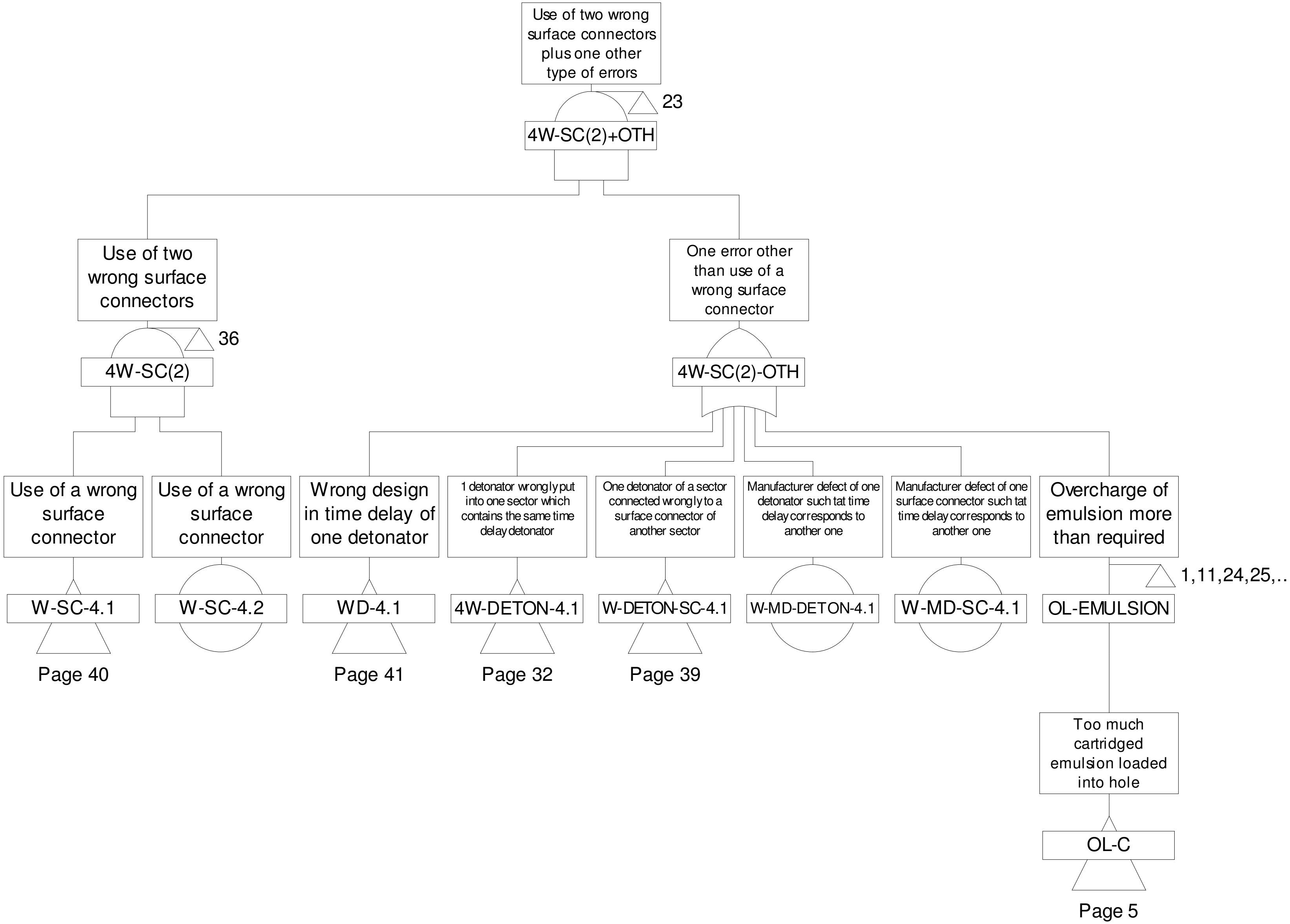
Three detonators wrongly put into one sector which contains the same time delay detonator
22
4W-DETON(3)
2 detonators wrongly put into one sector which contains the same time delay detonator
30
4W-DETON(2)
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.3
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.2
Wrong installation of one detonator in another sector and failure of detection/correction
W-DETON-4.3
The sector contains the same time delay detonator
HE-WS-US-4.1.3
Wrong installation of one detonator in another sector and failure of detection/correction
W-DETON-4.2
The sector contains the same time delay detonator
HE-WS-US-4.1.2

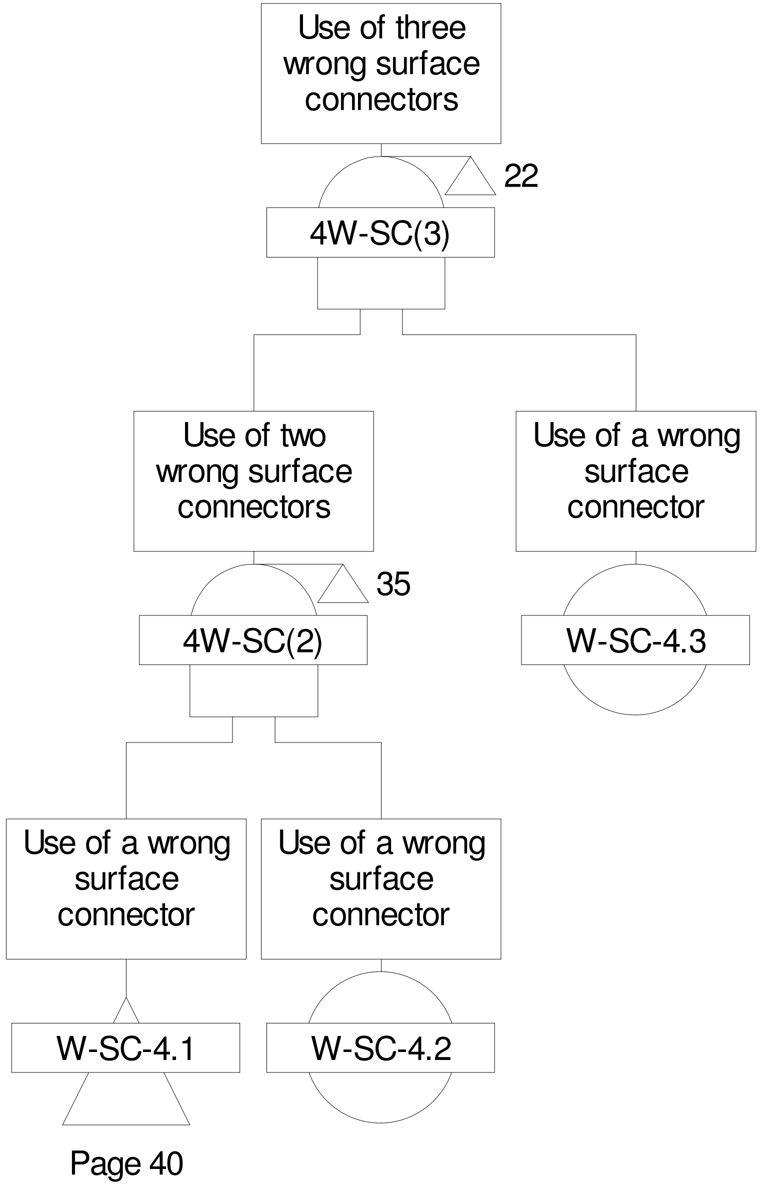

1 detonator wrongly put into one sector which contains the same time delay detonator
24,25,26,28,30,31,33,35,37
4W-DETON-4.1
Wrong installation of one detonator in another sector
SF fails to detect & correct error
The sector contains the same time delay detonator
HE-WS-4.1
HE-WS-R-4.1
HE-WS-US-4.1.1

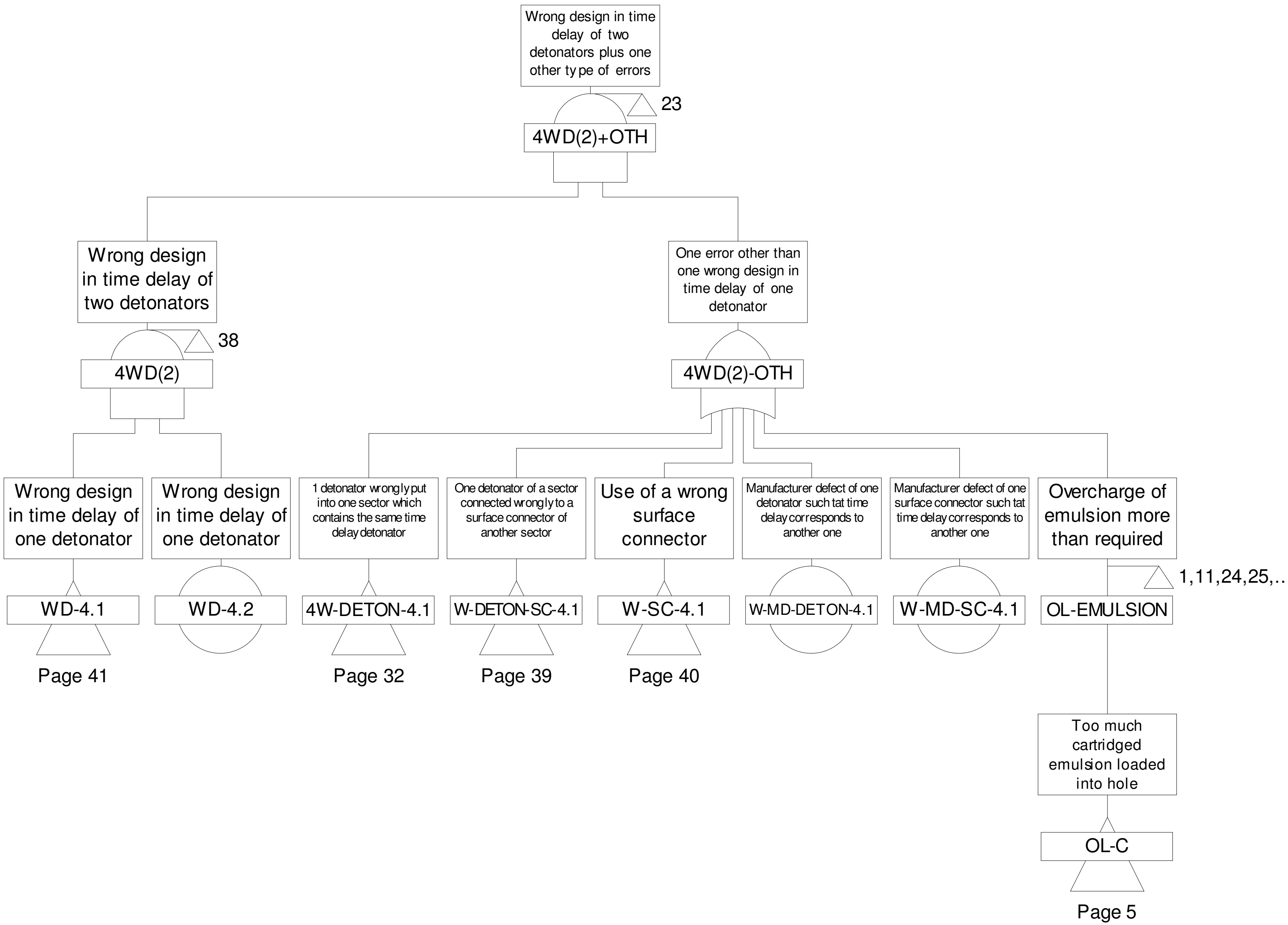


One detonator for each of two sectors connected wrongly to a surface connector of another sector plus one other error
23
4W-DETON-SC(2)+OTH
One detonator for each of two sectors connected wrongly to a surface connector of another sector
34
4W-DETON-SC(2)
One error other than one detonator for a sector connected wrongly to a surface connector of another sector
4W-DETON-SC(2)-OTH
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.2
Mis-connection of one detonator to surface connector of another sector and failure of detection/correction
W-DETON-SC-4.2
The sector contains the same time delay detonator
HE-DETON-SC-US-4.1.2
Wrong design in time delay of one detonator
WD-4.1
Page 41
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
Use of a wrong surface connector
W-SC-4.1
Page 40
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1
Overcharge of emulsion more than required
1,11,24,25,..
OL-EMULSION
Too much cartridged emulsion loaded into hole
OL-C
Page 5

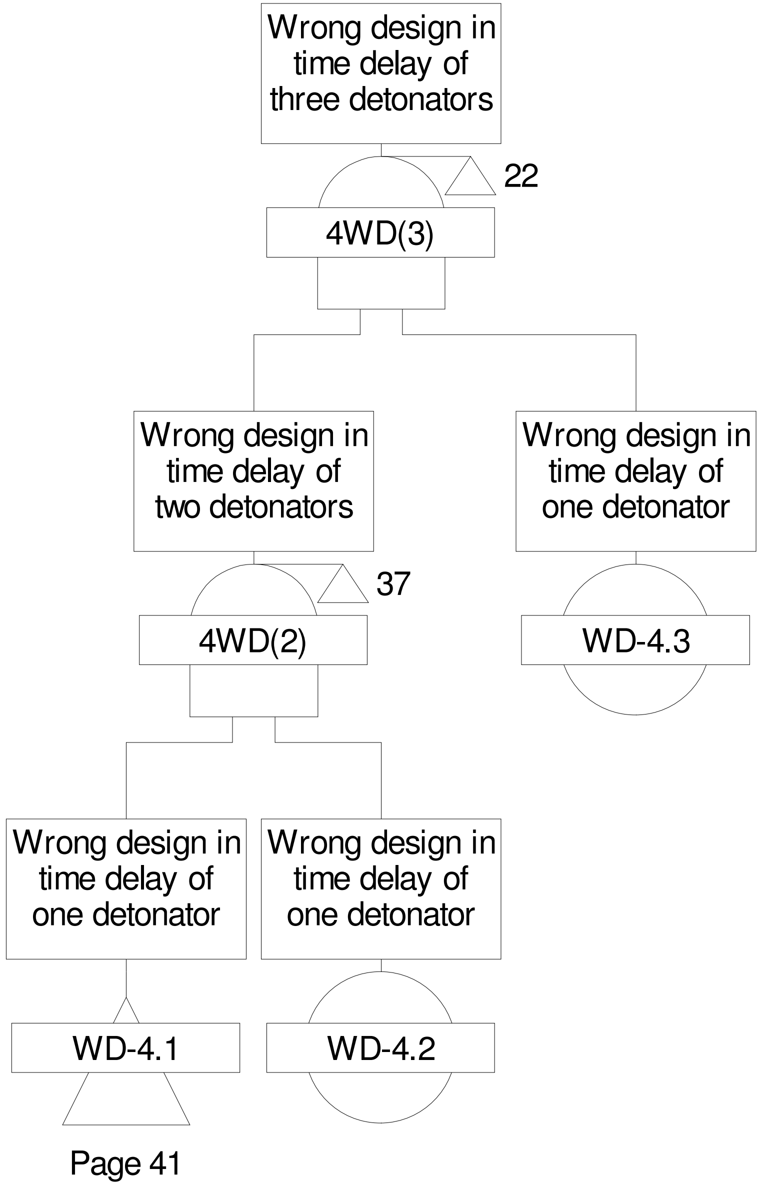

One detonator for each of three sectors connected wrongly to a surface connector of another sector
22
4W-DETON-SC(3)
One detonator for each of two sectors connected wrongly to a surface connector of another sector
33
4W-DETON-SC(2)
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.3
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.2
Mis-connection of one detonator to surface connector of another sector and failure of detection/correction
W-DETON-SC-4.3
The sector contains the same time delay detonator
HE-WS-US-4.1.6
Mis-connection of one detonator to surface connector of another sector and failure of detection/correction
W-DETON-SC-4.2
The sector contains the same time delay detonator
HE-DETON-SC-US-4.1.2

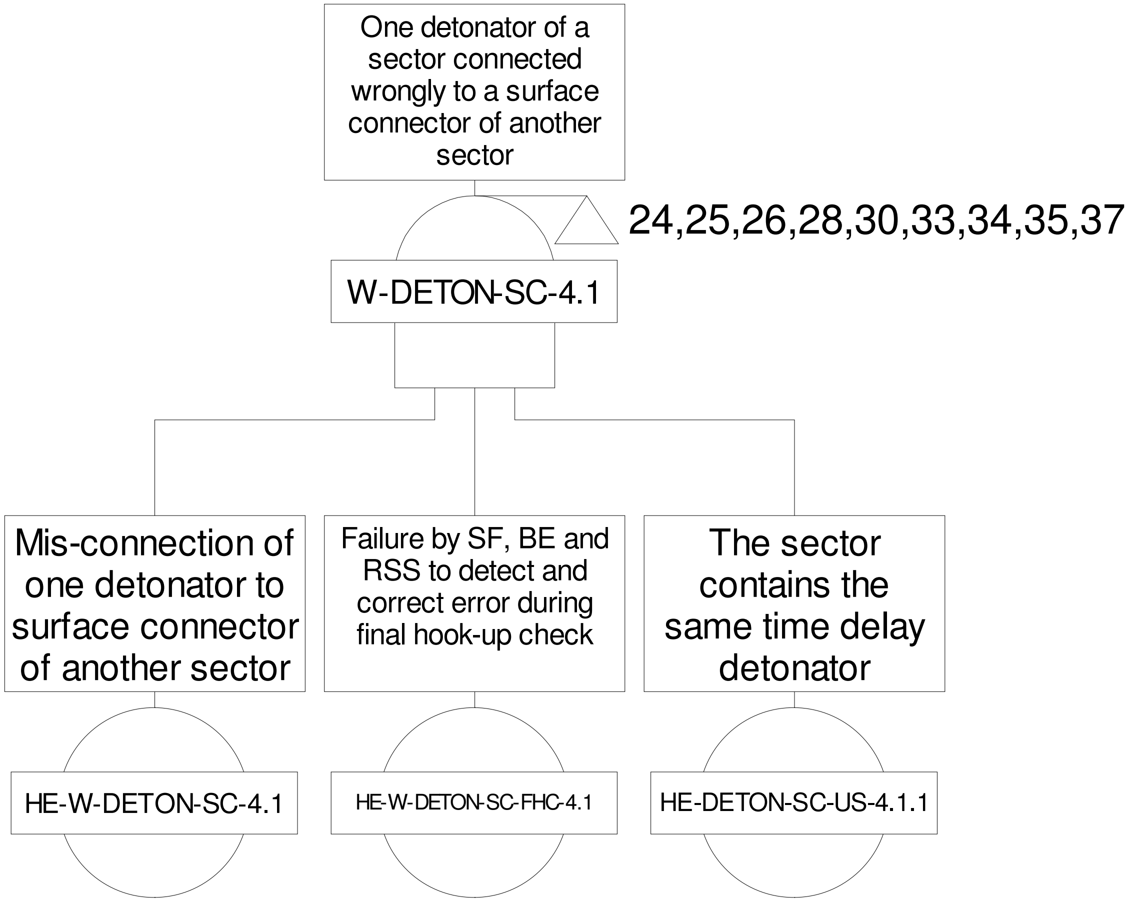

Use of two wrong surface connectors plus one other type of errors
23
4W-SC(2)+OTH
Use of two wrong surface connectors
36
4W-SC(2)
One error other than use of a wrong surface connector
4W-SC(2)-OTH
Use of a wrong surface connector
W-SC-4.1
Page 40
Use of a wrong surface connector
W-SC-4.2
Wrong design in time delay of one detonator
WD-4.1
Page 41
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1
Overcharge of emulsion more than required
1,11,24,25,..
OL-EMULSION
Too much cartridged emulsion loaded into hole
OL-C
Page 5

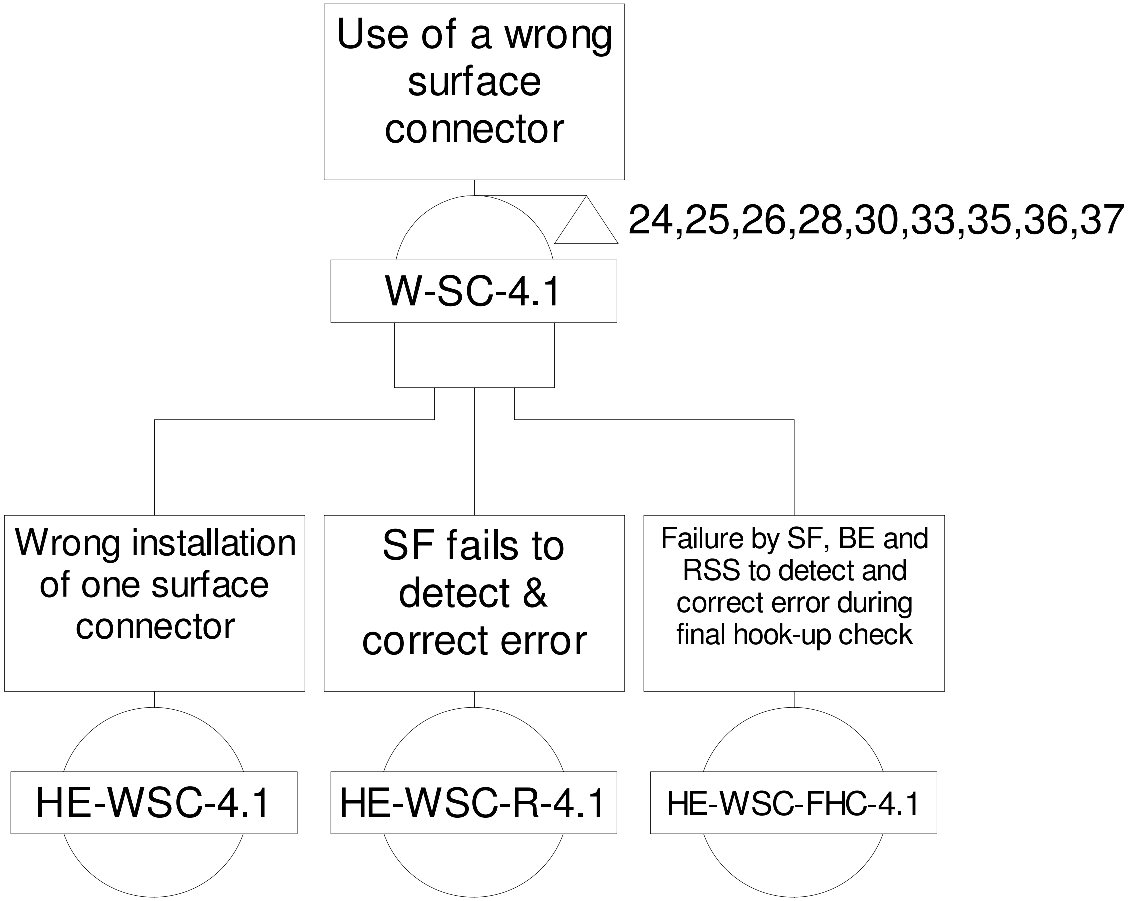

Use of three wrong surface connectors
22
4W-SC(3)
Use of two wrong surface connectors
35
4W-SC(2)
Use of a wrong surface connector
W-SC-4.3
Use of a wrong surface connector
W-SC-4.1
Page 40
Use of a wrong surface connector
W-SC-4.2

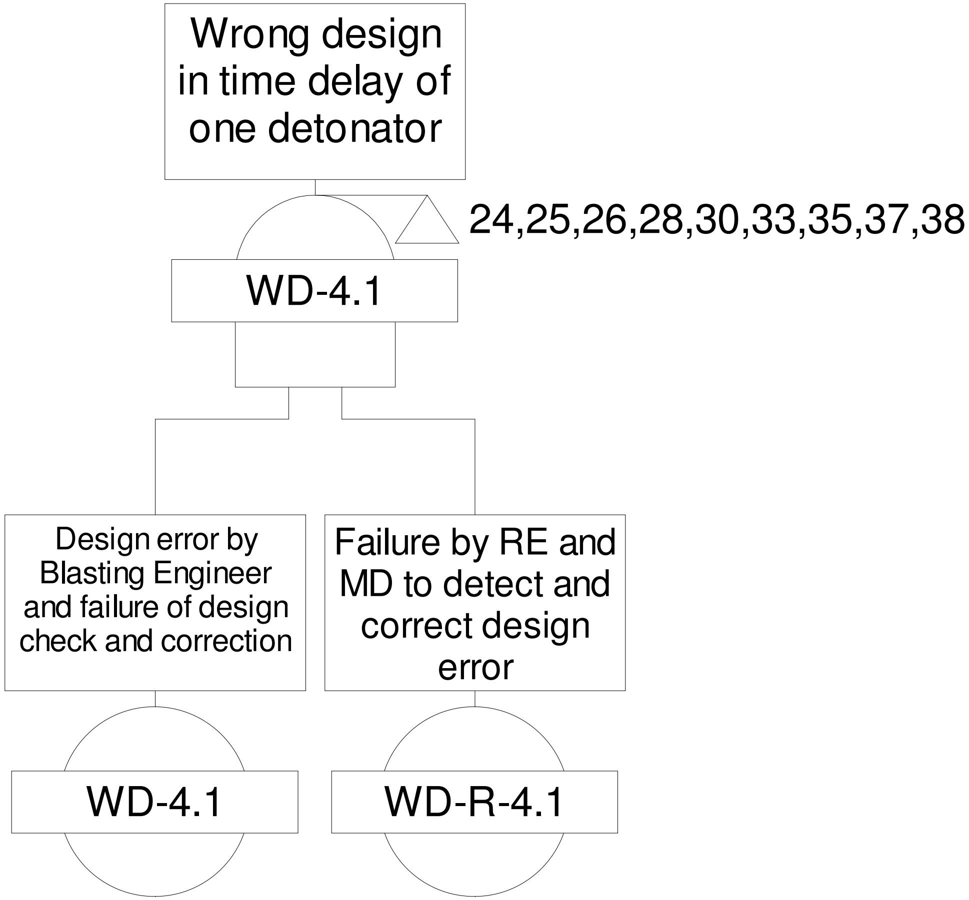


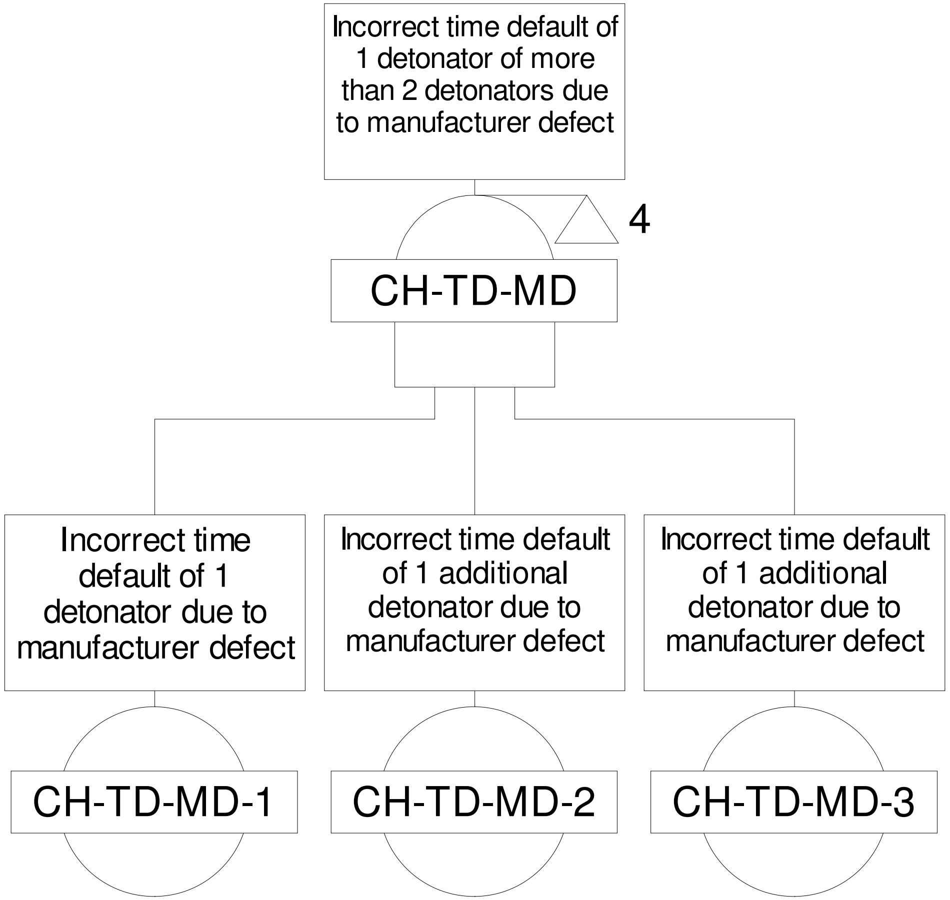
Wrong design in time delay of two detonators plus one other type of errors
23
4WD(2)+OTH
Wrong design in time delay of two detonators
38
4WD(2)
One error other than one wrong design in time delay of one detonator
4WD(2)-OTH
Wrong design in time delay of one detonator
WD-4.1
Page 41
Wrong design in time delay of one detonator
WD-4.2
1 detonator wrongly put into one sector which contains the same time delay detonator
4W-DETON-4.1
Page 32
One detonator of a sector connected wrongly to a surface connector of another sector
W-DETON-SC-4.1
Page 39
Use of a wrong surface connector
W-SC-4.1
Page 40
Manufacturer defect of one detonator such tat time delay corresponds to another one
W-MD-DETON-4.1
Manufacturer defect of one surface connector such tat time delay corresponds to another one
W-MD-SC-4.1
Overcharge of emulsion more than required
1,11,24,25,..
OL-EMULSION
Too much cartridged emulsion loaded into hole
OL-C
Page 5

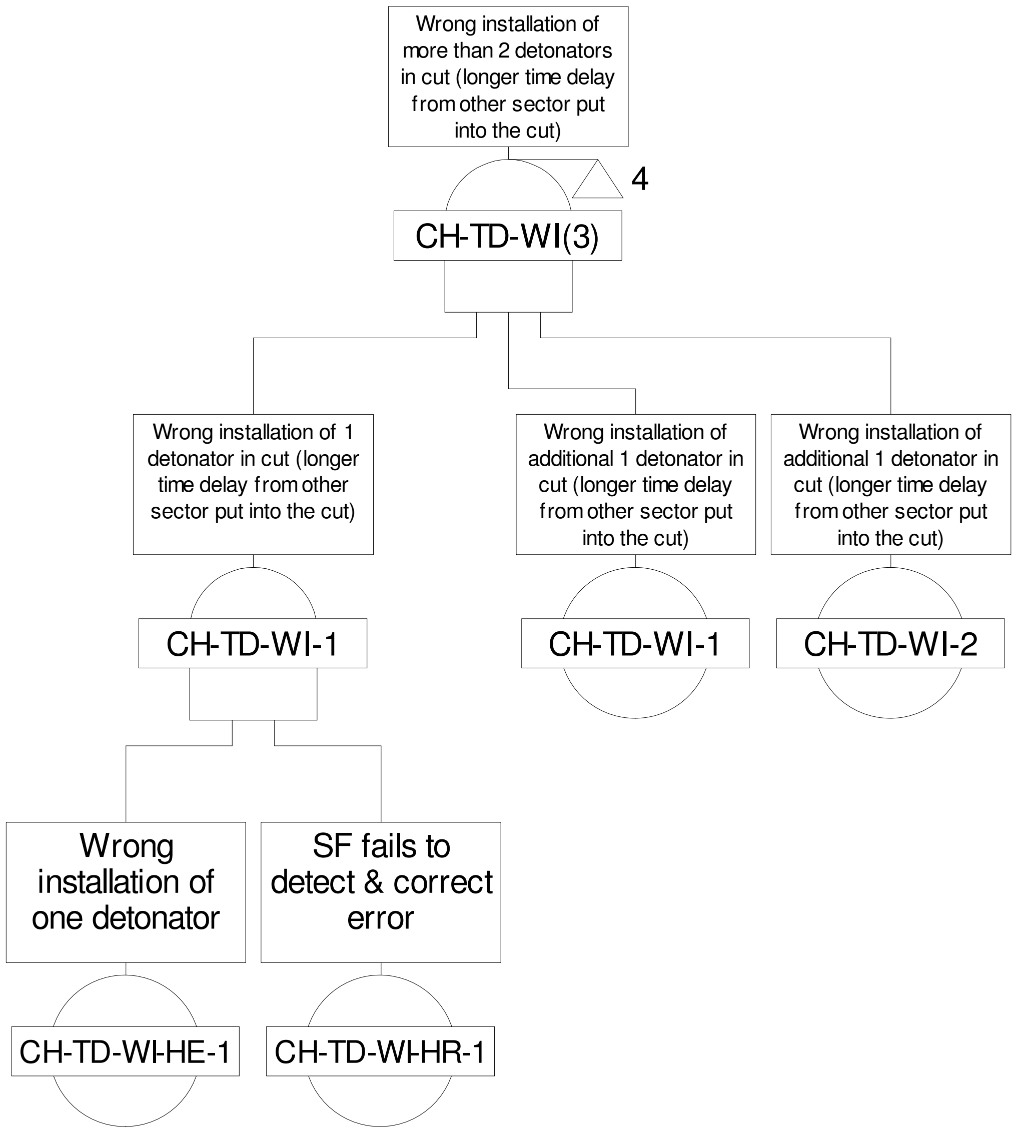

Wrong design in time delay of three detonators
22
4WD(3)
Wrong design in time delay of two detonators
37
4WD(2)
Wrong design in time delay of one detonator
WD-4.3
Wrong design in time delay of one detonator
WD-4.1
Page 41
Wrong design in time delay of one detonator
WD-4.2


One detonator of a sector connected wrongly to a surface connector of another sector
24,25,26,28,30,33,34,35,37
W-DETON-SC-4.1
Mis-connection of one detonator to surface connector of another sector
Failure by SF, BE and RSS to detect and correct error during final hook-up check
The sector contains the same time delay detonator
HE-W-DETON-SC-4.1
HE-W-DETON-SC-FHC-4.1
HE-DETON-SC-US-4.1.1

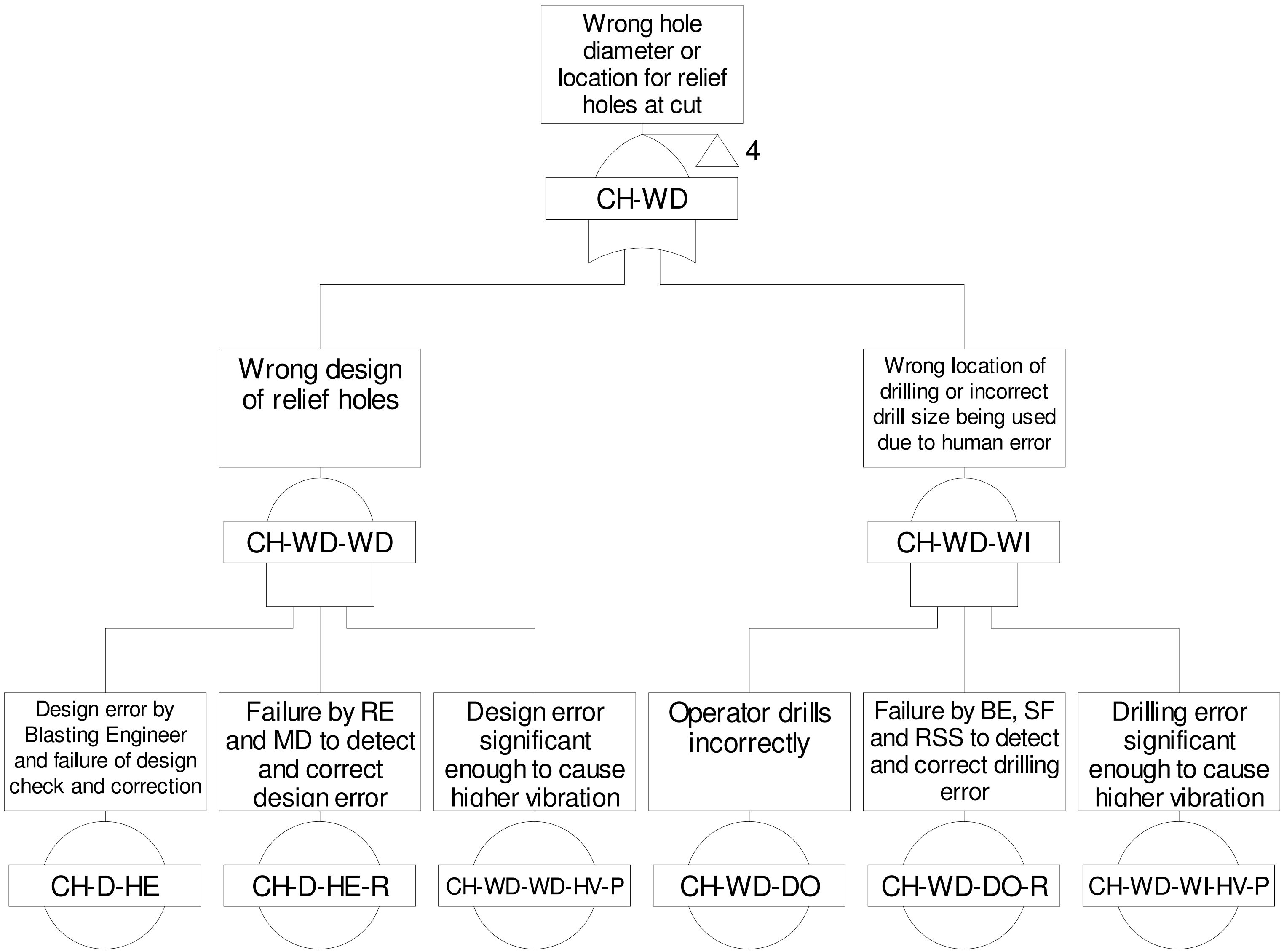

Use of a wrong surface connector
24,25,26,28,30,33,35,36,37
W-SC-4.1
Wrong installation of one surface connector
SF fails to detect & correct error
Failure by SF, BE and RSS to detect and correct error during final hook-up check
HE-WSC-4.1
HE-WSC-R-4.1
HE-WSC-FHC-4.1

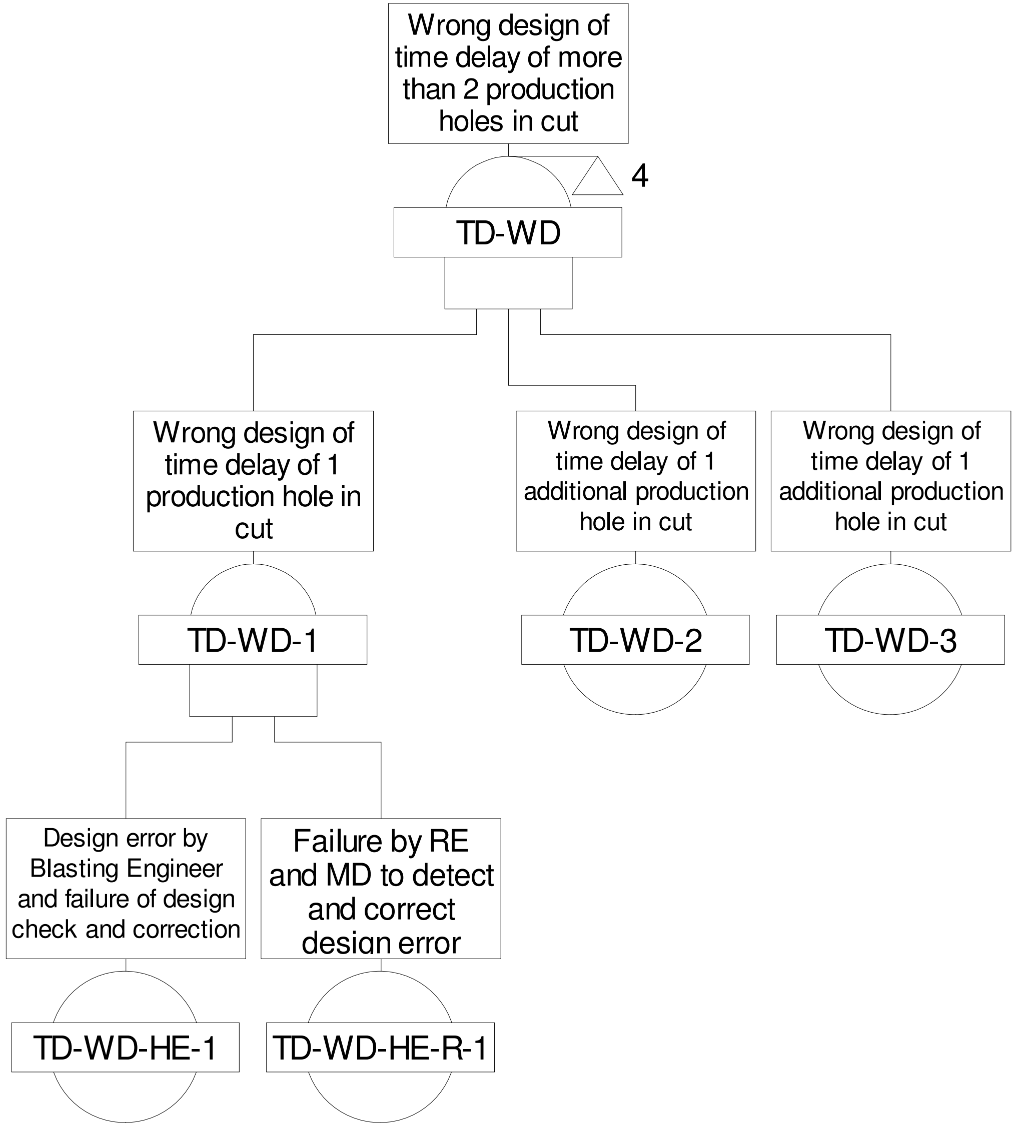

Wrong design in time delay of one detonator
24,25,26,28,30,33,35,37,38
WD-4.1
Design error by Blasting Engineer and failure of design check and correction
Failure by RE and MD to detect and correct design error
WD-4.1
WD-R-4.1


Incorrect time default of 1 detonator of more than 2 detonators due to manufacturer defect
4
CH-TD-MD
Incorrect time default of 1 detonator due to manufacturer defect
Incorrect time default of 1 additional detonator due to manufacturer defect
Incorrect time default of 1 additional detonator due to manufacturer defect
CH-TD-MD-1
CH-TD-MD-2
CH-TD-MD-3



Wrong installation of more than 2 detonators in cut (longer time delay from other sector put into the cut)
4
CH-TD-WI(3)
Wrong installation of 1 detonator in cut (longer time delay from other sector put into the cut)
CH-TD-WI-1
Wrong installation of additional 1 detonator in cut (longer time delay from other sector put into the cut)
CH-TD-WI-1
Wrong installation of additional 1 detonator in cut (longer time delay from other sector put into the cut)
CH-TD-WI-2
Wrong installation of one detonator
CH-TD-WI-HE-1
SF fails to detect & correct error
CH-TD-WI-HR-1


Wrong hole diameter or location for relief holes at cut
4
CH-WD
Wrong design of relief holes
Wrong location of drilling or incorrect drill size being used due to human error
CH-WD-WD
CH-WD-WI
Design error by Blasting Engineer and failure of design check and correction
Failure by RE and MD to detect and correct design error
Design error significant enough to cause higher vibration
Operator drills incorrectly
Failure by BE, SF and RSS to detect and correct drilling error
Drilling error significant enough to cause higher vibration
CH-D-HE
CH-D-HE-R
CH-WD-WD-HV-P
CH-WD-DO
CH-WD-DO-R
CH-WD-WI-HV-P


Wrong design of time delay of more than 2 production holes in cut
4
TD-WD
Wrong design of time delay of 1 production hole in cut
TD-WD-1
Wrong design of time delay of 1 additional production hole in cut
TD-WD-2
Wrong design of time delay of 1 additional production hole in cut
TD-WD-3
Design error by Blasting Engineer and failure of design check and correction
TD-WD-HE-1
Failure by RE and MD to detect and correct design error
TD-WD-HE-R-1

Annex F

Use of Explosives – Human Factor Assessment & Reduction Technique

CONTENTS

F1 HUMAN ERROR ASSESSMENT & REDUCTION TECHNIQUE (HEART)

F1.1 OVERVIEW

In order to assess how likely it is that a process will fail based on the potential for human error, a human reliability assessment (HRA) has been undertaken. HRA addresses the following questions:

- Which types of human error may occur (e.g. action error, information retrieval error, communication error, violation)?
- What is estimated frequency of such errors being made?
- What factors may influence this frequency (e.g. time pressure, stress, poor working environment, low morale)
- How can the identified human errors be prevented in the design or how can their impact be reduced by additional mitigating controls?

The Human Error Assessment and Reduction Technique (HEART) is a HRA method based on human performance literature; it has been used in this assessment to quantify human error probabilities. HEART assesses the interactions between humans, their specific tasks and performance shaping/human factors (error producing conditions).

F1.2 METHODOLOGY

The blasting process is inherently complex and is composed of numerous subtasks, carried out by different individuals. It is therefore important to identify these subtasks, the roles and responsibilities associated with these tasks and to assess the risks arising from human performance failure.

In consultation with an experienced Blasting Engineer/Shotfirer, fault trees were constructed to identify possible sources of human error during four critical blasting subtasks:

1) Cut failure
2) 2 MICs detonated in the same face
3) Excessive loading of cartridge emulsion
4) Excessive loading of bulk emulsion.

Fault Tree Analysis examines the logical relationship between the circumstances, failures events, and human/management errors which must occur in order for these specified undesired events to occur.

A human factors specialist reviewed the assumptions made by the risk specialist and adapted the fault trees where necessary before undertaking the HEART assessment. Analyses were undertaken for each scenario to identify the base human error probability. To ensure all potential human errors were identified and taken into account in the risk assessment, errors were quantified for the entire blasting life cycle, from the design of the blast plan to the installation of the explosives. Manufacture was not taken into account as this would require interviews with operators and observation of the manufacturing tasks to quantify human error probability.

F1.2.1 HEART methodology

The HEART technique was developed by Williams (1986) and is based on human performance literature. The human factors specialist must undertake the steps summarised in *Table 1.1* in order to estimate the probability of failure for a specific task.

