7.3Defination of MCA

MCA stands for Maximum Credible Accident or in other words, an accident with maximum damage distance, which is believed to be probable. MCA analysis does not include quantification of the probability of occurrence of an accident. In practice the selection of accident scenarios for MCA analysis is carried out on the basis of engineering judgement and expertise in the field of risk analysis especially in accident analysis.

MCA analysis encompasses defined techniques to identify the hazards and compute the consequent effects in terms of damage distances due to heat radiation, toxic releases, vapour cloud explosion etc. A list of probable or potential accidents of the major units in the complex arising due to use, Transporation of R-NATURAL GAS are examined to establish their credibility. Depending upon the effective hazardous attributes and their impact on the event, the maximum effect on the surrounding environment and the respective damage caused can be assessed. Flow chart of accidental release of hazardous chemicals and calculation flow chart for the effect of flammable material released are presented in **Fig. 7.1** and **Fig. 7.2** respectively.

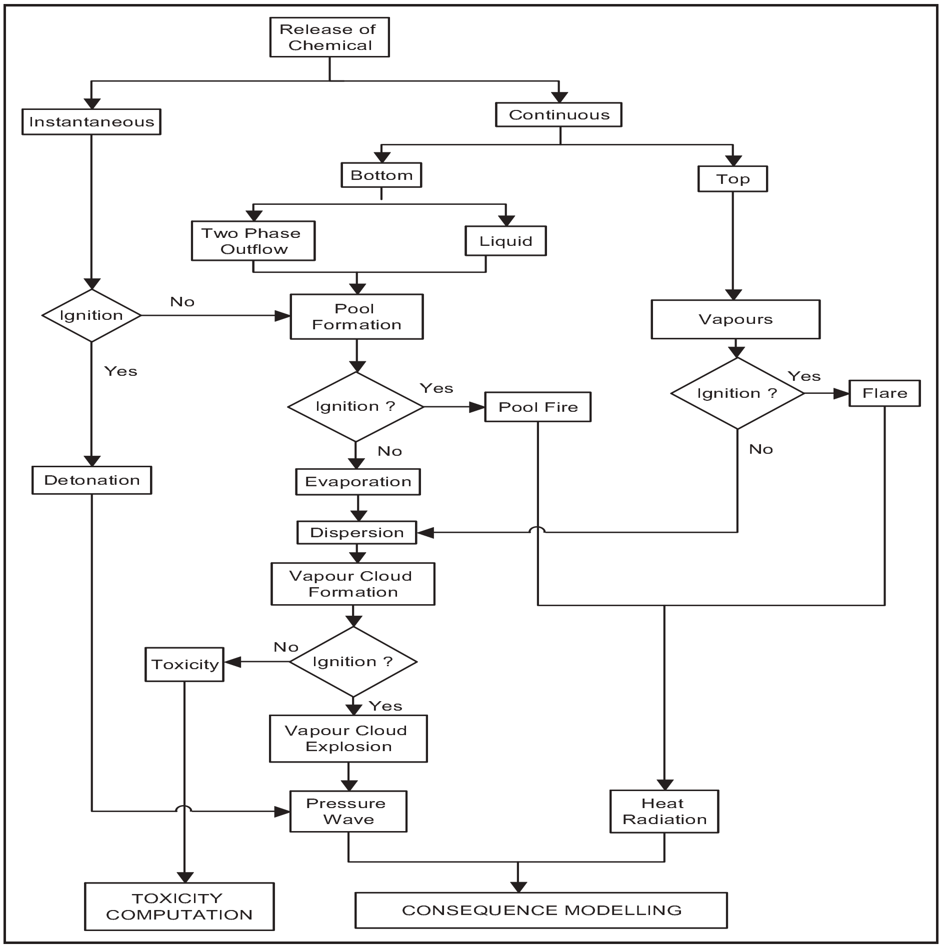

Figure 7.1: Accidental Release of Chemicals: A Scenario

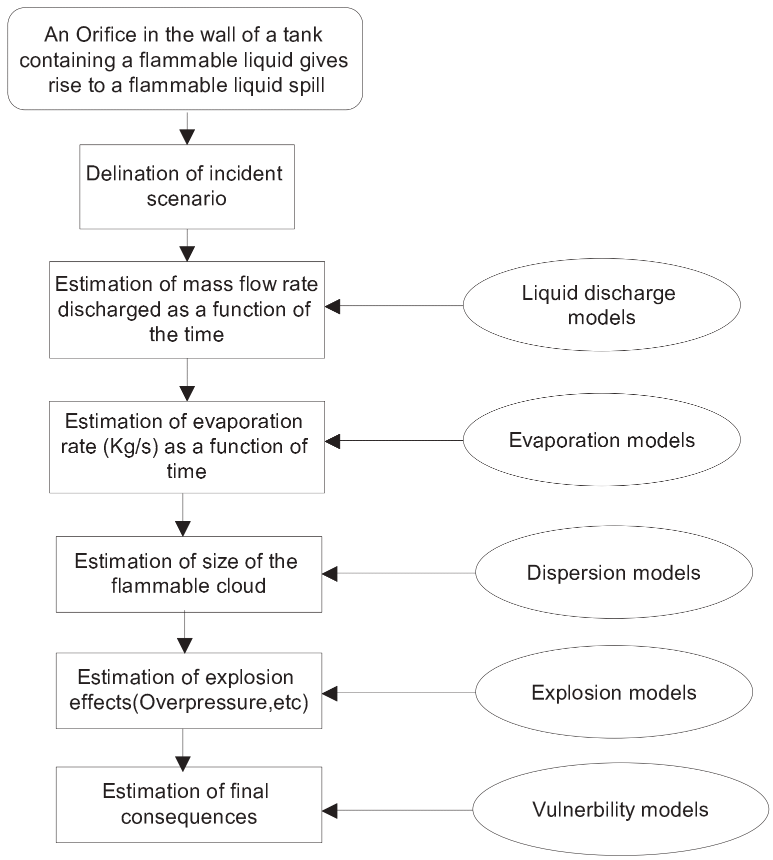

Figure 7.2: Calculation flowchart for the effects of a flammable Material release