Table 1.1 HEART methodology

Step	Task	Output
1	Classify the task in terms of its generic human unreliability into one of the 8 generic HEART task types	Nominal human unreliability probability
2	Identify relevant error producing conditions (EPCs) which may negatively influence performance	Maximum predicted nominal amount by which unreliability may increase (multiplier)
3	Estimate the impact of each EPC on the task	Value between 0 and 1
4	Calculate the 'assessed impact' for each EPC according to the formula: (EPC multiplier -1) x Impact	Assessed impact value
5	Calculate overall probability of failure of task based on the formula: Nominal human unreliability x assessed effects 1 x assessed effects 2… etc	Overall probability of failure

Each scenario has been analysed separately in *Sections F2 to F5* to determine the overall probability of human failure. Hence for each contributing error, the following sections present and discuss the generic HEART task type and the EPCs and their impacts, culminating in an overall probability of failure. It should be noted that the overall probabilities of failures are probabilities *per occasion the task is undertaken*.

F1.2.2 General Assumptions

- Where a task is undertaken by more than one individual at a time e.g. two Shotfirers, a reduction in the *assessed proportion of* effect of 1/3 has been calculated to reflect the presence of two individuals. The value of 1/3 is thought to be appropriate (rather than ½) due to the potential distraction introduced when more than one individual is present.
- The Shotfirers and Blasting Engineers are experienced and competent to perform their tasks.
- The working environment in the tunnel is not optimal for human performance. It is understood that it is wet, dusty (due to poor ventilation), hot, poorly lit for the tasks to be carried out and noisy. Therefore for all tasks taking place within the tunnel, the maximum weighting for the EPC *hostile environment* has been used.

- For all tasks apart from design checking and error correction, a disruption to sleep has been assumed. Shotfirers work a forward-rotating shift pattern, and the Blasting Engineer must also be present. The Resident Site Staff will have to be present at the magazine during the early hours of the morning; therefore they too will also experience some degree of sleep disruption.
- The Resident Site Staff will perform the supervisory roles on the blast site. Mines Division will carry out on-site audit checking for some blasts where no credit will be taken for the human error assessment.

F2 SCENARIO ONE: CUT FAILURE

Attachment F1 presents the fault tree of human error leading to cut failure. MS Excel spreadsheet was used to calculate the overall probabilities for events.

F2.1 EVENT 1.1: WRONG DESIGN OF HOLE DIAMETER/LOCATION FOR CUT

The overall probability of the wrong design being released to the project team is **5.29 E-7**, based on the failure of some or all of the tasks analysed below.

F2.1.1 *1.1.1: Design error by Blasting Engineer and failure of design check*

The overall probability that the wrong blast plan is submitted to the Resident Engineer and Mines Division for review is **1.92 E-2,** based on the failure of all of the tasks analysed below.

F2.1.2 *1.1.1-1 - Design error by Blasting Engineer leads to wrong relief hole diameter being drilled*

If an error is made by the Blasting Engineer during the design process and the incorrect drawings are distributed to the blasting team, the drilling operator may utilise what s/he believes to be the correct diameters to drill the relief holes, when in fact they are incorrect. The generic HEART task type taken to represent this checking task, utilising a modelling system is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09*. The EPCs and their impacts are shown in *Table 2.1*.

Table 2.1 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Design error by Blasting Engineer	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.36 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **1.36 E-1**.

F2.1.3 1.1.1-2/3 - Failure to detect and correct error by Blasting Engineer during modelling

If the relief hole diameters are calculated incorrectly, the Blasting Engineer should detect the error during the checking phase, and subsequently correct the error. However, due to time pressure, stress, lack of sleep and workload, it is possible that design errors may slip through.

Failure to detect the error

The Blasting Engineer utilises a modelling programme which will highlight any inconsistencies or mistakes. However, it is possible that the Blasting Engineer does not detect the errors highlighted by the modelling programme, or simply does not utilise the software to check the design. The generic HEART task type taken to represent this checking task, utilising a modelling system is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 2.2.*

Table 2.2 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Blasting Engineer during modelling	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.36 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **1.36 E-1**.

Failure to correct the error

If the Blasting Engineer identifies a problem with the design, there is potential that he may not act upon this information and fail to rectify the mistake. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 2.3*.

Table 2.3 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Blasting Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.54 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **4.54 E-3**.

F2.1.4 ***1.1.2: Failure to detect and correct error by Resident Engineer and Mines Division***

The overall probability of failure to detect and correct the design error by the Resident Engineer and the Mines Division is **2.76 E-5,** based on the failure of all of the tasks analysed below.

1.1.2-1 - Failure to detect error by the Resident Engineer

Once the Blasting Engineer has finalised the design, it is passed to the Resident Engineer and to the Mines Division. The Resident Engineer should check the design before giving his endorsement to the Mines Division. It has been assumed that the Resident Engineer is not as competent or experienced as the Blasting Engineer as this is not his sole task within the project. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid tasks involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 2.4*.

Table 2.4 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Resident Engineer	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.92 E-2
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.92 E-2**.

1.1.2.-2 - Failure to detect error by Mines Division

As specified earlier, Mines Division will also check the design for errors, although it is possible that errors may be made during the check which allows the incorrect design to go unnoticed. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid tasks involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 2.5*.

Table 2.5 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Resident Engineer	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.76 E-2
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.76 E-2**.

1.1.2-3 - Failure to correct error by the Resident Engineer

As above, the Resident Engineer may detect the error, but then fail to act on this to correct the design error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* . The EPCs and their impacts are shown in *Table 2.6.*

Table 2.6 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Resident Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.37 E-3
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	

Based on the above estimates, the likelihood of producing an error is **4.37 E-3**.

1.1.2-4 – Failure to correct error by Mines Division

As above, the Mines Division may fail to correct the error in the design. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for

which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 2.7*.

Table 2.7 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Mines Division	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.14 E-3
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.01	1.003	

Based on the above estimates, the likelihood of producing an error is **4.14 E-3**.

1.1.2-5 – Failure to detect error by Shotfirer

The Shotfirer will review the blast plan before blasting commences. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 2.8*.

Table 2.8 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	2.25 E-2
		Channel capacity overload	6	0.015	1.075	
		High level of emotional stress	1.3	0.06	1.018	

Based on the above estimates, the likelihood of producing an error is **2.25 E-2**.

1.1.2-6 – Failure to correct error by Shotfirer

If the Shotfirer identifies an error in the blast plan, he must act to correct the error before the blast commences. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 2.9*.

Table 2.9 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	3.38 E-3
		Channel capacity overload	6	0.015	1.075	
		High level of emotional stress	1.3	0.06	1.018	

Based on the above estimates, the likelihood of producing an error is **3.38 E-3**.

F2.2 *EVENT 1.2: WRONG LOCATION OF DRILLING OR INCORRECT DRILL SIZE USED*

The overall probability of the wrong location/incorrect drill size being used is **3.89 E-5**, based on the failure of some or all of the tasks analysed below.

F2.2.1 ***1.2.1: Operator fails to drill correctly***

The overall probability of the operator failing to drill correctly is **2.26E-2,** based on the failure of all of the tasks analysed below.

1.2.1.-1 - Surveyors calculate incorrect co-ordinates, leading to operator having disc with incorrect information

The surveyors will pass the co-ordinates to the Blasting Engineer, who will then programme a computer disc to be used in the drill. However, if the surveyors miscalculate the co-ordinates, there is potential that the holes will be drilled incorrectly. The generic HEART task type taken to represent this action task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02*. The EPCs and their impacts are shown in *Table 2.10*.

Table 2.10 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Surveyors calculate incorrect co-ordinates	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.20 E-2

Based on the above estimates, the likelihood of producing an error is **2.20 E-2**.

1.2.1-2 - Blasting Engineer inputs wrong information on to disc (typo)

If the surveyors provide the correct information to the Blasting Engineer, it is possible that he may execute an action error or information retrieval error when programming the computer disc. The generic HEART task type taken to represent this action task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 2.11*.

Table 2.11 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer inputs wrong information on to disc	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	6.05 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **6.05 E-4**.

F2.2.2 1.2.1: Failure by Blasting Engineer/ Shotfirers to check and correct drilling error

The overall probability of operator fails to drill correctly is **1.72 E-3,** based on the failure of all of the tasks analysed below.

1.2.2-1 – Blasting Engineer fails to check holes are drilled correctly

Once the cut holes have been drilled, it is expected that the Blasting Engineer will check the location and size of the holes against the plans. However, it is possible that the Blasting Engineer will fail to check this, or check it completely. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 2.12*.

Table 2.12 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer fails to check holes are drilled correctly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.79 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	
		Poor/ hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.01	1.09	

Based on the above estimates, the likelihood of producing an error is **3.79 E-2**.

1.2.2-2 – Shotfirer fails to check holes are drilled correctly

In addition to the Blasting Engineer, the Shotfirers will also check the holes have been drilled correctly. The chief Shotfirer will have ultimate responsibility for this check. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 2.13*.

Table 2.13 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to check holes are drilled correctly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.48 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.003	1.027	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **3.48 E-2**.

1.2.2-3 – Blasting Engineer fails to correct drilling error

Although the Blasting Engineer may have detected the drilling error, it is possible that he will not do anything to correct it. This could be due to increased workload or distraction for example. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 2.14.*

Table 2.14 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer fails to correct drilling error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	5.22 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **5.22 E-3**.

1.2.2-4 – Shotfirer fails to correct drilling error

The Shotfirer must act to correct the drilling error if it is identified. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 2.15.*

Table 2.15 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer fails to correct drilling error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	5.08 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Poor/hostile environment	1.15	1	1.15	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **5.08 E-3**.

F2.3 EVENT 1.3: DETONATOR IS INSTALLED INCORRECTLY

The overall probability of a detonator being installed incorrectly based on the failure of all the tasks analysed below is **1.40 E-8.**

F2.3.1 1.3.1: Wrong Installation of one detonator by the Shotfirer

The overall probability of a detonator being wrongly installed is **5.02 E-7**, based on the failure of all of the tasks analysed below.

1.3.1 – 1 Shotfirers mark holes incorrectly

The chief Shotfirer will be responsible for marking the holes correctly, although the second Shotfirer will assist. There is potential for information retrieval errors to occur when looking at the plans and transferring this to the face as well as lapses in concentration when actually marking the holes. The generic HEART task type taken to represent this action task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 2.16*.

Table 2.16 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fail to mark holes correctly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.69 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **3.69 E-2**.

1.3.1-2 – Shotfirer fails to detect marking error

The Shotfirers should check their own work, and each others. However, there is potential that one or both Shotfirers to fail to check and therefore fail to detect the marking error. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 2.17*.

Table 2.17 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fails to detect marking error	0.09	Shortage of time available for error detection & correction	11	0.003	1.03	1.10 E-1
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		Channel capacity overload	6	0.015	1.075	
		High level of emotional stress	1.3	0.06	1.018	
		Low signal-noise ratio	10	0.003	1.027	
		Poor/ hostile environment	1.15	0.33	1.0495	

Based on the above estimates, the likelihood of producing an error is **1.10 E-1.**

1.3.1-3 Shotfirers fails to correct marking error

If the Shotfirers have detected the marking error, they must then correct the error to ensure it is recovered. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 2.18*.

Table 2.18 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fail to correct marking error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	3.64 E-3
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Channel capacity overload	6	0.015	1.075	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **3.64 E-3**

1.3.1-4 – Shotfirer picks up detonator of wrong time delay

When the Shotfirers picks up the detonator, they must ensure they choose one with the correct time delay. Due to an action execution error, the Shotfirer may pick up the wrong one to the intended one. The generic HEART task type taken to represent this action task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 2.19*.

Table 2.19 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer picks up detonator of wrong time delay	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

1.3.1-5 – Shotfirer fails to check shell & detonator delay tag before placing into the hole

The Shotfirer should check the shell and detonator delay tag before placing it in the hole. However, it is possible that due to time pressure, poor lighting etc that he omits to check before placing the detonator in the hole. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 2.20.*

Table 2.20 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to check shell and detonator delay tag before inserting into the hole	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

1.3.1-6 – Shotfirer puts detonator in a hole not within the cut

Alternatively, the Shotfirer may pick up a detonator but insert it into a hole not within the cut. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004*. The EPCs and their impacts are shown in *Table 2.21*.

Table 2.21 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer puts wrong detonator in the hole	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	6.77 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **6.77 E-4.**

1.3.1-7 – Shotfirer fails to check detonator delay tag after placing into the hole

The final check to prevent the wrong detonator being placed in the hole is the Shotfirer making a final check of the delay tag once it has been installed. Both Shotfirers will carry out their own checks and cross-check each others work. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 2.22*.

Table 2.22 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to check detonator delay tag after placing in the hole	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.2	1.06	
		High level of emotional stress	1.3	0.05	1.25	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

F2.3.2 ***1.3.2: Shotfirer fails to detect and correct that there are holes without detonators left in the face***

The overall probability of a Shotfirer failing to detect and correct empty holes is **2.79 E-2.**

1.3.2-1 – Shotfirer leaves empty holes in the blast face due to not realising there are detonators left over

Only the exact number of detonators should be delivered to site, therefore if there are any remaining detonators, it means that there must be some holes without detonators. However, if the Shotfirer does not realise there are detonators left over, he will not detect that there are empty holes to fill. The generic HEART task type taken to represent this action task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 2.23*.

Table 2.23 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fail to check if there are detonators left over	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	2.43 E-2
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Low signal-noise ratio	10	0.003	1.027	
		Channel capacity overload	6	0.015	1.075	

Based on the above estimates, the likelihood of producing an error is **2.43 E-2**.

1.3.2-2 – Shotfirer fails to fill empty holes before detonation

If the Shotfirers identify any errors during their final check of the delay tags, they must rectify these errors. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 2.24*.

Table 2.24 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	3.64 E-3
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		Low signal-noise ratio	10	0.003	1.027	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Channel capacity overload	6	0.015	1.075	

Based on the above estimates, the likelihood of producing an error is **3.64 E-3.**

F3 SCENARIO TWO: TWO MIC DETONATED IN THE SAME FACE

Attachment F1 presents the fault tree of human error leading to two MIC being detonated in the same face. MS Excel spreadsheet was used to calculate the overall probabilities for events.

F3.1 EVENT 2.1: WRONG DESIGN OF TIME DELAY

The overall probability of the wrong design being released to the project team is **5.29 E-7**, based on the failure of some or all of the tasks analysed below.

F3.1.1 2.1.1: Design error by Blasting Engineer and failure of design check and correction

The overall probability of a wrong blast plan submitted to the resident engineer and Mines Division for review is **1.92 E-2,** based on the failure of all of the tasks analysed below.

2.1.1-1 - Design error by Blasting Engineer

As before, if an error is made by the Blasting Engineer during the design process and the incorrect drawings are distributed to the blasting team, they will utilise the plans believing them to be correct when in fact they are incorrect. The generic HEART task type taken to represent this checking task, utilising a modelling system is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 3.1*.

Table 3.1 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Design error by Blasting Engineer	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.36 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **1.36 E-1**.

2.1.1-2/3 - Failure to detect and correct error by Blasting Engineer during modelling

If the time delay is specified incorrectly, the Blasting Engineer should detect the error during the checking phase, and subsequently correct the error. However, due to time pressure, stress, lack of sleep and workload, it is possible that design errors may slip through.

Failure to detect the error

The Blasting Engineer utilises a modelling programme which will highlight any inconsistencies or mistakes. However, it is possible that the Blasting Engineer does not detect the errors highlighted by the modelling programme, or simply does not utilise the software to check the design. The generic HEART task type taken to represent this checking task, utilising a modelling system is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 3.2*.

Table 3.2 **HEART calculation**

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Blasting Engineer during modelling	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.36 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **1.36 E-1**.

Failure to correct the error

If the Blasting Engineer identifies a problem with the design, there is potential that he may not act upon this information and fail to rectify the mistake. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.3*.

Table 3.3 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Blasting Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.54 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **4.54 E-3**.

F3.1.2 ***2.1.2: Failure to detect and correct error by Resident Engineer and Mines Division***

The overall probability of Failure to detect and correct error by Resident Engineer and Mines Division is **2.76 E-5,** based on the failure of all of the tasks analysed below.

2.1.2-1 - Failure to detect error by the Resident Engineer

Once the Blasting Engineer has finalised the design, it is passed to the Resident Engineer and to the Mines Division. The Resident Engineer should check the design before giving his endorsement to the Mines Division. It has been assumed that the Resident Engineer is not as competent or experienced as the Blasting Engineer as this is not his sole task within the project. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid tasks involving relatively low level of skill"* for which the nominal human unreliability is *0.02*. The EPCs and their impacts are shown in *Table 3.4*.

Table 3.4 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Resident Engineer	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.92 E-2
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.92 E-2**.

2.1.2.-2 - Failure to detect error by Mines Division

As specified earlier, Mines Division will also check the design for errors, although it is possible that errors may be made during the check which allows the incorrect design to go unnoticed. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid tasks involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.5*.

Table 3.5 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Resident Engineer	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.76 E-2
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.76 E-2**.

2.1.2-3 - Failure to correct error by the Resident Engineer

As above, the Blasting Engineer may detect the error, but then fail to act on this to correct the design error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.6*.

Table 3.6 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Resident Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.37 E-3
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	

Based on the above estimates, the likelihood of producing an error is **4.37 E-3**.

2.1.2-4 – Failure to correct error by Mines Division

As above, the Mines Division may fail to correct the error in the design. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for

which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.7*.

Table 3.7 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Mines Division	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.14 E-3
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.01	1.003	

Based on the above estimates, the likelihood of producing an error is **4.14 E-3**.

2.1.2-5 – Failure to detect error by Shotfirer

The Shotfirer will review the blast plan before blasting commences. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.8*.

Table 3.8 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	2.25 E-2
		High level of emotional stress	1.3	0.015	1.075	
		Channel capacity overload	6	0.06	1.018	

Based on the above estimates, the likelihood of producing an error is **2.25 E-2**.

2.1.2-6 – Failure to correct error by Shotfirer

If the Shotfirer identifies an error in the blast plan, he must act to correct the error before the blast commences. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.9*.

Table 3.9 *HEART calculation*

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct error	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	3.38 E-3
		High level of emotional stress	1.3	0.015	1.075	
		Channel capacity overload	6	0.06	1.018	

Based on the above estimates, the likelihood of producing an error is **3.38 E-3**.

F3.2 *EVENT 2.2: DETONATOR PUT INTO WRONG HOLE*

The overall probability of one detonator being put into a wrong hole is **1.53 E-8**, based on the failure of some or all of the tasks analysed below.

F3.2.1 *2.2.1: Delivery of incorrect detonators from the magazine to the blast site*

The overall probability of a delivery of incorrect detonators from the magazine to the blast site is **2.10 E-6,** based on the failure of all of the tasks analysed below. If the Shotfirer fails to check the detonator delay label both before and after installing, then the delivery error will not be discovered on site. The overall probability of wrong delivery is insignificant when compared to the probability that the Shotfirer fails to check the detonator delay label before installing (even when the delivery is correct); hence it is not considered in deriving the overall probability for Event 2.2.

2.2.1-1 – Detonators are picked incorrectly by the Shotfirer from the magazine

The Shotfirer must utilise the blast plan to pick the correct detonators from the magazine. There is potential for the Shotfirer to have a lapse in concentration, selecting the wrong detonators from the magazine. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.10.*

Table 3.10 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer selects wrong detonators at the magazine	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	3.53 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	

Based on the above estimates, the likelihood of producing an error is **3.53 E-3**.

2.2.1-2 – Shotfirer fails to detect error

The Shotfirer will check that the detonators he has picked are the correct ones. However, he may misread the information, or forget to check at all. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.11*.

Table 3.11 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.94 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.94 E-2**.

2.2.1-5 – Shotfirer fails to correct error

If the Shotfirer detects a selection error, he can recover this by acting to change the detonators to the correct ones. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.12*.

Table 3.12 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.42 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.01	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **4.42 E-3**.

2.2.1-3 – Resident Engineer's Inspector fails to check correct detonators have been picked

The Resident Engineer's Inspector must check that the correct detonators have been selected. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 3.13*.

Table 3.13 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Resident Engineer's Inspector fail to detect error	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.32 E-1
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **1.32 E-1**.

2.2.1-6 – Resident Engineer's Inspector site staff fail to correct error

If the Resident Engineer's Inspector identifies the error, they must then act on this to prevent the wrong detonators being sent to the face. The generic

HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.14.*

Table 3.14 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Resident Engineer's Inspector fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.39 E-3
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **4.39 E-3**.

2.2.1-4 – Contractor's Representative fails to check correct detonators have been picked

Contractor's Representative must also check that the correct detonators have been selected. Again, the generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 3.15.*

Table 3.15 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Contractor Represent-ative fails to detect error	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.25 E-1
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **1.25 E-1**.

2.2.1-7 Contractor's Representative fails to correct error

If the Contractor Representative identifies an error, in order to prevent the wrong detonators being delivered, they must act to correct the error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.16*.

Table 3.16 ***HEART calculation***

Task	**Generic task unreliability**	**EPCs**	**Multiplier**	**Assessed Proportion of Effect**	**Assessed Effect**	**Human Error Probability**
Contractor Representative fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.16 E-3
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **4.16 E-3**.

F3.2.2 ***2.2.2: Installation of one detonator by Shotfirer into a sector already containing a detonator of that delay period***

The overall probability of a detonator being wrongly installed is **5.47 E-7**, based on the failure of all of the tasks analysed below.

2.2.2 – 1 Shotfirers mark holes incorrectly

The chief Shotfirer will be responsible for marking the holes correctly, although the junior Shotfirer will assist. There is potential for information retrieval errors to occur when looking at the plans and transferring this to the face as well as lapses in concentration when actually marking the holes. The generic HEART task type taken to represent this action task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table* 3.17.

Table 3.17 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fail to mark holes correctly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.69 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **3.69 E-2**.

2.2.2-2 – Shotfirer fails to detect marking error

The Shotfirers should check their own work, and each others. However, there is potential that one or both Shotfirers fail to check and therefore detect the marking error. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 3.18*.

Table 3.18 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fails to detect marking error	0.09	Shortage of time available for error detection & correction	11	0.003	1.03	1.10 E-1
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.33	1.0495	
		Channel capacity overload	6	0.015	1.075	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **1.10E -01**

2.2.2-3 Shotfirers fails to correct marking error

If the Shotfirers have detected the marking error, they must then correct the error to ensure it is recovered. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.19*.

Table 3.19 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fail to correct marking error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	3.64 E-3
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Channel capacity overload	6	0.015	1.075	
		Poor/hostile environment	1.15	0.3	1.045	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **3.64 E-3**

2.2.2-4 – Shotfirer picks up detonator of wrong time delay

When the Shotfirers pick up the detonator, they must ensure they choose one with the correct time delay. Due to an action execution error, the Shotfirer may pick up the wrong one to the intended one. The generic HEART task type taken to represent this action task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 3.20*.

Table 3.20 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer picks up detonator of wrong time delay	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

2.2.2-5 – Shotfirer fails to check shell & detonator delay tag before placing into the hole

The Shotfirer should check the detonator shell and delay tag before placing it in the hole. However, it is possible that due to time pressure, poor lighting etc that he omits to check before placing the detonator in the hole. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 3.21.*

Table 3.21 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to check shell and detonator delay tag before inserting into the hole	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

2.2.2-6 – Shotfirer puts detonator into a wrong hole

Alternatively, the Shotfirer may pick up a detonator with the right time delay, but insert it into the wrong hole. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004*. The EPCs and their impacts are shown in *Table 3.22*.

Table 3.22 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer puts wrong detonator in the hole	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

2.2.2-7 – Shotfirer fails to check detonator delay tag after placing into the hole

The final check to prevent the wrong detonator being placed in the hole is the Shotfirer making a final check of the delay tag once it has been installed. Both Shotfirers will carry out their own checks and cross-check each others work. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 3.23*.

Table 3.23 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to check detonator delay tag after placing into the hole	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

F3.2.3 2.2.3: Shotfirer fails to check and correct installation error

The overall probability of the Shotfirer failing to check and correct an installation error is **2.79 E-2**, based on the failure of all of the tasks analysed below.

2.2.3-1 – Shotfirer leaves empty holes in the blast face due to not realising there are detonators left over

Only the exact number of detonators should be delivered to site, therefore if there are any remaining detonators, it means that there must be some holes without detonators. However, if the Shotfirer does not realise there are detonators left over, he will not detect that there are empty holes to fill. The generic HEART task type taken to represent this action task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table* 3.24.

Table 3.24 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers leaves empty holes	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	2.43 E-2
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Low signal-noise ratio	10	0.003	1.027	
		Channel capacity overload	6	0.015	1.075	

Based on the above estimates, the likelihood of producing an error is **2.43 E-2**.

2.2.3-2 – Shotfirer fails to fill empty holes before detonation

If the Shotfirers identify any errors during their final check of the delay tags, they must rectify these errors. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.25*.

Table 3.25 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	3.64 E-3
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		Channel capacity overload	6	0.015	1.075	
		Low signal-noise ratio	10	0.003	1.027	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/ hostile environment	1.15	0.3	1.045	

Based on the above estimates, the likelihood of producing an error is **3.64 E-3**

F3.3 EVENT 2.3: DETONATOR CONNECTED TO A SURFACE CONNECTOR FROM ANOTHER SECTOR

The overall probability of one detonator being connected to a surface connector from another sector is **2.84 E-6**, based on the failure of some or all of the tasks analysed below.

F3.3.1 2.3.1: Shotfirer misconnects one detonator to the wrong surface connector

The overall probability of the Shotfirer making a misconnection is **1.97 E-2**, based on the failure of some or all of the tasks analysed below.

2.3.1-1 – Shotfirer marks sectors incorrectly

The chief Shotfirer will be responsible for marking the sectors correctly, although the junior Shotfirer will assist. There is potential for information retrieval errors to occur when looking at the plans and transferring this to the face as well as lapses in concentration when actually marking the sectors. The generic HEART task type taken to represent this action task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.26*.

Table 3.26 *HEART calculation*

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fail to mark sectors correctly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.39 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **3.39 E-2**.

2.3.1-2 – Shotfirer fails to detect marking error

The Shotfirers should check their own work, and each others. However, there is potential that one or both Shotfirers fail to check and therefore detect the marking error. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 3.27*.

Table 3.27 *HEART calculation*

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fails to check sectors are marked correctly	0.09	Shortage of time available for error detection & correction	11	0.003	1.03	1.28 E-1
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.33	1.0495	
		Channel capacity overload	6	0.05	1.25	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **1.28 E-1**

2.3.1-3 Shotfirers fails to correct marking error

If the Shotfirers have detected the marking error, they must then correct the error to ensure it is recovered. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.28*.

Table 3.28 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirers fail to correct marking error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	3.39 E-3
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **3.39 E-3**

2.3.1-4 – Shotfirer bundles a detonator from another sector into wrong section

In order to connect the surface connector, the Shotfirer will bundle the detonators together. Where one sector meets another, due to the proximity of the bundles and a poorly lit environment, there is potential that a detonator from another sector may be introduced into the bundle. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 3.29*.

Table 3.29 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer bundles detonator from another sector into bundle	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	3.72 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.5	5.5	
		Poor/hostile environment	1.15	1	1.15	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **3.72 E-3**

2.3.1-5 - Helper bundles a detonator from another sector into wrong section

The Shotfirers may enlist helpers from the blast team to bundle the detonators. These individuals will not be as competent as the Shotfirer; therefore there is greater potential to make misconnections between sectors. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.30*.

Table 3.30 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Helper bundles detonators incorrectly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.38 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.01	1.003	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.5	5.5	
		Operator inexperienced	3	0.7	2.4	

Based on the above estimates, the likelihood of producing an error is **3.38 E-1**.

2.3.1-6 – Shotfirer fails to detect bundling error by helper

The Shotfirers should check that the detonators have been bundled correctly by the helper. However, due to time pressure for example, one or both may not carry out the check. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.31*.

Table 3.31 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	2.83 E-2
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.006	1.018	
		Channel capacity overload	6	0.05	1.25	
		Low signal-noise ratio	10	0.003	1.027	
		Poor/ hostile environment	1.15	0.33	1.0495	

Based on the above estimates, the likelihood of producing an error is **2.83 E-2**.

2.3.1-7 – Shotfirer fails to correct bundling error by helper

If the Shotfirer detects a bundling error, he can recover this by re-bundling the detonators. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.32*.

Table 3.32 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct bundling error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	3.64 E-3
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Channel capacity overload	6	0.015	1.075	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **3.64 E-3**.

2.3.1-8 – Shotfirer connects wrong detonator

The final action error is that the Shotfirer connects the wrong detonator, due to a lapse in concentration. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 3.33*.

Table **3.33** ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer connects wrong detonator	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.01	1.09	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4**

F3.3.2 2.3.2 – Failure to detect and correct connection error

The overall probability of failure to detect and correct a connection error is **1.44 E-4**, based on the failure of some or all of the tasks analysed below.

2.3.2-1 – Shotfirer fails to detect connection error

The Shotfirers should check that the surface connectors have been connected correctly. However, due to time pressure, sleep deprivation, and/or the poor working environment for example, one or both may not carry out the check. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.34*.

Table 3.34 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	2.83 E-2
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.33	1.0495	
		Channel capacity overload	6	0.05	1.25	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **2.83 E-2**.

2.3.2-2 – Shotfirer fails to correct connection error

If the Shotfirer detects a bundling error, he can recover this by re-bundling the detonators. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.35*.

Table 3.35 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct connection error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	3.64 E-3
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		Channel capacity overload	6	0.015	1.075	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **3.64 E-3**.

2.3.2-3 – Blasting Engineer fails to detect connection error

The Blasting Engineer should check that the surface connectors have been connected correctly. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.36*.

Table 3.36 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.79 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Channel capacity overload	6	1	1.15	
		Low signal-noise ratio	10	0.05	1.25	
		Poor/ hostile environment	1.15	0.01	1.09	

Based on the above estimates, the likelihood of producing an error is **3.79 E-2**.

2.3.2-4 – Blasting Engineer fails to correct connection error

Following identification of a connection error, the Blasting Engineer should take steps to correct the error. However, it is possible that his attention may be drawn elsewhere due to high workload for example. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.37*.

Table 3.37 HEART calculation

Task	**Generic task unreliability**	**EPCs**	**Multiplier**	**Assessed Proportion of Effect**	**Assessed Effect**	**Human Error Probability**
Blasting Engineer fails to correct connection error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.55 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/hostile environment	1.15	1	1.15	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **4.55 E-3**.

2.3.2-5 – Resident Site Staff fails to detect connection error

Representatives from the Resident Site Staff must also check that the detonators have been connected correctly. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 3.38*.

Table 3.38 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Resident Site Staff fails to detect error	0.09	Shortage of time available for error detection & correction	11	0.003	1.03	1.03 E-1
		Channel capacity overload	6	0.015	1.075	
		High level of emotional stress	1.3	0.003	1.0009	
		Low signal-noise ratio	10	0.003	1.027	
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	

Based on the above estimates, the likelihood of producing an error is **1.03 E-1**.

2.3.2-6 – Resident Site Staff fails to correct connection error

Upon detecting a connection error, representatives must act to correct the error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.39*.

Table 3.39 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Resident Site Staff fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	**3.42 E-3**
		High level of emotional stress	1.3	0.003	1.0009	
		Low signal-noise ratio	10	0.003	1.027	
		Channel capacity overload	6	0.015	1.075	
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	

Based on the above estimates, the likelihood of producing an error is **3.42 E-3**.

F3.4 EVENT 2.4: SHOTFIRER USES WRONG SURFACE CONNECTOR

The overall probability of the wrong surface connector being used is **7.43 E-9**, based on the failure of all of the tasks analysed below. As specified in *Section F3.2.1*, wrong delivery has not been factored into the calculation of the overall probability of this event due to its very small influence.

F3.4.1 2.4.1: Incorrect installation of surface connector

*The overall probability of the Shotfirer making a misconnection is **1.48 E-3**, based on the failure of some or all of the tasks analysed below.*

2.4.1-1 – Shotfirer fails to check the colour of the surface connector before installing

The Shotfirer must check the colour of the surface connector before connecting to the detonator bundle. The generic HEART task type taken to represent this action task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 3.40*.

Table 3.40 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to check colour of surface connector	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

2.4.1-2 – Shotfirer connects wrong surface connector

The Shotfirer may connect the wrong surface connector due to a lapse in concentration. The generic HEART task type taken to represent this action task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to* *correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 3.41*.

Table 3.41 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer connects wrong surface connector	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	
		Low signal-noise ratio	10	0.01	1.09	
		Poor/ hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4.**

F3.4.2 *2.4.2: Shotfirer fails to detect and respond to error*

The overall probability of failure to detect and correct a connection error by Shotfirer is **4.24 E-2**, based on the failure of some or all of the tasks analysed below.

2.4.2-1 – Shotfirer fails to detect error

The Shotfirer should check that the correct surface connector has been used following connection. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.42*.

Table 3.42 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.69 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.01	1.09	

Based on the above estimates, the likelihood of producing an error is **3.69 E-2**.

2.4.2-2 – Shotfirer fails to correct error

The Shotfirer must take action to correct the error in order to recover it. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.43*.

Table 3.43 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct connection error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	5.54 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.01	1.09	

Based on the above estimates, the likelihood of producing an error is **5.54 E-3**.

F3.4.3 2.4.3: Failure to detect and respond during final hook-up check

The overall probability of failure to detect and correct a connection error is **1.10 E-3**, based on the failure of some or all of the tasks analysed below.

2.4.3-1 – Blasting Engineer fails to detect error

The Blasting Engineer should check that the correct surface connectors have been used. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 3.44.*

Table 3.44 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.04 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.01	1.09	
		Channel capacity overload	6	0.1	1.5	

Based on the above estimates, the likelihood of producing an error is **3.04 E-2**.

2.4.3-2 – Blasting Engineer fails to correct error

Following identification of a connection error, the Blasting Engineer should take steps to correct the error. However, it is possible that his attention may be drawn elsewhere due to high workload for example. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.45.*

Table 3.45 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer fails to correct connection error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	6.83 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Low signal-noise ratio	10	0.01	1.09	
		Channel capacity overload	6	0.1	1.5	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **6.83 E-3**.

2.4.3-3 – Resident Site Staff fails to detect error

Representatives from the Resident Site Staff must also check the correct surface connectors have been used. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 3.46*.

Table 3.46 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Resident Site Staff fails to detect error	0.09	Shortage of time available for error detection & correction	11	0.003	1.03	1.02 E-1
		Channel capacity overload	6	0.0175	1.07508	
		High level of emotional stress	1.3	0.003	1.0009	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **1.02 E-1**.

2.4.3-4 – Resident Site Staff fails to correct error

Upon detecting a surface connector error, representatives must act to correct the error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some* *checking"* for which the nominal human unreliability is *0.003*. The EPCs and their impacts are shown in *Table 3.46*.

Table 3.47 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Resident Site Staff fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	**3.50 E-3**
		High level of emotional stress	1.3	0.09	1.027	
		Low signal-noise ratio	10	0.003	1.027	
		Channel capacity overload	6	0.015	1.075	

Based on the above estimates, the likelihood of producing an error is **3.50 E-3**.

2.4.3-5 – Shotfirer fails to detect error

The Shotfirer should check that the correct surface connector has been used before the final check. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02*. The EPCs and their impacts are shown in *Table 3.48*.

Table 3.48 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	2.43 E-2
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Channel capacity overload	6	0.015	1.075	
		Poor/hostile environment	1.15	0.3	1.045	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **2.43 E-2**.

2.4.3-6 – Shotfirer fails to correct error

The Shotfirer must take action to correct the error in order to recover it. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 3.49*.

Table 3.49 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct error	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	3.64 E-3
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Channel capacity overload	6	0.015	1.075	
		Poor/hostile environment	1.15	0.3	1.045	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **3.6 E-3**.

F4 SCENARIO THREE: MIC EXCEEDED (BULK EMULSION)

Attachment F1 presents the fault tree of human error leading to the MIC being exceeded due to overloading of bulk emulsion. MS Excel spreadsheet was used to calculate the overall probabilities for events.

F4.1 EVENT 3.1: EXCESS EMULSION IS LOADED INTO A HOLE

The overall probability of excess emulsion being loaded is **1.09 E-6**, based on the failure of some or all of the tasks analysed below.

F4.1.1 3.1.1: Excess emulsion is loaded due to wrong density

The overall probability of excess emulsion being loaded due to it being the wrong density is **7.95 E-11**, based on the failure of some or all of the tasks analysed below.

3.1.1-1 – Truck Operator sets gassing flow meter incorrectly

The Truck Operator must set the gassing flow meter to the correct setting in order to provide the correct density of bulk emulsion. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 4.1*.

Table 4.1 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Truck Operator sets gassing flow meter incorrectly	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	3.95 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.1	1.03	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **3.95 E-3**.

3.1.1-2 – Truck Operator reads density chart incorrectly

Once the flow meter has been set, the operator must make checks utilising a density chart. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 4.2*.

Table 4.2 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Truck Operator reads density chart incorrectly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.63 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.1	1.03	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **2.63 E-2**.

3.1.1-3 – Truck Operator reads scales incorrectly

The truck operator must weigh the product using the scales on the truck. An information retrieval error may occur, leading to the operator reading the scales incorrectly. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 4.3*.

Table 4.3 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Truck Operator reads scales incorrectly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.63 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.1	1.03	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **2.63 E-2**.

3.1.1-4 – Truck Operator reads density chart incorrectly

Once the product has been weighed, the operator must make a further check utilising a density chart. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02*

Table 4.4 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Truck Operator reads density chart incorrectly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.63 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.1	1.03	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **2.63 E-2**.

3.1.1-5 – Failure to detect error by the Blasting Engineer

The Blasting Engineer should check that the density of the emulsion is correct. However, it is possible that the Blasting Engineer will not carry out this check, will carry it out incorrectly or may leave it incomplete. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 4.5*.

Table 4.5 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Blasting Engineer	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.57 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		Poor/hostile environment	1.15	1	1.15	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **1.57 E-1**.

3.1.1-6 – Failure to correct error by Blasting Engineer

Once the error has been identified, the Blasting Engineer must act to rectify the error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 4.6*.

Table 4.6 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Blasting Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	5.22 E-3
		Poor/hostile environment	1.15	1	1.15	
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **5.22 E-3**.

3.1.1-7 – Failure to detect error by Shotfirer

The Shotfirer will also check the product density before loading commences. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 4.7*.

Table 4.7 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Shotfirer	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.57 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		Poor/hostile environment	1.15	1	1.15	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **1.57 E-1**.

3.1.1-8 – Failure to correct error by Shotfirer

Once the Shotfirer has detected an error, he must communicate with the truck operator to correct the density. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 4.8*.

Table 4.8 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Shotfirer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	5.22 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Poor/hostile environment	1.15	1	1.15	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **5.22 E-3.**

F4.1.2 ***3.1.2: Shotfirer does not realise hole is overloaded***

The overall probability that the Shotfirer will not realise a hole is overloaded is **1.09 E-6** based on the failure of some or all of the tasks analysed below.

3.1.2-1 – Truck Operator inputs incorrect revolutions/weight into PLC

The Operator must input the appropriate number of revolutions to deliver the correct amount of bulk emulsion. However, a lapse in concentration could allow the Operator to make an action error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 4.9*.

Table 4.9 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Truck Operator inputs wrong information into PLC	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	3.95 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.1	1.03	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **3.95 E-3.**

3.1.2-2 – Shotfirer puts mark on hose in the wrong place

The Shotfirer must mark the emulsion hose to designate the correct loading depth. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 4.10*.

Table 4.10 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer marks hose incorrectly	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.39 -02
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Poor/hostile environment	1.15	1	1.15	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **3.39 E-2.**

3.1.2-3 – Shotfirers fail to detect hose marking error

The Shotfirers may realise before or once the emulsion begins to arrive that the hose is marked incorrectly. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 4.11*.

Table 4.11 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect error	0.02	Shortage of time available for error detection & correction	11	0.003	1.03	2.75E -02
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.75 E-2.**

3.1.2-4 – Shotfirer fails to correct error

The Shotfirer must correct the error once it has been identified. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 4.12*.

Table 4.12 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct error	0.003	Shortage of time available for error detection & correction	11	0.003	1.03	4.12E -03
		Disruption of normal work-sleep cycles	1.1	0.03	1.003	
		High level of emotional stress	1.3	0.06	1.018	
		Poor/hostile environment	1.15	0.3	1.045	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **4.12 E-3.**

3.1.2-5 – Truck Operator fails to check totaliser

The Truck Operator should obtain a print out detailing the total volume of emulsion delivered. This should highlight any differences between the volume expected and actually delivered. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 4.13*.

Table 4.13 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Truck Operator fails to check totaliser	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.63E -02
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.1	1.03	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **2.63 E-2.**

3.1.2-6 – Blasting Engineer fails to check totaliser

The Blasting Engineer should also check the print out to ensure there is a match between the amount contained in the blast plan and that actually delivered. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 4.14.*

Table 4.14 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer fails to check totaliser	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.48E -02
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Poor/hostile environment	1.15	1	1.15	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **3.48 E-2.**

F4.2 EVENT 3.2: WRONG DESIGN OF MIC

The overall probability of the Blasting Engineer designing the MIC incorrectly and associated failure of detecting and correcting is **9.06 E-8.**

F4.2.1 3.2.1: Design error by Blasting Engineer

The overall probability of a design with an unsafe MIC being released to the Mines Division and Resident Engineer is **8.52 E-5.**

3.2.1-1 – Design error by Blasting Engineer

The Blasting Engineer may design an unsafe MIC. The process involves the use of a simple equation, which means the task is less complex than the other design tasks. The generic HEART task type taken to represent this task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and* *experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in Table 4.15.

Table 4.15 HEART calculation

Task	**Generic task unreliability**	**EPCs**	**Multiplier**	**Assessed Proportion of Effect**	**Assessed Effect**	**Human Error Probability**
Design error by Blasting Engineer	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	6.05 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **6.05 E-4.**

3.2.1-2 – Failure to detect error by Blasting Engineer

The Blasting Engineer should utilise a modelling programme to detect any design errors. The generic HEART task type taken to represent this checking task, utilising a modelling system is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 4.16*.

Table 4.16 HEART calculation

Task	**Generic task unreliability**	**EPCs**	**Multiplier**	**Assessed Proportion of Effect**	**Assessed Effect**	**Human Error Probability**
Failure to detect design error by Blasting Engineer	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.36 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **1.36 E-1.**

3.2.1-3 – Failure to correct error by Blasting Engineer

If an error is identified during the checking phase, the Blasting Engineer must act on this to correct the error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 4.17*.

Table 4.17 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct design error by Blasting Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.54 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **4.54 E-3.**

F4.2.2 ***3.2.2: Failure to detect and correct design error***

The overall probability of failure to detect and correct the design error is **1.06 E-3** based on the failure of all the tasks analysed below.

3.2.2-1 – Failure to detect error by Resident Engineer

The Resident Engineer will examine the design for potential errors. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 4.18*.

Table 4.18 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Resident Engineer	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.92 E-2
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.92 E-2**.

3.2.2-2 – Failure to correct error by Resident Engineer

The Resident Engineer may detect the error, but then fail to act on this to correct the design error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 4.19*.

Table 4.19 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Resident Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.37 E-3
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	

Based on the above estimates, the likelihood of producing an error is **4.37 E-3**.

3.2.2-3 – Failure to detect error by the Mines Division

The Mines Division will also check the design to ensure a safe MIC is designed. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid tasks involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 4.20*.

Table 4.20 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Resident Engineer	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.76 E-2
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.76 E-2**.

3.2.2-4 – Failure to correct error by the Mines Division

As above, the Mines Division may fail to correct the error in the design. The generic HEART task type taken to represent this action task is *"Restore or shift* *a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 4.21*.

Table 4.21 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Mines Division	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.14 E-3
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.01	1.003	

Based on the above estimates, the likelihood of producing an error is **4.14 E-3**.

F5 SCENARIO FOUR: MIC EXCEEDED (CARTRIDGE EMULSION)

F5.1 EVENT 4.1: EXCESS CARTRIDGES ARE LOADED INTO HOLES

Attachment F1 presents the fault tree of human error leading to the MIC being exceeded due to overloading of cartridge emulsion. MS Excel spreadsheet was used to calculate the overall probabilities for events.

F5.1.1 4.1.1: Excess Cartridges are loaded into holes

The overall probability of excess cartridges being loaded is **8.13 E-3**, based on the failure the task analysed below.

4.1.1-1 – Shotfirer does not count number of cartridges picked up and loads too many

The Shotfirer may have a lapse in concentration, causing him to pick up and load too many cartridges. The generic HEART task type taken to represent this manual task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 5.1*.

Table 5.1 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer loads too many cartridges	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	7.38 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.01	1.09	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **7.38 E-4**

F5.1.2 ***4.1.2: Cartridges from blocked holes are not disposed of correctly***

The overall probability of holes being overloaded due to incorrect disposal of additional cartridges is **8.13 E-3.**

4.1.2-1 – Shotfirer intentionally overloads lifter holes

If there are any cartridges left over due to the presence of blocked holes, the Shotfirer may not dispose of them as advised by the Resident Site Staff. Instead, he may load additional cartridges into the lifter holes to ensure a good blast. This can be seen as a violation of procedure, although the Shotfirer will be well aware of the risks he is taking. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 5.2*.

Table 5.2 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer overloads lifter holes	0.003	An incentive to use more dangerous procedures	2	1	2	8.13 E-3
		Shortage of time available for error detection & correction	11	0.01	1.1	
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Poor/hostile environment	1.15	1	1.15	

Based on the above estimates, the likelihood of producing an error is **8.13 E-3.**

F5.1.3 ***4.1.3: Shotfirer does not realise holes are overloaded***

The overall probability of the Shotfirer not realising that there are some holes overloaded is **1.69 E-5,** based on the failure of some or all of the tasks analysed below.

4.1.3-1 – Shotfirer collects too many Kgs of cartridge from the magazine

The Shotfirer must only collect the exact amount of cartridges from the magazine to ensure that he does not overload any holes. The generic HEART task type taken to represent this manual task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the* *benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 5.3*.