Hazardous substance, on release can cause damage on a large scale. The extent of the damage is dependent upon the nature of the release and the physical state of the material. In the present report the consequences for flammable hazards are considered and the damages caused due to such releases are assessed with recourse to MCA analysis. Overall Logic Diagram for the Consequence models for releases of volatile Hazardous substances is shown in Fig.7.3.

7.3.1 Methodology of MCA Analysis

The MCA analysis involves ordering and ranking of various sections in terms of potential vulnerability. The data requirements for MCA analysis are:

1. Operating manual
2. Flow diagram and P&I diagrams
3. Detailed design parameters
4. Physical and chemical properties of all the chemicals
5. Detailed plant layout

6. Detailed area layout
7. Past accident data
8. Following steps are involved in the MCA analysis:
9. Identification of potential hazardous sections and representative failure cases
10. Visualization of release scenarios considering type and the quantity of the hazardous material
11. Damage distance computations for the released cases at different wind velocities and atmospheric stability classes for heat radiations and pressure waves

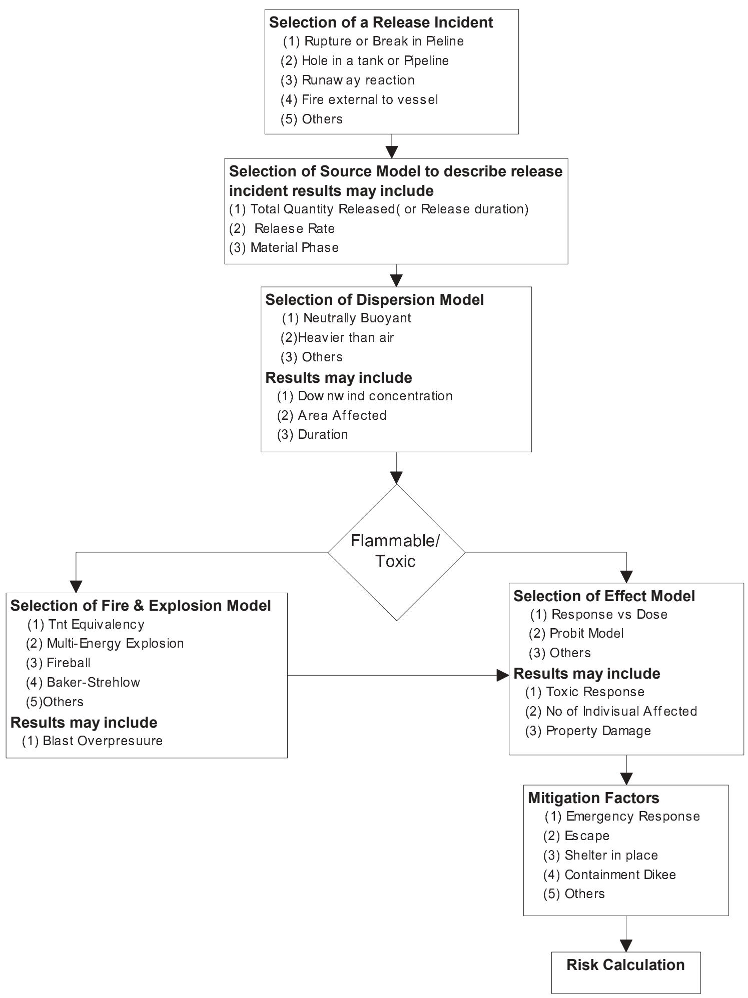

Figure 7.3: Overall Logic Diagram for the consequence models for releases of volatile hazardous substances

Flammable substances on release may cause Jet fire and less likely unconfined vapour cloud explosion causing possible damage to the surrounding area. The extent of damage depends upon the nature of the release. The release of flammable materials and subsequent ignition result in heat radiation wave or vapour cloud depending upon the flammability and its physical state. Damage distances due to release of hazardous materials depend on atmospheric stability and wind speed. It is important to visualize the consequence of the release of such substances and the damage caused to the surrounding areas.

Past Accident Data

Table 7.1: Past accident data for R-LNG

Date	Location	Accident
2004	Ghislenghien, Belgium	A pipeline carrying natural gas from the Belgian port of Zeebrugge to northern France exploded, resulting in 23 known fatalities. The cause of the incident is still under investigation but it appears that a contractor accidentally damaged the pipe.

7.3.2 Pasquill Stability

One of the most important characteristics of atmosphere is its stability. Stability of atmosphere is its tendency to resist vertical motion or to suppress existing turbulence. This tendency directly influences the ability of atmosphere to disperse pollutants released from the facilities. In most dispersion scenarios, the relevant atmospheric layer is that nearest to the ground, varying in thickness from a few meters to a few thousand meters. Turbulence induced by buoyancy forces in the atmosphere is closely related to the vertical temperature gradient.

Temperature normally decreases with increasing height in the atmosphere. The rate at which the temperature of air decreases with height is called Environmental Lapse Rate (ELR). It varies from time to time and place to place. The atmosphere is considered to be stable, neutral or unstable according to ELR is less than, equal to or greater than Dry Adiabatic Lapse Rate (DALR), which is a constant value of 0.98°C/100 meters.

Pasquill stability parameter, based on Pasquill – Gifford categorization, is a meteorological parameter, which describes the stability of atmosphere, i.e., the degree of convective turbulence. Pasquill has defined six stability classes ranging from `A' (extremely unstable) to `F' (stable). Wind speeds, intensity of solar radiation (daytime insulation) and night time sky cover have been identified as prime factors defining these stability categories.

The following table indicates the Pasquill stability classes.

Table 7.2: Pasquill stability classes

** Class D & F are considered for modelling Worst case scenario

Sr. No.	Stability Class	Weather Conditions
1.	A	Very unstable – sunny, light wind
2.	A/B	Unstable - as with A only less sunny or more windy
3.	B	Unstable - as with A/B only less sunny or more windy
4.	B/C	Moderately unstable – moderate sunny and moderate wind
5.	C	Moderately unstable – very windy / sunny or overcast / light wind
6.	C/D	Moderate unstable – moderate sun and high wind
7.	D	Neutral – little sun and high wind or overcast / windy night
8.	E	Moderately stable – less overcast and less windy night
9.	F	Stable – night with moderate clouds and light / moderate wind
10.	G	Very stable – possibly fog
Source: *Hanna , S. R. and Drivas, P. J. (1996) Guidelines for Use of Vapour Cloud Dispersion Models. AIChE, CCPS, New York*		

When the atmosphere is unstable and wind speed is moderate or high or gusty, rapid dispersion of pollutants will occur. Under these conditions, pollutant concentration in air will be moderate or low and the material will be dispersed rapidly. When the atmosphere is stable and wind speed is low, dispersion of material will be limited and pollutant concentration in air will be high. Stability category for this study is identified based on the cloud amount, day time solar radiation and wind speed.

Table 7.3: Weather parameters for consequence analysis

S. No.	Wind Speed(m/s)	Pasquill Stability
1.	2	F
2.	3	D
3.	5	D

7.4 Overview of Risk Assessment

Risk Assessment (RA) provides a numerical measure of the risk that a particular facility poses to the public. It begins with the identification of probable potential hazardous events at an industry and categorization as per the predetermined criteria. The consequences of major credible events are calculated for different combinations of weather conditions to simulate worst possible scenario. These consequence predictions are combined to provide numerical measures of the risk for the entire facility.

Detailed Risk Assessment study helps in plotting the damage contours on the detailed plot plan in order to assess the magnitude of a particular event. A disastrous situation is the outcome of fire, explosion or toxic hazards in addition to other natural causes that eventually lead to loss of life, property and ecological imbalances.