Table 5.3 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer collects too many cartridges from the magazine	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	5.89 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **5.89 E-4.**

4.1.3-2 – Shotfirer fails to detect collection error

The Shotfirer should check that he has selected the correct amount of cartridges for delivery to the site. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 5.4*.

Table 5.4 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to detect collection error	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.94 E-2
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.94 E-2.**

4.1.3-3 – Shotfirer fails to correct collection error

If the Shotfirer detects the error, he must correct it to ensure only the exact number of cartridges are delivered to the blasting site. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 5.5.*

Table 5.5 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to correct collection error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.42 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **4.42 E-3.**

4.1.3-4 – Resident Engineer's Inspector fails to detect error

The Resident Engineer's Inspector should check the number of cartridges selected before they leave the magazine. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 5.6.*

Table 5.6 *HEART calculation*

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Resident Engineer's Inspector fails to detect collection error	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.32 E-1
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **1.32 E-1.**

4.1.3-5 – Resident Engineer's Inspector fails to correct collection error

The Resident Engineer's Inspector must act to correct any errors identified during the checking process. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 5.7*.

Table 5.7 *HEART calculation*

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Resident Engineer's Inspector fails to correct collection error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.39 E-3
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **4.39 E-3.**

4.1.3-6 – Contractor's Representative fails to detect error

The Contractor's Representative will also be present when the Shotfirer collects cartridges from the magazine; therefore it represents a further check. The generic HEART task type taken to represent this checking task is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 5.8*.

Table 5.8 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Contractor's Represent-ative fails to detect collection error	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.28 E-1
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.1	1.03	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **1.28 E-1.**

4.1.3-7 – Contractor's Representative fails to correct error

If the Contractor's Representative fails to act on an identified error, too many cartridges could be delivered to site. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 5.9*.

Table 5.9 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Contractor's Represent-ative fails to correct collection error	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.16 E-3
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **4.16 E-3.**

4.1.3-8 – Shotfirer fails to check for any remaining detonator bundles

If there are any bundles detonator remaining on the face, it means that the Shotfirer has not yet loaded any emulsion and attached the detonator/ booster. This may be difficult as some holes will be under water and/or poorly lit. However, the Shotfirer could become distracted and not make this check. The generic HEART task type taken to represent this manual checking task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004.* The EPCs and their impacts are shown in *Table 5.10.*

Table 5.10 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer does not check face for remaining bundles	0.0004	Shortage of time available for error detection & correction	11	0.003	1.03	4.76 E-4
		Disruption of normal work-sleep cycles	1.1	0.015	1.0015	
		High level of emotional stress	1.3	0.003	1.0009	
		Channel capacity overload	6	0.015	1.075	
		Poor/hostile environment	1.15	0.3	1.045	
		Low signal-noise ratio	10	0.003	1.027	

Based on the above estimates, the likelihood of producing an error is **4.76 E-4.**

4.1.3-9 – Blasting Engineer fails to check face for remaining detonator bundles/ empty holes

The Blasting Engineer should check if there are any detonator bundles remaining on the face. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 5.11*.

Table 5.11 ***HEART calculation***

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Blasting Engineer fails to check face for remaining bundles/ empty holes	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.47E-02
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	
		Poor/hostile environment	1.15	1	1.15	

		Low signal-noise ratio	10	0.01	1.09	

Based on the above estimates, the likelihood of producing an error is **3.47 E-2.**

F5.1.4 4.1.4: Shotfirer/ Blasting Engineer do not realise the cartridges left over due to presence of blocked holes are not disposed of

The overall probability of the Shotfirer/ Blasting Engineer not realising that the cartridges left over due to presence of blocked holes are not disposed of is **1.21 E-3,** based on the failure of some or all of the tasks analysed below.

4.1.4-1 – Shotfirer fails to check for remaining cartridges leftover due to blocked holes

A Shotfirer may not dispose of the cartridges left over due to the presence of blocked holes and load additional cartridges into the lifter holes. However, the other Shotfirer will be aware of the presence of blocked and attempt to locate the left over. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 5.14*.

Table 5.12 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to check for remaining cartridges leftover due to blocked holes	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.47E-02
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.01	1.09	

Based on the above estimates, the likelihood of producing an error is **3.47 E-2.**

4.1.3-2 – Blast Engineer fails to check for remaining cartridges leftover due to blocked holes

The Blast Engineer will also be aware of the presence of blocked holes and will check the cartridges will be disposed of correctly. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised,* *rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02*. The EPCs and their impacts are shown in *Table 5.15*.

Table 5.13 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Shotfirer fails to check for remaining cartridges leftover due to blocked holes	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	3.47E-02
		Disruption of normal work-sleep cycles	1.1	0.05	1.005	
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	
		Poor/hostile environment	1.15	1	1.15	
		Low signal-noise ratio	10	0.01	1.09	

Based on the above estimates, the likelihood of producing an error is **3.47 E-2.**

F5.2 EVENT 4.2 WRONG DESIGN OF MIC

The overall probability of a design error by the Blasting Engineer being released to the Resident Engineer and the Mines Division and not detected or corrected is **9.06 E-8.**

F5.2.1 4.2.1: Design error by Blasting Engineer

The overall probability of a design with an unsafe MIC being released to the Mines Division and Resident Engineer is **8.52 E-5** based on the failure of some or all of the tasks analysed below.

4.2.1-1 – Design error by Blasting Engineer

The Blasting Engineer may design an unsafe MIC. The process involves the use of a simple equation, which means the task is less complex than the other design tasks. The generic HEART task type taken to represent this task is *"Completely familiar, well designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated and experienced person, totally aware of the implications of failure, with time to correct potential error, but without the benefit of significant job aids"* for which the nominal human unreliability is *0.0004*. The EPCs and their impacts are shown in *Table 5.14*.

Table 5.14 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Design error by Blasting Engineer	0.0004	Shortage of time available for error detection & correction	11	0.01	1.1	6.05 E-4
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		High level of emotional stress	1.3	0.3	1.09	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **6.05 E-4.**

4.2.1-2 – Failure to detect error by Blasting Engineer

The Blasting Engineer should utilise a modelling programme to detect any design errors. The generic HEART task type taken to represent this checking task, utilising a modelling system is *"Fairly simple task performed rapidly or given scant attention"* for which the nominal human unreliability is *0.09.* The EPCs and their impacts are shown in *Table 5.15*.

Table 5.15 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect design error by Blasting Engineer	0.09	Shortage of time available for error detection & correction	11	0.01	1.1	1.36 E-1
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **1.36 E-1.**

4.2.1-3 – Failure to correct error by Blasting Engineer

If an error is identified during the checking phase, the Blasting Engineer must act on this to correct the error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 5.16*.

Table 5.16 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct design error by Blasting Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.54 E-3
		Disruption of normal work-sleep cycles	1.1	0.1	1.01	
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.3	1.09	

Based on the above estimates, the likelihood of producing an error is **4.54 E-3.**

F5.2.2 4.2.2: Failure to detect and correct design error

The overall probability of failure to detect and correct the design error is **1.06 E-3** based on the failure of all the tasks analysed below.

4.2.2-1 – Failure to detect error by Resident Engineer

The Resident Engineer will examine the design for potential errors. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid task involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 5.17*.

Table 5.17 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Resident Engineer	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.92 E-2
		High level of emotional stress	1.3	0.2	1.06	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.92 E-2**.

4.2.2-2 – Failure to correct error by Resident Engineer

The Resident Engineer may detect the error, but then fail to act on this to correct the design error. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 5.18*.

Table 5.18 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Resident Engineer	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.37 E-3
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.2	1.06	

Based on the above estimates, the likelihood of producing an error is **4.37 E-3**.

4.2.2-3 – Failure to detect error by the Mines Division

The Mines Division will also check the design to ensure a safe MIC is designed in. The generic HEART task type taken to represent this manual checking task is *"Routine, highly practised, rapid tasks involving relatively low level of skill"* for which the nominal human unreliability is *0.02.* The EPCs and their impacts are shown in *Table 5.19*.

Table 5.19 HEART calculation

Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to detect error by Resident Engineer	0.02	Shortage of time available for error detection & correction	11	0.01	1.1	2.76 E-2
		High level of emotional stress	1.3	0.01	1.003	
		Channel capacity overload	6	0.05	1.25	

Based on the above estimates, the likelihood of producing an error is **2.76 E-2**.

4.2.2-4 – Failure to correct error by the Mines Division

As above, the Mines Division may fail to correct the error in the design. The generic HEART task type taken to represent this action task is *"Restore or shift a system to original or new state following procedures, with some checking"* for

which the nominal human unreliability is *0.003.* The EPCs and their impacts are shown in *Table 5.20*.

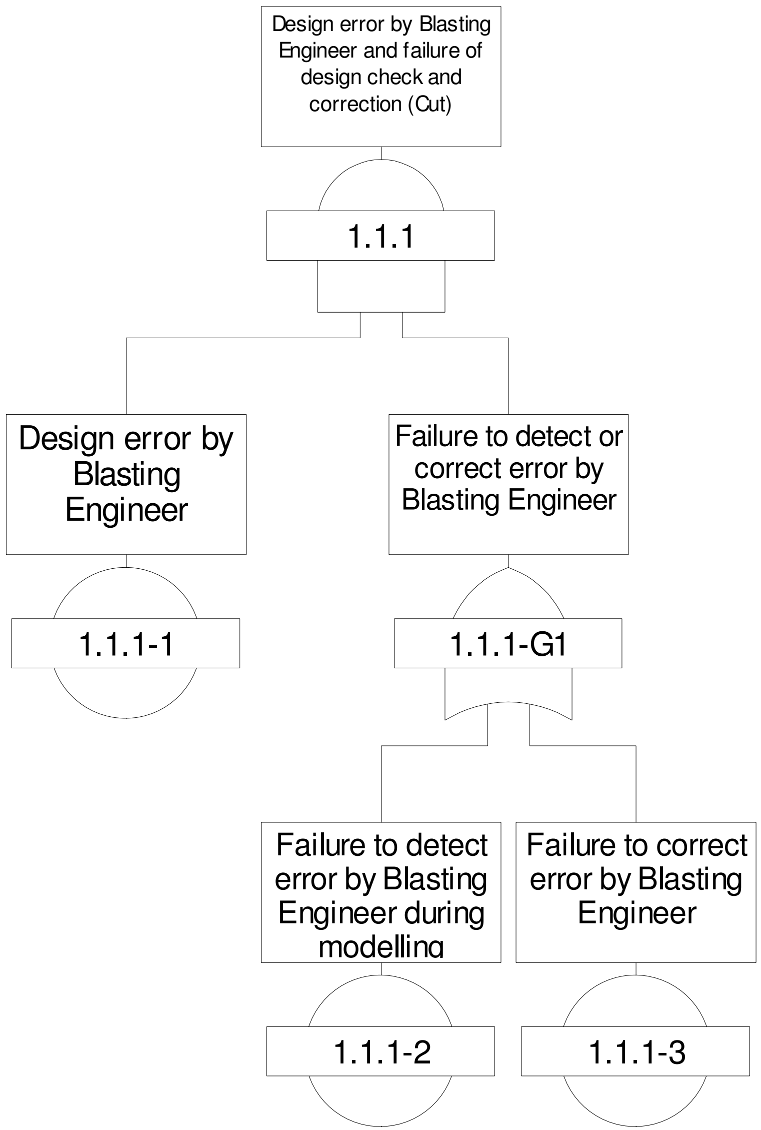
Table 5.20 HEART calculation

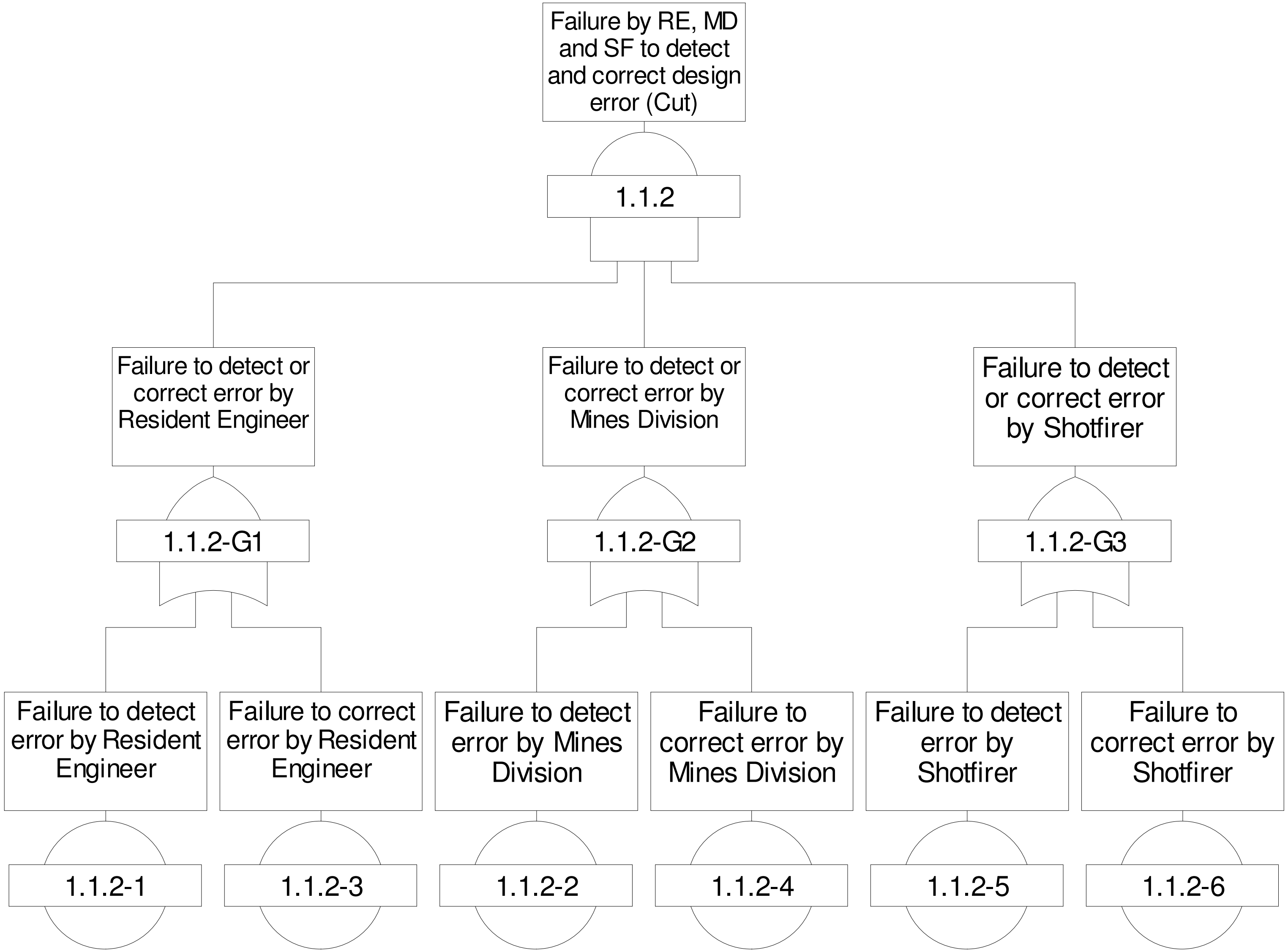
Task	Generic task unreliability	EPCs	Multiplier	Assessed Proportion of Effect	Assessed Effect	Human Error Probability
Failure to correct error by Mines Division	0.003	Shortage of time available for error detection & correction	11	0.01	1.1	4.14 E-3
		Channel capacity overload	6	0.05	1.25	
		High level of emotional stress	1.3	0.01	1.003	

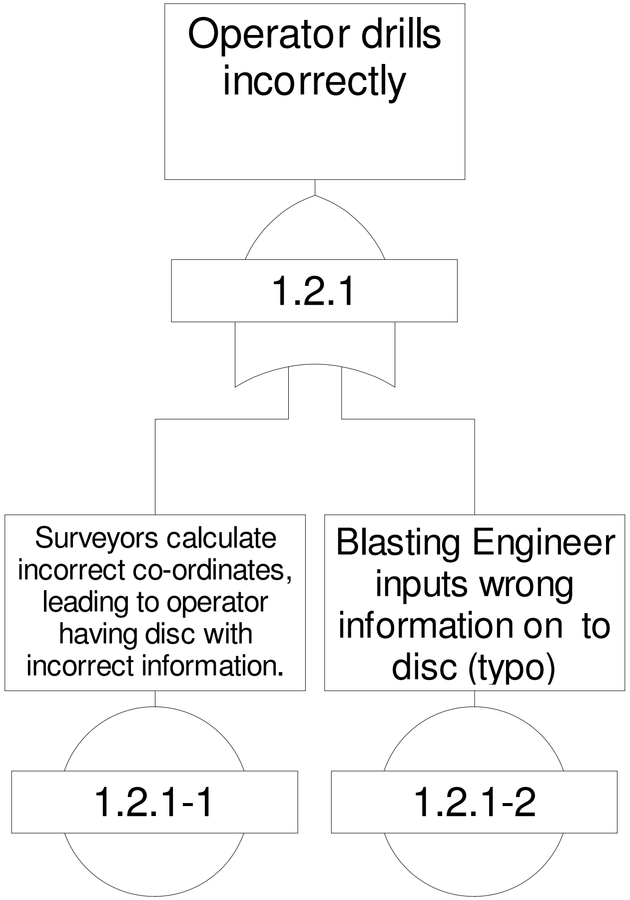
Based on the above estimates, the likelihood of producing an error is **4.14 E-3**.

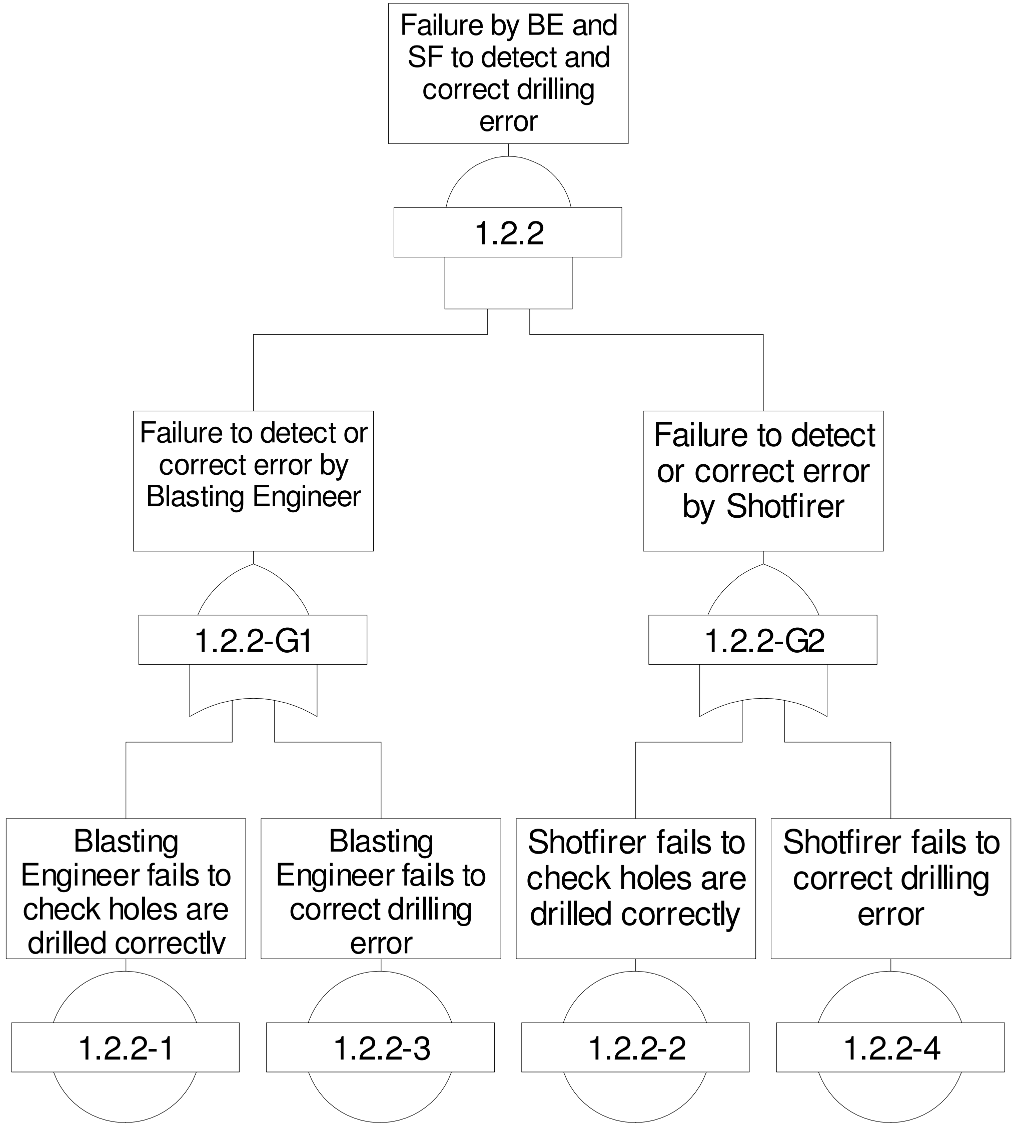
Attachment F1

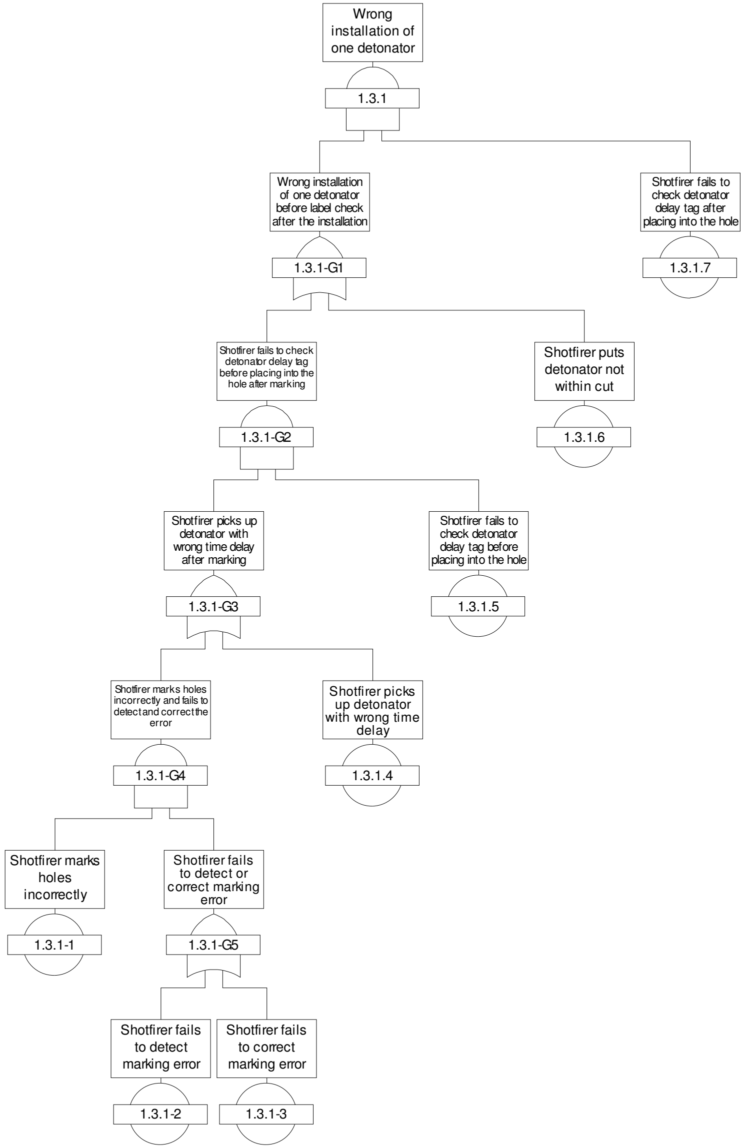
Fault Tree Models for Human Reliability Assessment

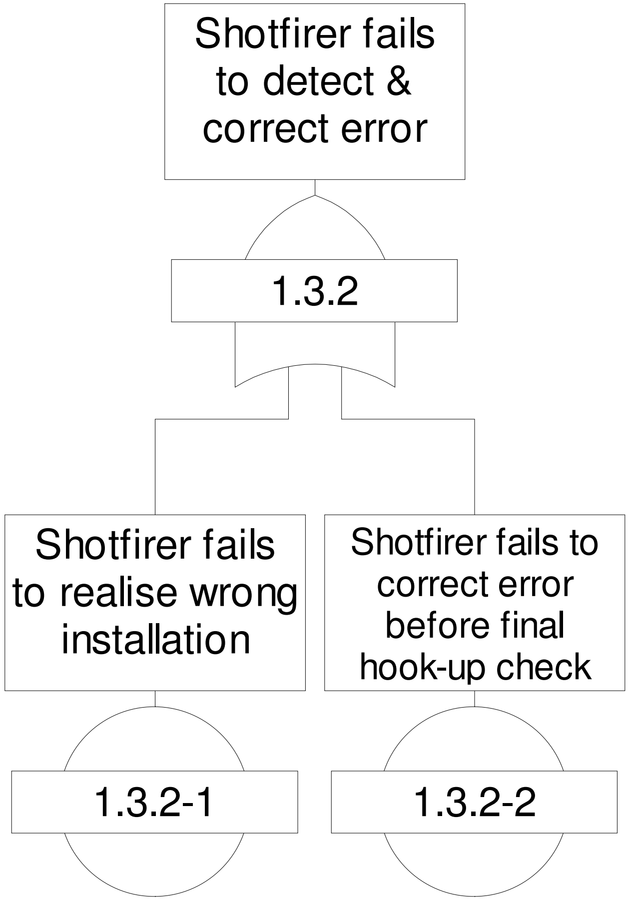

Design error by Blasting Engineer and failure of design check and correction (Cut)
1.1.1
Design error by Blasting Engineer
1.1.1-1
Failure to detect or correct error by Blasting Engineer
1.1.1-G1
Failure to detect error by Blasting Engineer during modelling
1.1.1-2
Failure to correct error by Blasting Engineer
1.1.1-3

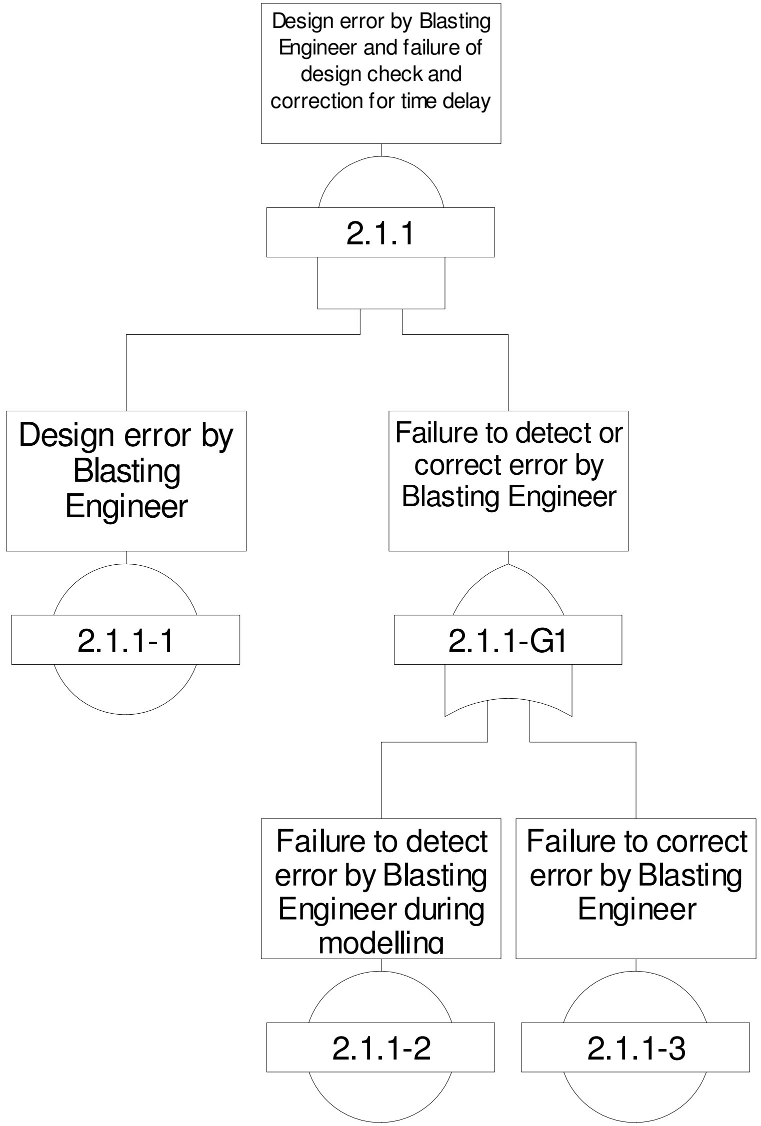

Failure by RE, MD and SF to detect and correct design error (Cut)
1.1.2
Failure to detect or correct error by Resident Engineer
Failure to detect or correct error by Mines Division
Failure to detect or correct error by Shotfirer
1.1.2-G1
1.1.2-G2
1.1.2-G3
Failure to detect error by Resident Engineer
Failure to correct error by Resident Engineer
Failure to detect error by Mines Division
Failure to correct error by Mines Division
Failure to detect error by Shotfirer
Failure to correct error by Shotfirer
1.1.2-1
1.1.2-3
1.1.2-2
1.1.2-4
1.1.2-5
1.1.2-6

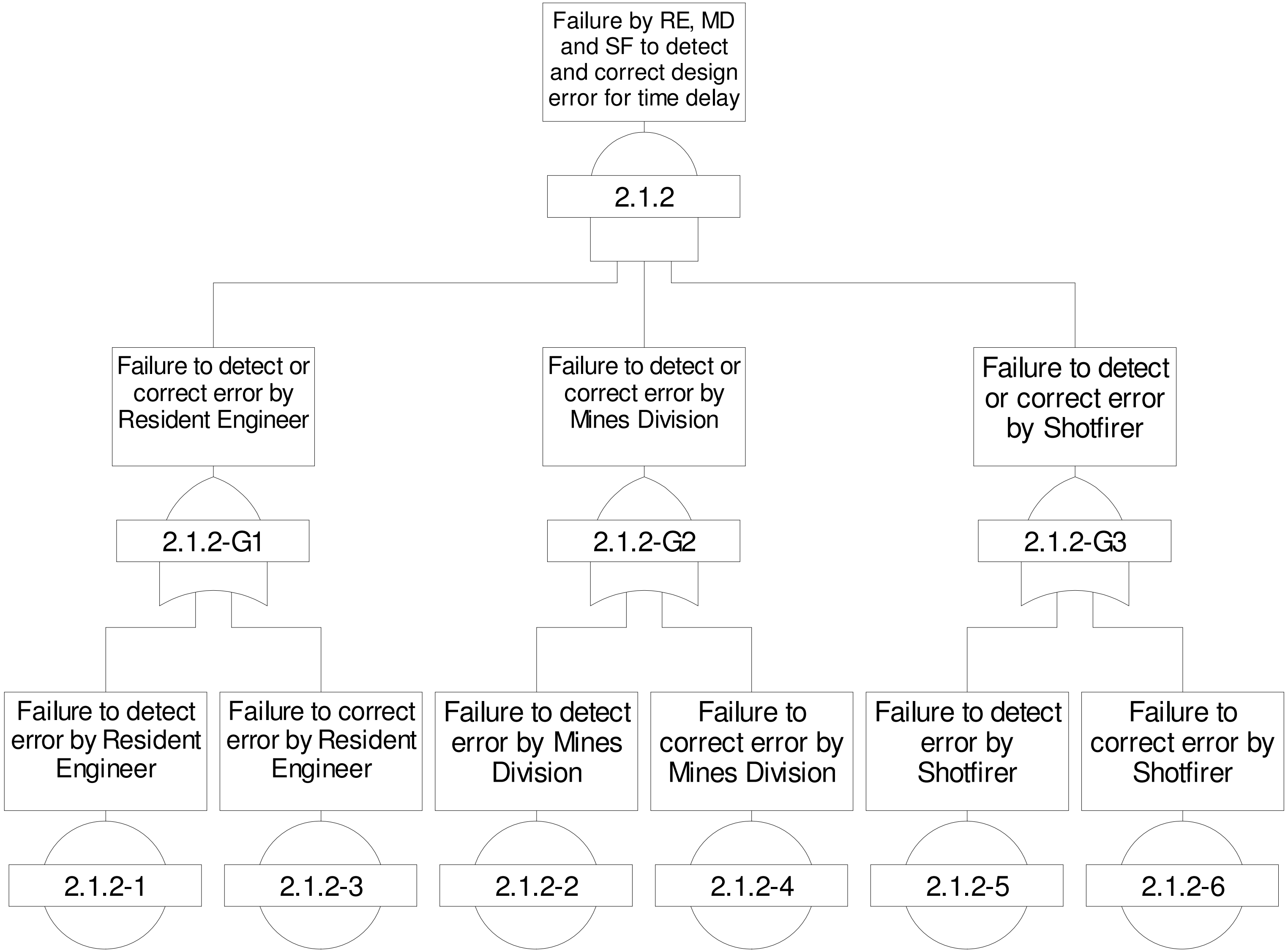

Operator drills incorrectly
1.2.1
Surveyors calculate incorrect co-ordinates, leading to operator having disc with incorrect information.
Blasting Engineer inputs wrong information on to disc (typo)
1.2.1-1
1.2.1-2


Failure by BE and SF to detect and correct drilling error
1.2.2
Failure to detect or correct error by Blasting Engineer
Failure to detect or correct error by Shotfirer
1.2.2-G1
1.2.2-G2
Blasting Engineer fails to check holes are drilled correctly
Blasting Engineer fails to correct drilling error
Shotfirer fails to check holes are drilled correctly
Shotfirer fails to correct drilling error
1.2.2-1
1.2.2-3
1.2.2-2
1.2.2-4


Wrong installation of one detonator
1.3.1
Wrong installation of one detonator before label check after the installation
1.3.1-G1
Shotfirer fails to check detonator delay tag after placing into the hole
1.3.1.7
Shotfirer fails to check detonator delay tag before placing into the hole after marking
1.3.1-G2
Shotfirer puts detonator not within cut
1.3.1.6
Shotfirer picks up detonator with wrong time delay after marking
1.3.1-G3
Shotfirer fails to check detonator delay tag before placing into the hole
1.3.1.5
Shotfirer marks holes incorrectly and fails to detect and correct the error
1.3.1-G4
Shotfirer picks up detonator with wrong time delay
1.3.1.4
Shotfirer marks holes incorrectly
1.3.1-1
Shotfirer fails to detect or correct marking error
1.3.1-G5
Shotfirer fails to detect marking error
1.3.1-2
Shotfirer fails to correct marking error
1.3.1-3

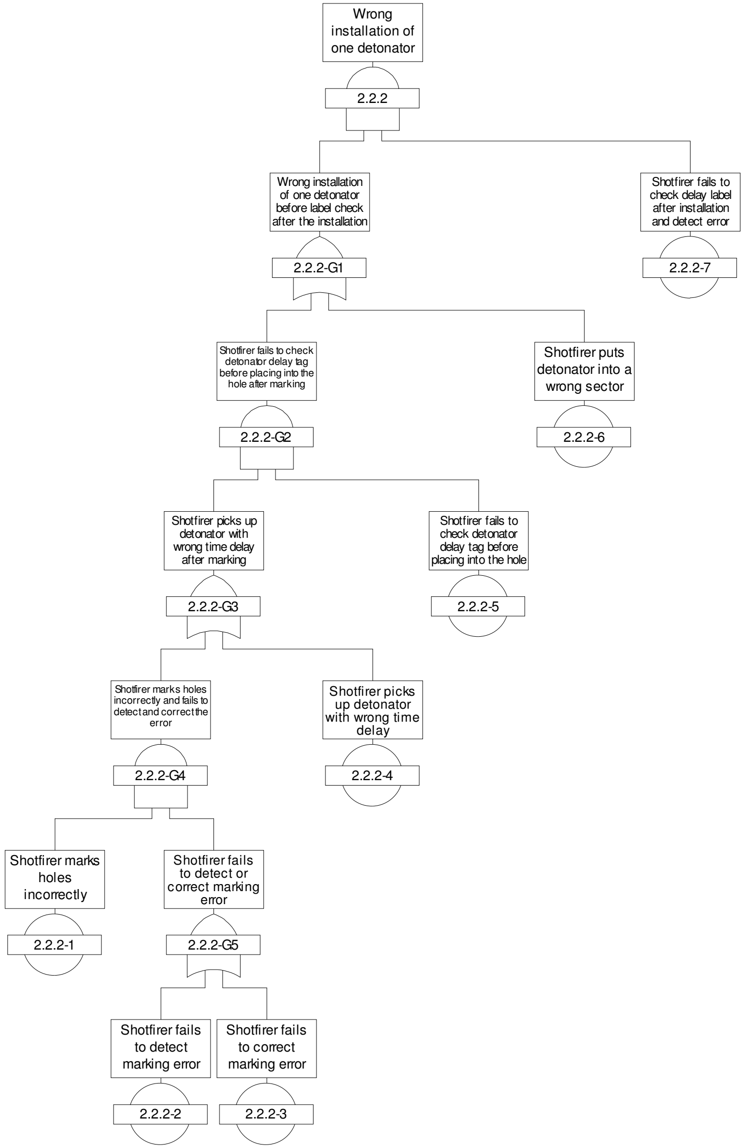

Shotfirer fails to detect & correct error
1.3.2
Shotfirer fails to realise wrong installation
Shotfirer fails to correct error before final hook-up check
1.3.2-1
1.3.2-2


Design error by Blasting Engineer and failure of design check and correction for time delay
2.1.1
Design error by Blasting Engineer
2.1.1-1
Failure to detect or correct error by Blasting Engineer
2.1.1-G1
Failure to detect error by Blasting Engineer during modelling
2.1.1-2
Failure to correct error by Blasting Engineer
2.1.1-3

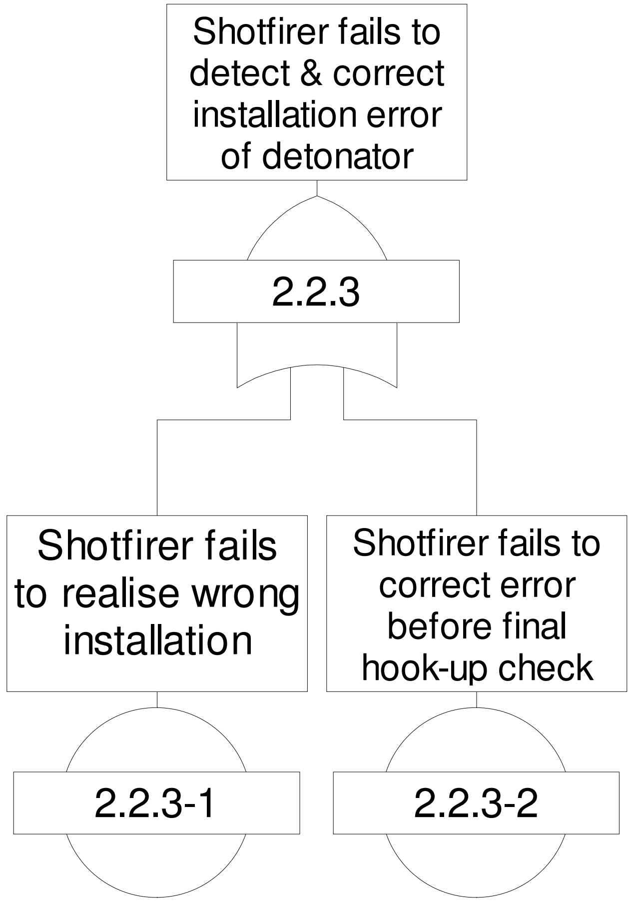


Failure by RE, MD and SF to detect and correct design error for time delay
2.1.2
Failure to detect or correct error by Resident Engineer
2.1.2-G1
Failure to detect or correct error by Mines Division
2.1.2-G2
Failure to detect or correct error by Shotfirer
2.1.2-G3
Failure to detect error by Resident Engineer
2.1.2-1
Failure to correct error by Resident Engineer
2.1.2-3
Failure to detect error by Mines Division
2.1.2-2
Failure to correct error by Mines Division
2.1.2-4
Failure to detect error by Shotfirer
2.1.2-5
Failure to correct error by Shotfirer
2.1.2-6

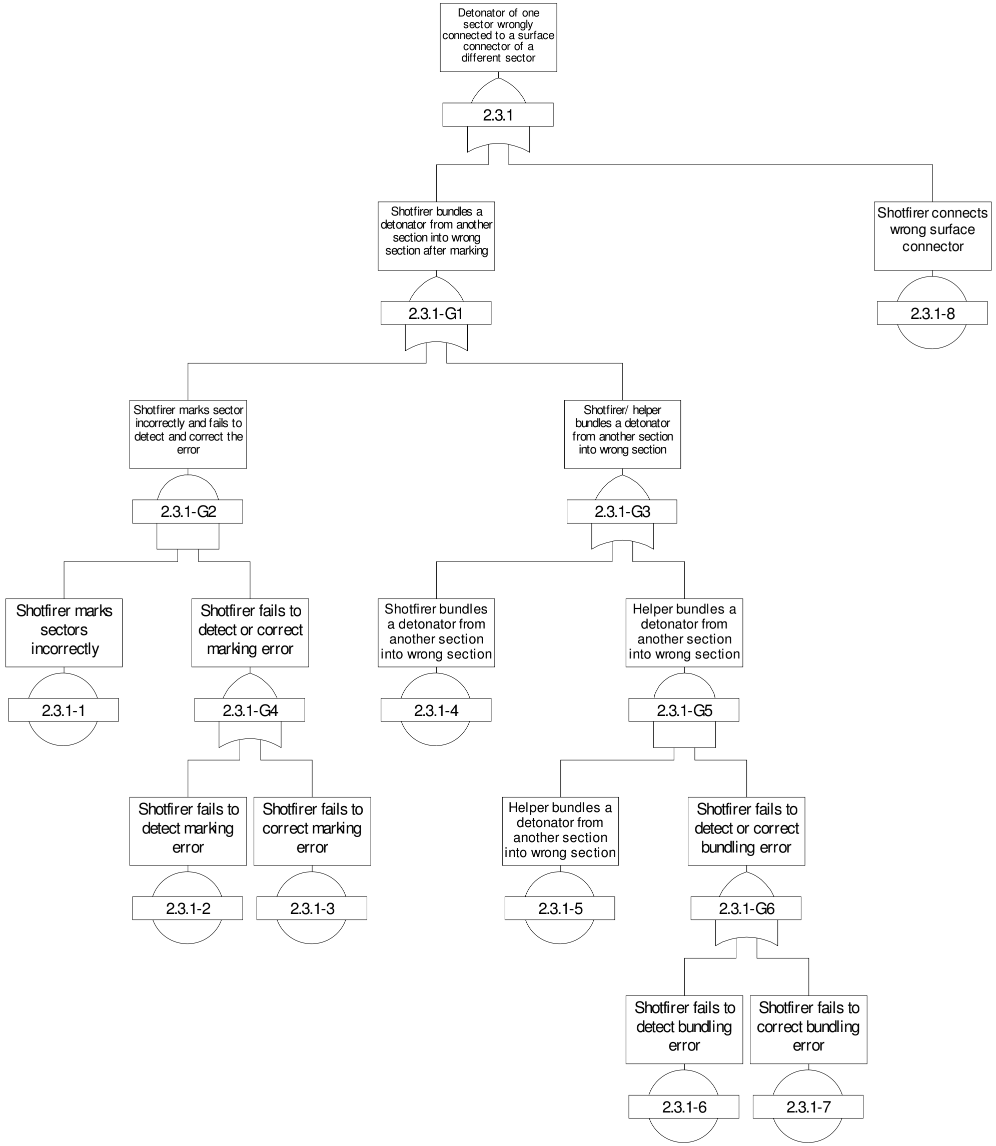

Wrong delivery of detonators
2.2.1
Detonators are picked incorrectly by Shotfirer from magazine
2.2.1-1
Failure to detect ad correct selection error
2.2.1-G1
Shotfirer fails to detect or correct selection error
2.2.1-G2
Resident Engineer's Inspector fails to check correct detonators have been picked and correct the error
2.2.1-G3
Contractor's Representative fails to check correct detonators have been picked and correct the error
2.2.1-G4
Shotfirer fails to detect error
2.2.1-2
Shotfirer fails to correct selection error
2.2.1-5
Resident Engineer's Inspector fails to check correct detonators have been picked
2.2.1-3
Resident Engineer's Inspector fails to correct error
2.2.1-6
Contractor's Representative fails to check correct detonators have been picked
2.2.1-4
Contractor's Representative fails to correct error
2.2.1-7