7.5 Hazard Identification

Risk Assessment (RA) begins with Hazard Identification (HAZID). Hazard identification is necessary, as hazards that have not been identified cannot be assessed. There are many forms of hazard identification technique. Each has its particular benefits and drawbacks when applied to different risk assessment processes. For this study, hazard identification is required simply to identify those events, which have the potential to cause a significant impact on the safety of proposed development concept or on the environment. These hazards are then taken forward in the process for more detailed analysis of their potential safety and environmental risks.

Identification of hazards is an important step in Risk Assessment as it leads to the generation of accidental scenarios. The merits of including the hazard for further investigation are subsequently determined by its significance, normally using a cut-off or threshold quantity.

Once a hazard has been identified, it is necessary to evaluate it in terms of the risk it presents to the employees and the neighbouring community. In principle, both probability and consequences should be considered, but there are occasions where it either the probability or the consequence can show to be sufficiently low or sufficiently high, decisions can be made on just one factor.

During the hazard identification component, the following considerations are taken into account.

1. Chemical identities
2. Location of process unit facilities for hazardous materials.
3. The types and design of process units
4. The quantity of material that could be involved in an airborne release and
5. The nature of the hazard (e.g. airborne toxic vapors or mists, fire, explosion, large

quantities stored or processed handling conditions) most likely to accompany hazardous materials spills or releases

7.6 MATERIAL IDENTIFICATION

Liquefied natural gas (**natural gas**) is natural gas (predominantly methane, CH_4, with some mixture of ethane C_2H_6) that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport. It takes up about 1/600th the volume of natural gas in the gaseous state (at standard conditions for temperature and pressure).It is odorless, colorless, non-toxic and non-corrosive. Hazards include flammability after vaporization into a gaseous state, freezing and asphyxia. The liquefaction process involves removal of certain components, such as dust, acid gases, helium, water, and heavy hydrocarbons, which could cause difficulty downstream. The natural gas is then condensed into a liquid at close to atmospheric pressure by cooling it to approximately −162 °C (−260 °F); maximum transport pressure is set at around 25 kPa (4 psi). Regasified natural gas **(R-LNG)** means gas derived from the conversion of natural gas (received by Terminal Owner at the Receipt Point) from its liquid state to a gaseous state.

7.7 Gas Composition

Table7.4: R-LNG Composition

Composition of Gas	
Component	**Specification (Mol %)**
Methane(C_1)	84.5 to 98.77
Ethane(C_2)	9 to 0.69
Propane(C_3)	3 to 0.03
Butanes(C_4) & heavier	2 to 0
Pentanes(C_5) and heavier	0.25 to 0
Nitrogen(N_2)	1.25 to 0.51
Oxygen(O_2)	not more than 0.5Mol %
Total Non Hydrocarbons	not more than 2.0 Mol %

Total Sulphur including H_2S	Not more than 10ppm by weight expected H2S content not more than 4 ppm by volume.
Carbon-Dioxide	0
Impurities**	Gas shall be reasonably free from dust (max size 5 microns), gum forming constituents and other deleterious solid and/or liquid matter which will cause damage to or interfere with the Operations of Transporter's Facilities.
Water Content	Not more than 112 Kg/MMSCM

7.8 Hazard identification as per NFPA

Standard System for the Identification of the Hazards of Materials for Emergency Response" is a standard maintained by the U.S.-based National Fire Protection Association. "fire diamond" used by emergency personnel to quickly and easily identify the risks posed by hazardous materials. The four divisions are typically color-coded with red indicating flammability, blue indicating level of health hazard, yellow for chemical reactivity, and white containing codes for special hazards. Each of health, flammability and reactivity is rated on a scale from 0 (no hazard) to 4 (severe risk).

The numeric values in the first column are designated in the standard by "Degree of Hazard" using numerals (0, 1, 2, 3, 4).

Table 7.5: NFPA Classification

IMPACT	NFPA CODE	COLOUR
Flammability hazard	Nf	
Health hazard	Nh	
Reactivity hazard	Nr	
Special hazards	W	

Table-7.6: Explanation of NFPA classification

Classification	Definition
Health Hazard	
4	Materials, which on very short exposure could cause death or major residual injury even though prompt medical treatments were given.
3	Materials, which on short exposure could cause serious temporary or residual injury even though prompt medical treatments were given.
2	Materials, which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given.
1	Materials, which on exposure would cause irritation but only minor residual injury even if no treatment is given.
0	Materials, which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.
Flammability	
4	Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or which are readily dispersed in air and which will burn readily.
3	Liquids and solids that can be ignited under almost all ambient temperature conditions.
2	Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.
1	Material that must be preheated before ignition can occur.
0	Materials that will not burn.
Reactivity	
4	Materials which in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperature and pressures.

3	Materials which in themselves are capable of detonation or explosive reaction but require a strong initiating source or which must be heated under confinement before initiation or which react explosively with water.
2	Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Also materials which may react violently with water or which may form potentially explosive mixtures with water.
1	Materials which in themselves are normally stable, but which can become unstable at elevated temperature and pressures or which may react with water with some release of energy but not violently.
0	Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

Table 7.7:Table showing NFPA Classification of natural gas

Sl No.	Material Name	NF	NH	NR
1.	R-LNG	4	3	1

7.9 Fire and Explosion Index (FEI)

Fire and Explosion Index (FEI) is useful in identification of areas in which the potential risk reaches a certain level. It estimates the global risk associated with a process unit and classifies the units according to their general level of risk. FEI covers aspects related to the intrinsic hazard of materials, the quantities handled and operating conditions. This factor gives index value for the area which could be affected by an accident, the damage to property within the area and the working days lost due to accidents. The method for evaluation of FEI involves following stages.

Selection of pertinent process unit which can have serious impact on plant safety

Determination of Material Factor (MF): This factor for a given substance in the process unit gives intrinsic potential to release energy in case of fire or an explosion. Material Factor can be directly obtained from Dow's Fire and Explosion Index Hazard Classification Guide of American Institute of Chemical Engineers, New York. The factor can also be evaluated from NFPA indices of danger, health, flammability and reactivity.

Determination of Unit Hazard Factor: The Unit Hazard Factor is obtained by multiplication of

General Process Hazard (GPH) factor and Special Process Hazard (SPH) factor. GPH factor is computed according to presence of exothermic reactions and loading and unloading operations. The penalties due to each of these reactions / operations are summed up to compute GPH factor. Similarly, SPH factor can be evaluated for the operations close to flammable range or pressures different from atmospheric. Penalties of these operations for both factors can be obtained from Dow's F&EI index form.

Fire and explosion index are then calculated as the product of Material Factor (MF) and Unit Hazard Factor. Degree of hazards based on FEI is given in the following:

Table 7.8: Degree of Hazards Based on FEI

FEI Range	Degree of Hazard
0 – 60	Light
61-96	Moderate
97 – 127	Intermediate
128 - 158	Heavy
159 and Above	Severe

Preventive and protective control measures are recommended based on degree of hazard. Therefore, FEI indicates the efforts to be taken to reduce risks for a particular unit. FEI computed for various process equipments are given in the following table:

Table 7.9: Fire and Explosion Index for TBPL Pipeline

Sr. No.	Unit Name	FEI	Category/Risk Level
TBPL Pipeline			
1	16” TBPL	107	Intermediate
2	6” Spur Pipeline	98	Intermediate

7.9.1 SELECTED FAILURE CASES for Pipeline Transport

A list of failure cases was prepared based on process knowledge, engineering judgment, experience, past incidents associated with such facilities and considering the general mechanisms for loss of containment. The cases have been identified for the consequence analysis is based on the following-

-Cases with high chance of occurrence but having low consequence

-Cases with low chance of occurrence but having high consequence

(The example includes Line Rupture, Catastrophic failure of lines, process pressure vessels, etc.)

Table 7.10: Selected Failure scenario

S. No	Scenario Considered	Flow rate	Temperature	Pressure	Failure Frequency Mainline (as per OGP Guidelines	Failure Frequency Spur line (as per OGP Guidelines)	Failure Category
1.	Leak Scenario 10 MM	1000kl/hr	-20 to 30 Deg	95 Bar(g)	1.5E-05	1.70E-05	Credible Scenario
2.	Leak Scenario 25MM	1000kl/hr	-20 to 30 Deg	95 Bar(g)	6.5E-06	7.40E-06	
3.	Line Rupture	1000kl/hr	-20 to 30 Deg	95 Bar(g)	5.9E-06	7.60E-06	Worst Case Scenario

7.9.2 Types of Fire and Explosion Scenarios

Combustible materials within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. For Pipelines this normally occurs as a result of a leakage or spillage. Depending on the physical properties of the material and the operating parameters, the combustion of material may take on a number of forms like jet fire, flash fire and pool fire.

Jet Fire

Jet fire occurs when flammable material of a high exit velocity ignites. In process industries this may be due to design (flares) or an accidental. Ejection of flammable material from a vessel, pipe or pipe flange may give rise to a jet fire and in some instances the jet flame could have substantial "reach". Depending on wind speed, the flame may tilt and impinge on pipeline, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance from the source of the flames.