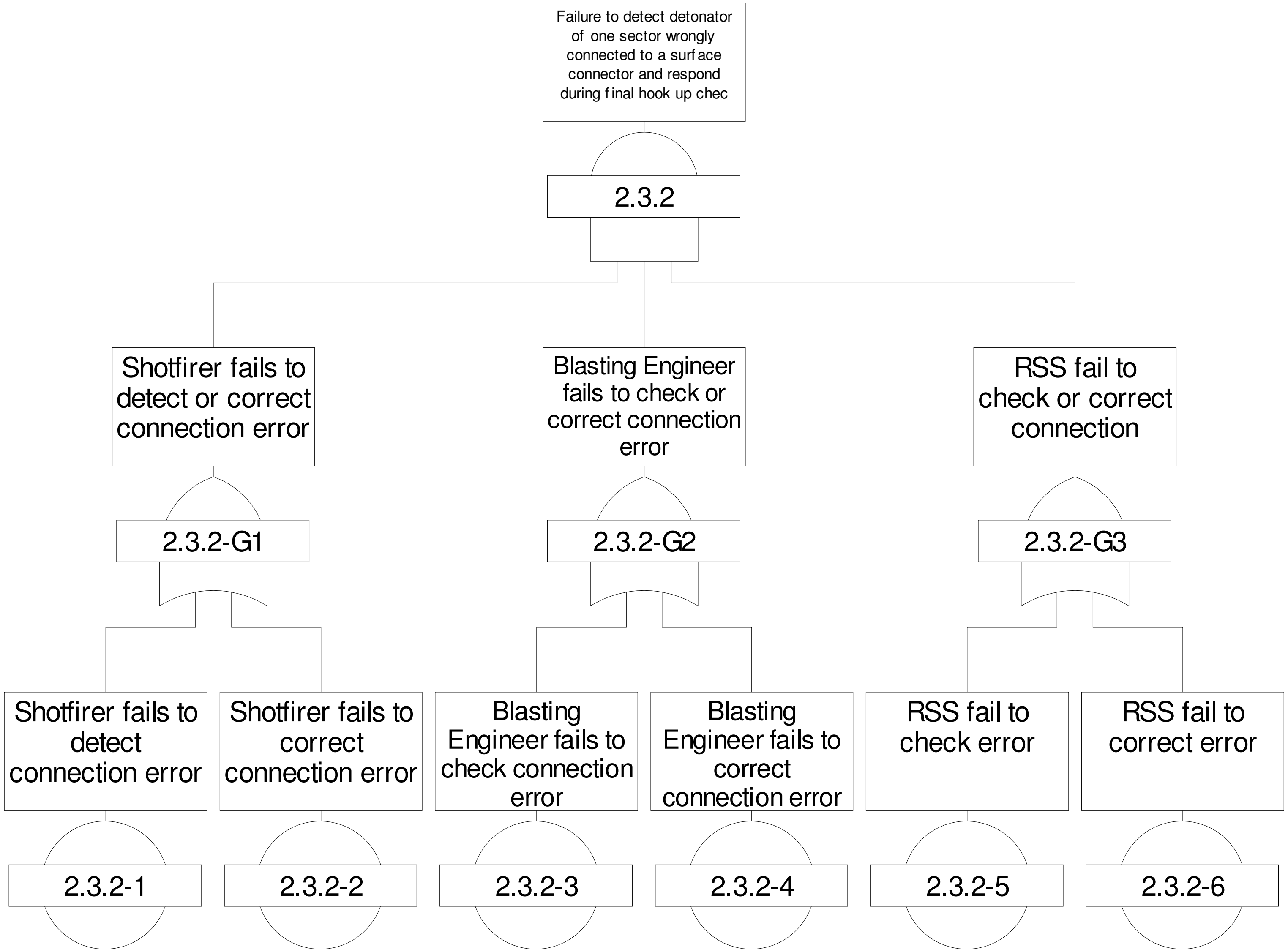


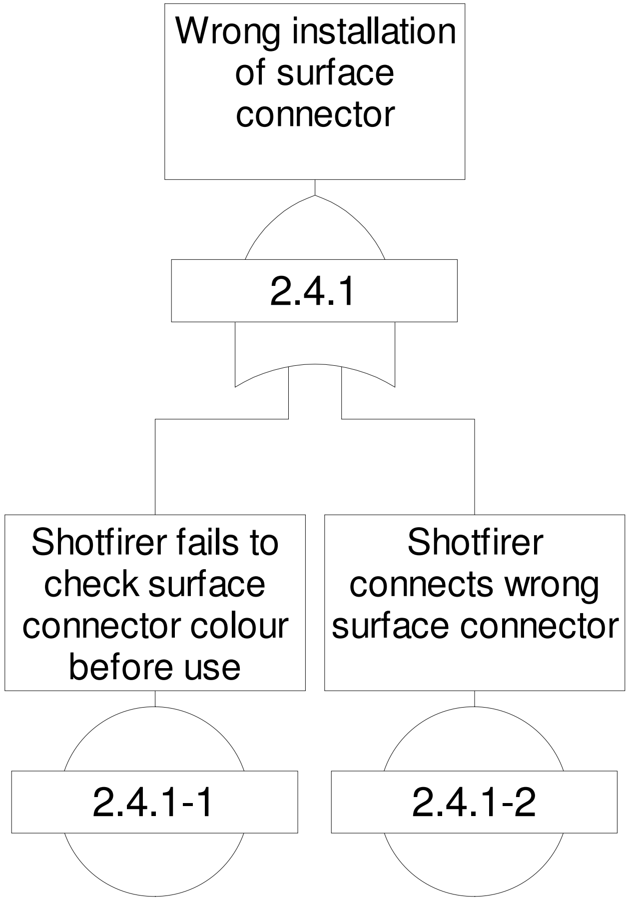
Wrong installation of one detonator
2.2.2
Wrong installation of one detonator before label check after the installation
2.2.2-G1
Shotfirer fails to check delay label after installation and detect error
2.2.2-7
Shotfirer fails to check detonator delay tag before placing into the hole after marking
2.2.2-G2
Shotfirer puts detonator into a wrong sector
2.2.2-6
Shotfirer picks up detonator with wrong time delay after marking
2.2.2-G3
Shotfirer fails to check detonator delay tag before placing into the hole
2.2.2-5
Shotfirer marks holes incorrectly and fails to detect and correct the error
2.2.2-G4
Shotfirer picks up detonator with wrong time delay
2.2.2-4
Shotfirer marks holes incorrectly
2.2.2-1
Shotfirer fails to detect or correct marking error
2.2.2-G5
Shotfirer fails to detect marking error
2.2.2-2
Shotfirer fails to correct marking error
2.2.2-3

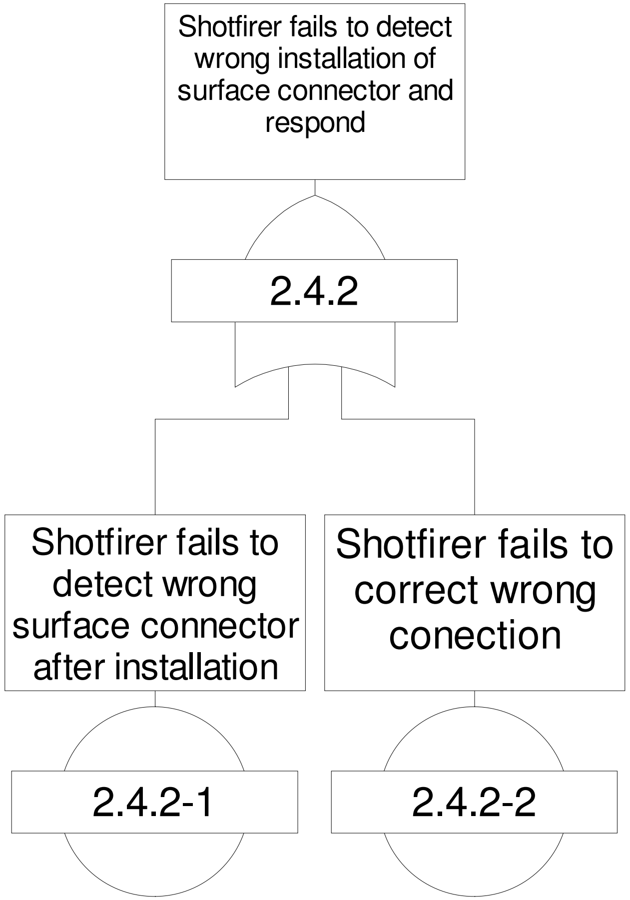


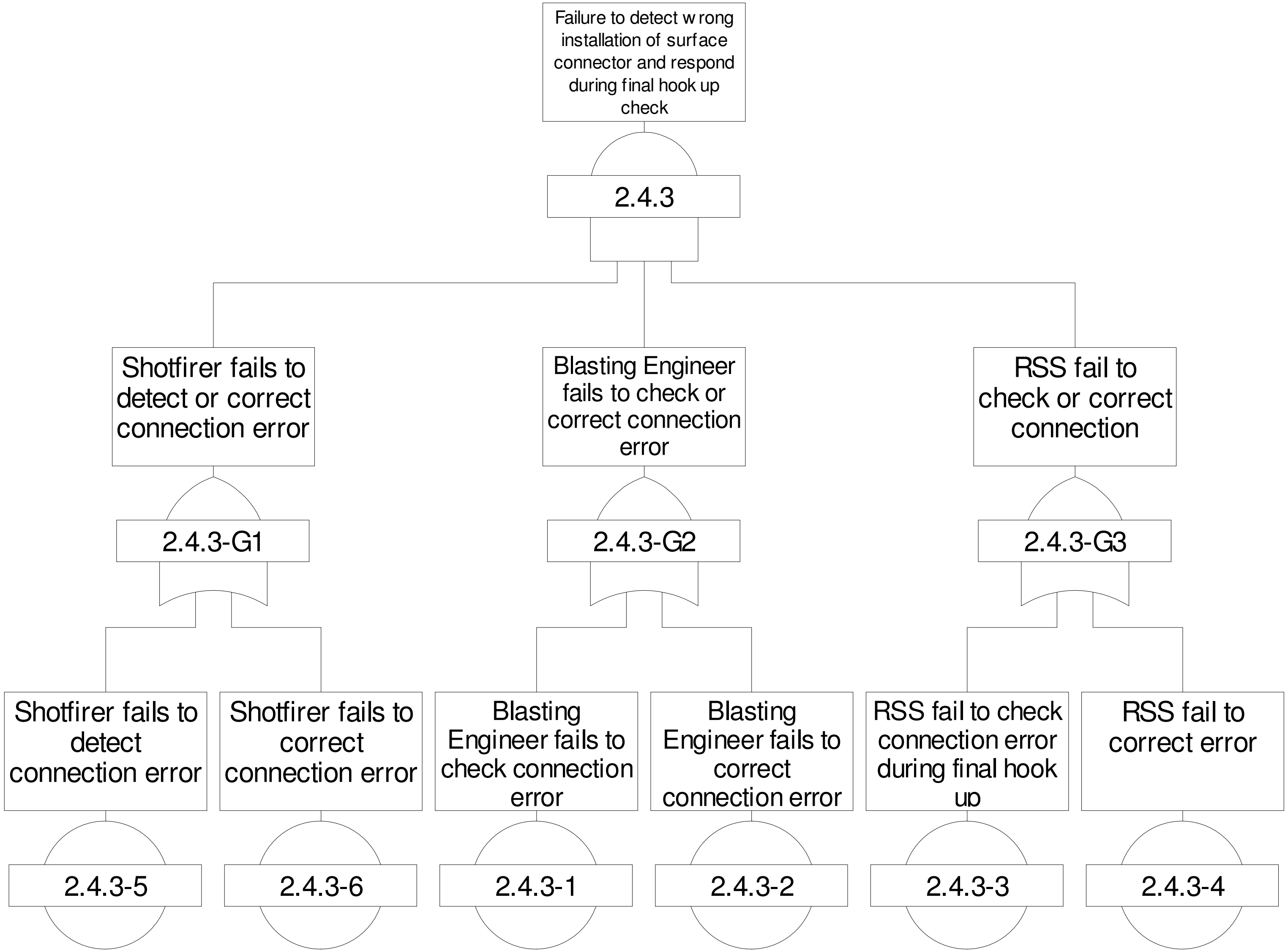
Shotfirer fails to detect & correct installation error of detonator
2.2.3
Shotfirer fails to realise wrong installation
Shotfirer fails to correct error before final hook-up check
2.2.3-1
2.2.3-2

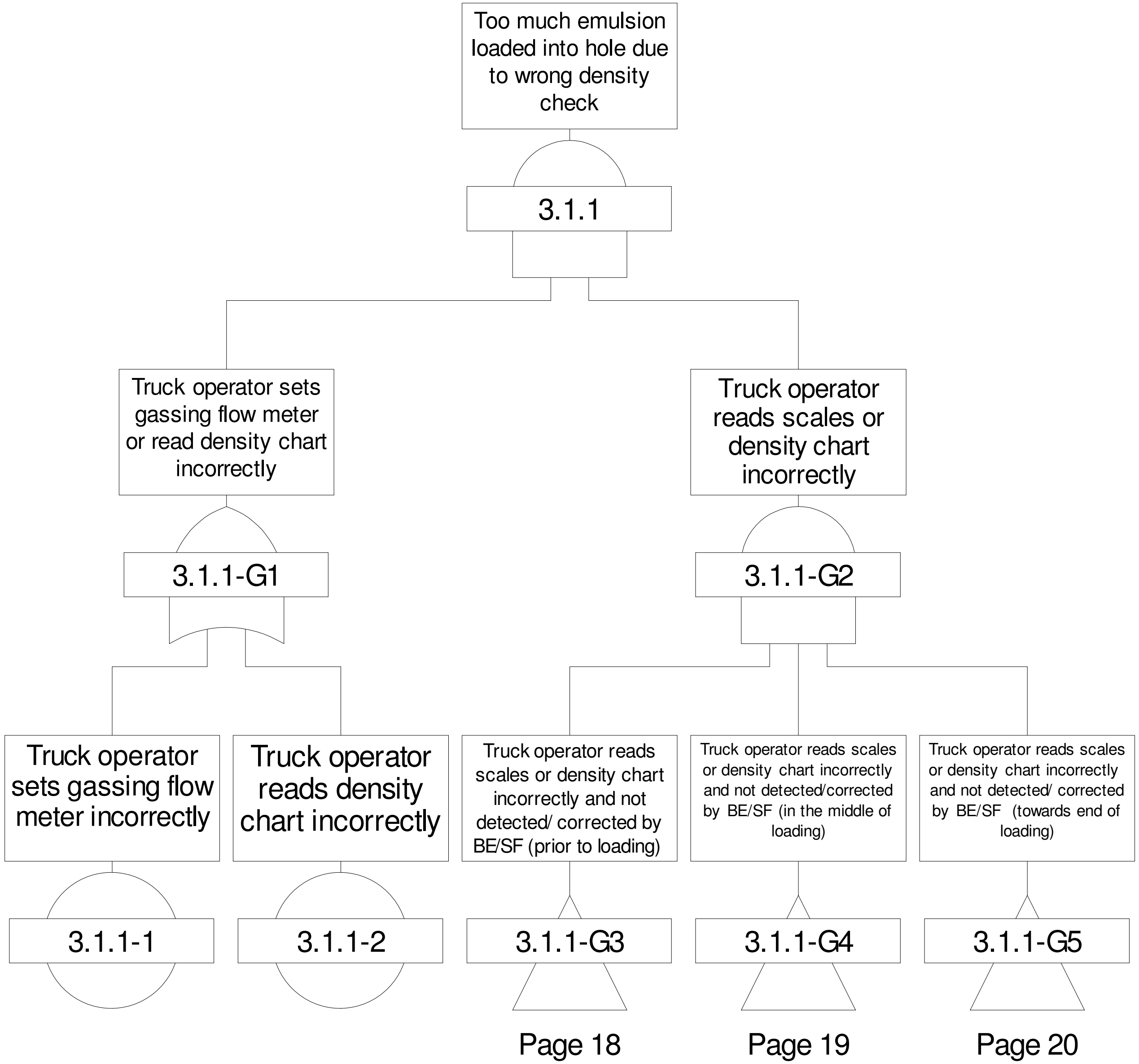

Detonator of one sector wrongly connected to a surface connector of a different sector
2.3.1
Shotfirer bundles a detonator from another section into wrong section after marking
2.3.1-G1
Shotfirer connects wrong surface connector
2.3.1-8
Shotfirer marks sector incorrectly and fails to detect and correct the error
2.3.1-G2
Shotfirer/ helper bundles a detonator from another section into wrong section
2.3.1-G3
Shotfirer marks sectors incorrectly
2.3.1-1
Shotfirer fails to detect or correct marking error
2.3.1-G4
Shotfirer bundles a detonator from another section into wrong section
2.3.1-4
Helper bundles a detonator from another section into wrong section
2.3.1-G5
Shotfirer fails to detect marking error
2.3.1-2
Shotfirer fails to correct marking error
2.3.1-3
Helper bundles a detonator from another section into wrong section
2.3.1-5
Shotfirer fails to detect or correct bundling error
2.3.1-G6
Shotfirer fails to detect bundling error
2.3.1-6
Shotfirer fails to correct bundling error
2.3.1-7


Failure to detect detonator of one sector wrongly connected to a surface connector and respond during final hook up chec
2.3.2
Shotfirer fails to detect or correct connection error
2.3.2-G1
Blasting Engineer fails to check or correct connection error
2.3.2-G2
RSS fail to check or correct connection
2.3.2-G3
Shotfirer fails to detect connection error
2.3.2-1
Shotfirer fails to correct connection error
2.3.2-2
Blasting Engineer fails to check connection error
2.3.2-3
Blasting Engineer fails to correct connection error
2.3.2-4
RSS fail to check error
2.3.2-5
RSS fail to correct error
2.3.2-6

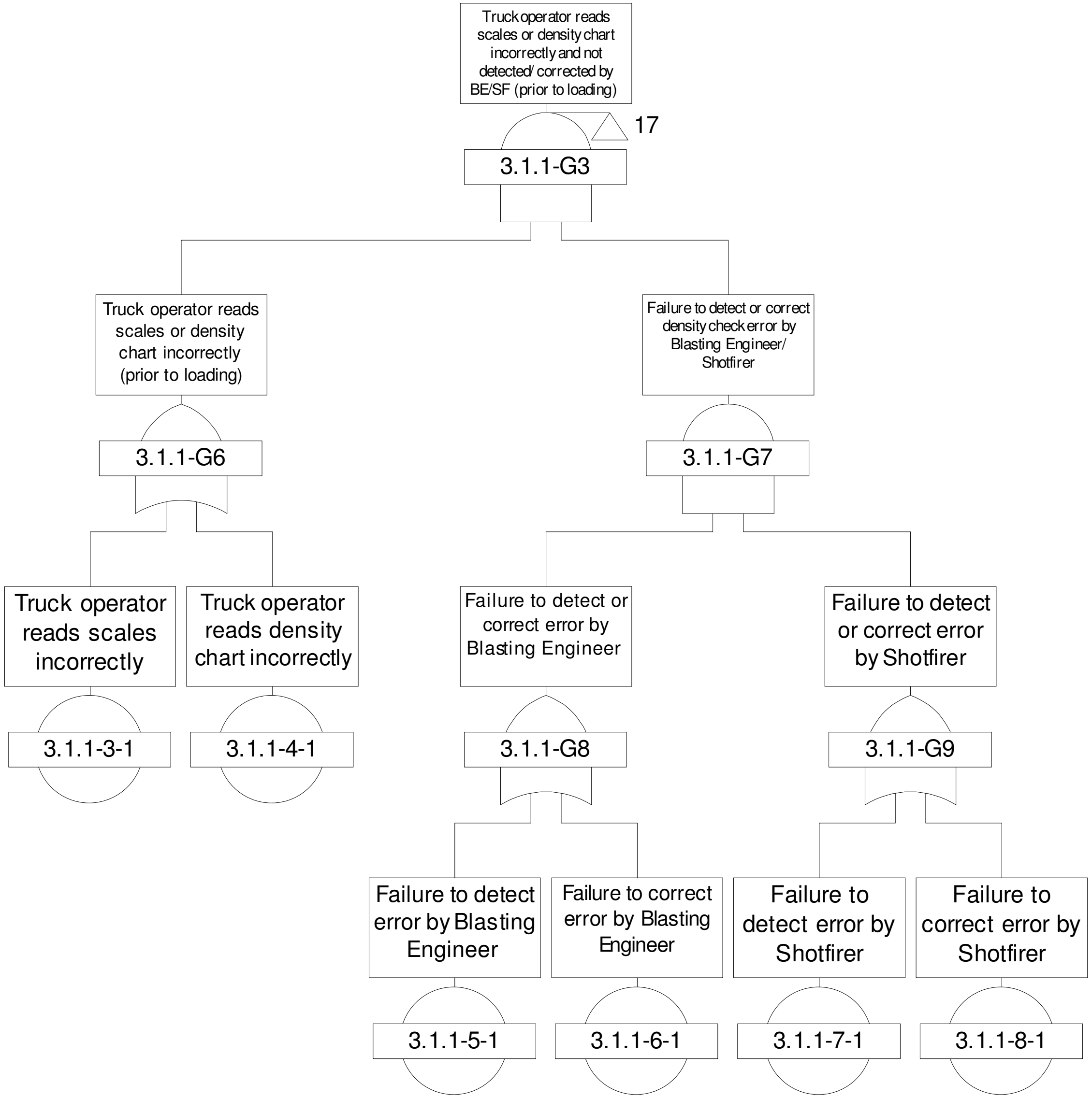

Wrong installation of surface connector
2.4.1
Shotfirer fails to check surface connector colour before use
Shotfirer connects wrong surface connector
2.4.1-1
2.4.1-2


Shotfirer fails to detect wrong installation of surface connector and respond
2.4.2
Shotfirer fails to detect wrong surface connector after installation
Shotfirer fails to correct wrong conection
2.4.2-1
2.4.2-2

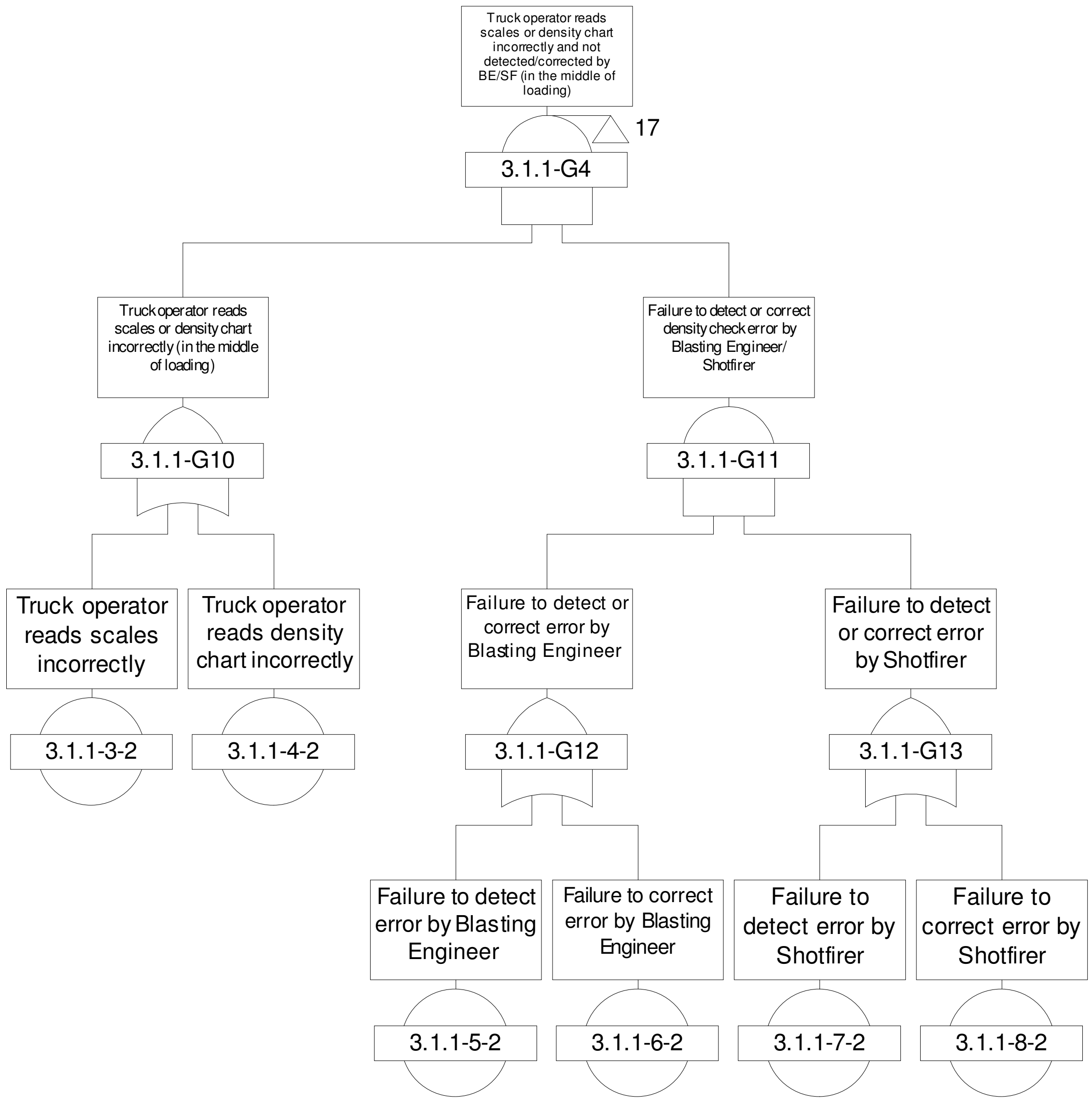

Failure to detect wrong installation of surface connector and respond during final hook up check
2.4.3
Shotfirer fails to detect or correct connection error
2.4.3-G1
Blasting Engineer fails to check or correct connection error
2.4.3-G2
RSS fail to check or correct connection
2.4.3-G3
Shotfirer fails to detect connection error
2.4.3-5
Shotfirer fails to correct connection error
2.4.3-6
Blasting Engineer fails to check connection error
2.4.3-1
Blasting Engineer fails to correct connection error
2.4.3-2
RSS fail to check connection error during final hook up
2.4.3-3
RSS fail to correct error
2.4.3-4

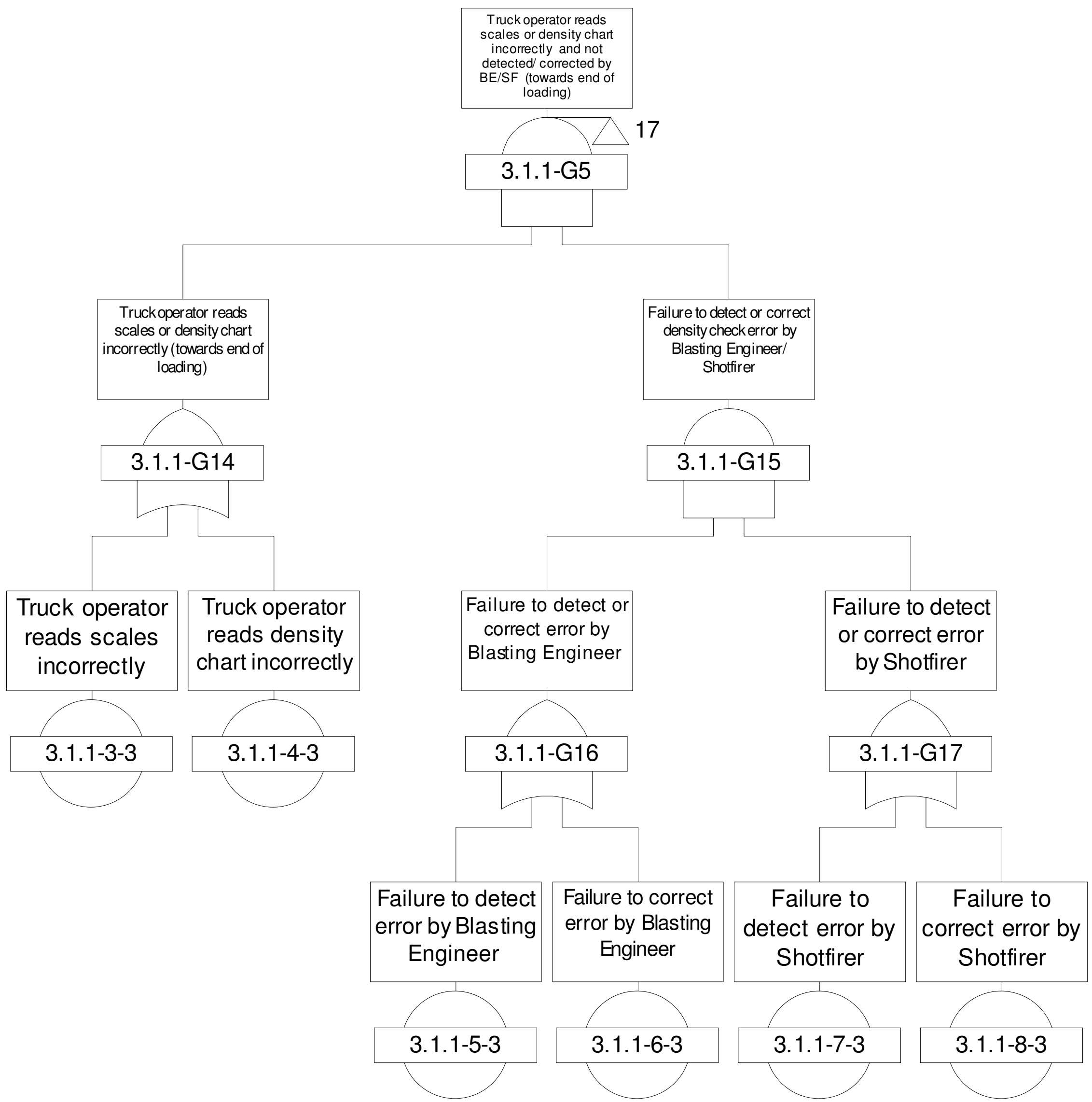


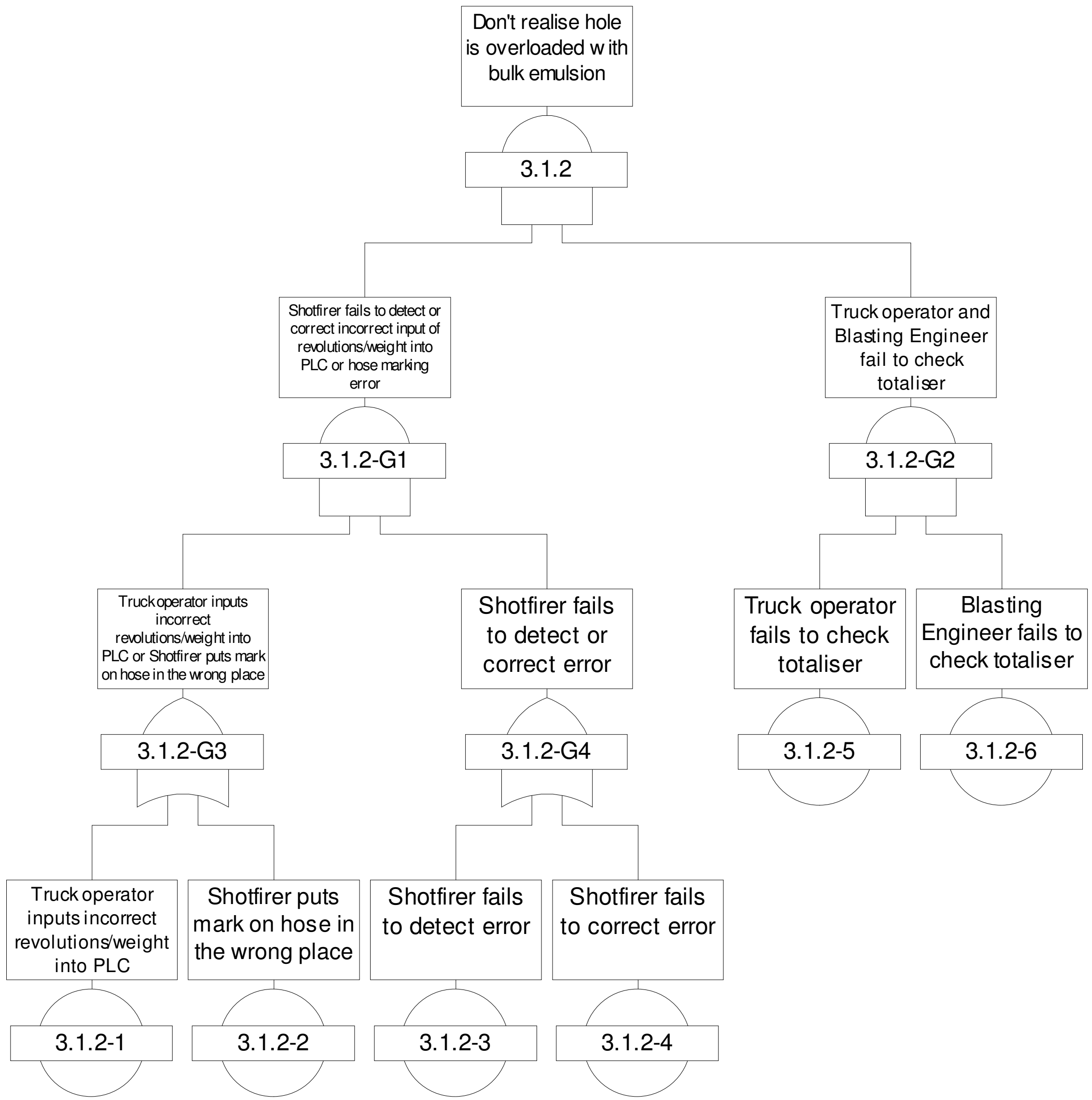
Too much emulsion loaded into hole due to wrong density check
3.1.1
Truck operator sets gassing flow meter or read density chart incorrectly
3.1.1-G1
Truck operator reads scales or density chart incorrectly
3.1.1-G2
Truck operator sets gassing flow meter incorrectly
3.1.1-1
Truck operator reads density chart incorrectly
3.1.1-2
Truck operator reads scales or density chart incorrectly and not detected/ corrected by BE/SF (prior to loading)
3.1.1-G3
Page 18
Truck operator reads scales or density chart incorrectly and not detected/corrected by BE/SF (in the middle of loading)
3.1.1-G4
Page 19
Truck operator reads scales or density chart incorrectly and not detected/ corrected by BE/SF (towards end of loading)
3.1.1-G5
Page 20

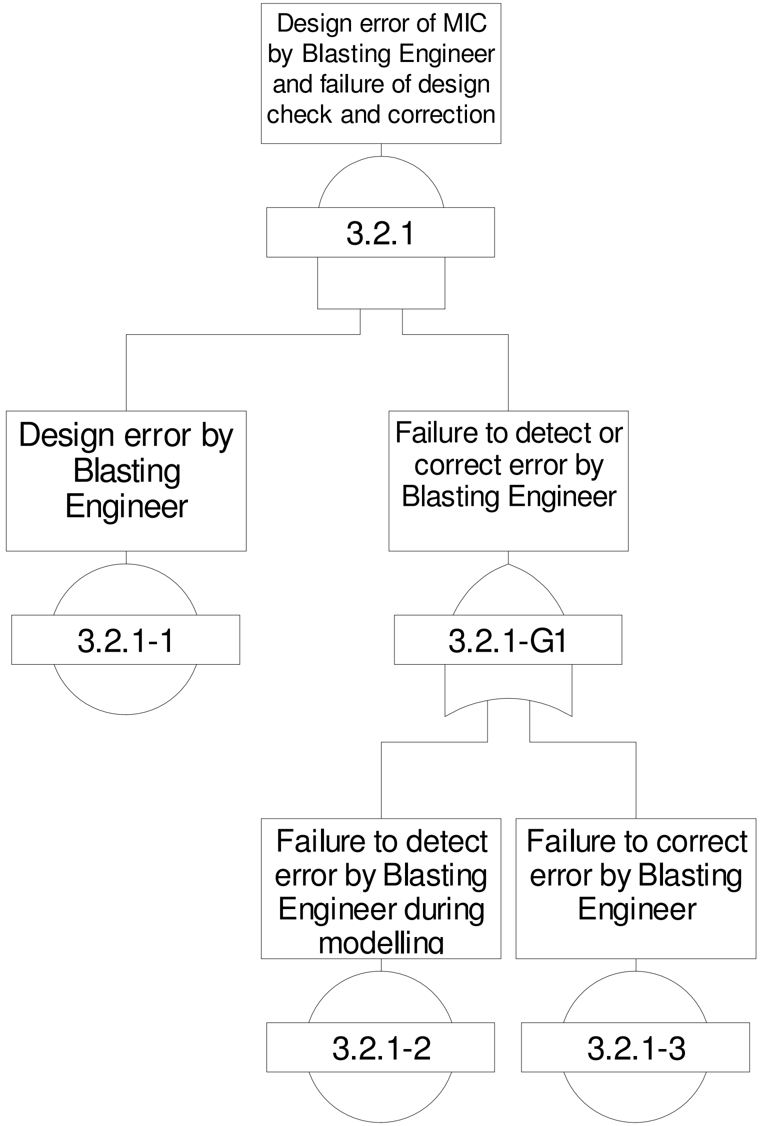


Truck operator reads scales or density chart incorrectly and not detected/ corrected by BE/SF (prior to loading)
17
3.1.1-G3
Truck operator reads scales or density chart incorrectly (prior to loading)
3.1.1-G6
Failure to detect or correct density check error by Blasting Engineer/ Shotfirer
3.1.1-G7
Truck operator reads scales incorrectly
3.1.1-3-1
Truck operator reads density chart incorrectly
3.1.1-4-1
Failure to detect or correct error by Blasting Engineer
3.1.1-G8
Failure to detect or correct error by Shotfirer
3.1.1-G9
Failure to detect error by Blasting Engineer
3.1.1-5-1
Failure to correct error by Blasting Engineer
3.1.1-6-1
Failure to detect error by Shotfirer
3.1.1-7-1
Failure to correct error by Shotfirer
3.1.1-8-1

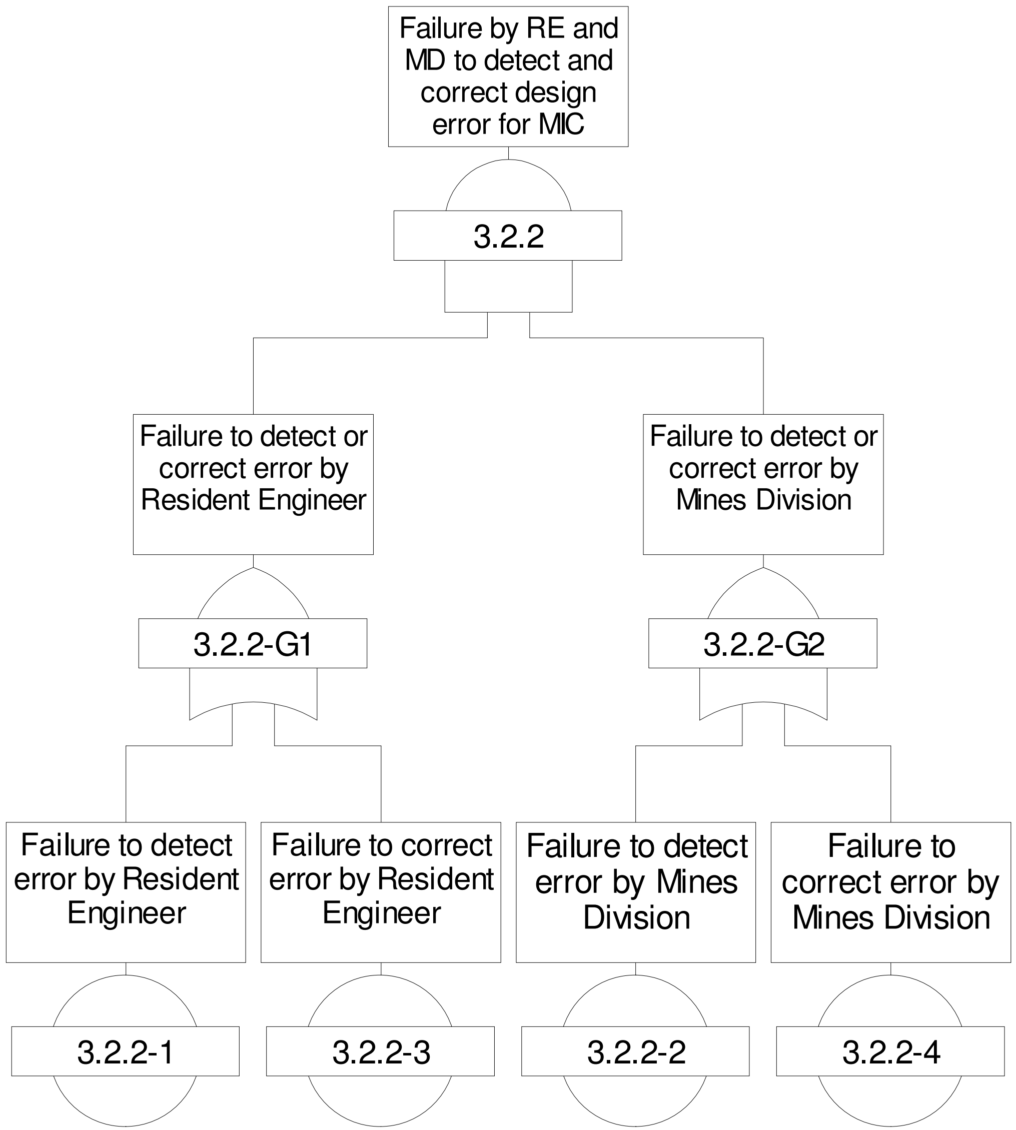

Truck operator reads scales or density chart incorrectly and not detected/corrected by BE/SF (in the middle of loading)
17
3.1.1-G4
Truck operator reads scales or density chart incorrectly (in the middle of loading)
3.1.1-G10
Failure to detect or correct density check error by Blasting Engineer/ Shotfirer
3.1.1-G11
Truck operator reads scales incorrectly
3.1.1-3-2
Truck operator reads density chart incorrectly
3.1.1-4-2
Failure to detect or correct error by Blasting Engineer
3.1.1-G12
Failure to detect or correct error by Shotfirer
3.1.1-G13
Failure to detect error by Blasting Engineer
3.1.1-5-2
Failure to correct error by Blasting Engineer
3.1.1-6-2
Failure to detect error by Shotfirer
3.1.1-7-2
Failure to correct error by Shotfirer
3.1.1-8-2

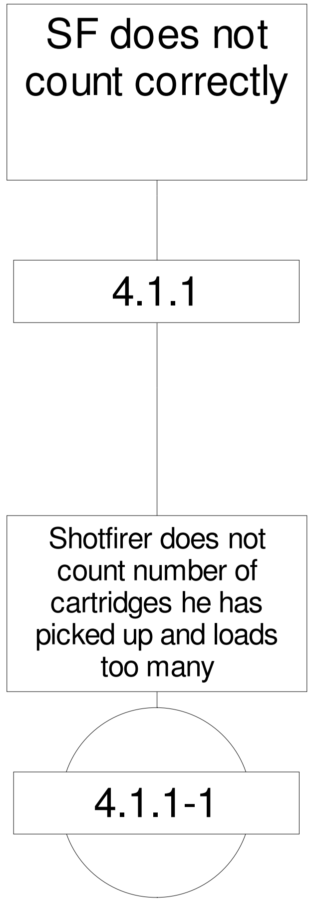

Truck operator reads scales or density chart incorrectly and not detected/ corrected by BE/SF (towards end of loading)
17
3.1.1-G5
Truck operator reads scales or density chart incorrectly (towards end of loading)
3.1.1-G14
Failure to detect or correct density check error by Blasting Engineer/ Shotfirer
3.1.1-G15
Truck operator reads scales incorrectly
3.1.1-3-3
Truck operator reads density chart incorrectly
3.1.1-4-3
Failure to detect or correct error by Blasting Engineer
3.1.1-G16
Failure to detect or correct error by Shotfirer
3.1.1-G17
Failure to detect error by Blasting Engineer
3.1.1-5-3
Failure to correct error by Blasting Engineer
3.1.1-6-3
Failure to detect error by Shotfirer
3.1.1-7-3
Failure to correct error by Shotfirer
3.1.1-8-3

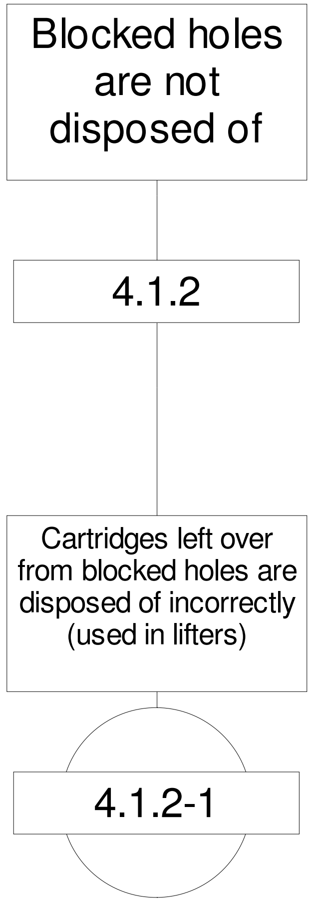

Don't realise hole is overloaded with bulk emulsion
3.1.2
Shotfirer fails to detect or correct incorrect input of revolutions/weight into PLC or hose marking error
3.1.2-G1
Truck operator and Blasting Engineer fail to check totaliser
3.1.2-G2
Truck operator inputs incorrect revolutions/weight into PLC or Shotfirer puts mark on hose in the wrong place
3.1.2-G3
Shotfirer fails to detect or correct error
3.1.2-G4
Truck operator fails to check totaliser
3.1.2-5
Blasting Engineer fails to check totaliser
3.1.2-6
Truck operator inputs incorrect revolutions/weight into PLC
3.1.2-1
Shotfirer puts mark on hose in the wrong place
3.1.2-2
Shotfirer fails to detect error
3.1.2-3
Shotfirer fails to correct error
3.1.2-4