Flash Fire

A flash fire is the non-explosive combustion of a vapour cloud resulting from a release of flammable material into the open air, which after mixing with air, ignites. A flash fire results from the ignition of a released flammable cloud in which there is essentially no increase in combustion rate. The ignition source could be electric spark, a hot surface, and friction between moving parts of a machine or an open fire.

Flash fire may occur due to its less vapour temperature than ambient temperature. Hence, as a result of a spill, they are dispersed initially by the negative buoyancy of cold vapours and subsequently by the atmospheric turbulence. After the release and dispersion of the flammable fuel the resulting vapour cloud is ignited and when the fuel vapour is not mixed with sufficient air prior to ignition, it results in diffusion fire burning. Therefore the rate at which the fuel vapour and air are mixed together during combustion determines the rate of burning in the flash fire.

The main dangers of flash fire are radiation and direct flame contact. The size of the flammable cloud determines the area of possible direct flame contact effects. Radiation effects on a target depend on several factors including its distance from the flames, flame height, flame emissive power, local atmospheric transitivity and cloud size. Most of the time, flash combustion lasts for no more than a few seconds.

7.9.3 Vapour Cloud Explosion(VCE)

The Vapour Cloud Explosion (VCE) begins with a release of a large quantity of flammable vaporizing liquid or gas from a storage tank, transport vessel or pipeline producing a dangerous overpressure. These explosions follow a well-determined pattern. There are basically four features, which must be present for an effective vapour cloud explosion to occur with an effective blast. These are:

First, the release material must be flammable and at a suitable condition of temperature and pressure which depends on the chemical. The materials which come under this category, range from liquefied gases under pressure (e.g. butane, propane); Second, before the ignition, a cloud of sufficient size must have been formed. Normally ignition delays of few minutes are considered the most probable for generating the vapour cloud explosions

Third, a sufficient amount of the cloud must be within the flammable range of the material to cause extensive overpressure

Fourth, the flame speed determines the blast effects of the vapour cloud explosions, which can vary greatly

The flammable content of a gas cloud is calculated by three-dimensional integration of the concentration profiles, which fall within the flammable limits. If the gas cloud ignites, two situations can occur, namely non-explosive combustion (flash fire) and explosive combustion (flash fire + explosion).

The following **Table 7.11** illustrates the damage effect of blast overpressure.

Table 7.11: Damage due to Overpressures

Peak Overpressure	Damage Type
12.04 psi	Total Destruction
4.35 psi	Heavy Damage
1.45 psi	Moderate Damage

0.44 psi	Significant Damage
0.15 psi	Minor Damage

7.9.4 Blast Effects

Petroleum Vapors evaporated from a large pool of spillage would normally spread out in the direction of wind and if a source of ignition is found before the lower inflammable level is reached, a flash fire preceded by a vapour cloud explosion will result. The resultant blast over pressure of the explosion may have serious damaging effects on building, structural and equipment, which are summarized below.

Table 7.12: Blast Overpressure Effects

Overpressure bar/ psi	Mechanical damage to equipment	Damage to people
0.3/4.41	Heavy damage of plant and structure	Fatality probability = 1 for humans indoor as well as outdoor 50 eardrum damage > 50 serious wounds from flying objects.
0.1/ 1.47	Repairable damage	1 % death > 1% eardrum damage > 1 serious wound from flying objects.
0.03/ 0.441	Major glass damage	Slight injury from flying objects
0.01/0.147	10 % glass damage	--

7.9.5 Boiling Liquid Expanding Vapour cloud Explosion(BLEVE)

If the liquid is stored under pressure at a temperature above its boiling point, the initial physical explosion that breaks the receptacle produces a sudden decompression giving rise to a massive evaporation of the saturated liquid. This is known as Boiling Liquid Expanding Vapour Explosion (BLEVE). These explosions are of great destructive power due to the high increase in pressure caused by the sudden incorporation of liquid into the gas phase. The ignition of BLEVE produces a mass of gases at high temperature known as 'fireball' with significant thermal effects. Historically, BLEVEs have been produced with some frequency and have almost caused human casualties.

7.9.6 Lower and Upper Flammability Limit

In case of any spillage and leakages of hydrocarbons / flammable material, probability of getting ignited is depending on whether the air borne mixture is in the flammable region. The Lower flammability limit corresponds to minimum proportion of combustible vapour in air for combustion. The Upper flammability limit Correspond to maximum proportion of combustible vapour in air for combustion and the concentration range lying between the lower and the upper limit is called as flammable range.

7.10 Models for the Calculation of Heat load and Shock Waves

If a flammable gas or liquid is released, damage resulting from heat radiation or explosion may occur on ignition. Models used in this study for the effects in the event of immediate ignition (torch and pool fire) and the ignition of a gas cloud will be discussed in succession. These models calculate the heat radiation or peak overpressure as a function of the distance from the torch, the ignited pool or gas cloud. The physical significance of the various heat loads is depicted in **Table 7.13**.

Table 7.13: List of Damages Envisaged at Various Heat Loads

Sr. No.	Heat loads (kW/m^2)	Type of Damage Intensity	
		Damage to Equipment	Damage to People
1	37.5	Damage to process equipment	100% lethality in 1 min. 1% lethality in 10 sec
2	25.0	Minimum energy required to ignite wood	50% Lethality in 1 min. Significant injury in 10 sec
3	19.0	Maximum thermal radiation intensity allowed on thermally unprotected equipment	-
4	12.5	Minimum energy required to melt plastic tubing	1% lethality in 1 min
5	4.0	-	First degree burns, causes pain for exposure longer than 10 sec
6	1.6	-	Causes no discomfort on long exposures

Source: *World Bank (1988). Technical Report No. 55: Techniques for Assessing Industrial Hazards. , Washington, D.C: The World Bank.*

Model for Pressure Wave

A pressure wave can be caused by gas cloud explosion. The following damage criteria are assumed as a result of the peak overpressure of a pressure wave:

1. 0.03 bar over pressure wave is taken as the limit for the occurrence of wounds as a result of flying fragments of glass
2. Following assumptions are used to translate an explosion in terms of damage to the surrounding area:

Within the contour area of the exploding gas cloud, Casualties are due to burns or asphyxiation. Houses and buildings in this zone will be severely damaged.

In houses with serious damage, it is assumed that one out of eight persons present will be killed as a result of the building collapse. Within the zone of a peak over pressure of 0.3 bar the risk of death in houses is 0.9 x 1/8 = 0.1125, and in the zone with a peak over pressure of 0.1 bar the probability of death is 0.1 x 1/8 = 0.0125, i.e. one out of eighty people will be killed.

The significance of the peak over pressure 0.3 bar, 0.1 bar, 0.03 bar and 0.01 bar are depicted in **Table 7.14**.

Table 7.14: Damage Criteria for Pressure Waves

Human Injury		Structural Damage	
Peak Over Pressure (bar)	Type of Damage	Peak Over Pressure (bar)	Type of Damage
5-8	100% lethality	0.3	Heavy (90% damage)
3.5-5	50% lethality	0.1	Repairable (10% damage)
2-3	Threshold lethality	0.03	Damage of Glass
1.33-2	Severe lung damage	0.01	Crack of windows
1-1.33	50% Eardrum rupture	-	-

Source: *Marshall, V.C. (1977)' How lethal Is explosives and toxic escapes'.*

7.11 Vulnerability Models

Vulnerability models are used in order to determine how people are injured by exposure to heat load. Such models are designed on the basis of animal experiments or on the basis of the analysis of injuries resulting from accidents, which have occurred. Vulnerability models often make use of a probit function. In this function, a link is made between the heat load and the percentage of people exposed to a particular type of injury.

It is assumed that everyone inside the area covered or gas cloud will be burnt to death or will asphyxiate. Human fatality is a function of heat flux and exposure time. The probit expressions for the prediction of mortality due tot thermal radiation from fire scenarios are proportional to the product of t and $q^{4/3}$. The probit equation usually used is that proposed by Eisenberg and co-workers*

$$Pr= -14.9 + 2.56 \ln (10^{-4} q^{4/3} t)$$

In which,

Pr = Probit the measure of the percentage of people exposed to a particular injury

t = exposure time in seconds

q = thermal load in W/m^2

For 1% lethality in the exposed persons the corresponding probit value is 2.67. Table 7.15 gives time is seconds for percentage of fatality at various heat radiations.

Table 7.15: Range of Thermal Flux Levels and their Potential Effects

Heat Flux (kW/m^2)	Seconds Exposure For % Fatality		
	1%	50%	99%
1.6	500	1300	3200
4	150	370	930
12.5	30	80	200
37.5	8	20	50

Source: **Eisenberg, N. A., Lynch C. J. and Breeding, R. J. (1975) Vulnerability Model. A Simulation System for Assessing Damage Resulting from Marine Spills. National Technology Information Service Report AD-A015-245, Springfield, MA*

7.12 Computation of Damage Distances(Consequence Analysis)

Damage distances for the accidental release of hazardous materials have been computed at 2F, 3D and 5D weather conditions. In these conditions, 2, 3 and 5 are wind velocities in m/s and F and D are atmospheric stability classes. These weather conditions have been selected to accommodate worst case scenarios to get maximum effective distances.

7.13 Damage Distance Impact Distance

DNV based PHAST Micro software has been used to carry out consequence analysis. Damage distances computed for Transporation of Gas are described below.