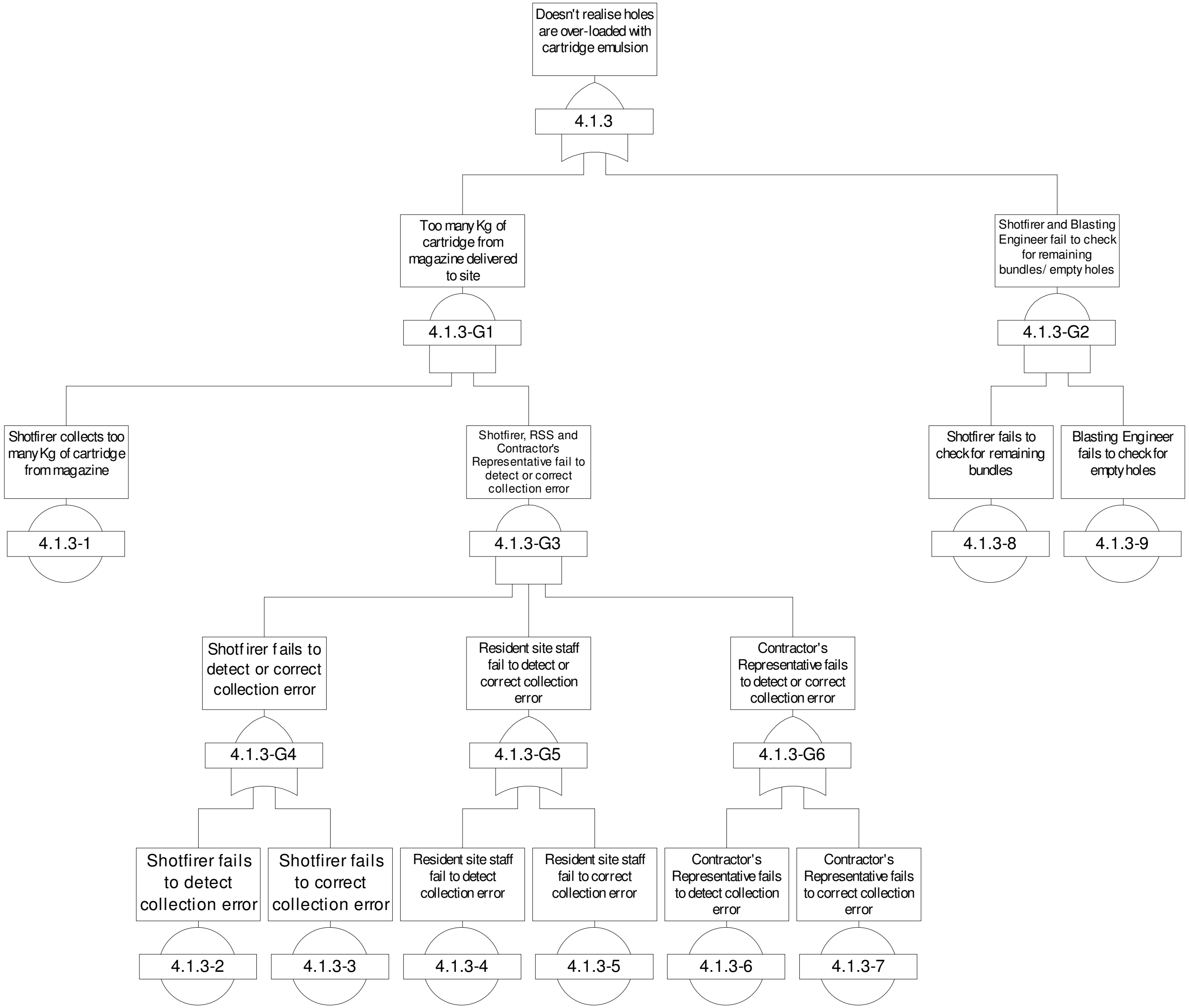


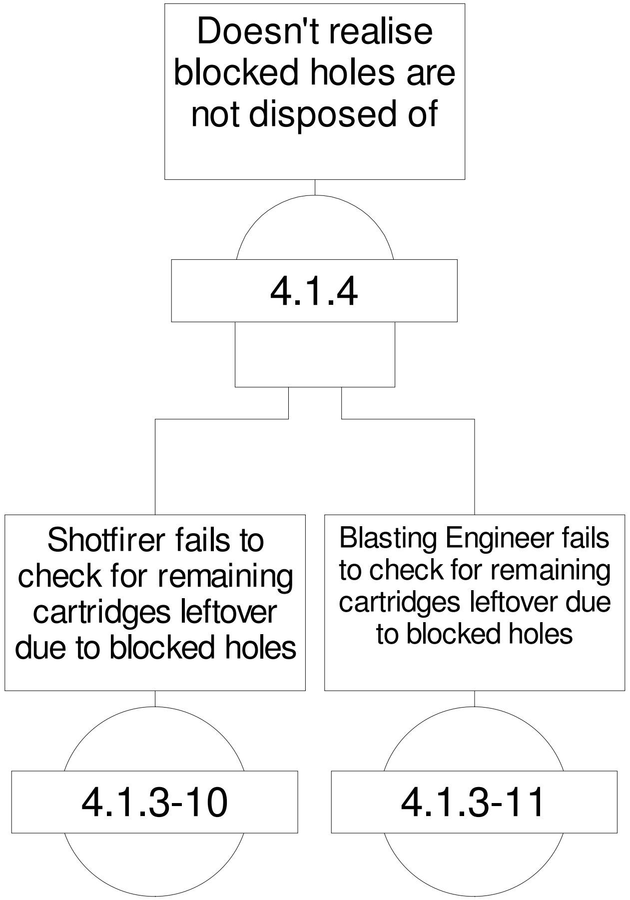
Design error of MIC by Blasting Engineer and failure of design check and correction
3.2.1
Design error by Blasting Engineer
3.2.1-1
Failure to detect or correct error by Blasting Engineer
3.2.1-G1
Failure to detect error by Blasting Engineer during modelling
3.2.1-2
Failure to correct error by Blasting Engineer
3.2.1-3

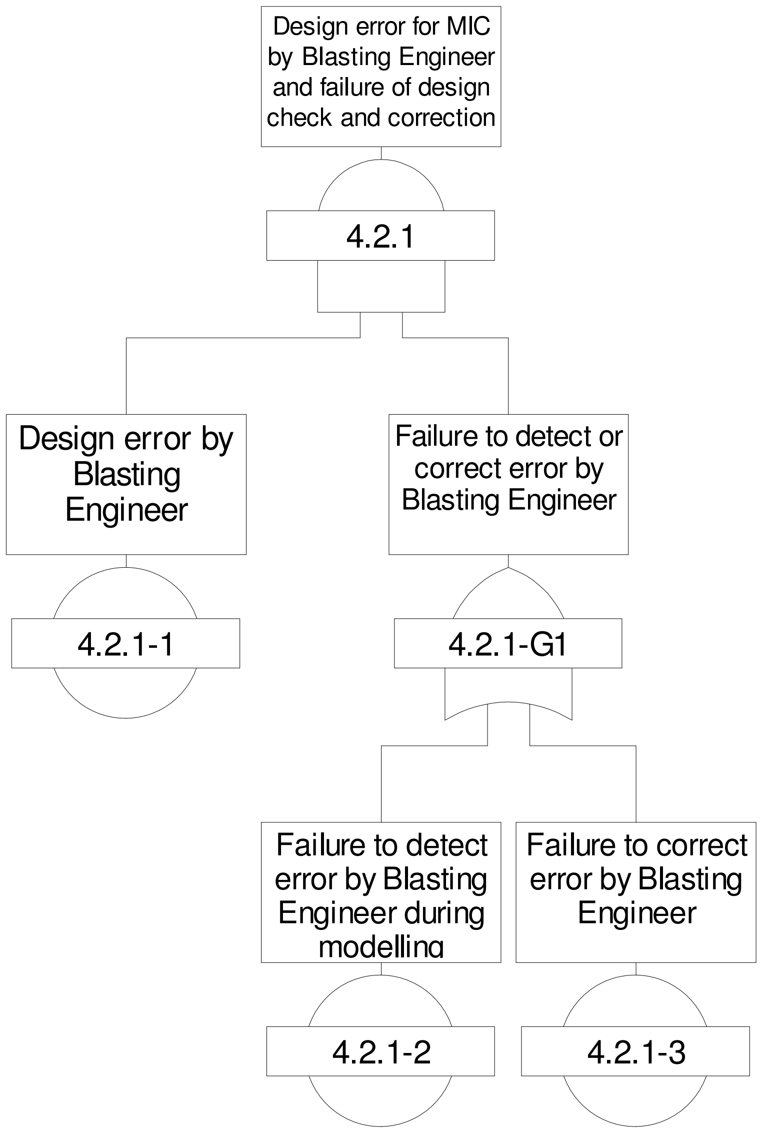

Failure by RE and MD to detect and correct design error for MIC
3.2.2
Failure to detect or correct error by Resident Engineer
3.2.2-G1
Failure to detect or correct error by Mines Division
3.2.2-G2
Failure to detect error by Resident Engineer
3.2.2-1
Failure to correct error by Resident Engineer
3.2.2-3
Failure to detect error by Mines Division
3.2.2-2
Failure to correct error by Mines Division
3.2.2-4

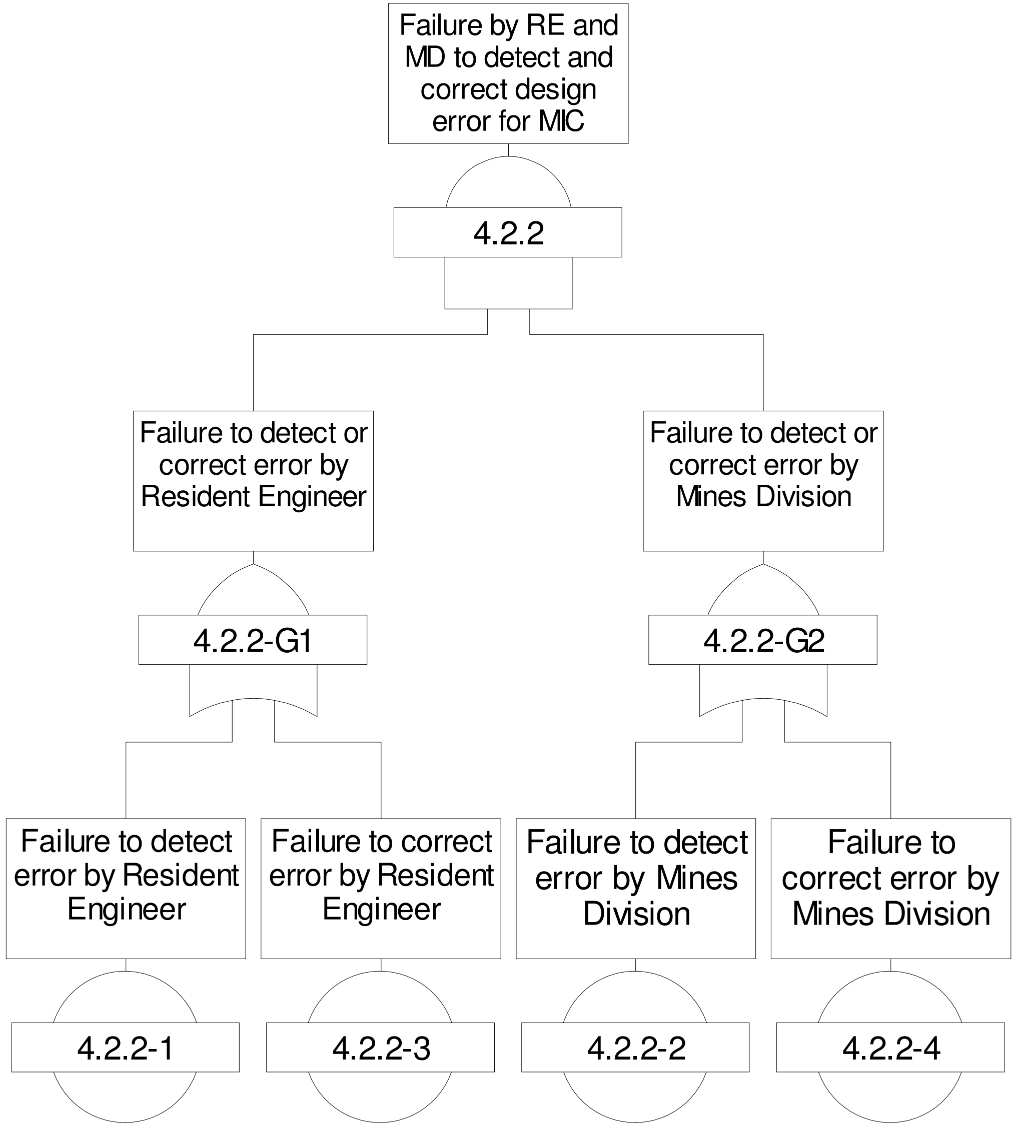

SF does not count correctly
4.1.1
Shotfirer does not count number of cartridges he has picked up and loads too many
4.1.1-1


Blocked holes are not disposed of
4.1.2
Cartridges left over from blocked holes are disposed of incorrectly (used in lifters)
4.1.2-1


Doesn't realise holes are over-loaded with cartridge emulsion
4.1.3
Too many Kg of cartridge from magazine delivered to site
4.1.3-G1
Shotfirer and Blasting Engineer fail to check for remaining bundles/ empty holes
4.1.3-G2
Shotfirer collects too many Kg of cartridge from magazine
4.1.3-1
Shotfirer, RSS and Contractor's Representative fail to detect or correct collection error
4.1.3-G3
Shotfirer fails to check for remaining bundles
4.1.3-8
Blasting Engineer fails to check for empty holes
4.1.3-9
Shotfirer fails to detect or correct collection error
4.1.3-G4
Resident site staff fail to detect or correct collection error
4.1.3-G5
Contractor's Representative fails to detect or correct collection error
4.1.3-G6
Shotfirer fails to detect collection error
4.1.3-2
Shotfirer fails to correct collection error
4.1.3-3
Resident site staff fail to detect collection error
4.1.3-4
Resident site staff fail to correct collection error
4.1.3-5
Contractor's Representative fails to detect collection error
4.1.3-6
Contractor's Representative fails to correct collection error
4.1.3-7


Doesn't realise blocked holes are not disposed of
4.1.4
Shotfirer fails to check for remaining cartridges leftover due to blocked holes
Blasting Engineer fails to check for remaining cartridges leftover due to blocked holes
4.1.3-10
4.1.3-11


Design error for MIC by Blasting Engineer and failure of design check and correction
4.2.1
Design error by Blasting Engineer
4.2.1-1
Failure to detect or correct error by Blasting Engineer
4.2.1-G1
Failure to detect error by Blasting Engineer during modelling
4.2.1-2
Failure to correct error by Blasting Engineer
4.2.1-3


Failure by RE and MD to detect and correct design error for MIC
4.2.2
Failure to detect or correct error by Resident Engineer
4.2.2-G1
Failure to detect or correct error by Mines Division
4.2.2-G2
Failure to detect error by Resident Engineer
4.2.2-1
Failure to correct error by Resident Engineer
4.2.2-3
Failure to detect error by Mines Division
4.2.2-2
Failure to correct error by Mines Division
4.2.2-4

Annex G

Use of Explosives – Blasting Route and Slopes Details

G1 USE OF EXPLOSIVES - BLASTING ROUTE AND SLOPES DETAILS

G1.1 Use of Explosives – Blasting Route Details

Table 1.1 Charge of Explosives Per Blasthole Along Chainage

	*Description	Chainage	Actual Explosive per Charge (kg)
1	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 100023	100023	3.2
2	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 100013	100013	3.6
3	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 100003	100003	2.9
4	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99993	99993	2.3
5	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99983	99983	1.8
6	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99973	99973	1.3
7	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99963	99963	1.0
8	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99953	99953	0.8
9	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99943	99943	0.6
10	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99933	99933	0.6
11	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99923	99923	0.7
12	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99913	99913	0.6
13	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99903	99903	0.6
14	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99893	99893	0.5
15	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99883	99883	0.5
16	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99873	99873	0.5
17	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99863	99863	0.5
18	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99853	99853	0.6
19	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99843	99843	0.7
20	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99833	99833	0.9
21	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99823	99823	0.7
22	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99813	99813	0.6
23	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99803	99803	0.6
24	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99793	99793	0.7
25	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99783	99783	0.8
26	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99773	99773	1.0
27	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99763	99763	1.1
28	West Island Line - SYP to SHW Westbound (Volume 2), Chainage 99758	99758	1.1
29	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99747	99747	1.4
30	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99750	99750	1.3
31	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99760	99760	1.1
32	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99770	99770	0.9
33	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99780	99780	0.7
34	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99790	99790	0.7
35	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99800	99800	0.7
36	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99810	99810	0.8
37	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99820	99820	0.7
38	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99830	99830	0.6
39	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99840	99840	0.5
40	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99850	99850	0.5
41	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99860	99860	0.6
42	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99870	99870	0.7
43	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99880	99880	0.7
44	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99890	99890	0.8
45	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99900	99900	0.9
46	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99910	99910	0.9
47	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99920	99920	1.0
48	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99930	99930	1.0
49	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99940	99940	1.1
50	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99950	99950	1.2
51	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99960	99960	1.5
52	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99970	99970	1.8
53	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99980	99980	2.3

	*Description	Chainage	Actual Explosive per Charge (kg)
54	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 99990	99990	2.8
55	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 100000	100000	3.4
56	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 100010	100010	4.1
57	West Island Line - SYP to SHW Eastbound (Volume 2), Chainage 100020	100020	4.8
58	West Island Line - SYP Station Central Track (Volume 3), Chainage 99727	99727	1.3
59	West Island Line - SYP Station Central Track (Volume 3), Chainage 99717	99717	1.6
60	West Island Line - SYP Station Central Track (Volume 3), Chainage 99707	99707	1.5
61	West Island Line - SYP Station Central Track (Volume 3), Chainage 99697	99697	1.3
62	West Island Line - SYP Station Central Track (Volume 3), Chainage 99687	99687	1.1
63	West Island Line - SYP Station Central Track (Volume 3), Chainage 99677	99677	1.0
64	West Island Line - SYP Station Central Track (Volume 3), Chainage 99667	99667	0.9
65	West Island Line - SYP Station Central Track (Volume 3), Chainage 99657	99657	1.0
66	West Island Line - SYP Station Central Track (Volume 3), Chainage 99647	99647	1.0
67	West Island Line - SYP Station Central Track (Volume 3), Chainage 99637	99637	1.1
68	West Island Line - SYP Station Central Track (Volume 3), Chainage 99627	99627	1.1
69	West Island Line - SYP Station Central Track (Volume 3), Chainage 99617	99617	1.0
70	West Island Line - SYP Station Central Track (Volume 3), Chainage 99607	99607	0.9
71	West Island Line - SYP Station Central Track (Volume 3), Chainage 99597	99597	1.0
72	West Island Line - SYP Station Central Track (Volume 3), Chainage 99587	99587	1.1
73	West Island Line - SYP Station Central Track (Volume 3), Chainage 99577	99577	1.3
74	West Island Line - SYP Station Central Track (Volume 3), Chainage 99567	99567	1.6
75	West Island Line - SYP Station Central Track (Volume 3), Chainage 99557	99557	1.9
76	West Island Line - SYP Station Central Track (Volume 3), Chainage 99547	99547	2.3
77	West Island Line - SYP Station Central Track (Volume 3), Chainage 99537	99537	2.8
78	West Island Line - SYP Station Central Track (Volume 3), Chainage 99527	99527	3.0
79	West Island Line - SYP Station Central Track (Volume 3), Chainage 99517	99517	2.9
80	West Island Line - SYP Station Central Track (Volume 3), Chainage 99507	99507	2.9
81	West Island Line - SYP Station Central Track (Volume 3), Chainage 99497	99497	2.9
82	West Island Line - SYP Station Down Track (Volume 3), Chainage 99758	99758	1.1
83	West Island Line - SYP Station Down Track (Volume 3), Chainage 99750	99750	1.1
84	West Island Line - SYP Station Down Track (Volume 3), Chainage 99740	99740	1.2
85	West Island Line - SYP Station Down Track (Volume 3), Chainage 99730	99730	1.5
86	West Island Line - SYP Station Down Track (Volume 3), Chainage 99720	99720	1.4
87	West Island Line - SYP Station Down Track (Volume 3), Chainage 99710	99710	1.2
88	West Island Line - SYP Station Down Track (Volume 3), Chainage 99700	99700	1.1
89	West Island Line - SYP Station Down Track (Volume 3), Chainage 99690	99690	1.1
90	West Island Line - SYP Station Down Track (Volume 3), Chainage 99680	99680	1.0
91	West Island Line - SYP Station Down Track (Volume 3), Chainage 99670	99670	1.0
92	West Island Line - SYP Station Down Track (Volume 3), Chainage 99660	99660	1.2
93	West Island Line - SYP Station Down Track (Volume 3), Chainage 99650	99650	1.3
94	West Island Line - SYP Station Down Track (Volume 3), Chainage 99640	99640	1.2
95	West Island Line - SYP Station Down Track (Volume 3), Chainage 99630	99630	1.1
96	West Island Line - SYP Station Down Track (Volume 3), Chainage 99620	99620	1.1
97	West Island Line - SYP Station Down Track (Volume 3), Chainage 99610	99610	1.1
98	West Island Line - SYP Station Down Track (Volume 3), Chainage 99600	99600	1.2
99	West Island Line - SYP Station Down Track (Volume 3), Chainage 99590	99590	1.4
100	West Island Line - SYP Station Down Track (Volume 3), Chainage 99580	99580	1.7
101	West Island Line - SYP Station Down Track (Volume 3), Chainage 99570	99570	2.0
102	West Island Line - SYP Station Down Track (Volume 3), Chainage 99560	99560	2.4
103	West Island Line - SYP Station Down Track (Volume 3), Chainage 99550	99550	2.9
104	West Island Line - SYP Station Down Track (Volume 3), Chainage 99540	99540	3.3
105	West Island Line - SYP Station Down Track (Volume 3), Chainage 99530	99530	3.3
106	West Island Line - SYP Station Down Track (Volume 3), Chainage 99520	99520	3.2
107	West Island Line - SYP Station Down Track (Volume 3), Chainage 99510	99510	3.3
108	West Island Line - SYP Station Up Track (Volume 3), Chainage 99745	99745	1.4
109	West Island Line - SYP Station Up Track (Volume 3), Chainage 99737	99737	1.5
110	West Island Line - SYP Station Up Track (Volume 3), Chainage 99727	99727	1.5
111	West Island Line - SYP Station Up Track (Volume 3), Chainage 99717	99717	1.8
112	West Island Line - SYP Station Up Track (Volume 3), Chainage 99707	99707	1.7
113	West Island Line - SYP Station Up Track (Volume 3), Chainage 99697	99697	1.5
114	West Island Line - SYP Station Up Track (Volume 3), Chainage 99687	99687	1.3
115	West Island Line - SYP Station Up Track (Volume 3), Chainage 99677	99677	1.1
116	West Island Line - SYP Station Up Track (Volume 3), Chainage 99667	99667	1.0

	*Description	Chainage	Actual Explosive per Charge (kg)
117	West Island Line - SYP Station Up Track (Volume 3), Chainage 99657	99657	1.0
118	West Island Line - SYP Station Up Track (Volume 3), Chainage 99647	99647	1.0
119	West Island Line - SYP Station Up Track (Volume 3), Chainage 99637	99637	1.1
120	West Island Line - SYP Station Up Track (Volume 3), Chainage 99627	99627	1.1
121	West Island Line - SYP Station Up Track (Volume 3), Chainage 99617	99617	1.0
122	West Island Line - SYP Station Up Track (Volume 3), Chainage 99607	99607	1.0
123	West Island Line - SYP Station Up Track (Volume 3), Chainage 99597	99597	1.0
124	West Island Line - SYP Station Up Track (Volume 3), Chainage 99587	99587	1.1
125	West Island Line - SYP Station Up Track (Volume 3), Chainage 99577	99577	1.3
126	West Island Line - SYP Station Up Track (Volume 3), Chainage 99567	99567	1.6
127	West Island Line - SYP Station Up Track (Volume 3), Chainage 99557	99557	1.9
128	West Island Line - SYP Station Up Track (Volume 3), Chainage 99547	99547	2.3
129	West Island Line - SYP Station Up Track (Volume 3), Chainage 99537	99537	2.8
130	West Island Line - SYP Station Up Track (Volume 3), Chainage 99527	99527	2.8
131	West Island Line - SYP Station Up Track (Volume 3), Chainage 99517	99517	2.7
132	West Island Line - SYP Station Up Track (Volume 3), Chainage 99507	99507	2.7
133	West Island Line - SYP Station Up Track (Volume 3), Chainage 99497	99497	2.7
134	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 0	0	0.3
135	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 10	10	0.3
136	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 20	20	0.3
137	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 30	30	0.3
138	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 40	40	0.3
139	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 50	50	0.5
140	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 60	60	0.4
141	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 70	70	0.5
142	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 80	80	0.5
143	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 90	90	0.5
144	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 100	100	0.5
145	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 110	110	0.6
146	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 120	120	0.8
147	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 130	130	0.7
148	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 140	140	0.6
149	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 150	150	0.6
150	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 160	160	0.6
151	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 170	170	0.7
152	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 180	180	0.8
153	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 190	190	1.1
154	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 200	200	1.2
155	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 210	210	1.2
156	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 220	220	1.1
157	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 230	230	1.1
158	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 240	240	1.1
159	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 250	250	1.1
160	West Island Line - SYP Adit A1-4 (Volume 4), Chainage 260	260	1.1
161	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 0	0	1.3
162	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 10	10	1.0
163	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 20	20	0.9
164	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 30	30	0.7
165	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 40	40	0.7
166	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 50	50	0.7
167	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 60	60	0.7
168	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 70	70	0.9
169	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 80	80	1.1
170	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 90	90	1.3
171	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 100	100	1.3
172	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 110	110	1.3
173	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 120	120	1.2
174	West Island Line - SYP Adit B1-3 (Volume 4), Chainage 127	126.5	1.2
175	West Island Line - SYP Adit C1 (Volume 4), Chainage -10	-10	1.9
176	West Island Line - SYP Adit C1 (Volume 4), Chainage 0	0	2.0
177	West Island Line - SYP Adit C1 (Volume 4), Chainage 10	10	2.0
178	West Island Line - SYP Adit C1 (Volume 4), Chainage 20	20	2.0
179	West Island Line - SYP Adit C1 (Volume 4), Chainage 30	30	2.1

	*Description	Chainage	Actual Explosive per Charge (kg)
180	West Island Line - SYP Adit C1 (Volume 4), Chainage 40	40	2.2
181	West Island Line - SYP Adit C1 (Volume 4), Chainage 50	50	2.4
182	West Island Line - SYP Adit C1 (Volume 4), Chainage 60	60	2.6
183	West Island Line - SYP Adit C1 (Volume 4), Chainage 70	70	2.2
184	West Island Line - SYP Adit C1 (Volume 4), Chainage 80	80	2.0
185	West Island Line - SYP Adit C1 (Volume 4), Chainage 90	90	1.7
186	West Island Line - SYP Adit C1 (Volume 4), Chainage 96	96	1.6
187	West Island Line - SYP Adit C2-3 (Volume 4), Chainage -10	-10	1.6
188	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 0	0	1.7
189	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 10	10	1.8
190	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 20	20	1.9
191	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 30	30	2.0
192	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 40	40	2.2
193	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 50	50	2.5
194	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 60	60	2.9
195	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 70	70	3.4
196	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 80	80	3.9
197	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 90	90	4.5
198	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 100	100	4.7
199	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 110	110	4.8
200	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 120	120	4.8
201	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 130	130	4.4
202	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 140	140	4.1
203	West Island Line - SYP Adit C2-3 (Volume 4), Chainage 148	148	3.4
204	West Island Line - SYP Adit C4 (Volume 4), Chainage 0	0	4.1
205	West Island Line - SYP Adit C4 (Volume 4), Chainage 10	10	4.2
206	West Island Line - SYP Adit C4 (Volume 4), Chainage 20	20	3.7
207	West Island Line - SYP Adit C4 (Volume 4), Chainage 30	30	3.5
208	West Island Line - SYP Adit C4 (Volume 4), Chainage 40	40	3.2
209	West Island Line - SYP Adit C4 (Volume 4), Chainage 50	50	3.0
210	West Island Line - SYP Adit C4 (Volume 4), Chainage 55	55	3.0
211	West Island Line - SYP Station Adit C5 (Volume 4), Chainage 0	0	1.3
212	West Island Line - SYP Station Adit C5 (Volume 4), Chainage 10	10	1.5
213	West Island Line - SYP Station Adit C5 (Volume 4), Chainage 20	20	1.5
214	West Island Line - SYP Station Adit C5 (Volume 4), Chainage 30	30	1.3
215	West Island Line - SYP Station Adit C5 (Volume 4), Chainage 35	35	1.2
216	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 0	0	1.6
217	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 10	10	1.5
218	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 20	20	1.5
219	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 30	30	1.6
220	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 40	40	1.6
221	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 50	50	1.6
222	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 60	60	1.7
223	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 70	70	1.4
224	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 80	80	1.3
225	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 90	90	1.2
226	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 100	100	1.2
227	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 110	110	1.3
228	West Island Line - SYP Adit C6-7 (Volume 4), Chainage 114	114	1.2
229	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 0	0	1.6
230	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 10	10	1.4
231	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 20	20	1.8
232	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 30	30	1.5
233	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 40	40	1.6
234	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 50	50	1.6
235	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 60	60	1.6
236	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 70	70	1.7
237	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 80	80	1.8
238	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 90	90	1.9
239	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 100	100	1.7
240	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 110	110	1.6
241	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 120	120	1.6
242	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 130	130	1.6

	*Description	Chainage	Actual Explosive per Charge (kg)
243	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 140	140	1.4
244	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 150	150	1.3
245	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 160	160	1.4
246	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 170	170	1.5
247	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 180	180	1.7
248	West Island Line - SYP Station Adit C8-11 (Volume 4), Chainage 186	186	1.7
249	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99515	99515	5.0
250	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99513	99513	5.0
251	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99503	99503	5.0
252	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99493	99493	5.0
253	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99483	99483	5.0
254	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99473	99473	5.0
255	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99463	99463	5.0
256	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99453	99453	5.0
257	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99443	99443	5.0
258	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99433	99433	5.0
259	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99423	99423	5.0
260	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99413	99413	5.0
261	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99403	99403	5.0
262	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99393	99393	5.0
263	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99383	99383	5.0
264	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99373	99373	5.0
265	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99363	99363	5.0
266	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99353	99353	5.0
267	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99343	99343	5.0
268	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99333	99333	5.0
269	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99323	99323	5.0
270	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99312	99312	5.0
271	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99302	99302	5.0
272	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99292	99292	5.0
273	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99282	99282	5.0
274	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99272	99272	5.0
275	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99262	99262	4.7
276	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99252	99252	4.3

	*Description	Chainage	Actual Explosive per Charge (kg)
277	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99242	99242	4.0
278	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99232	99232	3.8
279	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99222	99222	3.6
280	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99212	99212	3.6
281	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99202	99202	3.6
282	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99192	99192	3.6
283	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99182	99182	3.8
284	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99172	99172	3.6
285	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99162	99162	3.1
286	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99152	99152	2.7
287	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99142	99142	2.4
288	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99132	99132	2.2
289	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99122	99122	2.0
290	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99112	99112	1.9
291	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99102	99102	1.9
292	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99092	99092	1.8
293	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99082	99082	1.8
294	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99072	99072	1.8
295	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99062	99062	1.8
296	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99052	99052	1.7
297	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99042	99042	1.7
298	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99032	99032	1.8
299	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99022	99022	1.8
300	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99012	99012	1.8
301	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 99002	99002	1.9
302	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 98992	98992	2.1
303	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 98982	98982	2.3
304	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 98972	98972	2.7
305	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 98962	98962	2.9
306	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 98952	98952	3.0
307	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 98942	98942	3.1

	*Description	Chainage	Actual Explosive per Charge (kg)
308	WEST ISLAND LINE - SYP-UNV Tunnel (downtrack) (Volume 5), Chainage 98937	98937	3.2
309	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99502	99502	4.3
310	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99500	99500	4.4
311	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99490	99490	4.7
312	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99480	99480	5.0
313	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99470	99470	5.0
314	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99460	99460	5.0
315	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99450	99450	5.0
316	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99440	99440	5.0
317	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99430	99430	5.0
318	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99420	99420	5.0
319	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99410	99410	5.0
320	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99400	99400	5.0
321	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99390	99390	5.0
322	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99380	99380	5.0
323	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99370	99370	5.0
324	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99360	99360	5.0
325	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99350	99350	5.0
326	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99340	99340	5.0
327	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99330	99330	5.0
328	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99320	99320	5.0
329	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99310	99310	5.0
330	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99300	99300	5.0
331	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99290	99290	5.0
332	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99280	99280	4.7
333	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99270	99270	4.2
334	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99260	99260	3.7
335	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99250	99250	3.4
336	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99240	99240	3.1
337	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99230	99230	3.0
338	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99220	99220	2.9

	*Description	Chainage	Actual Explosive per Charge (kg)
339	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99210	99210	2.8
340	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99200	99200	2.9
341	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99190	99190	3.1
342	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99180	99180	3.3
343	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99170	99170	3.3
344	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99160	99160	2.9
345	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99150	99150	2.6
346	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99140	99140	2.3
347	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99130	99130	2.1
348	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99120	99120	2.0
349	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99110	99110	1.9
350	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99100	99100	1.9
351	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99090	99090	1.8
352	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99080	99080	1.8
353	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99070	99070	1.8
354	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99060	99060	1.8
355	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99050	99050	1.7
356	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99040	99040	1.7
357	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99030	99030	1.7
358	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99020	99020	1.7
359	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99010	99010	1.8
360	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 99000	99000	1.9
361	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 98990	98990	2.1
362	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 98980	98980	2.2
363	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 98970	98970	2.1
364	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 98960	98960	2.1
365	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 98950	98950	2.2
366	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 98940	98940	2.3
367	WEST ISLAND LINE - SYP-UNV Tunnel (uptrack) (Volume 5), Chainage 98938	98938	2.4
368	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98938	98938	3.0
369	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98928	98928	2.8

	*Description	Chainage	Actual Explosive per Charge (kg)
370	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98918	98918	2.5
371	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98908	98908	2.3
372	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98898	98898	2.3
373	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98888	98888	2.6
374	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98878	98878	2.5
375	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98868	98868	2.4
376	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98858	98858	2.4
377	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98848	98848	2.5
378	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98838	98838	2.4
379	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98828	98828	2.3
380	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98818	98818	2.3
381	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98808	98808	2.4
382	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98798	98798	2.3
383	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98788	98788	2.3
384	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98778	98778	2.3
385	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98768	98768	2.4
386	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98758	98758	2.6
387	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98748	98748	2.8
388	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98738	98738	3.1
389	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98728	98728	3.5
390	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98718	98718	3.9
391	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98708	98708	4.4
392	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98698	98698	5.0
393	WEST ISLAND LINE - UNV STATION (CENTRE PORTION) (Volume 6), Chainage 98687	98687	5.0
394	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98937	98937	3.2
395	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98927	98927	2.7
396	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98917	98917	2.4
397	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98907	98907	2.2
398	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98897	98897	2.2
399	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98887	98887	2.4
400	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98877	98877	2.8

	*Description	Chainage	Actual Explosive per Charge (kg)
401	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98867	98867	2.9
402	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98857	98857	2.8
403	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98847	98847	2.7
404	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98837	98837	2.7
405	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98827	98827	2.7
406	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98817	98817	2.7
407	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98807	98807	2.7
408	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98797	98797	2.7
409	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98787	98787	2.7
410	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98777	98777	2.7
411	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98767	98767	2.8
412	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98757	98757	3.0
413	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98747	98747	3.2
414	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98737	98737	3.5
415	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98727	98727	3.9
416	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98717	98717	4.3
417	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98707	98707	4.9
418	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98697	98697	5.0
419	V6_WEST ISLAND LINE - UNV STATION (DOWN TRACK), Chainage 98687	98687	5.0
420	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98938	98938	2.6
421	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98928	98928	2.6
422	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98918	98918	2.6
423	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98908	98908	2.8
424	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98898	98898	2.9
425	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98888	98888	2.9
426	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98878	98878	2.5
427	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98868	98868	2.3
428	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98858	98858	2.4
429	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98848	98848	2.5
430	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98838	98838	2.3
431	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98828	98828	2.2

	*Description	Chainage	Actual Explosive per Charge (kg)
432	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98818	98818	2.2
433	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98808	98808	2.2
434	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98798	98798	2.1
435	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98788	98788	2.0
436	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98778	98778	2.1
437	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98768	98768	2.1
438	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98758	98758	2.3
439	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98748	98748	2.5
440	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98738	98738	2.8
441	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98728	98728	3.2
442	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98718	98718	3.6
443	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98708	98708	4.2
444	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98698	98698	4.7
445	WEST ISLAND LINE - UNV STATION (UP TRACK) (Volume 6), Chainage 98687	98687	5.0
446	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 0	0	4.5
447	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 10	10	4.3
448	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 20	20	4.2
449	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 30	30	4.1
450	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 40	40	3.9
451	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 50	50	4.0
452	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 60	60	4.0
453	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 70	70	4.1
454	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 80	80	4.0
455	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 90	90	4.1
456	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 100	100	4.1
457	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 110	110	3.7
458	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 120	120	3.3
459	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 130	130	3.0
460	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 140	140	2.5
461	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 150	150	2.3
462	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 160	160	2.0
463	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 170	170	1.7
464	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 180	180	1.6
465	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 190	190	1.5
466	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 200	200	1.5
467	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 210	210	1.4
468	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 220	220	1.4
469	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 230	230	1.5
470	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 240	240	1.5
471	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 250	250	1.3
472	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 260	260	1.2
473	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 270	270	1.1
474	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 280	280	1.1
475	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 290	290	1.1
476	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 300	300	1.1
477	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 310	310	1.1
478	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 320	320	1.1
479	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 330	330	1.1
480	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 340	340	1.2

	*Description	Chainage	Actual Explosive per Charge (kg)
481	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 350	350	1.3
482	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 360	360	1.4
483	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 370	370	1.6
484	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 380	380	1.8
485	West Island Line - SYP Station Construction Adit (Volume 7), Chainage 386	386	1.9
486	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98687	98687	5.0
487	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98678	98678	5.0
488	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98668	98668	5.0
489	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98658	98658	5.0
490	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98648	98648	4.4
491	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98638	98638	3.8
492	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98628	98628	3.4
493	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98618	98618	3.0
494	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98608	98608	2.7
495	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98598	98598	2.4
496	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98588	98588	2.3
497	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98578	98578	2.2
498	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98568	98568	2.3
499	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98558	98558	2.4
500	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98548	98548	2.5
501	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98538	98538	2.8
502	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98528	98528	2.7
503	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98518	98518	2.6
504	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98508	98508	2.6
505	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98498	98498	2.4
506	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98488	98488	2.0
507	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98478	98478	1.6
508	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98468	98468	1.3
509	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98458	98458	1.1
510	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98448	98448	0.9
511	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98438	98438	0.8
512	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98428	98428	0.8
513	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98418	98418	0.8
514	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98408	98408	0.8

	*Description	Chainage	Actual Explosive per Charge (kg)
515	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98398	98398	1.0
516	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98388	98388	1.1
517	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98378	98378	1.4
518	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98368	98368	1.7
519	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98358	98358	1.7
520	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98348	98348	1.8
521	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98338	98338	1.9
522	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98328	98328	2.1
523	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98318	98318	2.4
524	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98308	98308	2.7
525	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98298	98298	2.7
526	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98288	98288	2.5
527	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98278	98278	2.3
528	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98268	98268	2.2
529	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98258	98258	2.2
530	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98248	98248	2.0
531	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98238	98238	1.9
532	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98228	98228	1.8
533	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98218	98218	1.8
534	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98208	98208	1.8
535	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98198	98198	2.0
536	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98188	98188	2.2
537	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98177	98177	2.5
538	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98168	98168	2.9
539	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98158	98158	3.3
540	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98148	98148	3.9
541	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98138	98138	4.4
542	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98128	98128	4.3
543	WEST ISLAND LINE - UNV TO KET TUNNEL (UP TRACK) (Volume 8), Chainage 98126	98126	4.3
544	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98687	98687	5.0
545	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98678	98678	5.0

	*Description	Chainage	Actual Explosive per Charge (kg)
546	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98667	98667	5.0
547	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98657	98657	5.0
548	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98647	98647	4.8
549	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98637	98637	4.3
550	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98627	98627	3.9
551	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98617	98617	3.5
552	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98607	98607	3.3
553	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98597	98597	3.1
554	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98587	98587	3.0
555	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98577	98577	3.0
556	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98567	98567	3.0
557	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98557	98557	3.2
558	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98547	98547	3.1
559	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98537	98537	2.9
560	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98527	98527	2.7
561	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98517	98517	2.6
562	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98507	98507	2.5
563	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98497	98497	2.0
564	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98487	98487	1.6
565	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98477	98477	1.4
566	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98467	98467	1.1
567	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98457	98457	1.0
568	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98447	98447	0.9
569	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98437	98437	0.9
570	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98427	98427	0.9
571	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98417	98417	0.9
572	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98407	98407	1.1
573	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98397	98397	1.3
574	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98387	98387	1.5
575	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98377	98377	1.9
576	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98367	98367	2.3

	*Description	Chainage	Actual Explosive per Charge (kg)
577	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98357	98357	2.8
578	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98347	98347	3.1
579	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98337	98337	3.3
580	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98327	98327	3.5
581	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98317	98317	3.8
582	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98307	98307	3.2
583	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98297	98297	2.7
584	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98287	98287	2.6
585	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98277	98277	2.4
586	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98267	98267	2.1
587	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98257	98257	1.9
588	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98247	98247	1.7
589	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98237	98237	1.6
590	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98227	98227	1.6
591	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98217	98217	1.6
592	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98207	98207	1.8
593	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98197	98197	2.0
594	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98187	98187	2.2
595	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98177	98177	2.6
596	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98167	98167	3.0
597	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98157	98157	3.5
598	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98147	98147	4.1
599	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98137	98137	3.9
600	WEST ISLAND LINE - UNV TO KET TUNNEL (DOWN TRACK) (Volume 8), Chainage 98131	98131	3.9
601	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 0	0	4.3
602	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 10	10	4.9
603	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 20	20	5.0
604	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 30	30	5.0
605	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 40	40	4.9
606	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 50	50	4.3
607	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 60	60	3.7
608	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 70	70	3.3
609	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 80	80	2.8
610	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 90	90	2.5
611	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 100	100	2.2
612	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 110	110	2.0
613	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 120	120	1.8
614	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 130	130	1.8
615	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 140	140	1.8

	*Description	Chainage	Actual Explosive per Charge (kg)
616	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 150	150	1.8
617	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (40mPD)	Shaft VS-Z4 (40mPD)	0.2
618	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (40mPD)	Shaft VS-Z4 (40mPD)	0.3
619	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (40mPD)	Shaft VS-Z4 (40mPD)	0.4
620	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (40mPD)	Shaft VS-Z4 (40mPD)	0.2
621	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (30mPD)	Shaft VS-Z4 (30mPD)	0.3
622	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (30mPD)	Shaft VS-Z4 (30mPD)	0.5
623	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (30mPD)	Shaft VS-Z4 (30mPD)	0.5
624	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (30mPD)	Shaft VS-Z4 (30mPD)	0.3
625	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (20mPD)	Shaft VS-Z4 (20mPD)	0.4
626	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (20mPD)	Shaft VS-Z4 (20mPD)	0.6
627	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (20mPD)	Shaft VS-Z4 (20mPD)	0.6
628	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (20mPD)	Shaft VS-Z4 (20mPD)	0.4
629	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (10mPD)	Shaft VS-Z4 (10mPD)	0.5
630	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (10mPD)	Shaft VS-Z4 (10mPD)	0.9
631	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (10mPD)	Shaft VS-Z4 (10mPD)	0.8
632	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (10mPD)	Shaft VS-Z4 (10mPD)	0.6
633	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (0mPD)	Shaft VS-Z4 (0mPD)	0.7
634	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (0mPD)	Shaft VS-Z4 (0mPD)	1.1
635	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (0mPD)	Shaft VS-Z4 (0mPD)	1.1
636	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (0mPD)	Shaft VS-Z4 (0mPD)	0.9

	*Description	Chainage	Actual Explosive per Charge (kg)
637	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (-11mPD)	Shaft VS-Z4 (-11mPD)	1.3
638	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (-11mPD)	Shaft VS-Z4 (-11mPD)	1.5
639	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (-11mPD)	Shaft VS-Z4 (-11mPD)	1.5
640	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage Shaft VS-Z4 (-11mPD)	Shaft VS-Z4 (-11mPD)	1.3
641	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 160	160	2.0
642	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 170	170	2.2
643	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 180	180	2.4
644	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 190	190	2.5
645	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 200	200	2.7
646	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 210	210	3.1
647	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 220	220	3.2
648	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 230	230	2.9
649	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 240	240	2.6
650	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 250	250	2.3
651	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 260	260	2.1
652	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 270	270	2.0
653	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 280	280	2.0
654	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 290	290	2.0
655	WEST ISLAND LINE - UNV ADITS - Shaft VS-Z4, Chainage 299	299.04	2.1
656	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 0	0	4.1
657	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 10	10	3.4
658	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 20	20	3.0
659	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 30	30	2.9
660	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 40	40	3.2
661	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 50	50	3.8
662	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 60	60	4.7
663	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 70	70	4.7
664	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 80	80	4.5
665	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 90	90	3.9
666	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 100	100	2.8
667	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 110	110	2.0
668	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 120	120	1.5
669	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 130	130	1.4
670	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 140	140	1.6
671	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 150	150	2.0
672	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 160	160	2.7
673	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 170	170	3.1

	*Description	Chainage	Actual Explosive per Charge (kg)
674	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 180	180	2.3
675	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 190	190	1.9
676	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 200	200	1.6
677	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 210	210	1.4
678	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 220	220	1.2
679	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 230	230	1.2
680	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 240	240	1.4
681	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 250	250	1.8
682	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 260	260	2.5
683	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 270	270	3.1
684	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 280	280	3.2
685	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 290	290	3.4
686	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 300	300	3.7
687	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 310	310	4.0
688	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 320	320	4.4
689	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 330	330	4.9
690	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 340	340	5.0
691	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 350	350	5.0
692	WEST ISLAND LINE - UNV ADITS - Access Shaft of KET Praya (Volume 7), Chainage 351	351.08	5.0
693	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 0	0	1.1
694	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 10	10	1.8
695	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 20	20	1.9
696	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 30	30	1.6
697	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 40	40	1.2
698	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 50	50	0.9
699	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 60	60	0.6
700	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 70	70	0.5
701	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 80	80	0.4
702	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 90	90	0.4
703	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 100	100	0.4
704	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 110	110	0.6
705	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 120	120	0.8

	*Description	Chainage	Actual Explosive per Charge (kg)
706	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 130	130	1.1
707	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 140	140	1.5
708	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 150	150	1.9
709	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 160	160	2.4
710	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 170	170	2.9
711	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 180	180	3.0
712	WEST ISLAND LINE - UNV CONSTRUCTION ADIT (Volume 7), Chainage 186	185.57	2.9
713	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (40mPD)	Shaft A (40mPD)	0.7
714	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (40mPD)	Shaft A (40mPD)	0.5
715	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (40mPD)	Shaft A (40mPD)	0.5
716	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (40mPD)	Shaft A (40mPD)	1.5
717	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (30mPD)	Shaft A (30mPD)	1.0
718	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (30mPD)	Shaft A (30mPD)	0.9
719	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (30mPD)	Shaft A (30mPD)	1.2
720	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (30mPD)	Shaft A (30mPD)	1.8
721	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (20mPD)	Shaft A (20mPD)	1.3
722	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (20mPD)	Shaft A (20mPD)	1.5
723	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (20mPD)	Shaft A (20mPD)	2.1
724	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (20mPD)	Shaft A (20mPD)	2.1
725	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (10mPD)	Shaft A (10mPD)	1.8
726	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (10mPD)	Shaft A (10mPD)	2.3
727	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (10mPD)	Shaft A (10mPD)	2.9
728	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (10mPD)	Shaft A (10mPD)	2.6
729	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (-1mPD)	Shaft A (-1mPD)	2.4
730	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (-1mPD)	Shaft A (-1mPD)	2.7
731	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (-1mPD)	Shaft A (-1mPD)	3.6
732	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage Shaft A (-1mPD)	Shaft A (-1mPD)	3.3
733	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 0	0	2.8
734	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 10	10	2.8
735	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 20	20	2.6
736	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 30	30	2.3
737	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 40	40	2.1
738	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 50	50	2.0
739	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 60	60	1.9
740	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 70	70	2.0
741	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 80	80	2.3

	*Description	Chainage	Actual Explosive per Charge (kg)
742	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 90	90	2.7
743	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 100	100	3.1
744	WEST ISLAND LINE - UNV ADITS - ENTRANCE A (Volume 7), Chainage 107	106.68	3.0
745	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 0	0	0.2
746	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 3	3	0.2
747	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 13	13	0.2
748	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 23	23	0.1
749	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 33	33	0.1
750	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 43	43	0.3
751	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 53	53	0.4
752	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 63	63	0.3
753	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 73	73	0.4
754	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 83	83	0.5
755	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 93	93	0.6
756	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 103	103	0.9
757	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 113	113	1.2
758	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 123	123	1.5
759	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 133	133	2.0
760	WEST ISLAND LINE - UNV ADITS - ENTRANCE B1 (Volume 7), Chainage 142	141.82	2.1
761	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 0	0	1.0
762	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 10	10	1.5
763	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 20	20	1.6
764	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 30	30	1.9
765	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 40	40	1.6
766	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 50	50	1.4
767	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 60	60	1.4
768	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 70	70	1.5
769	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 80	80	1.8
770	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 90	90	1.9
771	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 100	100	1.9
772	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 110	110	2.1
773	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 120	120	2.6
774	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 130	130	2.4

	*Description	Chainage	Actual Explosive per Charge (kg)
775	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 140	140	2.2
776	WEST ISLAND LINE - UNV ADITS - ENTRANCE B2 (Volume 7), Chainage 145	144.91	2.3
777	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-1 (40mPD)	C1-1 (40mPD)	1.1
778	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-2 (40mPD)	C1-2 (40mPD)	0.6
779	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-3 (40mPD)	C1-3 (40mPD)	1.3
780	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-41 (40mPD)	C1-41 (40mPD)	0.8
781	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-5 (40mPD)	C1-5 (40mPD)	1.5
782	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-6 (40mPD)	C1-6 (40mPD)	1.1
783	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-7 (40mPD)	C1-7 (40mPD)	1.4
784	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-8 (40mPD)	C1-8 (40mPD)	1.3
785	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-1 (30mPD)	C1-1 (30mPD)	1.2
786	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-2 (30mPD)	C1-2 (30mPD)	0.7
787	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-3 (30mPD)	C1-3 (30mPD)	1.3
788	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-41 (30mPD)	C1-41 (30mPD)	0.9
789	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-5 (30mPD)	C1-5 (30mPD)	1.6
790	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-6 (30mPD)	C1-6 (30mPD)	1.2
791	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-7 (30mPD)	C1-7 (30mPD)	1.6
792	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-8 (30mPD)	C1-8 (30mPD)	1.3
793	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-1 (20mPD)	C1-1 (20mPD)	0.8
794	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-2 (20mPD)	C1-2 (20mPD)	0.9
795	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-3 (20mPD)	C1-3 (20mPD)	1.5
796	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-41 (20mPD)	C1-41 (20mPD)	1.0
797	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-5 (20mPD)	C1-5 (20mPD)	1.8
798	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-6 (20mPD)	C1-6 (20mPD)	1.3
799	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-7 (20mPD)	C1-7 (20mPD)	1.7
800	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-8 (20mPD)	C1-8 (20mPD)	1.5
801	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-1 (10mPD)	C1-1 (10mPD)	0.7
802	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-2 (10mPD)	C1-2 (10mPD)	0.8
803	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-3 (10mPD)	C1-3 (10mPD)	1.7
804	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-41 (10mPD)	C1-41 (10mPD)	1.2
805	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-5 (10mPD)	C1-5 (10mPD)	2.0

	*Description	Chainage	Actual Explosive per Charge (kg)
806	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-6 (10mPD)	C1-6 (10mPD)	1.5
807	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-7 (10mPD)	C1-7 (10mPD)	1.9
808	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-8 (10mPD)	C1-8 (10mPD)	1.7
809	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-1 (0mPD)	C1-1 (0mPD)	0.9
810	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-2 (0mPD)	C1-2 (0mPD)	1.0
811	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-3 (0mPD)	C1-3 (0mPD)	2.0
812	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-41 (0mPD)	C1-41 (0mPD)	1.5
813	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-5 (0mPD)	C1-5 (0mPD)	2.3
814	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-6 (0mPD)	C1-6 (0mPD)	1.8
815	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-7 (0mPD)	C1-7 (0mPD)	2.2
816	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-8 (0mPD)	C1-8 (0mPD)	2.0
817	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-1 (-3mPD)	C1-1 (-3mPD)	1.0
818	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-2 (-3mPD)	C1-2 (-3mPD)	1.1
819	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-3 (-3mPD)	C1-3 (-3mPD)	2.1
820	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-4 (-3mPD)	C1-4 (-3mPD)	1.6
821	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-5 (-3mPD)	C1-5 (-3mPD)	2.4
822	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-6 (-3mPD)	C1-6 (-3mPD)	1.9
823	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-7 (-3mPD)	C1-7 (-3mPD)	2.3
824	WEST ISLAND LINE - UNV ADITS - ENTRANCE C1 & SHAFT (Volume 7), Chainage C1-8 (-3mPD)	C1-8 (-3mPD)	2.1
825	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 0	0	0.1
826	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 10	10	0.3
827	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 20	20	0.8
828	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 30	30	1.5
829	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 40	40	2.5
830	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 50	50	2.8
831	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 60	60	2.2
832	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 70	70	1.7
833	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 80	80	0.9
834	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 90	90	0.5
835	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 100	100	0.3
836	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 110	110	0.5
837	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 120	120	1.0

	*Description	Chainage	Actual Explosive per Charge (kg)
838	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 130	130	1.8
839	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 140	140	2.9
840	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 150	150	3.5
841	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 160	160	3.7
842	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 170	170	3.9
843	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 180	180	4.2
844	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 190	190	4.7
845	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 200	200	5.0
846	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 210	210	4.7
847	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 220	220	4.0
848	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 230	230	3.4
849	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 240	240	2.9
850	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 250	250	2.4
851	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 260	260	2.0
852	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 270	270	1.7
853	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 280	280	1.5
854	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 290	290	1.3
855	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 300	300	1.1
856	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 310	310	1.3
857	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 320	320	1.6
858	WEST ISLAND LINE - UNV ADITS - ENTRANCE C2 (Volume 7), Chainage 328	328.37	1.9
859	WEST ISLAND LINE - KET station and adits (1), Chainage 97219	97219.22	0.3
860	WEST ISLAND LINE - KET station and adits (1), Chainage 97221	97221.22	0.3
861	WEST ISLAND LINE - KET station and adits (1), Chainage 97223	97223.22	0.3
862	WEST ISLAND LINE - KET station and adits (1), Chainage 97225	97225.22	0.3
863	WEST ISLAND LINE - KET station and adits (1), Chainage 97227	97227.22	0.3
864	WEST ISLAND LINE - KET station and adits (1), Chainage 97229	97229.22	0.3
865	WEST ISLAND LINE - KET station and adits (1), Chainage 97231	97231.22	0.3
866	WEST ISLAND LINE - KET station and adits (1), Chainage 97233	97233.22	0.3
867	WEST ISLAND LINE - KET station and adits (1), Chainage 97235	97235.22	0.3
868	WEST ISLAND LINE - KET station and adits (1), Chainage 97237	97237.22	0.2
869	WEST ISLAND LINE - KET station and adits (1), Chainage 97239	97239.22	0.2
870	WEST ISLAND LINE - KET station and adits (1), Chainage 97241	97241.22	0.2
871	WEST ISLAND LINE - KET station and adits (1), Chainage 97243	97243.22	0.2
872	WEST ISLAND LINE - KET station and adits (1), Chainage 97245	97245.22	0.2
873	WEST ISLAND LINE - KET station and adits (1), Chainage 97247	97247.22	0.2
874	WEST ISLAND LINE - KET station and adits (1), Chainage 97249	97249.22	0.2
875	WEST ISLAND LINE - KET station and adits (1), Chainage 97251	97251.22	0.2
876	WEST ISLAND LINE - KET station and adits (1), Chainage 97253	97253.22	0.2
877	WEST ISLAND LINE - KET station and adits (1), Chainage 97255	97255.22	0.2
878	WEST ISLAND LINE - KET station and adits (1), Chainage 97257	97257.22	0.2
879	WEST ISLAND LINE - KET station and adits (1), Chainage 97259	97259.22	0.2

	*Description	Chainage	Actual Explosive per Charge (kg)
880	WEST ISLAND LINE - KET station and adits (1), Chainage 97261	97261.22	0.2
881	WEST ISLAND LINE - KET station and adits (1), Chainage 97263	97263.22	0.2
882	WEST ISLAND LINE - KET station and adits (1), Chainage 97265	97265.22	0.2
883	WEST ISLAND LINE - KET station and adits (1), Chainage 97267	97267.22	0.2
884	WEST ISLAND LINE - KET station and adits (1), Chainage 97269	97269.22	0.2
885	WEST ISLAND LINE - KET station and adits (1), Chainage 97271	97271.22	0.2
886	WEST ISLAND LINE - KET station and adits (1), Chainage 97273	97273.22	0.3
887	WEST ISLAND LINE - KET station and adits (1), Chainage 97275	97275.22	0.3
888	WEST ISLAND LINE - KET station and adits (1), Chainage 97277	97277.22	0.3
889	WEST ISLAND LINE - KET station and adits (1), Chainage 97279	97279.22	0.3
890	WEST ISLAND LINE - KET station and adits (1), Chainage 97281	97281.22	0.3
891	WEST ISLAND LINE - KET station and adits (1), Chainage 97283	97283.22	0.3
892	WEST ISLAND LINE - KET station and adits (1), Chainage 97285	97285.22	0.3
893	WEST ISLAND LINE - KET station and adits (1), Chainage 97287	97287.22	0.3
894	WEST ISLAND LINE - KET station and adits (1), Chainage 97289	97289.22	0.3
895	WEST ISLAND LINE - KET station and adits (1), Chainage 97291	97291.22	0.3
896	WEST ISLAND LINE - KET station and adits (1), Chainage 97293	97293.22	0.4
897	WEST ISLAND LINE - KET station and adits (1), Chainage 97295	97295.22	0.4
898	WEST ISLAND LINE - KET station and adits (1), Chainage 97297	97297.22	0.4
899	WEST ISLAND LINE - KET station and adits (1), Chainage 97299	97299.22	0.4
900	WEST ISLAND LINE - KET station and adits (1), Chainage 97301	97301.22	0.4
901	WEST ISLAND LINE - KET station and adits (1), Chainage 97303	97303.22	0.4
902	WEST ISLAND LINE - KET station and adits (1), Chainage 97305	97305.22	0.4
903	WEST ISLAND LINE - KET station and adits (1), Chainage 97307	97307.22	0.4
904	WEST ISLAND LINE - KET station and adits (1), Chainage 97309	97309.22	0.4
905	WEST ISLAND LINE - KET station and adits (1), Chainage 97311	97311.22	0.4
906	WEST ISLAND LINE - KET station and adits (1), Chainage 97313	97313.22	0.4
907	WEST ISLAND LINE - KET station and adits (1), Chainage 97315	97315.22	0.4
908	WEST ISLAND LINE - KET station and adits (1), Chainage 97317	97317.22	0.4
909	WEST ISLAND LINE - KET station and adits (1), Chainage 97319	97319.22	0.4
910	WEST ISLAND LINE - KET station and adits (1), Chainage 97321	97321.22	0.5
911	WEST ISLAND LINE - KET station and adits (1), Chainage 97323	97323.22	0.5
912	WEST ISLAND LINE - KET station and adits (1), Chainage 97325	97325.22	0.5
913	WEST ISLAND LINE - KET station and adits (1), Chainage 97327	97327.22	0.5
914	WEST ISLAND LINE - KET station and adits (1), Chainage 97329	97329.22	0.5
915	WEST ISLAND LINE - KET station and adits (1), Chainage 97331	97331.22	0.5
916	WEST ISLAND LINE - KET station and adits (1), Chainage 97333	97333.22	0.5
917	WEST ISLAND LINE - KET station and adits (1), Chainage 97335	97335.22	0.5
918	WEST ISLAND LINE - KET station and adits (1), Chainage 97337	97337.22	0.6
919	WEST ISLAND LINE - KET station and adits (1), Chainage 97339	97339.22	0.6
920	WEST ISLAND LINE - KET station and adits (1), Chainage 97341	97341.22	0.6
921	WEST ISLAND LINE - KET station and adits (1), Chainage 97343	97343.22	0.5
922	WEST ISLAND LINE - KET station and adits (1), Chainage 97345	97345.22	0.5
923	WEST ISLAND LINE - KET station and adits (1), Chainage 97347	97347.22	0.5
924	WEST ISLAND LINE - KET station and adits (1), Chainage 97349	97349.22	0.4
925	WEST ISLAND LINE - KET station and adits (1), Chainage 97351	97351.22	0.4
926	WEST ISLAND LINE - KET station and adits (1), Chainage 97353	97353.22	0.4
927	WEST ISLAND LINE - KET station and adits (1), Chainage 97355	97355.22	0.4
928	WEST ISLAND LINE - KET station and adits (1), Chainage 97357	97357.22	0.4
929	WEST ISLAND LINE - KET station and adits (1), Chainage 97359	97359.22	0.4
930	WEST ISLAND LINE - KET station and adits (1), Chainage 97361	97361.22	0.4
931	WEST ISLAND LINE - KET station and adits (1), Chainage 97363	97363.22	0.4
932	WEST ISLAND LINE - KET station and adits (1), Chainage 97365	97365.22	0.3
933	WEST ISLAND LINE - KET station and adits (1), Chainage 97367	97367.22	0.3
934	WEST ISLAND LINE - KET station and adits (1), Chainage 97369	97369.22	0.4
935	WEST ISLAND LINE - KET station and adits (1), Chainage 97371	97371.22	0.4
936	WEST ISLAND LINE - KET station and adits (1), Chainage 97373	97373.22	0.4
937	WEST ISLAND LINE - KET station and adits (1), Chainage 97375	97375.22	0.4
938	WEST ISLAND LINE - KET station and adits (1), Chainage 97377	97377.22	0.4
939	WEST ISLAND LINE - KET station and adits (1), Chainage 97379	97379.22	0.4
940	WEST ISLAND LINE - KET station and adits (1), Chainage 97381	97381.22	0.4
941	WEST ISLAND LINE - KET station and adits (1), Chainage 97383	97383.22	0.4
942	WEST ISLAND LINE - KET station and adits (1), Chainage 97385	97385.22	0.5

	*Description	Chainage	Actual Explosive per Charge (kg)
943	WEST ISLAND LINE - KET station and adits (1), Chainage 97387	97387.22	0.5
944	WEST ISLAND LINE - KET station and adits (1), Chainage 97389	97389.22	0.5
945	WEST ISLAND LINE - KET station and adits (1), Chainage 97391	97391.22	0.5
946	WEST ISLAND LINE - KET station and adits (1), Chainage 97393	97393.22	0.6
947	WEST ISLAND LINE - KET station and adits (1), Chainage 97395	97395.22	0.6
948	WEST ISLAND LINE - KET station and adits (1), Chainage 97397	97397.22	0.6
949	WEST ISLAND LINE - KET station and adits (1), Chainage 97399	97399.22	0.7
950	WEST ISLAND LINE - KET station and adits (1), Chainage 97401	97401.22	0.7
951	WEST ISLAND LINE - KET station and adits (1), Chainage 97403	97403.22	0.7
952	WEST ISLAND LINE - KET station and adits (1), Chainage 97405	97405.22	0.8
953	WEST ISLAND LINE - KET station and adits (1), Chainage 97407	97407.22	0.8
954	WEST ISLAND LINE - KET station and adits (1), Chainage 97409	97409.22	0.8
955	WEST ISLAND LINE - KET station and adits (1), Chainage 97411	97411.22	0.9
956	WEST ISLAND LINE - KET station and adits (1), Chainage 97413	97413.22	0.9
957	WEST ISLAND LINE - KET station and adits (1), Chainage 97415	97415.22	0.9
958	WEST ISLAND LINE - KET station and adits (1), Chainage 97417	97417.22	1.0
959	WEST ISLAND LINE - KET station and adits (1), Chainage 97419	97419.22	1.0
960	WEST ISLAND LINE - KET station and adits (1), Chainage 97421	97421.22	1.1
961	WEST ISLAND LINE - KET station and adits (1), Chainage 97423	97423.22	1.1
962	WEST ISLAND LINE - KET station and adits (1), Chainage 97425	97425.22	1.2
963	WEST ISLAND LINE - KET station and adits (1), Chainage 97427	97427.22	1.2
964	WEST ISLAND LINE - KET station and adits (1), Chainage 97429	97429.22	1.3
965	WEST ISLAND LINE - KET station and adits (1), Chainage 97431	97431.22	1.3
966	WEST ISLAND LINE - KET station and adits (1), Chainage 97433	97433.22	1.4
967	WEST ISLAND LINE - KET station and adits (1), Chainage 97435	97435.22	1.4
968	WEST ISLAND LINE - KET station and adits (1), Chainage 97437	97437.22	1.5
969	WEST ISLAND LINE - KET station and adits (1), Chainage 97439	97439.22	1.6
970	WEST ISLAND LINE - KET station and adits (1), Chainage 97441	97441.22	1.7
971	WEST ISLAND LINE - KET station and adits (1), Chainage 97443	97443.22	1.8
972	WEST ISLAND LINE - KET station and adits (1), Chainage 97445	97445.22	1.9
973	WEST ISLAND LINE - KET station and adits (1), Chainage 97447	97447.22	2.0
974	WEST ISLAND LINE - KET station and adits (1), Chainage 97449	97449.22	1.9
975	WEST ISLAND LINE - KET station and adits (1), Chainage 97451	97451.22	1.9
976	WEST ISLAND LINE - KET station and adits (1), Chainage 97453	97453.22	1.9
977	WEST ISLAND LINE - KET station and adits (1), Chainage 97455	97455.22	1.8
978	WEST ISLAND LINE - KET station and adits (1), Chainage 97457	97457.22	1.8
979	WEST ISLAND LINE - KET station and adits (1), Chainage 97459	97459.22	1.8
980	WEST ISLAND LINE - KET station and adits (1), Chainage 97461	97461.22	1.8
981	WEST ISLAND LINE - KET station and adits (1), Chainage 97463	97463.22	1.8
982	WEST ISLAND LINE - KET station and adits (1), Chainage 97465	97465.22	1.7
983	WEST ISLAND LINE - KET station and adits (1), Chainage 97467	97467.22	1.7
984	WEST ISLAND LINE - KET station and adits (1), Chainage 97469	97469.22	1.7
985	WEST ISLAND LINE - KET station and adits (1), Chainage 97471	97471.22	1.7
986	WEST ISLAND LINE - KET station and adits (1), Chainage 97473	97473.22	1.6
987	WEST ISLAND LINE - KET station and adits (1), Chainage 97475	97475.22	1.6
988	WEST ISLAND LINE - KET station and adits (1), Chainage 97477	97477.22	1.6
989	WEST ISLAND LINE - KET station and adits (1), Chainage 97479	97479.22	1.5
990	WEST ISLAND LINE - KET station and adits (1), Chainage 97481	97481.22	1.5
991	WEST ISLAND LINE - KET station and adits (1), Chainage 97483	97483.22	1.5
992	WEST ISLAND LINE - KET station and adits (1), Chainage 97485	97485.22	1.4
993	WEST ISLAND LINE - KET station and adits (1), Chainage 97487	97487.22	1.4
994	WEST ISLAND LINE - KET station and adits (1), Chainage 97489	97489.22	1.4
995	WEST ISLAND LINE - KET station and adits (1), Chainage 97491	97491.22	1.4
996	WEST ISLAND LINE - KET station and adits (1), Chainage 97493	97493.22	1.3
997	WEST ISLAND LINE - KET station and adits (1), Chainage 97495	97495.22	1.3
998	WEST ISLAND LINE - KET station and adits (1), Chainage 97497	97497.22	1.3
999	WEST ISLAND LINE - KET station and adits (1), Chainage 97499	97499.22	1.3
1000	WEST ISLAND LINE - KET station and adits (1), Chainage 97501	97501.22	1.3
1001	WEST ISLAND LINE - KET station and adits (1), Chainage 97503	97503.22	1.3
1002	WEST ISLAND LINE - KET station and adits (1), Chainage 97503	97503.303	1.3
1003	WEST ISLAND LINE - KET station and adits (1), Chainage 97505	97505.22	1.3
1004	WEST ISLAND LINE - KET station and adits (1), Chainage 97507	97507.22	1.3
1005	WEST ISLAND LINE - KET station and adits (1), Chainage 97509	97509.22	1.3

	*Description	Chainage	Actual Explosive per Charge (kg)
1006	WEST ISLAND LINE - KET station and adits (1), Chainage 97511	97511.22	1.3
1007	WEST ISLAND LINE - KET station and adits (1), Chainage 97513	97513.22	1.3
1008	WEST ISLAND LINE - KET station and adits (1), Chainage 97515	97515.22	1.3
1010	WEST ISLAND LINE - KET station and adits (2), Chainage 97575	97575.22	1.7
1011	WEST ISLAND LINE - KET station and adits (2), Chainage 97577	97577.22	1.7
1012	WEST ISLAND LINE - KET station and adits (2), Chainage 97579	97579.22	1.8
1013	WEST ISLAND LINE - KET station and adits (2), Chainage 97581	97581.22	1.8
1014	WEST ISLAND LINE - KET station and adits (2), Chainage 97583	97583.22	1.9
1015	WEST ISLAND LINE - KET station and adits (2), Chainage 97585	97585.22	1.9
1016	WEST ISLAND LINE - KET station and adits (2), Chainage 97587	97587.22	2.0
1017	WEST ISLAND LINE - KET station and adits (2), Chainage 97589	97589.22	2.1
1018	WEST ISLAND LINE - KET station and adits (2), Chainage 97591	97591.22	2.1
1019	WEST ISLAND LINE - KET station and adits (2), Chainage 97593	97593.22	2.2
1020	WEST ISLAND LINE - KET station and adits (2), Chainage 97595	97595.22	2.3
1021	WEST ISLAND LINE - KET station and adits (2), Chainage 97597	97597.22	2.3
1022	WEST ISLAND LINE - KET station and adits (2), Chainage 97599	97599.22	2.4
1023	WEST ISLAND LINE - KET station and adits (2), Chainage 97601	97601.22	2.5
1024	WEST ISLAND LINE - KET station and adits (2), Chainage 97603	97603.22	2.6
1025	WEST ISLAND LINE - KET station and adits (2), Chainage 97605	97605.22	2.7
1026	WEST ISLAND LINE - KET station and adits (2), Chainage 97607	97607.22	2.8
1027	WEST ISLAND LINE - KET station and adits (2), Chainage 97609	97609.22	2.8
1028	WEST ISLAND LINE - KET station and adits (2), Chainage 97611	97611.22	2.9
1029	WEST ISLAND LINE - KET station and adits (2), Chainage 97613	97613.22	3.0
1030	WEST ISLAND LINE - KET station and adits (2), Chainage 97615	97615.22	3.1
1031	WEST ISLAND LINE - KET station and adits (2), Chainage 97617	97617.22	3.0
1032	WEST ISLAND LINE - KET station and adits (2), Chainage 97619	97619.22	2.9
1033	WEST ISLAND LINE - KET station and adits (2), Chainage 97621	97621.22	2.8
1034	WEST ISLAND LINE - KET station and adits (2), Chainage 97623	97623.22	2.8
1035	WEST ISLAND LINE - KET station and adits (2), Chainage 97625	97625.22	2.7
1036	WEST ISLAND LINE - KET station and adits (2), Chainage 97627	97627.22	2.6
1037	WEST ISLAND LINE - KET station and adits (2), Chainage 97629	97629.22	2.5
1038	WEST ISLAND LINE - KET station and adits (2), Chainage 97631	97631.22	2.5
1039	WEST ISLAND LINE - KET station and adits (2), Chainage 97633	97633.22	2.4
1040	WEST ISLAND LINE - KET station and adits (2), Chainage 97635	97635.22	2.3
1041	WEST ISLAND LINE - KET station and adits (2), Chainage 97637	97637.22	2.3
1042	WEST ISLAND LINE - KET station and adits (2), Chainage 97639	97639.22	2.2
1043	WEST ISLAND LINE - KET station and adits (2), Chainage 97641	97641.22	2.1
1044	WEST ISLAND LINE - KET station and adits (2), Chainage 97643	97643.22	2.1
1045	WEST ISLAND LINE - KET station and adits (2), Chainage 97645	97645.22	2.0
1046	WEST ISLAND LINE - KET station and adits (2), Chainage 97647	97647.22	2.0
1047	WEST ISLAND LINE - KET station and adits (2), Chainage 97649	97649.22	1.9
1048	WEST ISLAND LINE - KET station and adits (2), Chainage 97651	97651.22	1.9
1049	WEST ISLAND LINE - KET station and adits (2), Chainage 97653	97653.22	1.8
1050	WEST ISLAND LINE - KET station and adits (2), Chainage 97655	97655.22	1.8
1051	WEST ISLAND LINE - KET station and adits (2), Chainage 97657	97657.22	1.7
1052	WEST ISLAND LINE - KET station and adits (2), Chainage 97659	97659.22	1.7
1053	WEST ISLAND LINE - KET station and adits (2), Chainage 97661	97661.22	1.7
1054	WEST ISLAND LINE - KET station and adits (2), Chainage 97663	97663.22	1.6
1055	WEST ISLAND LINE - KET station and adits (2), Chainage 97665	97665.22	1.6
1056	WEST ISLAND LINE - KET station and adits (2), Chainage 97667	97667.22	1.6
1057	WEST ISLAND LINE - KET station and adits (2), Chainage 97669	97669.22	1.5
1058	WEST ISLAND LINE - KET station and adits (2), Chainage 97671	97671.22	1.5
1059	WEST ISLAND LINE - KET station and adits (2), Chainage 97673	97673.22	1.5
1060	WEST ISLAND LINE - KET station and adits (2), Chainage 97675	97675.22	1.5
1061	WEST ISLAND LINE - KET station and adits (2), Chainage 97677	97677.22	1.4
1062	WEST ISLAND LINE - KET station and adits (2), Chainage 97679	97679.22	1.4
1063	WEST ISLAND LINE - KET station and adits (2), Chainage 97681	97681.22	1.4
1064	WEST ISLAND LINE - KET station and adits (2), Chainage 97683	97683.22	1.4
1065	WEST ISLAND LINE - KET station and adits (2), Chainage 97685	97685.22	1.3
1066	WEST ISLAND LINE - KET station and adits (2), Chainage 97687	97687.22	1.3
1067	WEST ISLAND LINE - KET station and adits (2), Chainage 97689	97689.22	1.2
1068	WEST ISLAND LINE - KET station and adits (2), Chainage 97691	97691.22	1.2
1069	WEST ISLAND LINE - KET station and adits (2), Chainage 97693	97693.22	1.1

	*Description	Chainage	Actual Explosive per Charge (kg)
1070	WEST ISLAND LINE - KET station and adits (2), Chainage 97695	97695.22	1.1
1071	WEST ISLAND LINE - KET station and adits (2), Chainage 97697	97697.22	1.1
1072	WEST ISLAND LINE - KET station and adits (2), Chainage 97699	97699.22	1.0
1073	WEST ISLAND LINE - KET station and adits (2), Chainage 97701	97701.22	1.0
1074	WEST ISLAND LINE - KET station and adits (2), Chainage 97703	97703.22	1.0
1075	WEST ISLAND LINE - KET station and adits (2), Chainage 97705	97705.22	0.9
1076	WEST ISLAND LINE - KET station and adits (2), Chainage 97707	97707.22	0.9
1077	WEST ISLAND LINE - KET station and adits (2), Chainage 97709	97709.22	0.9
1078	WEST ISLAND LINE - KET station and adits (2), Chainage 97711	97711.22	0.9
1079	WEST ISLAND LINE - KET station and adits (2), Chainage 97713	97713.22	0.9
1080	WEST ISLAND LINE - KET station and adits (2), Chainage 97715	97715.22	0.9
1081	WEST ISLAND LINE - KET station and adits (2), Chainage 97717	97717.22	0.9
1082	WEST ISLAND LINE - KET station and adits (2), Chainage 97719	97719.22	0.8
1083	WEST ISLAND LINE - KET station and adits (2), Chainage 97721	97721.22	0.8
1084	WEST ISLAND LINE - KET station and adits (2), Chainage 97723	97723.22	0.8
1085	WEST ISLAND LINE - KET station and adits (2), Chainage 97725	97725.22	0.8
1086	WEST ISLAND LINE - KET station and adits (2), Chainage 97727	97727.22	0.8
1087	WEST ISLAND LINE - KET station and adits (2), Chainage 97729	97729.22	0.8
1088	WEST ISLAND LINE - KET station and adits (2), Chainage 97731	97731.22	0.8
1089	WEST ISLAND LINE - KET station and adits (2), Chainage 97733	97733.22	0.8
1090	WEST ISLAND LINE - KET station and adits (2), Chainage 97735	97735.22	0.8
1091	WEST ISLAND LINE - KET station and adits (2), Chainage 97737	97737.22	0.7
1092	WEST ISLAND LINE - KET station and adits (2), Chainage 97739	97739.22	0.7
1093	WEST ISLAND LINE - KET station and adits (2), Chainage 97741	97741.22	0.7
1094	WEST ISLAND LINE - KET station and adits (2), Chainage 97743	97743.22	0.7
1095	WEST ISLAND LINE - KET station and adits (2), Chainage 97745	97745.22	0.7
1096	WEST ISLAND LINE - KET station and adits (2), Chainage 97747	97747.22	0.7
1097	WEST ISLAND LINE - KET station and adits (2), Chainage 97749	97749.22	0.6
1098	WEST ISLAND LINE - KET station and adits (2), Chainage 97751	97751.22	0.6
1099	WEST ISLAND LINE - KET station and adits (2), Chainage 97753	97753.22	0.6
1100	WEST ISLAND LINE - KET station and adits (2), Chainage 97755	97755.22	0.6
1101	WEST ISLAND LINE - KET station and adits (2), Chainage 97757	97757.22	0.6
1102	WEST ISLAND LINE - KET station and adits (2), Chainage 97759	97759.22	0.5
1103	WEST ISLAND LINE - KET station and adits (2), Chainage 97761	97761.22	0.5
1104	WEST ISLAND LINE - KET station and adits (2), Chainage 97763	97763.22	0.5
1105	WEST ISLAND LINE - KET station and adits (2), Chainage 97765	97765.22	0.5
1106	WEST ISLAND LINE - KET station and adits (2), Chainage 97767	97767.22	0.5
1107	WEST ISLAND LINE - KET station and adits (2), Chainage 97769	97769.22	0.4
1108	WEST ISLAND LINE - KET station and adits (2), Chainage 97771	97771.22	0.4
1109	WEST ISLAND LINE - KET station and adits (2), Chainage 97773	97773.22	0.4
1110	WEST ISLAND LINE - KET station and adits (2), Chainage 97775	97775.22	0.4
1111	WEST ISLAND LINE - KET station and adits (2), Chainage 97777	97777.22	0.4
1112	WEST ISLAND LINE - KET station and adits (2), Chainage 97779	97779.22	0.4
1113	WEST ISLAND LINE - KET station and adits (2), Chainage 97781	97781.22	0.4
1114	WEST ISLAND LINE - KET station and adits (2), Chainage 97783	97783.22	0.4
1115	WEST ISLAND LINE - KET station and adits (2), Chainage 97785	97785.22	0.4
1116	WEST ISLAND LINE - KET station and adits (2), Chainage 97787	97787.22	0.4
1117	WEST ISLAND LINE - KET station and adits (2), Chainage 97789	97789.22	0.4
1118	WEST ISLAND LINE - KET station and adits (2), Chainage 97791	97791.22	0.4
1119	WEST ISLAND LINE - KET station and adits (2), Chainage 97793	97793.22	0.4
1120	WEST ISLAND LINE - KET station and adits (2), Chainage 97795	97795.22	0.4
1121	WEST ISLAND LINE - KET station and adits (2), Chainage 97797	97797.22	0.4
1122	WEST ISLAND LINE - KET station and adits (2), Chainage 97799	97799.22	0.4
1123	WEST ISLAND LINE - KET station and adits (2), Chainage 97801	97801.22	0.4
1124	WEST ISLAND LINE - KET station and adits (2), Chainage 97803	97803.22	0.4
1125	WEST ISLAND LINE - KET station and adits (2), Chainage 97804	97803.649	0.3
1126	WEST ISLAND LINE - KET station and adits (2), Chainage 97805	97805.22	0.3
1127	WEST ISLAND LINE - KET station and adits (2), Chainage 97807	97807.22	0.3
1128	WEST ISLAND LINE - KET station and adits (2), Chainage 97809	97809.22	0.2
1129	WEST ISLAND LINE - KET station and adits (2), Chainage 97811	97811.22	0.2
1130	WEST ISLAND LINE - KET station and adits (2), Chainage 97813	97813.22	0.2
1131	WEST ISLAND LINE - KET station and adits (2), Chainage 97815	97815.22	0.2
1132	WEST ISLAND LINE - KET station and adits (2), Chainage 97817	97817.22	0.1

	*Description	Chainage	Actual Explosive per Charge (kg)
1133	WEST ISLAND LINE - KET station and adits (2), Chainage 97819	97819.22	0.1
1134	WEST ISLAND LINE - KET station and adits (2), Chainage 97821	97821.22	0.1
1135	WEST ISLAND LINE - KET station and adits (2), Chainage 97823	97823.22	0.1
1136	WEST ISLAND LINE - KET station and adits (2), Chainage 97825	97825.22	0.1
1137	WEST ISLAND LINE - KET station and adits (2), Chainage 97827	97827.22	0.1
1138	WEST ISLAND LINE - KET station and adits (2), Chainage 97829	97829.22	0.1
1139	WEST ISLAND LINE - KET station and adits (2), Chainage 97831	97831.22	0.1
1140	WEST ISLAND LINE - KET station and adits (2), Chainage 0	0	1.6
1141	WEST ISLAND LINE - KET station and adits (2), Chainage 2	2	1.7
1142	WEST ISLAND LINE - KET station and adits (2), Chainage 4	4	1.7
1143	WEST ISLAND LINE - KET station and adits (2), Chainage 6	6	1.7
1144	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8	1.6
1145	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10	1.5
1146	WEST ISLAND LINE - KET station and adits (2), Chainage 12	12	1.4
1147	WEST ISLAND LINE - KET station and adits (2), Chainage 14	14	1.3
1148	WEST ISLAND LINE - KET station and adits (2), Chainage 16	16	1.2
1149	WEST ISLAND LINE - KET station and adits (2), Chainage 18	18	1.1
1150	WEST ISLAND LINE - KET station and adits (2), Chainage 20	20	1.0
1151	WEST ISLAND LINE - KET station and adits (2), Chainage 22	22	1.0
1152	WEST ISLAND LINE - KET station and adits (2), Chainage 24	24	0.9
1153	WEST ISLAND LINE - KET station and adits (2), Chainage 26	26	0.2
1154	WEST ISLAND LINE - KET station and adits (2), Chainage 28	28	0.0
1155	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.4
1156	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.3
1157	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.4
1158	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.4
1159	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.4
1160	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.5
1161	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.5
1162	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.5
1163	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.6
1164	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.6
1165	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.6
1166	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.7
1167	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.7
1168	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.8
1169	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.8
1170	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.9
1171	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.9
1172	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.9
1173	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.8
1174	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.8
1175	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.8
1176	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.7
1177	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.7
1178	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.7
1179	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.6
1180	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.6
1181	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.6
1182	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.5
1183	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.5
1184	WEST ISLAND LINE - KET station and adits (2), Chainage 8	8.081	0.4
1185	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.4
1186	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.3
1187	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.3
1188	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.4
1189	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.4
1190	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.4
1191	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.4
1192	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.5
1193	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.5
1194	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.5
1195	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.6

	*Description	Chainage	Actual Explosive per Charge (kg)
1196	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.6
1197	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.7
1198	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.7
1199	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.7
1200	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.8
1201	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.9
1202	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.8
1203	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.8
1204	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.7
1205	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.7
1206	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.7
1207	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.6
1208	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.6
1209	WEST ISLAND LINE - KET station and adits (2), Chainage 10	10.081	0.6
1211	WEST ISLAND LINE - KET station and adits (3), Chainage 10	10.081	0.5
1212	WEST ISLAND LINE - KET station and adits (3), Chainage 10	10.081	0.5
1213	WEST ISLAND LINE - KET station and adits (3), Chainage 10	10.081	0.5
1214	WEST ISLAND LINE - KET station and adits (3), Chainage 10	10.081	0.5
1215	WEST ISLAND LINE - KET station and adits (3), Chainage 10	10.081	0.4
1216	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.3
1217	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.3
1218	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.3
1219	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.3
1220	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.4
1221	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.4
1222	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.4
1223	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.4
1224	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.4
1225	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.5
1226	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.5
1227	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.6
1228	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.6
1229	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.7
1230	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.7
1231	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.7
1232	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.8
1233	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.8
1234	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.7
1235	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.7
1236	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.6
1237	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.6
1238	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.6
1239	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.5
1240	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.5
1241	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.5
1242	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.5
1243	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.4
1244	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.4
1245	WEST ISLAND LINE - KET station and adits (3), Chainage 12	12.081	0.4
1246	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.3
1247	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.3
1248	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.3
1249	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.3
1250	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.3
1251	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.3
1252	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.3
1253	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.4
1254	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.4
1255	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.4
1256	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.5
1257	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.5
1258	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.6
1259	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.6

	*Description	Chainage	Actual Explosive per Charge (kg)
1260	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.6
1261	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.7
1262	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.8
1263	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.7
1264	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.7
1265	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.6
1266	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.6
1267	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.5
1268	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.5
1269	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.5
1270	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.5
1271	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.4
1272	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.4
1273	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.4
1274	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.4
1275	WEST ISLAND LINE - KET station and adits (3), Chainage 14	14.081	0.4
1276	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1277	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.2
1278	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.2
1279	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.2
1280	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1281	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1282	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1283	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1284	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1285	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.4
1286	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.4
1287	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.5
1288	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.5
1289	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.6
1290	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.6
1291	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.6
1292	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.7
1293	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.7
1294	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.6
1295	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.6
1296	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.5
1297	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.5
1298	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.5
1299	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.4
1300	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.4
1301	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.4
1302	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.4
1303	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1304	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1305	WEST ISLAND LINE - KET station and adits (3), Chainage 16	16.081	0.3
1306	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.2
1307	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.2
1308	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.2
1309	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.2
1310	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.2
1311	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.2
1312	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.2
1313	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.3
1314	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.3
1315	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.3
1316	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.4
1317	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.4
1318	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.5
1319	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.5
1320	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.6
1321	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.6
1322	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.7

	*Description	Chainage	Actual Explosive per Charge (kg)
1323	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.6
1324	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.6
1325	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.5
1326	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.5
1327	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.5
1328	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.4
1329	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.4
1330	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.4
1331	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.3
1332	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.3
1333	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.3
1334	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.3
1335	WEST ISLAND LINE - KET station and adits (3), Chainage 18	18.081	0.3
1336	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1337	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1338	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1339	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1340	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1341	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1342	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1343	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1344	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.3
1345	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.3
1346	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.3
1347	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.4
1348	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.4
1349	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.5
1350	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.5
1351	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.6
1352	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.6
1353	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.6
1354	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.5
1355	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.5
1356	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.5
1357	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.4
1358	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.4
1359	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.3
1360	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.3
1361	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.3
1362	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.3
1363	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.3
1364	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1365	WEST ISLAND LINE - KET station and adits (3), Chainage 20	20.081	0.2
1366	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.1
1367	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.1
1368	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.1
1369	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.1
1370	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.1
1371	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.2
1372	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.2
1373	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.2
1374	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.2
1375	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.3
1376	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.3
1377	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.3
1378	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.4
1379	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.5
1380	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.5
1381	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.5
1382	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.6
1383	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.6
1384	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.5
1385	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.5

	*Description	Chainage	Actual Explosive per Charge (kg)
1386	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.4
1387	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.4
1388	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.3
1389	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.3
1390	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.3
1391	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.3
1392	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.2
1393	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.2
1394	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.2
1395	WEST ISLAND LINE - KET station and adits (3), Chainage 22	22.081	0.2
1396	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.1
1397	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.1
1398	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.1
1399	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.1
1400	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.1
1401	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.1
1402	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.1
1403	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.2
1404	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.2
1405	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.2
1406	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.3
1407	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.3
1408	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.4
1409	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.4
1410	WEST ISLAND LINE - KET station and adits (3), Chainage 24	24.081	0.5
1412	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.5
1413	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.6
1414	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.5
1415	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.5
1416	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.4
1417	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.4
1418	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.4
1419	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.3
1420	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.3
1421	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.3
1422	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.2
1423	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.2
1424	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.2
1425	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.2
1426	WEST ISLAND LINE - KET station and adits (4), Chainage 24	24.081	0.2
1427	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1428	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1429	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1430	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1431	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1432	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1433	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1434	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1435	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.2
1436	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.2
1437	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.3
1438	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.3
1439	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.3
1440	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.4
1441	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.4
1442	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.5
1443	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.5
1444	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.5
1445	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.5
1446	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.4
1447	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.4
1448	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.3
1449	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.3

	*Description	Chainage	Actual Explosive per Charge (kg)
1450	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.3
1451	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.2
1452	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.2
1453	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.2
1454	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.2
1455	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1456	WEST ISLAND LINE - KET station and adits (4), Chainage 26	26.081	0.1
1457	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1458	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.0
1459	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.0
1460	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1461	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1462	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1463	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1464	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1465	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.2
1466	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.2
1467	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.2
1468	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.3
1469	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.3
1470	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.4
1471	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.4
1472	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.5
1473	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.5
1474	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.5
1475	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.4
1476	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.4
1477	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.4
1478	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.3
1479	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.3
1480	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.2
1481	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.2
1482	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.2
1483	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1484	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1485	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1486	WEST ISLAND LINE - KET station and adits (4), Chainage 28	28.081	0.1
1487	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.0
1488	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.0
1489	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.0
1490	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.0
1491	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1492	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1493	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1494	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1495	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1496	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.2
1497	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.2
1498	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.3
1499	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.3
1500	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.4
1501	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.4
1502	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.4
1503	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.5
1504	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.5
1505	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.4
1506	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.4
1507	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.3
1508	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.3
1509	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.3
1510	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.2
1511	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.2
1512	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.2

	*Description	Chainage	Actual Explosive per Charge (kg)
1513	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1514	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1515	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1516	WEST ISLAND LINE - KET station and adits (4), Chainage 30	30.081	0.1
1517	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.0
1518	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.0
1519	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.0
1520	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.0
1521	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.0
1522	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1523	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1524	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1525	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1526	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.2
1527	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.2
1528	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1529	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1530	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1531	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1532	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1533	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.4
1534	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1535	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1536	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1537	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1538	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.3
1539	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.2
1540	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.2
1541	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.2
1542	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1543	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1544	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1545	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1546	WEST ISLAND LINE - KET station and adits (4), Chainage 32	32.081	0.1
1547	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.0
1548	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.0
1549	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.0
1550	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.0
1551	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.0
1552	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.1
1553	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.1
1554	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.1
1555	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.1
1556	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1557	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1558	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1559	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1560	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1561	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1562	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1563	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.3
1564	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1565	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1566	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1567	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1568	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1569	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1570	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1571	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.2
1572	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.1
1573	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.1
1574	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.1
1575	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.1

	*Description	Chainage	Actual Explosive per Charge (kg)
1576	WEST ISLAND LINE - KET station and adits (4), Chainage 34	34.081	0.0

* Reference to Blast Assessment Report (BAR)

G1.2 Use of Explosives – Slopes Details

Table 1.2 Slopes Assessed in the QRA

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-AR453	Near SHW-SYP tunnel	832959	816443	10
11SW-A/R940	Near UNI Station	832063.836	816266.918	11
11SW-A/R914	Near SYP-UNI tunnel	832266	816089	61
11SW-A/R914	Near UNI Station	832248.983	816089.85	63
11SW-A/R908	Near SYP Station	832831	816183	52
11SW-A/R907	Near SYP Station	832712	816116	62
11SW-A/R898	Near SYP Station	832640	816292	32
11SW-A/R897	Near SYP-UNI tunnel	832620	816292	36
11SW-A/R896	Near SYP-UNI tunnel	832371	816182	40
11SW-A/R889	Near SYP Station	832627	816166	60
11SW-A/R889	Near SYP-UNI tunnel	832620	816162	64
11SW-A/R874	Near SYP-UNI tunnel	832568	816099	63
11SW-A/R873	Near SYP-UNI tunnel	832545	816121	59
11SW-A/R867	Near SYP-UNI tunnel	832416	816159	47
11SW-A/R866	Near SYP-UNI tunnel	832404	816152	47
11SW-A/R864	Near SYP-UNI tunnel	832295	816073	64
11SW-A/R827	Near SYP-UNI tunnel	832176	816212	42
11SW-A/R827	Near UNI Station	832178.043	816219.531	46
11SW-A/R756	Near UNI Station	832020.37	816242.837	41
11SW-A/R754	Near SYP-UNI tunnel	832026	816229	26
11SW-A/R754	Near UNI Station	832020.143	816230.388	28
11SW-A/R752	Near SYP-UNI tunnel	832103	816262	17
11SW-A/R752	Near UNI Station	832106.553	816260.821	20
11SW-A/R751	Near SYP-UNI tunnel	832106	816257	17
11SW-A/R751	Near UNI Station	832106.77	816256.65	21
11SW-A/R750	Near SYP-UNI tunnel	832138	816220	24
11SW-A/R750	Near UNI Station	832102.225	816228.794	25
11SW-A/R718	Near SYP-UNI tunnel	832153	816190	37
11SW-A/R718	Near UNI Station	832150.568	816199.339	41
11SW-A/R717	Near SYP-UNI tunnel	832147	816175	37
11SW-A/R717	Near UNI Station	832149.239	816176.986	42
11SW-A/R716	Near SYP-UNI tunnel	832093	816186	36
11SW-A/R714	Near SYP-UNI tunnel	832294	816187	36
11SW-A/R713	Near SYP-UNI tunnel	832195	816183	43
11SW-A/R713	Near UNI Station	832239.658	816203.272	46
11SW-A/R712	Near SYP-UNI tunnel	832164	816142	52
11SW-A/R712	Near UNI Station	832160.636	816138.314	57
11SW-A/R711	Near SYP-UNI tunnel	832220	816175	55
11SW-A/R710	Near SYP-UNI tunnel	832366	816107	51
11SW-A/R709	Near SYP-UNI tunnel	832506	816087	62
11SW-A/R600	Near SYP-UNI tunnel	832540	816040	69
11SW-A/R599	Near SYP-UNI tunnel	832535	816082	65
11SW-A/R595	Near SYP-UNI tunnel	832619	816064	82
11SW-A/R590	Near SYP Station	832678	816100	73
11SW-A/R588	Near SYP Station	832663	816124	75
11SW-A/R587	Near SYP Station	832700	816136	63
11SW-A/R587	Near SYP-UNI tunnel	832689	816134	69

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/R584	Near SYP-UNI tunnel	832551	816079	65
11SW-A/R583	Near SYP-UNI tunnel	832592	816084	69
11SW-A/R579	Near SYP Station	832598	816140	72
11SW-A/R578	Near SYP Station	832618	816155	67
11SW-A/R578	Near SYP-UNI tunnel	832616	816155	64
11SW-A/R577	Near SYP Station	832690	816172	57
11SW-A/R563	Near SYP-UNI tunnel	832392	816145	48
11SW-A/R561	Near SYP-UNI tunnel	832333	816203	40
11SW-A/R559	Near SYP-UNI tunnel	832464	816201	44
11SW-A/R558	Near SYP-UNI tunnel	832428	816164	47
11SW-A/R557	Near SYP-UNI tunnel	832495	816137	59
11SW-A/R556	Near SYP-UNI tunnel	832529	816168	51
11SW-A/R555	Near SYP-UNI tunnel	832519	816152	51
11SW-A/R552	Near SYP Station	832760	816194	52
11SW-A/R551	Near SYP Station	832775	816188	51
11SW-A/R543	Near SYP Station	832890	816193	57
11SW-A/R542	Near SYP-UNI tunnel	832284	816241	46
11SW-A/R527	Near SYP-UNI tunnel	832472	816204	44
11SW-A/R526	Near SYP-UNI tunnel	832512	816213	42
11SW-A/R525	Near SYP-UNI tunnel	832428	816221	42
11SW-A/R507	Near SYP Station	832606	816279	35
11SW-A/R507	Near SYP-UNI tunnel	832626	816278	45
11SW-A/R504	Near SYP-UNI tunnel	832595	816294	32
11SW-A/R503	Near SYP Station	832671	816289	33
11SW-A/R503	Near SYP-UNI tunnel	832674	816290	32
11SW-A/R502	Near SYP Station	832669	816275	40
11SW-A/R502	Near SYP-UNI tunnel	832677	816275	37
11SW-A/R501	Near SYP-UNI tunnel	832564	816218	53
11SW-A/R500	Near SYP Station	832620	816232	56
11SW-A/R499	Near SYP Station	832678	816216	47
11SW-A/R499	Near SYP-UNI tunnel	832663	816216	49
11SW-A/R498	Near SYP Station	832755	816201	47
11SW-A/R498	Near SYP-UNI tunnel	832730	816202	55
11SW-A/R490	Near SYP Station	832745	816329	32
11SW-A/R489	Near SYP Station	832675	816328	25
11SW-A/R486	Near SHW-SYP tunnel	832812	816340	24
11SW-A/R483	Near SYP Station	832723	816232	46
11SW-A/R482	Near SYP Station	832762	816226	39
11SW-A/R481	Near SYP Station	832778	816216	47
11SW-A/R479	Near SYP Station	832800	816245	40
11SW-A/R478	Near SYP Station	832834	816212	45
11SW-A/R476	Near SYP Station	832887	816206	54
11SW-A/R473	Near SYP Station	832845	816243	41
11SW-A/R472	Near SYP Station	832851	816329	37
11SW-A/R471	Near SYP Station	832860	816325	37
11SW-A/R470	Near SYP Station	832890	816351	37
11SW-A/R469	Near SYP Station	832892	816342	37
11SW-A/R461	Near SHW-SYP tunnel	832875	816404	24
11SW-A/R458	Near SYP Station	832952	816390	28
11SW-A/R457	Near SHW-SYP tunnel	832905	816420	19
11SW-A/R349	Near SYP-UNI tunnel	832145	816161	41
11SW-A/R349	Near UNI Station	832144.474	816160.852	43
11SW-A/R346	Near UNI Station	831933.874	816138.914	64
11SW-A/R345	Near UNI-KET Tunnel	831543.917	815889.176	42

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/R341	Near UNI-KET Tunnel	831662.594	815979.346	64
11SW-A/R339	Near UNI-KET Tunnel	831629.419	815990.613	44
11SW-A/R338	Near UNI-KET Tunnel	831543.188	815945.506	38
11SW-A/R337	Near UNI-KET Tunnel	831592.061	815997.763	32
11SW-A/R333	Near UNI-KET Tunnel	831470.005	815963.554	10
11SW-A/R320	Near UNI-KET Tunnel	831407.677	815747.363	30
11SW-A/R13	Near SYP-UNI tunnel	832145	816233	25
11SW-A/R13	Near UNI Station	832144.902	816233.96	6
11SW-A/R1163	Near SYP-UNI tunnel	832574	816059	75
11SW-A/R1144	Near SYP-UNI tunnel	832181	816049	63
11SW-A/R1144	Near UNI Station	832181.224	816050.746	66
11SW-A/R1142	Near SYP Station	832789	816286	29
11SW-A/R1138	Near SHW-SYP tunnel	832952	816444	18
11SW-A/R1130	Near UNI-KET Tunnel	831708.162	816078.707	68
11SW-A/R1129	Near UNI Station	831779.289	816146.549	62
11SW-A/R1128	Near UNI Station	831778.673	816155.568	59
11SW-A/R1127	Near UNI-KET Tunnel	831736.14	816093.159	67
11SW-A/R1110	Near SYP Station	832718	816273	32
11SW-A/R1094	Near UNI-KET Tunnel	831381.721	815921.898	9
11SW-A/R1083	Near UNI-KET Tunnel	831481.574	815933.084	38
11SW-A/R1074	Near SYP-UNI tunnel	832037	816138	40
11SW-A/R1074	Near UNI Station	832036.949	816144.808	43
11SW-A/R1046	Near SYP Station	832640	816162	70
11SW-A/R1004	Near SYP-UNI tunnel	832146	816070	56
11SW-A/R1004	Near UNI Station	832146.169	816071.978	58
11SW-A/R1001	Near SYP-UNI tunnel	832089	816109	49
11SW-A/R1001	Near UNI Station	832084.791	816116.309	43
11SW-A/R 993	Near KET Overrun Tunnel	831022.528	815821.322	22
11SW-A/R 993	Near KET Overrun Tunnel	831026.852	815823.8319	22
11SW-A/R 993	Near KET Overrun Tunnel	831030.961	815826.217	23
11SW-A/R 992	Near KET Overrun Tunnel	831010.859	815778.744	40
11SW-A/R 992	Near KET Overrun Tunnel	831014.7928	815775.6577	40
11SW-A/R 992	Near KET Overrun Tunnel	831018.7266	815772.5714	40
11SW-A/R 992	Near KET Overrun Tunnel	831022.322	815769.7505	40
11SW-A/R 985	Near KET Overrun Tunnel	830440.7447	815790.4151	23
11SW-A/R 985	Near KET Overrun Tunnel	830445.5977	815791.6186	23
11SW-A/R 985	Near KET Overrun Tunnel	830450.4507	815792.8222	23
11SW-A/R 985	Near KET Overrun Tunnel	830455.3037	815794.0257	23
11SW-A/R 985	Near KET Overrun Tunnel	830460.1567	815795.2292	23
11SW-A/R 985	Near KET Overrun Tunnel	830465.0096	815796.4328	23
11SW-A/R 985	Near KET Overrun Tunnel	830467.93	815797.157	23
11SW-A/R 983	Near KET Overrun Tunnel	830693.2075	815811.6035	31
11SW-A/R 983	Near KET Overrun Tunnel	830693.145	815818.753	31
11SW-A/R 983	Near KET Overrun Tunnel	830694.8002	815816.3431	31
11SW-A/R 983	Near KET Overrun Tunnel	830697.2831	815821.5594	31
11SW-A/R 983	Near KET Overrun Tunnel	830701.4213	815824.3658	31
11SW-A/R 983	Near KET Overrun Tunnel	830702.237	815824.919	31
11SW-A/R 980	Near KET Overrun Tunnel	830471.991	815765.226	32
11SW-A/R 980	Near KET Overrun Tunnel	830476.9827	815765.236	32
11SW-A/R 980	Near KET Overrun Tunnel	830481.9744	815765.2461	31
11SW-A/R 980	Near KET Overrun Tunnel	830486.9661	815765.2561	31
11SW-A/R 980	Near KET Overrun Tunnel	830491.9578	815765.2661	31
11SW-A/R 980	Near KET Overrun Tunnel	830496.9495	815765.2762	30
11SW-A/R 980	Near KET Overrun Tunnel	830498.864	815765.28	30

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/R 979	Near KET Overrun Tunnel	830425.7111	815755.4997	33
11SW-A/R 979	Near KET Overrun Tunnel	830429.1924	815756.4802	33
11SW-A/R 979	Near KET Overrun Tunnel	830434.0052	815757.8356	33
11SW-A/R 979	Near KET Overrun Tunnel	830438.818	815759.191	33
11SW-A/R 838	Near KET Overrun Tunnel	831097.374	815805.629	8
11SW-A/R 838	Near KET Overrun Tunnel	831106.425	815811.1077	8
11SW-A/R 838	Near KET Overrun Tunnel	831111.3416	815812.0176	8
11SW-A/R 838	Near KET Overrun Tunnel	831116.2581	815812.9274	8
11SW-A/R 838	Near KET Overrun Tunnel	831121.1746	815813.8373	8
11SW-A/R 838	Near KET Overrun Tunnel	831126.0911	815814.7472	8
11SW-A/R 838	Near KET Overrun Tunnel	831131.0076	815815.657	8
11SW-A/R 838	Near KET Overrun Tunnel	831135.9241	815816.5669	8
11SW-A/R 838	Near KET Overrun Tunnel	831140.8407	815817.4767	8
11SW-A/R 838	Near KET Overrun Tunnel	831145.7572	815818.3866	8
11SW-A/R 838	Near KET Overrun Tunnel	831150.6737	815819.2965	8
11SW-A/R 838	Near KET Overrun Tunnel	831155.5902	815820.2063	8
11SW-A/R 838	Near KET Overrun Tunnel	831160.5067	815821.1162	8
11SW-A/R 838	Near KET Overrun Tunnel	831165.4233	815822.0261	8
11SW-A/R 838	Near KET Overrun Tunnel	831170.3398	815822.9359	8
11SW-A/R 838	Near KET Overrun Tunnel	831173.8677	815823.5888	8
11SW-A/R 830	Near KET Overrun Tunnel	831023.0013	815808.5846	26
11SW-A/R 830	Near KET Overrun Tunnel	831024.0419	815803.6941	26
11SW-A/R 830	Near KET Overrun Tunnel	831025.0824	815798.8035	26
11SW-A/R 830	Near KET Overrun Tunnel	831026.123	815793.913	26
11SW-A/R 776	Near KET Overrun Tunnel	830447.208	815771.5235	30
11SW-A/R 776	Near KET Overrun Tunnel	830448.7352	815771.6228	30
11SW-A/R 776	Near KET Overrun Tunnel	830453.7247	815771.9471	30
11SW-A/R 776	Near KET Overrun Tunnel	830458.7141	815772.2714	30
11SW-A/R 776	Near KET Overrun Tunnel	830463.7036	815772.5957	30
11SW-A/R 775	Near KET Overrun Tunnel	830479.127	815784.653	22
11SW-A/R 775	Near KET Overrun Tunnel	830483.3938	815787.2596	22
11SW-A/R 775	Near KET Overrun Tunnel	830487.6606	815789.8662	22
11SW-A/R 775	Near KET Overrun Tunnel	830491.9274	815792.4728	22
11SW-A/R 775	Near KET Overrun Tunnel	830492.468	815792.803	22
11SW-A/R 773	Near KET Overrun Tunnel	830546.784	815770.845	47
11SW-A/R 773	Near KET Overrun Tunnel	830551.7601	815770.3803	47
11SW-A/R 773	Near KET Overrun Tunnel	830556.7362	815769.9156	47
11SW-A/R 773	Near KET Overrun Tunnel	830561.7123	815769.451	47
11SW-A/R 773	Near KET Overrun Tunnel	830566.6884	815768.9863	47
11SW-A/R 773	Near KET Overrun Tunnel	830571.6645	815768.5216	47
11SW-A/R 773	Near KET Overrun Tunnel	830576.6406	815768.0569	47
11SW-A/R 773	Near KET Overrun Tunnel	830581.6166	815767.5922	46
11SW-A/R 773	Near KET Overrun Tunnel	830584.532	815767.32	46
11SW-A/R 323	Near KET Overrun Tunnel	831107.077	815765.433	18
11SW-A/R 323	Near KET Overrun Tunnel	831111.991	815766.3565	18
11SW-A/R 323	Near KET Overrun Tunnel	831121.8189	815768.2034	18
11SW-A/R 323	Near KET Overrun Tunnel	831126.7329	815769.1268	18
11SW-A/R 323	Near KET Overrun Tunnel	831131.6469	815770.0503	18
11SW-A/R 323	Near KET Overrun Tunnel	831136.5609	815770.9738	18
11SW-A/R 323	Near KET Overrun Tunnel	831141.4749	815771.8972	18
11SW-A/R 323	Near KET Overrun Tunnel	831145.438	815772.642	18
11SW-A/R 322	Near KET Overrun Tunnel	831160.496	815779.37	13
11SW-A/R 322	Near KET Overrun Tunnel	831165.4113	815780.2863	13
11SW-A/R 322	Near KET Overrun Tunnel	831170.3266	815781.2026	13

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/R 322	Near KET Overrun Tunnel	831175.242	815782.1189	13
11SW-A/R 322	Near KET Overrun Tunnel	831180.1573	815783.0353	13
11SW-A/R 322	Near KET Overrun Tunnel	831185.0726	815783.9516	13
11SW-A/R 322	Near KET Overrun Tunnel	831188.9505	815784.6745	13
11SW-A/R 321	Near KET Overrun Tunnel	831153.364	815819.053	14
11SW-A/R 321	Near KET Overrun Tunnel	831154.2301	815814.1286	14
11SW-A/R 321	Near KET Overrun Tunnel	831155.0962	815809.2042	14
11SW-A/R 321	Near KET Overrun Tunnel	831155.9624	815804.2798	14
11SW-A/R 321	Near KET Overrun Tunnel	831156.8285	815799.3553	14
11SW-A/R 321	Near KET Overrun Tunnel	831157.6946	815794.4309	14
11SW-A/R 321	Near KET Overrun Tunnel	831159.4268	815784.5821	14
11SW-A/R 321	Near KET Overrun Tunnel	831158.5607	815789.5065	14
11SW-A/R 321	Near KET Overrun Tunnel	831160.031	815781.147	14
11SW-A/R 315	Near KET Overrun Tunnel	831037.2463	815801.8132	12
11SW-A/R 315	Near KET Overrun Tunnel	831036.511	815803.411	12
11SW-A/R 315	Near KET Overrun Tunnel	831039.3367	815797.2711	12
11SW-A/R 315	Near KET Overrun Tunnel	831041.427	815792.729	12
11SW-A/R 314	Near KET Overrun Tunnel	830989.147	815807.331	34
11SW-A/R 314	Near KET Overrun Tunnel	830993.9684	815808.3125	33
11SW-A/R 314	Near KET Overrun Tunnel	830998.7897	815809.294	32
11SW-A/R 314	Near KET Overrun Tunnel	831003.6111	815810.2756	31
11SW-A/R 314	Near KET Overrun Tunnel	831008.4325	815811.2571	31
11SW-A/R 314	Near KET Overrun Tunnel	831010.559	815811.69	30
11SW-A/R 313	Near KET Overrun Tunnel	830989.3402	815805.2422	34
11SW-A/R 313	Near KET Overrun Tunnel	830993.3762	815802.2915	34
11SW-A/R 313	Near KET Overrun Tunnel	830997.4121	815799.3409	34
11SW-A/R 313	Near KET Overrun Tunnel	831001.4481	815796.3902	34
11SW-A/R 313	Near KET Overrun Tunnel	831005.484	815793.4396	35
11SW-A/R 313	Near KET Overrun Tunnel	831008.862	815790.97	35
11SW-A/R 308	Near KET Overrun Tunnel	831102.4801	815789.7087	18
11SW-A/R 308	Near KET Overrun Tunnel	831101.532	815794.618	18
11SW-A/R 308	Near KET Overrun Tunnel	831103.4282	815784.7994	18
11SW-A/R 308	Near KET Overrun Tunnel	831104.3762	815779.8901	18
11SW-A/R 308	Near KET Overrun Tunnel	831105.3243	815774.9808	18
11SW-A/R 308	Near KET Overrun Tunnel	831106.2724	815770.0715	18
11SW-A/R 301	Near KET Overrun Tunnel	830739.1336	815831.3561	19
11SW-A/R 301	Near KET Overrun Tunnel	830743.5598	815833.6818	19
11SW-A/R 301	Near KET Overrun Tunnel	830747.986	815836.0074	19
11SW-A/R 301	Near KET Overrun Tunnel	830752.4122	815838.3331	19
11SW-A/R 301	Near KET Overrun Tunnel	830756.8384	815840.6587	19
11SW-A/R 301	Near KET Overrun Tunnel	830761.2646	815842.9844	19
11SW-A/R 301	Near KET Overrun Tunnel	830765.6909	815845.31	19
11SW-A/R 301	Near KET Overrun Tunnel	830768.9428	815847.0187	19
11SW-A/R 1169	Near KET Overrun Tunnel	830496.137	815791.247	26
11SW-A/R 1169	Near KET Overrun Tunnel	830500.5688	815793.5583	26
11SW-A/R 1169	Near KET Overrun Tunnel	830505.0007	815795.8697	26
11SW-A/R 1169	Near KET Overrun Tunnel	830509.4325	815798.181	26
11SW-A/R 1169	Near KET Overrun Tunnel	830513.8643	815800.4923	26
11SW-A/R 1169	Near KET Overrun Tunnel	830516.782	815802.014	27
11SW-A/R 1095	Near KET Overrun Tunnel	831163.8	815772.742	18
11SW-A/R 1095	Near KET Overrun Tunnel	831168.7089	815773.692	18
11SW-A/R 1095	Near KET Overrun Tunnel	831173.6178	815774.642	18
11SW-A/R 1095	Near KET Overrun Tunnel	831178.5268	815775.592	18
11SW-A/R 1095	Near KET Overrun Tunnel	831183.4357	815776.542	18

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11SW-A/R 1095	Near KET Overrun Tunnel	831188.3446	815777.492	18
11SW-A/R 1095	Near KET Overrun Tunnel	831190.0422	815777.8205	18
11SW-A/R 1080	Near KET Overrun Tunnel	831020.226	815786.351	29
11SW-A/R 1080	Near KET Overrun Tunnel	831023.2779	815782.9384	31
11SW-A/R 1080	Near KET Overrun Tunnel	831026.3298	815779.5258	33
11SW-A/R 1080	Near KET Overrun Tunnel	831029.3817	815776.1133	35
11SW-A/R 1080	Near KET Overrun Tunnel	831032.4336	815772.7007	37
11SW-A/R 1080	Near KET Overrun Tunnel	831033.891	815771.071	38
11SW-A/R 1079	Near KET Overrun Tunnel	831019.4895	815808.1393	27
11SW-A/R 1079	Near KET Overrun Tunnel	831018.51	815813.008	26
11SW-A/R 1079	Near KET Overrun Tunnel	831020.469	815803.2706	27
11SW-A/R 1079	Near KET Overrun Tunnel	831021.4485	815798.4019	28
11SW-A/R 1079	Near KET Overrun Tunnel	831022.495	815793.2	29
11SW-A/R 1079	Near KET Overrun Tunnel	831022.428	815793.5333	29
11SW-A/R 1037	Near KET Overrun Tunnel	831041.8198	815799.1073	12
11SW-A/R 1037	Near KET Overrun Tunnel	831042.8579	815794.2163	12
11SW-A/R 1037	Near KET Overrun Tunnel	831043.8961	815789.3252	12
11SW-A/R 1036	Near KET Overrun Tunnel	831045.167	815799.863	12
11SW-A/R 1036	Near KET Overrun Tunnel	831046.2467	815795.0229	13
11SW-A/R 1036	Near KET Overrun Tunnel	831047.282	815790.382	14
11SW-A/R 1035	Near KET Overrun Tunnel	831008.465	815824.685	25
11SW-A/R 1035	Near KET Overrun Tunnel	831013.2438	815826.1558	25
11SW-A/R 1035	Near KET Overrun Tunnel	831016.1711	815834.6004	25
11SW-A/R 1035	Near KET Overrun Tunnel	831016.8196	815832.4878	25
11SW-A/R 1035	Near KET Overrun Tunnel	831018.0226	815827.6266	25
11SW-A/R 1018	Near KET Overrun Tunnel	830427.258	815746.086	42
11SW-A/R 1018	Near KET Overrun Tunnel	830431.1905	815747.2564	42
11SW-A/R 1018	Near KET Overrun Tunnel	830435.9827	815748.6827	42
11SW-A/R 1018	Near KET Overrun Tunnel	830440.775	815750.109	42
11SW-A/FR96	Near SYP-UNI tunnel	832474	816091	63
11SW-A/FR83	Near SYP-UNI tunnel	832000	816159	51
11SW-A/FR83	Near UNI Station	831999.396	816162.354	58
11SW-A/FR57	Near SYP-UNI tunnel	832154	816097	59
11SW-A/FR57	Near UNI Station	832161.561	816106.188	62
11SW-A/FR41	Near SYP-UNI tunnel	832315	816111	54
11SW-A/FR36	Near SYP-UNI tunnel	832089	816088	55
11SW-A/FR36	Near UNI Station	832088.366	816087.804	57
11SW-A/FR34	Near UNI-KET Tunnel	831810.903	816089.145	78
11SW-A/FR270	Near SYP-UNI tunnel	832409	816138	54
11SW-A/FR267	Near SYP-UNI tunnel	832330	816345	46
11SW-A/FR253	Near SYP-UNI tunnel	832297	816144	54
11SW-A/FR252	Near SYP-UNI tunnel	832295	816164	58
11SW-A/FR246	Near SYP-UNI tunnel	832155	816048	59
11SW-A/FR24	Near UNI Station	831958.854	816191.744	46
11SW-A/FR230	Near UNI-KET Tunnel	831479.281	815901.278	40
11SW-A/FR23	Near UNI-KET Tunnel	831511.749	815877.228	50
11SW-A/FR226	Near UNI Station	831829.268	816193.569	40
11SW-A/FR220	Near SYP-UNI tunnel	832133	816149	45
11SW-A/FR220	Near UNI Station	832132.166	816149.155	46
11SW-A/FR191	Near SYP Station	832594	816148	62
11SW-A/FR191	Near SYP-UNI tunnel	832592	816143	64
11SW-A/FR186	Near SYP-UNI tunnel	832511	816057	85
11SW-A/FR151	Near UNI-KET Tunnel	831576.105	815885.067	53
11SW-A/FR145	Near UNI-KET Tunnel	831626.434	815899.253	45

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11SW-A/FR141	Near SYP Station	832800	816112	72
11SW-A/FR14	Near SYP Station	832952	816255	45
11SW-A/FR116	Near SYP-UNI tunnel	832141	816269	16
11SW-A/FR116	Near UNI Station	832142.483	816272.781	16
11SW-A/FR 79	Near KET Overrun Tunnel	830802.4825	815718.111	72
11SW-A/FR 79	Near KET Overrun Tunnel	830807.4799	815718.2419	72
11SW-A/FR 79	Near KET Overrun Tunnel	830812.4773	815718.3727	72
11SW-A/FR 79	Near KET Overrun Tunnel	830813.2135	815718.392	73
11SW-A/FR 79	Near KET Overrun Tunnel	830818.0091	815716.9771	72
11SW-A/FR 79	Near KET Overrun Tunnel	830821.565	815715.928	72
11SW-A/FR 79	Near KET Overrun Tunnel	830824.9186	815719.3336	71
11SW-A/FR 79	Near KET Overrun Tunnel	830828.2722	815722.7392	69
11SW-A/FR 79	Near KET Overrun Tunnel	830831.6258	815726.1448	68
11SW-A/FR 79	Near KET Overrun Tunnel	830832.141	815726.668	68
11SW-A/FR 50	Near KET Overrun Tunnel	831046.433	815765.296	38
11SW-A/FR 50	Near KET Overrun Tunnel	831047.0182	815765.4773	38
11SW-A/FR 50	Near KET Overrun Tunnel	831051.758	815766.946	38
11SW-A/FR 49	Near KET Overrun Tunnel	831004.197	815747.8445	52
11SW-A/FR 49	Near KET Overrun Tunnel	831007.6025	815751.181	50
11SW-A/FR 49	Near KET Overrun Tunnel	831011.0079	815754.5176	49
11SW-A/FR 49	Near KET Overrun Tunnel	831014.4134	815757.8541	47
11SW-A/FR 49	Near KET Overrun Tunnel	831017.758	815761.131	46
11SW-A/FR 47	Near KET Overrun Tunnel	830948.775	815772.981	59
11SW-A/FR 47	Near KET Overrun Tunnel	830952.5533	815769.7062	59
11SW-A/FR 47	Near KET Overrun Tunnel	830956.3316	815766.4314	59
11SW-A/FR 47	Near KET Overrun Tunnel	830960.1099	815763.1566	59
11SW-A/FR 47	Near KET Overrun Tunnel	830963.8882	815759.8817	59
11SW-A/FR 47	Near KET Overrun Tunnel	830965.457	815758.522	59
11SW-A/FR 47	Near KET Overrun Tunnel	830968.2127	815762.0545	57
11SW-A/FR 47	Near KET Overrun Tunnel	830970.9684	815765.587	55
11SW-A/FR 47	Near KET Overrun Tunnel	830973.7241	815769.1195	52
11SW-A/FR 47	Near KET Overrun Tunnel	830974.1468	815769.6613	52
11SW-A/FR 47	Near KET Overrun Tunnel	830984.153	815768.8992	50
11SW-A/FR 47	Near KET Overrun Tunnel	830986.1745	815772.1016	47
11SW-A/FR 47	Near KET Overrun Tunnel	830988.196	815775.304	44
11SW-A/FR 47	Near KET Overrun Tunnel	830990.2175	815778.5065	41
11SW-A/FR 184	Near KET Overrun Tunnel	830997.378	815752.292	51
11SW-A/FR 184	Near KET Overrun Tunnel	831000.2873	815756.2642	50
11SW-A/FR 184	Near KET Overrun Tunnel	831003.1966	815760.2363	49
11SW-A/FR 184	Near KET Overrun Tunnel	831006.1059	815764.2085	48
11SW-A/FR 184	Near KET Overrun Tunnel	831009.0151	815768.1807	47
11SW-A/FR 183	Near KET Overrun Tunnel	831030.453	815786.34	38
11SW-A/FR 183	Near KET Overrun Tunnel	831033.6091	815786.9686	34
11SW-A/FR 183	Near KET Overrun Tunnel	831036.7652	815787.5973	30
11SW-A/FR 183	Near KET Overrun Tunnel	831039.9213	815788.2259	27
11SW-A/FR 183	Near KET Overrun Tunnel	831040.68	815788.377	26
11SW-A/FR 181	Near KET Overrun Tunnel	830935.33	815788.9825	59
11SW-A/FR 181	Near KET Overrun Tunnel	830939.0112	815791.3684	57
11SW-A/FR 181	Near KET Overrun Tunnel	830942.6923	815793.7542	54
11SW-A/FR 181	Near KET Overrun Tunnel	830946.3735	815796.1401	52
11SW-A/FR 181	Near KET Overrun Tunnel	830950.0546	815798.5259	50
11SW-A/FR 181	Near KET Overrun Tunnel	830951.593	815799.523	49
11SW-A/FR 180	Near KET Overrun Tunnel	830983.7368	815759.8285	49
11SW-A/FR 180	Near KET Overrun Tunnel	830986.3718	815763.4411	47

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11SW-A/FR 180	Near KET Overrun Tunnel	830989.0068	815767.0537	44
11SW-A/FR 180	Near KET Overrun Tunnel	830991.6418	815770.6663	42
11SW-A/FR 180	Near KET Overrun Tunnel	830994.2768	815774.2789	40
11SW-A/FR 180	Near KET Overrun Tunnel	830996.9119	815777.8915	38
11SW-A/FR 140	Near KET Overrun Tunnel	830954.203	815795.34	49
11SW-A/FR 140	Near KET Overrun Tunnel	830957.6067	815797.7955	46
11SW-A/FR 140	Near KET Overrun Tunnel	830961.0105	815800.2511	43
11SW-A/FR 140	Near KET Overrun Tunnel	830964.4142	815802.7066	40
11SW-A/FR 140	Near KET Overrun Tunnel	830967.818	815805.1622	38
11SW-A/F99	Near SYP-UNI tunnel	832486	816032	82
11SW-A/F78	Near UNI-KET Tunnel	831739.5	816142.351	55
11SW-A/F46	Near SYP-UNI tunnel	832519	816041	81
11SW-A/F39	Near UNI-KET Tunnel	831659.685	816057.867	51
11SW-A/F37	Near SYP-UNI tunnel	832051	816132	43
11SW-A/F37	Near UNI Station	832055.806	816136.375	46
11SW-A/F28	Near UNI Station	831695.364	816197.643	33
11SW-A/F229	Near UNI-KET Tunnel	831702.613	816160.258	50
11SW-A/F228	Near UNI-KET Tunnel	831734.25	816179.137	43
11SW-A/F227	Near UNI Station	831766.758	816224.228	50
11SW-A/F217	Near SYP-UNI tunnel	832415	816126	56
11SW-A/F147	Near SYP-UNI tunnel	832030	816109	50
11SW-A/F147	Near UNI Station	832029.802	816110.268	55
11SW-A/F 257	Near KET Overrun Tunnel	830562.627	815733.544	66
11SW-A/F 257	Near KET Overrun Tunnel	830563.197	815735.508	65
11SW-A/F 257	Near KET Overrun Tunnel	830564.1051	815733.1103	66
11SW-A/F 257	Near KET Overrun Tunnel	830564.8025	815736.2494	65
11SW-A/F 257	Near KET Overrun Tunnel	830568.8809	815731.7092	66
11SW-A/F 257	Near KET Overrun Tunnel	830573.6567	815730.3081	67
11SW-A/F 257	Near KET Overrun Tunnel	830578.4325	815728.907	67
11SW-A/F 257	Near KET Overrun Tunnel	830583.2082	815727.5058	68
11SW-A/F 257	Near KET Overrun Tunnel	830587.984	815726.1047	68
11SW-A/F 257	Near KET Overrun Tunnel	830622.8835	815722.4475	58
11SW-A/F 257	Near KET Overrun Tunnel	830622.9168	815724.7598	59
11SW-A/F 257	Near KET Overrun Tunnel	830622.987	815729.64	60
11SW-A/F 248	Near KET Overrun Tunnel	830545.429	815751.5	55
11SW-A/F 248	Near KET Overrun Tunnel	830546.397	815748.168	56
11SW-A/F 248	Near KET Overrun Tunnel	830551.0443	815749.2975	58
11SW-A/F 248	Near KET Overrun Tunnel	830554.873	815750.228	59
11SW-A/F 231	Near KET Overrun Tunnel	830668.221	815799.304	38
11SW-A/F 231	Near KET Overrun Tunnel	830673.1784	815798.6841	38
11SW-A/F 231	Near KET Overrun Tunnel	830675.6906	815798.3699	39
11SW-A/F 231	Near KET Overrun Tunnel	830680.0482	815800.8006	38
11SW-A/F 231	Near KET Overrun Tunnel	830684.4058	815803.2314	38
11SW-A/F 231	Near KET Overrun Tunnel	830687.797	815805.123	38
11SW-A/F 138	Near KET Overrun Tunnel	830458.246	815799.431	23
11SW-A/F 138	Near KET Overrun Tunnel	830462.0118	815811.1118	25
11SW-A/F 138	Near KET Overrun Tunnel	830463.1121	815798.449	24
11SW-A/F 138	Near KET Overrun Tunnel	830463.4805	815807.0378	25
11SW-A/F 138	Near KET Overrun Tunnel	830465.1598	815802.3799	24
11SW-A/F 138	Near KET Overrun Tunnel	830466.3975	815797.786	24
11SW-A/F 138	Near KET Overrun Tunnel	830466.839	815797.722	23
11SW-A/DT8	Near SYP-UNI tunnel	832418	816014	90
11SW-A/DT 6	Near KET Overrun Tunnel	830652.6004	815715.8528	56
11SW-A/DT 6	Near KET Overrun Tunnel	830654.1225	815716.9077	56

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11SW-A/DT 6	Near KET Overrun Tunnel	830658.2308	815719.7548	56
11SW-A/DT 6	Near KET Overrun Tunnel	830662.339	815722.602	57
11SW-A/DT 6	Near KET Overrun Tunnel	830662.917	815717.755	56
11SW-A/CR87	Near SYP-UNI tunnel	832593	816105	67
11SW-A/CR86	Near SYP-UNI tunnel	832549	816098	59
11SW-A/CR750	Near UNI-KET Tunnel	831684.923	815988.713	29
11SW-A/CR713	Near SYP-UNI tunnel	832016	816082	58
11SW-A/CR713	Near UNI Station	832006.767	816081.573	61
11SW-A/CR711	Near SYP-UNI tunnel	832030	816134	40
11SW-A/CR711	Near UNI Station	832028.369	816135.576	42
11SW-A/CR597	Near SYP-UNI tunnel	832013	816185	33
11SW-A/CR597	Near UNI Station	832010.77	816195.035	37
11SW-A/CR595	Near UNI-KET Tunnel	831620.543	816088.181	24
11SW-A/CR388	Near SYP-UNI tunnel	832391	816036	58
11SW-A/CR243	Near UNI Station	831937.798	816248.408	20
11SW-A/CR241	Near UNI Station	831984.153	816237.688	17
11SW-A/CR198	Near SYP-UNI tunnel	832435	816056	81
11SW-A/CR155	Near UNI-KET Tunnel	831704.652	816255.509	14
11SW-A/CR146	Near UNI Station	831873.562	816134.083	76
11SW-A/CR146	Near UNI Station	831923.562	816134.083	76
11SW-A/CR131	Near UNI-KET Tunnel	831485.468	815785.292	30
11SW-A/CR1167	Near SYP-UNI tunnel	832478	816082	65
11SW-A/CR 8	Near KET Overrun Tunnel	830905.485	815710.42	104
11SW-A/CR 8	Near KET Overrun Tunnel	830908.8385	815706.9737	105
11SW-A/CR 8	Near KET Overrun Tunnel	830910.381	815705.3885	106
11SW-A/CR 8	Near KET Overrun Tunnel	831049.4015	815756.0395	43
11SW-A/CR 8	Near KET Overrun Tunnel	831051.5989	815753.003	44
11SW-A/CR 8	Near KET Overrun Tunnel	831056.4149	815753.9232	43
11SW-A/CR 8	Near KET Overrun Tunnel	831061.2309	815754.8433	42
11SW-A/CR 8	Near KET Overrun Tunnel	831066.0469	815755.7635	41
11SW-A/CR 8	Near KET Overrun Tunnel	831078.9903	815760.0729	40
11SW-A/CR 8	Near KET Overrun Tunnel	831081.172	815760.831	40
11SW-A/CR 8	Near KET Overrun Tunnel	831080.945	815763.8786	38
11SW-A/CR 657	Near KET Overrun Tunnel	831071.938	815786.128	27
11SW-A/CR 657	Near KET Overrun Tunnel	831076.4045	815786.006	26
11SW-A/CR 641	Near KET Overrun Tunnel	830725.036	815828.369	20
11SW-A/CR 641	Near KET Overrun Tunnel	830727.237	815824.404	20
11SW-A/CR 641	Near KET Overrun Tunnel	830728.1486	815824.9038	22
11SW-A/CR 641	Near KET Overrun Tunnel	830730.416	815826.147	26
11SW-A/CR 566	Near KET Overrun Tunnel	831075.8125	815766.5101	37
11SW-A/CR 566	Near KET Overrun Tunnel	831077.9718	815767.4064	37
11SW-A/CR 566	Near KET Overrun Tunnel	831079.6718	815764.3823	40
11SW-A/CR 559	Near KET Overrun Tunnel	830556.46	815759.809	55
11SW-A/CR 559	Near KET Overrun Tunnel	830561.4277	815759.2425	55
11SW-A/CR 559	Near KET Overrun Tunnel	830566.3953	815758.6759	56
11SW-A/CR 559	Near KET Overrun Tunnel	830571.363	815758.1094	56
11SW-A/CR 559	Near KET Overrun Tunnel	830576.3307	815757.5429	56
11SW-A/CR 559	Near KET Overrun Tunnel	830581.2984	815756.9763	56
11SW-A/CR 559	Near KET Overrun Tunnel	830582.8225	815756.8025	56
11SW-A/CR 558	Near KET Overrun Tunnel	830542.5795	815738.4755	59
11SW-A/CR 558	Near KET Overrun Tunnel	830546.2495	815735.4758	61
11SW-A/CR 558	Near KET Overrun Tunnel	830550.395	815737.715	62
11SW-A/CR 557	Near KET Overrun Tunnel	830535.219	815731.885	59
11SW-A/CR 557	Near KET Overrun Tunnel	830537.703	815736.2165	59

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/CR 557	Near KET Overrun Tunnel	830538.544	815737.683	59
11SW-A/CR 557	Near KET Overrun Tunnel	830538.544	815739.1013	59
11SW-A/CR 556	Near KET Overrun Tunnel	830500.5975	815724.5275	53
11SW-A/CR 556	Near KET Overrun Tunnel	830502.5417	815721.173	57
11SW-A/CR 556	Near KET Overrun Tunnel	830504.9775	815723.558	54
11SW-A/CR 555	Near KET Overrun Tunnel	830502.172	815731.8798	53
11SW-A/CR 555	Near KET Overrun Tunnel	830503.327	815731.5509	53
11SW-A/CR 555	Near KET Overrun Tunnel	830507.627	815728.614	53
11SW-A/CR 555	Near KET Overrun Tunnel	830508.135	815730.182	53
11SW-A/CR 554	Near KET Overrun Tunnel	830504.37	815743.333	43
11SW-A/CR 554	Near KET Overrun Tunnel	830506.619	815743.158	43
11SW-A/CR 552	Near KET Overrun Tunnel	830424.8145	815728.565	45
11SW-A/CR 552	Near KET Overrun Tunnel	830425.593	815728.7962	45
11SW-A/CR 552	Near KET Overrun Tunnel	830430.2438	815730.1771	47
11SW-A/CR 552	Near KET Overrun Tunnel	830434.8946	815731.5581	48
11SW-A/CR 552	Near KET Overrun Tunnel	830439.5454	815732.9391	49
11SW-A/CR 552	Near KET Overrun Tunnel	830444.1962	815734.32	50
11SW-A/CR 552	Near KET Overrun Tunnel	830448.847	815735.701	52
11SW-A/CR 551	Near KET Overrun Tunnel	830440.738	815725.47	52
11SW-A/CR 551	Near KET Overrun Tunnel	830441.6501	815720.8575	53
11SW-A/CR 551	Near KET Overrun Tunnel	830442.5622	815716.2449	55
11SW-A/CR 536	Near KET Overrun Tunnel	830524.203	815761.999	41
11SW-A/CR 536	Near KET Overrun Tunnel	830527.8729	815765.3925	41
11SW-A/CR 536	Near KET Overrun Tunnel	830531.5428	815768.7861	41
11SW-A/CR 536	Near KET Overrun Tunnel	830535.2127	815772.1796	41
11SW-A/CR 536	Near KET Overrun Tunnel	830538.8826	815775.5731	41
11SW-A/CR 536	Near KET Overrun Tunnel	830539.67	815776.3012	41
11SW-A/CR 3	Near KET Overrun Tunnel	831127.3955	815690.361	44
11SW-A/CR 3	Near KET Overrun Tunnel	831131.9767	815692.3642	44
11SW-A/CR 3	Near KET Overrun Tunnel	831136.5579	815694.3674	44
11SW-A/CR 3	Near KET Overrun Tunnel	831141.139	815696.3706	44
11SW-A/CR 3	Near KET Overrun Tunnel	831145.7202	815698.3738	44
11SW-A/CR 3	Near KET Overrun Tunnel	831150.3014	815700.377	44
11SW-A/CR 3	Near KET Overrun Tunnel	831154.8826	815702.3802	44
11SW-A/CR 3	Near KET Overrun Tunnel	831156.849	815703.24	44
11SW-A/CR 3	Near KET Overrun Tunnel	831158.644	815703.893	44
11SW-A/CR 3	Near KET Overrun Tunnel	831160.942	815704.367	44
11SW-A/CR 267	Near KET Overrun Tunnel	830461.1772	815778.314	27
11SW-A/CR 267	Near KET Overrun Tunnel	830466.1743	815778.4352	27
11SW-A/CR 267	Near KET Overrun Tunnel	830471.1715	815778.5565	27
11SW-A/CR 267	Near KET Overrun Tunnel	830475.3586	815782.8566	26
11SW-A/CR 267	Near KET Overrun Tunnel	830474.876	815783.741	26
11SW-A/CR 267	Near KET Overrun Tunnel	830476.1687	815778.6778	27
11SW-A/CR 267	Near KET Overrun Tunnel	830477.62	815778.713	28
11SW-A/CR 263	Near KET Overrun Tunnel	830525.292	815779.565	36
11SW-A/CR 263	Near KET Overrun Tunnel	830527.234	815777.84	38
11SW-A/CR 263	Near KET Overrun Tunnel	830531.0532	815781.0658	37
11SW-A/CR 263	Near KET Overrun Tunnel	830533.779	815783.368	37
11SW-A/CR 263	Near KET Overrun Tunnel	830537.593	815784.525	39
11SW-A/CR 263	Near KET Overrun Tunnel	830537.822	815786.775	43
11SW-A/CR 263	Near KET Overrun Tunnel	830542.8196	815786.6314	43
11SW-A/CR 263	Near KET Overrun Tunnel	830547.8171	815786.4878	42
11SW-A/CR 263	Near KET Overrun Tunnel	830552.8147	815786.3442	42
11SW-A/CR 263	Near KET Overrun Tunnel	830557.8123	815786.2006	42

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/CR 263	Near KET Overrun Tunnel	830562.8099	815786.057	42
11SW-A/CR 263	Near KET Overrun Tunnel	830565.975	815785.966	42
11SW-A/CR 260	Near KET Overrun Tunnel	830591.3252	815807.3636	32
11SW-A/CR 260	Near KET Overrun Tunnel	830596.1179	815808.7884	32
11SW-A/CR 260	Near KET Overrun Tunnel	830597.58	815809.223	32
11SW-A/CR 255	Near KET Overrun Tunnel	830659.18	815815.114	35
11SW-A/CR 255	Near KET Overrun Tunnel	830664.1758	815814.9094	35
11SW-A/CR 255	Near KET Overrun Tunnel	830669.1716	815814.7047	35
11SW-A/CR 255	Near KET Overrun Tunnel	830670.068	815814.668	35
11SW-A/CR 253	Near KET Overrun Tunnel	830664.463	815843.194	23
11SW-A/CR 253	Near KET Overrun Tunnel	830669.4573	815842.9559	23
11SW-A/CR 253	Near KET Overrun Tunnel	830670.651	815842.899	23
11SW-A/CR 253	Near KET Overrun Tunnel	830672.091	815844.616	21
11SW-A/CR 253	Near KET Overrun Tunnel	830674.642	815845.395	21
11SW-A/CR 248	Near KET Overrun Tunnel	830693.476	815832.3145	23
11SW-A/CR 248	Near KET Overrun Tunnel	830698.4588	815831.9979	23
11SW-A/CR 248	Near KET Overrun Tunnel	830699.8335	815831.9105	23
11SW-A/CR 118	Near KET Overrun Tunnel	831106.234	815720.799	46
11SW-A/CR 118	Near KET Overrun Tunnel	831108.408	815712.33	52
11SW-A/CR 118	Near KET Overrun Tunnel	831108.283	815712.735	51
11SW-A/CR 118	Near KET Overrun Tunnel	831108.161	815714.504	48
11SW-A/CR 118	Near KET Overrun Tunnel	831107.6343	815716.2244	47
11SW-A/CR 118	Near KET Overrun Tunnel	831109.011	815711.47	52
11SW-A/CR 118	Near KET Overrun Tunnel	831109.1055	815718.8672	46
11SW-A/CR 118	Near KET Overrun Tunnel	831109.944	815710.886	52
11SW-A/CR 118	Near KET Overrun Tunnel	831111.783	815709.719	53
11SW-A/CR 118	Near KET Overrun Tunnel	831112.3972	815715.1036	46
11SW-A/CR 118	Near KET Overrun Tunnel	831113.8308	815705.2293	52
11SW-A/CR 118	Near KET Overrun Tunnel	831115.8787	815700.7397	51
11SW-A/CR 118	Near KET Overrun Tunnel	831115.6889	815711.34	46
11SW-A/CR 118	Near KET Overrun Tunnel	831117.384	815709.402	46
11SW-A/CR 118	Near KET Overrun Tunnel	831117.9265	815696.25	51
11SW-A/CR 118	Near KET Overrun Tunnel	831119.3264	815704.7947	46
11SW-A/CR 118	Near KET Overrun Tunnel	831119.9743	815691.7603	50
11SW-A/CR 118	Near KET Overrun Tunnel	831121.2688	815700.1874	46
11SW-A/CR 118	Near KET Overrun Tunnel	831121.949	815687.431	49
11SW-A/CR 118	Near KET Overrun Tunnel	831122.804	815686.24	48
11SW-A/CR 118	Near KET Overrun Tunnel	831123.2113	815695.5802	46
11SW-A/CR 118	Near KET Overrun Tunnel	831125.063	815691.188	46
11SW-A/CR 1119	Near KET Overrun Tunnel	830642.932	815786.866	41
11SW-A/CR 1119	Near KET Overrun Tunnel	830645.283	815781.428	39
11SW-A/CR 1119	Near KET Overrun Tunnel	830644.8204	815782.4979	40
11SW-A/CR 109	Near KET Overrun Tunnel	830943.437	815800.393	44
11SW-A/CR 109	Near KET Overrun Tunnel	830942.8744	815804.9322	42
11SW-A/CR 109	Near KET Overrun Tunnel	830942.6626	815806.6406	42
11SW-A/CR 109	Near KET Overrun Tunnel	830945.115	815800.199	44
11SW-A/CR 109	Near KET Overrun Tunnel	830945.3884	815800.75	44
11SW-A/CR 109	Near KET Overrun Tunnel	830947.584	815805.175	43
11SW-A/CR 109	Near KET Overrun Tunnel	830948.53	815805.787	42
11SW-A/CR 109	Near KET Overrun Tunnel	830951.1314	815806.2134	41
11SW-A/CR 109	Near KET Overrun Tunnel	830953.852	815802.209	42
11SW-A/CR 109	Near KET Overrun Tunnel	830956.556	815802.893	41
11SW-A/CR 109	Near KET Overrun Tunnel	830957.298	815803.523	41
11SW-A/CR 109	Near KET Overrun Tunnel	830958.0425	815806.3423	39

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/CR 109	Near KET Overrun Tunnel	830957.934	815811.025	38
11SW-A/CR 107	Near KET Overrun Tunnel	830672.028	815746.857	45
11SW-A/CR 107	Near KET Overrun Tunnel	830672.8988	815745.9555	46
11SW-A/CR 107	Near KET Overrun Tunnel	830675.3466	815743.4212	50
11SW-A/CR 107	Near KET Overrun Tunnel	830676.4444	815749.2012	45
11SW-A/CR 107	Near KET Overrun Tunnel	830677.7945	815740.8869	54
11SW-A/CR 107	Near KET Overrun Tunnel	830680.2423	815738.3526	57
11SW-A/CR 107	Near KET Overrun Tunnel	830680.8608	815751.5454	45
11SW-A/CR 107	Near KET Overrun Tunnel	830682.6902	815735.8183	61
11SW-A/CR 107	Near KET Overrun Tunnel	830685.138	815733.284	64
11SW-A/CR 107	Near KET Overrun Tunnel	830685.2773	815753.8896	45
11SW-A/CR 107	Near KET Overrun Tunnel	830686.669	815732.995	64
11SW-A/CR 107	Near KET Overrun Tunnel	830690.34	815733.8389	64
11SW-A/CR 107	Near KET Overrun Tunnel	830689.6937	815756.2337	45
11SW-A/CR 107	Near KET Overrun Tunnel	830693.638	815720.501	74
11SW-A/CR 107	Near KET Overrun Tunnel	830694.1101	815758.5779	45
11SW-A/CR 107	Near KET Overrun Tunnel	830695.1012	815724.4208	71
11SW-A/CR 107	Near KET Overrun Tunnel	830695.204	815734.957	64
11SW-A/CR 107	Near KET Overrun Tunnel	830695.6801	815717.0194	77
11SW-A/CR 107	Near KET Overrun Tunnel	830696.752	815715.192	79
11SW-A/CR 107	Near KET Overrun Tunnel	830696.5644	815728.3406	69
11SW-A/CR 107	Near KET Overrun Tunnel	830697.395	815734.034	66
11SW-A/CR 107	Near KET Overrun Tunnel	830697.914	815731.956	66
11SW-A/CR 107	Near KET Overrun Tunnel	830697.857	815733.168	66
11SW-A/CR 107	Near KET Overrun Tunnel	830698.5265	815760.9221	45
11SW-A/CR 107	Near KET Overrun Tunnel	830700.858	815715.455	80
11SW-A/CR 107	Near KET Overrun Tunnel	830702.943	815763.2663	45
11SW-A/CR 107	Near KET Overrun Tunnel	830704.077	815713.7506	83
11SW-A/CR 107	Near KET Overrun Tunnel	830704.2113	815763.9395	45
11SW-A/CR 107	Near KET Overrun Tunnel	830704.617	815713.4647	84
11SW-A/CR 107	Near KET Overrun Tunnel	830708.275	815764.893	45
11SW-A/CR 107	Near KET Overrun Tunnel	830708.7369	815711.1909	86
11SW-A/CR 107	Near KET Overrun Tunnel	830712.7645	815709.2395	88
11SW-A/CR 107	Near KET Overrun Tunnel	830713.0827	815764.3432	43
11SW-A/CR 107	Near KET Overrun Tunnel	830715.41	815706.8	89
11SW-A/CR 107	Near KET Overrun Tunnel	830717.2094	815703.2491	91
11SW-A/CR 107	Near KET Overrun Tunnel	830717.3068	815761.4135	43
11SW-A/CR 107	Near KET Overrun Tunnel	830719.3205	815699.0828	93
11SW-A/CR 107	Near KET Overrun Tunnel	830721.4317	815694.9165	94
11SW-A/CR 107	Near KET Overrun Tunnel	830721.3717	815758.5019	43
11SW-A/CR 107	Near KET Overrun Tunnel	830723.5428	815690.7503	96
11SW-A/CR 107	Near KET Overrun Tunnel	830725.4365	815755.5904	43
11SW-A/CR 107	Near KET Overrun Tunnel	830725.654	815686.584	98
11SW-A/CR 107	Near KET Overrun Tunnel	830728.192	815686.353	98
11SW-A/CR 107	Near KET Overrun Tunnel	830729.5014	815752.6788	43
11SW-A/CR 107	Near KET Overrun Tunnel	830731.497	815687.1863	95
11SW-A/CR 107	Near KET Overrun Tunnel	830733.5662	815749.7673	43
11SW-A/CR 107	Near KET Overrun Tunnel	830735.4313	815688.1782	92
11SW-A/CR 107	Near KET Overrun Tunnel	830737.631	815746.8557	43
11SW-A/CR 107	Near KET Overrun Tunnel	830739.3657	815689.1701	89
11SW-A/CR 107	Near KET Overrun Tunnel	830741.6959	815743.9442	43
11SW-A/CR 107	Near KET Overrun Tunnel	830743.3	815690.162	87
11SW-A/CR 107	Near KET Overrun Tunnel	830744.899	815691.0762	86
11SW-A/CR 107	Near KET Overrun Tunnel	830745.7607	815741.0326	43

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/CR 107	Near KET Overrun Tunnel	830748.951	815693.393	84
11SW-A/CR 107	Near KET Overrun Tunnel	830749.781	815738.153	43
11SW-A/CR 107	Near KET Overrun Tunnel	830751.2562	815695.5364	82
11SW-A/CR 107	Near KET Overrun Tunnel	830754.2229	815698.295	79
11SW-A/CR 107	Near KET Overrun Tunnel	830754.3764	815736.1826	43
11SW-A/CR 107	Near KET Overrun Tunnel	830757.1896	815701.0535	76
11SW-A/CR 107	Near KET Overrun Tunnel	830760.1564	815703.8121	73
11SW-A/CR 107	Near KET Overrun Tunnel	830760.6899	815734.6934	43
11SW-A/CR 107	Near KET Overrun Tunnel	830763.0405	815706.7016	70
11SW-A/CR 107	Near KET Overrun Tunnel	830765.7063	815709.7942	68
11SW-A/CR 107	Near KET Overrun Tunnel	830765.6097	815733.8017	43
11SW-A/CR 107	Near KET Overrun Tunnel	830767.76	815712.1086	66
11SW-A/CR 107	Near KET Overrun Tunnel	830767.992	815733.37	43
11SW-A/CR 107	Near KET Overrun Tunnel	830768.5095	815713.046	65
11SW-A/CR 107	Near KET Overrun Tunnel	830769.2997	815714.1165	64
11SW-A/CR 107	Near KET Overrun Tunnel	830771.7068	815717.2557	61
11SW-A/CR 107	Near KET Overrun Tunnel	830772.7559	815734.8884	43
11SW-A/CR 107	Near KET Overrun Tunnel	830774.1139	815720.3948	58
11SW-A/CR 107	Near KET Overrun Tunnel	830776.521	815723.534	55
11SW-A/CR 107	Near KET Overrun Tunnel	830777.5197	815736.4069	43
11SW-A/CR 107	Near KET Overrun Tunnel	830779.061	815725.468	55
11SW-A/CR 107	Near KET Overrun Tunnel	830779.2757	815725.5549	55
11SW-A/CR 107	Near KET Overrun Tunnel	830782.2836	815737.9253	43
11SW-A/CR 107	Near KET Overrun Tunnel	830783.09	815727.099	58
11SW-A/CR 107	Near KET Overrun Tunnel	830785.8625	815727.568	59
11SW-A/CR 107	Near KET Overrun Tunnel	830787.0474	815739.4438	43
11SW-A/CR 107	Near KET Overrun Tunnel	830790.4067	815728.3367	61
11SW-A/CR 107	Near KET Overrun Tunnel	830791.8113	815740.9622	43
11SW-A/CR 107	Near KET Overrun Tunnel	830794.9508	815729.1053	63
11SW-A/CR 107	Near KET Overrun Tunnel	830796.5751	815742.4807	43
11SW-A/CR 107	Near KET Overrun Tunnel	830799.495	815729.874	66
11SW-A/CR 107	Near KET Overrun Tunnel	830801.339	815743.9991	43
11SW-A/CR 107	Near KET Overrun Tunnel	830803.4381	815731.3995	65
11SW-A/CR 107	Near KET Overrun Tunnel	830804.0755	815731.8063	67
11SW-A/CR 107	Near KET Overrun Tunnel	830806.1028	815745.5176	43
11SW-A/CR 107	Near KET Overrun Tunnel	830806.4138	815765.1161	43
11SW-A/CR 107	Near KET Overrun Tunnel	830808.074	815733.493	67
11SW-A/CR 107	Near KET Overrun Tunnel	830808.2882	815760.4807	43
11SW-A/CR 107	Near KET Overrun Tunnel	830809.2138	815734.2749	65
11SW-A/CR 107	Near KET Overrun Tunnel	830809.3713	815762.0848	46
11SW-A/CR 107	Near KET Overrun Tunnel	830810.2841	815746.8503	43
11SW-A/CR 107	Near KET Overrun Tunnel	830810.1626	815755.8454	43
11SW-A/CR 107	Near KET Overrun Tunnel	830811.9336	815736.8567	61
11SW-A/CR 107	Near KET Overrun Tunnel	830812.037	815751.21	43
11SW-A/CR 107	Near KET Overrun Tunnel	830812.3676	815758.9577	48
11SW-A/CR 107	Near KET Overrun Tunnel	830814.6535	815739.4385	58
11SW-A/CR 107	Near KET Overrun Tunnel	830815.3639	815755.8305	51
11SW-A/CR 107	Near KET Overrun Tunnel	830815.944	815742.2855	57
11SW-A/CR 107	Near KET Overrun Tunnel	830817.9349	815746.6775	56
11SW-A/CR 107	Near KET Overrun Tunnel	830818.3602	815752.7034	53
11SW-A/CR 107	Near KET Overrun Tunnel	830819.9257	815751.0695	55
11SW-A/C89	Near SYP-UNI tunnel	832659	816078	81
11SW-A/C747	Near UNI-KET Tunnel	831435.903	815920.953	30
11SW-A/C714	Near SYP-UNI tunnel	832018	816170	33

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/C714	Near UNI Station	832017.299	816169.853	35
11SW-A/C594	Near UNI-KET Tunnel	831631.05	816048.583	33
11SW-A/C567	Near UNI-KET Tunnel	831497.012	815826.347	70
11SW-A/C565	Near UNI-KET Tunnel	831409.187	815898.749	30
11SW-A/C389	Near SYP-UNI tunnel	832463	816101	65
11SW-A/C370	Near UNI-KET Tunnel	831411.853	815840.053	30
11SW-A/C242	Near UNI Station	831903.881	816212.049	44
11SW-A/C240	Near UNI Station	831996.405	816233.826	20
11SW-A/C199	Near SYP-UNI tunnel	832380	816076	65
11SW-A/C154	Near UNI-KET Tunnel	831661.055	816190.836	30
11SW-A/C132	Near UNI-KET Tunnel	831540.642	815823.836	71
11SW-A/C130	Near UNI-KET Tunnel	831497.372	815853.805	62
11SW-A/C124	Near UNI-KET Tunnel	831443.304	815750.571	40
11SW-A/C1125	Near SYP-UNI tunnel	832346	816058	71
11SW-A/C1122	Near SYP-UNI tunnel	832331	816032	88
11SW-A/C1110	Near SYP-UNI tunnel	832289	816098	55
11SW-A/C1109	Near SYP-UNI tunnel	832190	816120	59
11SW-A/C1109	Near UNI Station	832189.006	816122.189	62
11SW-A/C1103	Near UNI-KET Tunnel	831574.98	815926.909	40
11SW-A/C1102	Near UNI-KET Tunnel	831653.054	816023.525	51
11SW-A/C1100	Near UNI-KET Tunnel	831736.114	816248.229	25
11SW-A/C1099	Near UNI Station	831796.433	816230.183	34
11SW-A/C1098	Near UNI-KET Tunnel	831689.072	816147.222	54
11SW-A/C1096	Near UNI-KET Tunnel	831673.926	816090.34	64
11SW-A/C 746	Near KET Overrun Tunnel	831143.85	815747.074	34
11SW-A/C 746	Near KET Overrun Tunnel	831144.043	815750.949	32
11SW-A/C 746	Near KET Overrun Tunnel	831143.9563	815752.0768	31
11SW-A/C 746	Near KET Overrun Tunnel	831143.656	815755.985	28
11SW-A/C 746	Near KET Overrun Tunnel	831144.0826	815757.6931	26
11SW-A/C 746	Near KET Overrun Tunnel	831145.2065	815743.1798	37
11SW-A/C 746	Near KET Overrun Tunnel	831144.9338	815761.101	23
11SW-A/C 746	Near KET Overrun Tunnel	831145.769	815741.565	38
11SW-A/C 746	Near KET Overrun Tunnel	831150.7256	815765.2775	19
11SW-A/C 746	Near KET Overrun Tunnel	831155.6662	815766.046	19
11SW-A/C 746	Near KET Overrun Tunnel	831160.6068	815766.8145	19
11SW-A/C 746	Near KET Overrun Tunnel	831165.5474	815767.583	19
11SW-A/C 746	Near KET Overrun Tunnel	831170.4879	815768.3515	19
11SW-A/C 746	Near KET Overrun Tunnel	831175.4285	815769.12	19
11SW-A/C 746	Near KET Overrun Tunnel	831180.3691	815769.8885	19
11SW-A/C 746	Near KET Overrun Tunnel	831185.3097	815770.657	19
11SW-A/C 746	Near KET Overrun Tunnel	831190.2503	815771.4255	19
11SW-A/C 746	Near KET Overrun Tunnel	831190.5449	815771.4713	19
11SW-A/C 718	Near KET Overrun Tunnel	830789.0885	815704.0035	76
11SW-A/C 718	Near KET Overrun Tunnel	830790.7282	815705.9804	75
11SW-A/C 718	Near KET Overrun Tunnel	830793.489	815709.3091	72
11SW-A/C 718	Near KET Overrun Tunnel	830794.3335	815707.4835	74
11SW-A/C 718	Near KET Overrun Tunnel	830795.498	815709.027	73
11SW-A/C 718	Near KET Overrun Tunnel	830797.3255	815704.4044	77
11SW-A/C 718	Near KET Overrun Tunnel	830799.0035	815702.6775	78
11SW-A/C 718	Near KET Overrun Tunnel	830803.7003	815702.6775	80
11SW-A/C 718	Near KET Overrun Tunnel	830806.9596	815705.7238	78
11SW-A/C 718	Near KET Overrun Tunnel	830811.1356	815703.0771	79
11SW-A/C 718	Near KET Overrun Tunnel	830814.3545	815701.037	80
11SW-A/C 718	Near KET Overrun Tunnel	830829.489	815699.979	74

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/C 718	Near KET Overrun Tunnel	830830.4004	815704.0845	71
11SW-A/C 718	Near KET Overrun Tunnel	830830.5	815704.533	71
11SW-A/C 718	Near KET Overrun Tunnel	830832.094	815704.66	71
11SW-A/C 718	Near KET Overrun Tunnel	830832.829	815700.056	74
11SW-A/C 718	Near KET Overrun Tunnel	830832.7569	815700.5078	74
11SW-A/C 569	Near KET Overrun Tunnel	830815.005	815760.002	52
11SW-A/C 569	Near KET Overrun Tunnel	830819.7299	815761.2595	53
11SW-A/C 569	Near KET Overrun Tunnel	830824.038	815762.406	54
11SW-A/C 569	Near KET Overrun Tunnel	830825.8288	815767.073	54
11SW-A/C 569	Near KET Overrun Tunnel	830827.6197	815771.74	54
11SW-A/C 569	Near KET Overrun Tunnel	830828.084	815772.95	54
11SW-A/C 562	Near KET Overrun Tunnel	831099.7707	815731.877	36
11SW-A/C 562	Near KET Overrun Tunnel	831101.561	815727.239	36
11SW-A/C 562	Near KET Overrun Tunnel	831101.948	815736.378	36
11SW-A/C 562	Near KET Overrun Tunnel	831105.592	815735.593	36
11SW-A/C 545	Near KET Overrun Tunnel	830528.813	815748.795	50
11SW-A/C 545	Near KET Overrun Tunnel	830532.9235	815750.5139	52
11SW-A/C 545	Near KET Overrun Tunnel	830534.863	815751.325	53
11SW-A/C 544	Near KET Overrun Tunnel	830510.345	815725.243	53
11SW-A/C 544	Near KET Overrun Tunnel	830513.784	815727.6835	52
11SW-A/C 544	Near KET Overrun Tunnel	830515.754	815723.7	51
11SW-A/C 544	Near KET Overrun Tunnel	830515.8488	815728.6016	50
11SW-A/C 544	Near KET Overrun Tunnel	830515.9065	815731.5815	50
11SW-A/C 542	Near KET Overrun Tunnel	830594.574	815717.718	71
11SW-A/C 542	Near KET Overrun Tunnel	830599.1295	815715.7718	71
11SW-A/C 542	Near KET Overrun Tunnel	830599.9522	815715.4203	70
11SW-A/C 542	Near KET Overrun Tunnel	830602.467	815712.499	71
11SW-A/C 542	Near KET Overrun Tunnel	830607.295	815711.5097	70
11SW-A/C 542	Near KET Overrun Tunnel	830612.123	815710.5204	69
11SW-A/C 542	Near KET Overrun Tunnel	830616.951	815709.5312	69
11SW-A/C 542	Near KET Overrun Tunnel	830619.3505	815709.0395	68
11SW-A/C 541	Near KET Overrun Tunnel	830624.003	815722.155	58
11SW-A/C 541	Near KET Overrun Tunnel	830624.4875	815725.1705	58
11SW-A/C 541	Near KET Overrun Tunnel	830627.8295	815721.7861	58
11SW-A/C 538	Near KET Overrun Tunnel	830586.406	815760.007	51
11SW-A/C 538	Near KET Overrun Tunnel	830591.3863	815759.5949	51
11SW-A/C 538	Near KET Overrun Tunnel	830593.41	815758.27	54
11SW-A/C 538	Near KET Overrun Tunnel	830593.451	815759.424	51
11SW-A/C 538	Near KET Overrun Tunnel	830598.087	815757.577	54
11SW-A/C 538	Near KET Overrun Tunnel	830598.367	815758.567	53
11SW-A/C 538	Near KET Overrun Tunnel	830603.3265	815757.9341	53
11SW-A/C 538	Near KET Overrun Tunnel	830608.286	815757.3013	53
11SW-A/C 538	Near KET Overrun Tunnel	830608.9153	815757.221	53
11SW-A/C 537	Near KET Overrun Tunnel	830539.071	815778.852	43
11SW-A/C 537	Near KET Overrun Tunnel	830542.1523	815775.9079	43
11SW-A/C 537	Near KET Overrun Tunnel	830546.998	815777.1325	43
11SW-A/C 537	Near KET Overrun Tunnel	830551.08	815777.2381	43
11SW-A/C 537	Near KET Overrun Tunnel	830556.0784	815777.3674	43
11SW-A/C 537	Near KET Overrun Tunnel	830561.0767	815777.4967	43
11SW-A/C 537	Near KET Overrun Tunnel	830566.075	815777.626	43
11SW-A/C 535	Near KET Overrun Tunnel	830522.019	815745.451	46
11SW-A/C 535	Near KET Overrun Tunnel	830525.2614	815749.2568	46
11SW-A/C 535	Near KET Overrun Tunnel	830528.5038	815753.0626	46
11SW-A/C 535	Near KET Overrun Tunnel	830531.7461	815756.8683	45

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/C 535	Near KET Overrun Tunnel	830533.834	815759.319	45
11SW-A/C 534	Near KET Overrun Tunnel	830526.1796	815733.0308	50
11SW-A/C 534	Near KET Overrun Tunnel	830527.5929	815735.5868	50
11SW-A/C 534	Near KET Overrun Tunnel	830530.0093	815739.9568	51
11SW-A/C 533	Near KET Overrun Tunnel	830516.972	815741.3828	48
11SW-A/C 533	Near KET Overrun Tunnel	830518.2934	815736.5611	48
11SW-A/C 533	Near KET Overrun Tunnel	830517.832	815738.508	48
11SW-A/C 533	Near KET Overrun Tunnel	830519.015	815733.928	48
11SW-A/C 533	Near KET Overrun Tunnel	830519.7832	815741.1791	48
11SW-A/C 533	Near KET Overrun Tunnel	830521.0149	815734.7779	49
11SW-A/C 533	Near KET Overrun Tunnel	830522.2277	815733.3567	50
11SW-A/C 531	Near KET Overrun Tunnel	830664.787	815717.658	66
11SW-A/C 531	Near KET Overrun Tunnel	830667.757	815721.0869	64
11SW-A/C 531	Near KET Overrun Tunnel	830669.589	815723.202	62
11SW-A/C 531	Near KET Overrun Tunnel	830675.3455	815716.247	57
11SW-A/C 531	Near KET Overrun Tunnel	830675.6339	815717.2922	57
11SW-A/C 531	Near KET Overrun Tunnel	830676.9638	815722.1121	57
11SW-A/C 4	Near KET Overrun Tunnel	831108.234	815745.718	32
11SW-A/C 4	Near KET Overrun Tunnel	831109.4312	815748.5157	29
11SW-A/C 4	Near KET Overrun Tunnel	831110.746	815751.5882	25
11SW-A/C 4	Near KET Overrun Tunnel	831112.0608	815754.6608	21
11SW-A/C 4	Near KET Overrun Tunnel	831113.3756	815757.7333	17
11SW-A/C 4	Near KET Overrun Tunnel	831114.6904	815760.8059	14
11SW-A/C 4	Near KET Overrun Tunnel	831116.0052	815763.8784	10
11SW-A/C 4	Near KET Overrun Tunnel	831117.32	815766.951	6
11SW-A/C 4	Near KET Overrun Tunnel	831119.9703	815767.439	6
11SW-A/C 4	Near KET Overrun Tunnel	831124.8876	815768.3444	6
11SW-A/C 4	Near KET Overrun Tunnel	831129.805	815769.2498	6
11SW-A/C 4	Near KET Overrun Tunnel	831134.7223	815770.1552	6
11SW-A/C 4	Near KET Overrun Tunnel	831139.6397	815771.0606	6
11SW-A/C 4	Near KET Overrun Tunnel	831144.9796	815769.3999	7
11SW-A/C 4	Near KET Overrun Tunnel	831144.557	815771.966	6
11SW-A/C 4	Near KET Overrun Tunnel	831145.785	815764.509	7
11SW-A/C 272	Near KET Overrun Tunnel	830453.376	815744.494	44
11SW-A/C 272	Near KET Overrun Tunnel	830456.636	815747.624	43
11SW-A/C 271	Near KET Overrun Tunnel	830482.2603	815737.4105	52
11SW-A/C 271	Near KET Overrun Tunnel	830484.3055	815739.4545	49
11SW-A/C 271	Near KET Overrun Tunnel	830483.818	815742.4265	47
11SW-A/C 270	Near KET Overrun Tunnel	830487.1493	815752.7293	42
11SW-A/C 270	Near KET Overrun Tunnel	830488.3823	815755.5821	39
11SW-A/C 270	Near KET Overrun Tunnel	830489.748	815758.742	35
11SW-A/C 268	Near KET Overrun Tunnel	830431.824	815775.035	27
11SW-A/C 268	Near KET Overrun Tunnel	830436.346	815775.6213	27
11SW-A/C 268	Near KET Overrun Tunnel	830441.3045	815776.2641	27
11SW-A/C 268	Near KET Overrun Tunnel	830446.263	815776.907	27
11SW-A/C 268	Near KET Overrun Tunnel	830451.2215	815777.5498	27
11SW-A/C 268	Near KET Overrun Tunnel	830456.18	815778.1927	27
11SW-A/C 268	Near KET Overrun Tunnel	830459.1383	815779.3419	26
11SW-A/C 268	Near KET Overrun Tunnel	830463.584	815781.069	25
11SW-A/C 265	Near KET Overrun Tunnel	830535.88	815759.336	47
11SW-A/C 265	Near KET Overrun Tunnel	830540.2065	815761.2532	49
11SW-A/C 265	Near KET Overrun Tunnel	830544.5331	815763.1704	51
11SW-A/C 264	Near KET Overrun Tunnel	830515.3322	815749.5209	46
11SW-A/C 264	Near KET Overrun Tunnel	830518.41	815753.3866	45

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/C 264	Near KET Overrun Tunnel	830521.4877	815757.2523	44
11SW-A/C 264	Near KET Overrun Tunnel	830524.114	815760.551	44
11SW-A/C 262	Near KET Overrun Tunnel	830563.839	815799.472	37
11SW-A/C 262	Near KET Overrun Tunnel	830568.6471	815800.8438	37
11SW-A/C 262	Near KET Overrun Tunnel	830572.118	815801.834	37
11SW-A/C 261	Near KET Overrun Tunnel	830494.856	815794.112	24
11SW-A/C 261	Near KET Overrun Tunnel	830499.4213	815796.131	24
11SW-A/C 261	Near KET Overrun Tunnel	830503.9866	815798.15	25
11SW-A/C 261	Near KET Overrun Tunnel	830508.5519	815800.1689	25
11SW-A/C 261	Near KET Overrun Tunnel	830513.1173	815802.1879	25
11SW-A/C 261	Near KET Overrun Tunnel	830517.6826	815804.2069	25
11SW-A/C 261	Near KET Overrun Tunnel	830522.2479	815806.2259	26
11SW-A/C 261	Near KET Overrun Tunnel	830526.8132	815808.2449	26
11SW-A/C 261	Near KET Overrun Tunnel	830531.3785	815810.2639	26
11SW-A/C 261	Near KET Overrun Tunnel	830535.9438	815812.2828	27
11SW-A/C 261	Near KET Overrun Tunnel	830540.5091	815814.3018	27
11SW-A/C 261	Near KET Overrun Tunnel	830545.0745	815816.3208	27
11SW-A/C 261	Near KET Overrun Tunnel	830549.6398	815818.3398	27
11SW-A/C 261	Near KET Overrun Tunnel	830554.2051	815820.3588	28
11SW-A/C 261	Near KET Overrun Tunnel	830558.7704	815822.3778	28
11SW-A/C 259	Near KET Overrun Tunnel	830630.127	815759.018	51
11SW-A/C 259	Near KET Overrun Tunnel	830633.5372	815760.2856	48
11SW-A/C 259	Near KET Overrun Tunnel	830634.8	815760.755	47
11SW-A/C 258	Near KET Overrun Tunnel	830628.8739	815751.001	54
11SW-A/C 258	Near KET Overrun Tunnel	830628.564	815752.132	53
11SW-A/C 258	Near KET Overrun Tunnel	830630.17	815746.27	55
11SW-A/C 258	Near KET Overrun Tunnel	830630.6042	815745.8139	55
11SW-A/C 258	Near KET Overrun Tunnel	830633.982	815742.266	54
11SW-A/C 258	Near KET Overrun Tunnel	830637.19	815742.336	52
11SW-A/C 257	Near KET Overrun Tunnel	830649.813	815730.4437	52
11SW-A/C 257	Near KET Overrun Tunnel	830651.1031	815726.4918	56
11SW-A/C 257	Near KET Overrun Tunnel	830650.9311	815727.0186	55
11SW-A/C 257	Near KET Overrun Tunnel	830651.9383	815724.8723	54
11SW-A/C 257	Near KET Overrun Tunnel	830652.6513	815723.4362	54
11SW-A/C 257	Near KET Overrun Tunnel	830655.999	815724.214	55
11SW-A/C 257	Near KET Overrun Tunnel	830656.737	815737.241	42
11SW-A/C 257	Near KET Overrun Tunnel	830660.4125	815723.0899	56
11SW-A/C 257	Near KET Overrun Tunnel	830661.43	815723.774	56
11SW-A/C 257	Near KET Overrun Tunnel	830660.701	815740.2863	42
11SW-A/C 257	Near KET Overrun Tunnel	830664.6651	815743.3317	42
11SW-A/C 257	Near KET Overrun Tunnel	830668.6291	815746.377	42
11SW-A/C 257	Near KET Overrun Tunnel	830669.22	815746.831	42
11SW-A/C 256	Near KET Overrun Tunnel	830647.3345	815778.1556	39
11SW-A/C 256	Near KET Overrun Tunnel	830646.6555	815780.9165	39
11SW-A/C 256	Near KET Overrun Tunnel	830648.5073	815773.3873	40
11SW-A/C 256	Near KET Overrun Tunnel	830649.68	815768.619	41
11SW-A/C 256	Near KET Overrun Tunnel	830663.572	815769.707	42
11SW-A/C 256	Near KET Overrun Tunnel	830668.0263	815771.9784	42
11SW-A/C 256	Near KET Overrun Tunnel	830672.4806	815774.2498	42
11SW-A/C 256	Near KET Overrun Tunnel	830676.9349	815776.5212	41
11SW-A/C 256	Near KET Overrun Tunnel	830681.3892	815778.7926	41
11SW-A/C 256	Near KET Overrun Tunnel	830685.8434	815781.064	41
11SW-A/C 256	Near KET Overrun Tunnel	830690.2977	815783.3354	41
11SW-A/C 256	Near KET Overrun Tunnel	830694.752	815785.6068	41

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/C 256	Near KET Overrun Tunnel	830699.2063	815787.8782	41
11SW-A/C 256	Near KET Overrun Tunnel	830703.6606	815790.1496	41
11SW-A/C 256	Near KET Overrun Tunnel	830708.1149	815792.421	41
11SW-A/C 256	Near KET Overrun Tunnel	830712.5692	815794.6924	41
11SW-A/C 256	Near KET Overrun Tunnel	830717.0235	815796.9637	41
11SW-A/C 256	Near KET Overrun Tunnel	830721.4778	815799.2351	41
11SW-A/C 256	Near KET Overrun Tunnel	830725.88	815801.48	41
11SW-A/C 254	Near KET Overrun Tunnel	830618.4922	815828.4277	35
11SW-A/C 254	Near KET Overrun Tunnel	830623.4899	815828.2766	35
11SW-A/C 254	Near KET Overrun Tunnel	830624.303	815828.252	35
11SW-A/C 254	Near KET Overrun Tunnel	830637.089	815829.027	33
11SW-A/C 254	Near KET Overrun Tunnel	830641.8534	815827.5255	33
11SW-A/C 254	Near KET Overrun Tunnel	830646.6177	815826.024	33
11SW-A/C 254	Near KET Overrun Tunnel	830648.144	815825.543	34
11SW-A/C 254	Near KET Overrun Tunnel	830658.094	815822.153	38
11SW-A/C 254	Near KET Overrun Tunnel	830662.1728	815824.7787	37
11SW-A/C 254	Near KET Overrun Tunnel	830666.2516	815827.4044	36
11SW-A/C 254	Near KET Overrun Tunnel	830670.31	815830.017	35
11SW-A/C 252	Near KET Overrun Tunnel	830681.337	815841.131	19
11SW-A/C 252	Near KET Overrun Tunnel	830685.1567	815840.9209	15
11SW-A/C 250	Near KET Overrun Tunnel	830668.793	815810.312	32
11SW-A/C 250	Near KET Overrun Tunnel	830673.3481	815811.5814	31
11SW-A/C 250	Near KET Overrun Tunnel	830674.653	815811.945	30
11SW-A/C 249	Near KET Overrun Tunnel	830671.3312	815832.0631	19
11SW-A/C 249	Near KET Overrun Tunnel	830675.5682	815832.9263	21
11SW-A/C 249	Near KET Overrun Tunnel	830679.5235	815833.732	24
11SW-A/C 247	Near KET Overrun Tunnel	830726.4875	815842.7005	19
11SW-A/C 247	Near KET Overrun Tunnel	830731.1514	815843.0313	17
11SW-A/C 247	Near KET Overrun Tunnel	830732.3845	815843.1187	16
11SW-A/C 160	Near KET Overrun Tunnel	830787.8153	815830.3942	27
11SW-A/C 160	Near KET Overrun Tunnel	830792.6294	815831.7448	27
11SW-A/C 160	Near KET Overrun Tunnel	830797.0581	815832.9872	27
11SW-A/C 1177	Near KET Overrun Tunnel	830561.631	815726.877	69
11SW-A/C 1177	Near KET Overrun Tunnel	830566.5034	815725.7597	69
11SW-A/C 1177	Near KET Overrun Tunnel	830571.3758	815724.6425	69
11SW-A/C 1177	Near KET Overrun Tunnel	830576.2481	815723.5252	69
11SW-A/C 1177	Near KET Overrun Tunnel	830581.1205	815722.4079	69
11SW-A/C 1177	Near KET Overrun Tunnel	830585.9929	815721.2906	69
11SW-A/C 1177	Near KET Overrun Tunnel	830590.8653	815720.1734	69
11SW-A/C 1177	Near KET Overrun Tunnel	830594.565	815719.325	68
11SW-A/C 1154	Near KET Overrun Tunnel	830634.3086	815741.454	54
11SW-A/C 1154	Near KET Overrun Tunnel	830635.0518	815739.7811	53
11SW-A/C 1154	Near KET Overrun Tunnel	830637.044	815735.297	52
11SW-A/C 1154	Near KET Overrun Tunnel	830637.8825	815735.6382	52
11SW-A/C 1146	Near KET Overrun Tunnel	830973.426	815765.583	49
11SW-A/C 1146	Near KET Overrun Tunnel	830978.3004	815764.4879	48
11SW-A/C 1146	Near KET Overrun Tunnel	830980.65	815763.96	48
11SW-A/C 108	Near KET Overrun Tunnel	830805.487	815779.831	42
11SW-A/C 108	Near KET Overrun Tunnel	830805.8717	815778.2112	43
11SW-A/C 108	Near KET Overrun Tunnel	830806.8828	815773.9541	46
11SW-A/C 108	Near KET Overrun Tunnel	830807.8939	815769.6971	48
11SW-A/C 108	Near KET Overrun Tunnel	830808.905	815765.44	51
11SW-A/C 108	Near KET Overrun Tunnel	830811.3317	815763.2767	51
11SW-A/C 108	Near KET Overrun Tunnel	830852.729	815762.307	66

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/C 108	Near KET Overrun Tunnel	830857.6784	815763.0162	66
11SW-A/C 108	Near KET Overrun Tunnel	830861.557	815763.572	66
11SW-A/C 108	Near KET Overrun Tunnel	830878.2145	815763.0545	69
11SW-A/C 108	Near KET Overrun Tunnel	830882.9065	815764.7806	69
11SW-A/C 108	Near KET Overrun Tunnel	830887.5985	815766.5068	69
11SW-A/C 108	Near KET Overrun Tunnel	830892.2905	815768.2329	69
11SW-A/C 108	Near KET Overrun Tunnel	830896.9825	815769.959	69
11SW-A/C 108	Near KET Overrun Tunnel	830901.6745	815771.6851	69
11SW-A/C 108	Near KET Overrun Tunnel	830906.3665	815773.4113	69
11SW-A/C 108	Near KET Overrun Tunnel	830909.697	815774.6365	69
11SW-A/C 106	Near KET Overrun Tunnel	830723.196	815771.786	42
11SW-A/C 106	Near KET Overrun Tunnel	830724.324	815769.461	42
11SW-A/C 106	Near KET Overrun Tunnel	830733.214	815776.166	43
11SW-A/C 106	Near KET Overrun Tunnel	830736.2544	815774.4731	43
11SW-A/C 106	Near KET Overrun Tunnel	830736.932	815777.5298	41
11SW-A/C 106	Near KET Overrun Tunnel	830740.6212	815772.0415	43
11SW-A/C 106	Near KET Overrun Tunnel	830740.7551	815774.6459	39
11SW-A/C 106	Near KET Overrun Tunnel	830744.9879	815769.61	43
11SW-A/C 106	Near KET Overrun Tunnel	830744.5782	815771.7621	38
11SW-A/C 106	Near KET Overrun Tunnel	830748.4013	815768.8782	37
11SW-A/C 106	Near KET Overrun Tunnel	830749.3547	815767.1785	42
11SW-A/C 106	Near KET Overrun Tunnel	830752.2244	815765.9943	35
11SW-A/C 106	Near KET Overrun Tunnel	830753.418	815765.094	35
11SW-A/C 106	Near KET Overrun Tunnel	830753.7215	815764.747	42
11SW-A/C 106	Near KET Overrun Tunnel	830758.0883	815762.3155	42
11SW-A/C 106	Near KET Overrun Tunnel	830757.9506	815762.9833	35
11SW-A/C 106	Near KET Overrun Tunnel	830759.623	815762.2045	35
11SW-A/C 106	Near KET Overrun Tunnel	830762.455	815759.884	42
11SW-A/C 106	Near KET Overrun Tunnel	830764.5626	815761.4298	35
11SW-A/C 106	Near KET Overrun Tunnel	830765.9736	815761.2085	35
11SW-A/C 106	Near KET Overrun Tunnel	830766.8218	815757.4525	42
11SW-A/C 106	Near KET Overrun Tunnel	830771.1886	815755.021	42
11SW-A/C 106	Near KET Overrun Tunnel	830770.538	815761.425	35
11SW-A/C 106	Near KET Overrun Tunnel	830774.6224	815764.2393	34
11SW-A/C 106	Near KET Overrun Tunnel	830775.7061	815756.2606	42
11SW-A/C 106	Near KET Overrun Tunnel	830778.7069	815767.0536	33
11SW-A/C 106	Near KET Overrun Tunnel	830780.5054	815757.5775	43
11SW-A/C 106	Near KET Overrun Tunnel	830782.7913	815769.8679	33
11SW-A/C 106	Near KET Overrun Tunnel	830785.3047	815758.8944	43
11SW-A/C 106	Near KET Overrun Tunnel	830786.8758	815772.6822	32
11SW-A/C 106	Near KET Overrun Tunnel	830790.104	815760.2113	44
11SW-A/C 106	Near KET Overrun Tunnel	830790.9602	815775.4965	32
11SW-A/C 106	Near KET Overrun Tunnel	830792.5163	815764.0471	44
11SW-A/C 106	Near KET Overrun Tunnel	830793.225	815777.057	31
11SW-A/C 106	Near KET Overrun Tunnel	830797.1678	815765.8812	44
11SW-A/C 106	Near KET Overrun Tunnel	830796.5994	815780.641	30
11SW-A/C 106	Near KET Overrun Tunnel	830796.8492	815783.6461	30
11SW-A/C 106	Near KET Overrun Tunnel	830799.65	815766.86	44
11SW-A/C 106	Near KET Overrun Tunnel	830802.054	815769.31	44
11SW-A/C 106	Near KET Overrun Tunnel	830806.132	815767.665	44
11SW-A/C 105	Near KET Overrun Tunnel	830725.416	815801.741	39
11SW-A/C 105	Near KET Overrun Tunnel	830726.2135	815805.7588	36
11SW-A/C 105	Near KET Overrun Tunnel	830727.011	815809.7766	33
11SW-A/C 105	Near KET Overrun Tunnel	830727.363	815811.55	32

Slope Register	Section	Easting (m)	Northing (m)	Level (mPD)
11SW-A/C 105	Near KET Overrun Tunnel	830727.5137	815797.7181	39
11SW-A/C 105	Near KET Overrun Tunnel	830728.3545	815812.2876	27
11SW-A/C 105	Near KET Overrun Tunnel	830728.55	815812.433	26
11SW-A/C 105	Near KET Overrun Tunnel	830731.3285	815809.0645	26
11SW-A/C 105	Near KET Overrun Tunnel	830731.6177	815794.9025	39
11SW-A/C 105	Near KET Overrun Tunnel	830733.02	815808.657	26
11SW-A/C 105	Near KET Overrun Tunnel	830735.7217	815792.0868	38
11SW-A/C 105	Near KET Overrun Tunnel	830736.6078	815805.1746	26
11SW-A/C 105	Near KET Overrun Tunnel	830739.8257	815789.2712	38
11SW-A/C 105	Near KET Overrun Tunnel	830740.1957	815801.6921	26
11SW-A/C 105	Near KET Overrun Tunnel	830743.9297	815786.4556	37
11SW-A/C 105	Near KET Overrun Tunnel	830743.7835	815798.2097	26
11SW-A/C 105	Near KET Overrun Tunnel	830747.3714	815794.7272	26
11SW-A/C 105	Near KET Overrun Tunnel	830748.0337	815783.6399	37
11SW-A/C 105	Near KET Overrun Tunnel	830749.36	815792.797	26
11SW-A/C 105	Near KET Overrun Tunnel	830750	815792.838	26
11SW-A/C 105	Near KET Overrun Tunnel	830752.1377	815780.8243	36
11SW-A/C 105	Near KET Overrun Tunnel	830753.6715	815789.4439	26
11SW-A/C 105	Near KET Overrun Tunnel	830756.2417	815778.0086	36
11SW-A/C 105	Near KET Overrun Tunnel	830757.343	815786.0497	26
11SW-A/C 105	Near KET Overrun Tunnel	830760.3457	815775.193	35
11SW-A/C 105	Near KET Overrun Tunnel	830761.0145	815782.6556	26
11SW-A/C 105	Near KET Overrun Tunnel	830764.4497	815772.3774	35
11SW-A/C 105	Near KET Overrun Tunnel	830764.686	815779.2615	26
11SW-A/C 105	Near KET Overrun Tunnel	830766.1585	815771.205	35
11SW-A/C 105	Near KET Overrun Tunnel	830768.715	815778.034	26
11SW-A/C 105	Near KET Overrun Tunnel	830769.8588	815774.4136	34
11SW-A/C 105	Near KET Overrun Tunnel	830772.764	815779.248	26
11SW-A/C 105	Near KET Overrun Tunnel	830773.559	815777.6222	33
11SW-A/C 105	Near KET Overrun Tunnel	830776.4582	815782.6174	26
11SW-A/C 105	Near KET Overrun Tunnel	830777.2593	815780.8309	32
11SW-A/C 105	Near KET Overrun Tunnel	830780.1525	815785.9867	26
11SW-A/C 105	Near KET Overrun Tunnel	830780.9596	815784.0395	31
11SW-A/C 105	Near KET Overrun Tunnel	830783.8467	815789.3561	26
11SW-A/C 105	Near KET Overrun Tunnel	830784.6598	815787.2481	30
11SW-A/C 105	Near KET Overrun Tunnel	830785.216	815790.605	26
11SW-A/C 105	Near KET Overrun Tunnel	830788.3601	815790.4567	29
11SW-A/C 105	Near KET Overrun Tunnel	830790.058	815791.929	28
11SW-A/ C 546	Near KET Overrun Tunnel	830540.3372	815731.4419	61
11SW-A/ C 546	Near KET Overrun Tunnel	830541.818	815734.0635	61
11SW-A/ C 546	Near KET Overrun Tunnel	830542.5795	815731.1974	64