Table 7.16: Probable Consequences of Failure at TBPL Pipeline

Sl no	FAILURE CASE: LIKELY CONSEQUENCES	Level
1.	leakage/ rupture – Flash Fire/ VCE (Large Leak)	Level 3
2.	leakage/ rupture – Fireball Fire/ VCE/ Late Ignition of Flammable mass released (Large Leak)	Level 3

3.	Failure of SV Pipeline- Flash Fire/ VCE (Large Leak)	Level 3
4.	Overheating/electrical spark/arc in control/administration/MCC room-Fire	Level 2
5.	Integrity failure of Pipeline structures due to flood/storm/earthquake/third party activity- Flash Fire/ VCE (Large Leak)	Level 3
6.	Accumulation of grass/other combustible material-Fire	Level 1

Table 7.17: Table showing Consequence Analysis of TBPL (16" Mainline)

Scenario considered	Wind stability class	Flash fire At LFL concentration distance (m)	Jet Fire Damage distance for various heat loads (m)			Distance downwind to overpressure 1 (0.02068 bar) [m]	Distance downwind to overpressure 2 (0.1379 bar) [m]	Distance downwind to overpressure 3 (0.2068 bar) [m]
			4 kW/m2	12.5 kW/m2	37.5 kW/m2			
10 MM LEAK (Credible Scenario)	2F	9.44648	19.9155	16.0255	12.61	44.9608	24.8513	23.6373
	3D	8.81075	19.8984	16.1608	12.7947	33.2636	14.5214	13.39
	5D	8.05602	19.8445	16.4157	13.2408	32.2257	14.3197	13.2388
25 MM LEAK	2F	9.44648	19.9155	16.0255	12.61	44.9608	24.8513	23.6373

Scenario considered	Wind stability class	Flash fire At LFL concentration distance (m)	Jet Fire Damage distance for various heat loads (m)			Distance downwind to overpressure 1 (0.02068 bar) [m]	Distance downwind to overpressure 2 (0.1379 bar) [m]	Distance downwind to overpressure 3 (0.2068 bar) [m]
			4 kW/m2	12.5 kW/m2	37.5 kW/m2			
(Credible Scenario)	3D	8.81075	19.8984	16.1608	12.7947	33.2636	14.5214	13.39
	5D	8.05602	19.8445	16.4157	13.2408	32.2257	14.3197	13.2388
Pipeline Line Rupture (Worst Case)	2F	803.153	714.689	491.266	372.284	2886.27	116.622	68.4388
	3D	783.508	719.342	497.733	376.352	2769.37	89.624	67.1967
	5D	839.361	724.159	510.43	229.806	2752.85	50.5153	37.8745

Table 7.18: Table showing Consequence Analysis of TBPL (6" Spur line)

Scenario considered	Wind stability class	Flash fire At LFL concentration distance (m)	Jet Fire Damage distance for various heat loads (m)			Distance downwind to overpressure 1 (0.02068 bar) [m]	Distance downwind to overpressure 2 (0.1379 bar) [m]	Distance downwind to overpressure 3 (0.2068 bar) [m]
			4 kW/m2	12.5 kW/m2	37.5 kW/m2			

Scenario considered	Wind stability class	Flash fire At LFL concentration distance (m)	Jet Fire Damage distance for various heat loads (m)			Distance downwind to overpressure 1 (0.02068 bar) [m]	Distance downwind to overpressure 2 (0.1379 bar) [m]	Distance downwind to overpressure 3 (0.2068 bar) [m]
			4 kW/m2	12.5 kW/m2	37.5 kW/m2			
10 MM LEAK (Credible Scenario)	**2F**	9.44648	19.9155	16.0255	12.61	44.9608	24.8513	23.6373
	3D	8.81075	19.8984	16.1608	12.7947	33.2636	14.5214	13.39
	5D	8.05602	19.8445	16.4157	13.2408	32.2257	14.3197	13.2388
25 MM LEAK (Credible Scenario)	**2F**	9.44648	19.9155	16.0255	12.61	44.9608	24.8513	23.6373
	3D	8.81075	19.8984	16.1608	12.7947	33.2636	14.5214	13.39
	5D	8.05602	19.8445	16.4157	13.2408	32.2257	14.3197	13.2388
Pipeline Line Rupture (Worst Case)	**2F**	274.077	282.271	198.26	147.796	1058.53	205.732	154.25
	3D	259.763	281.952	200.368	148.892	971.025	188.725	141.499
	5D	275.956	278.979	203.052	153.614	967.331	188.007	140.961

Computed Damage Distance Graphs for The TBPL(16" Main Line)

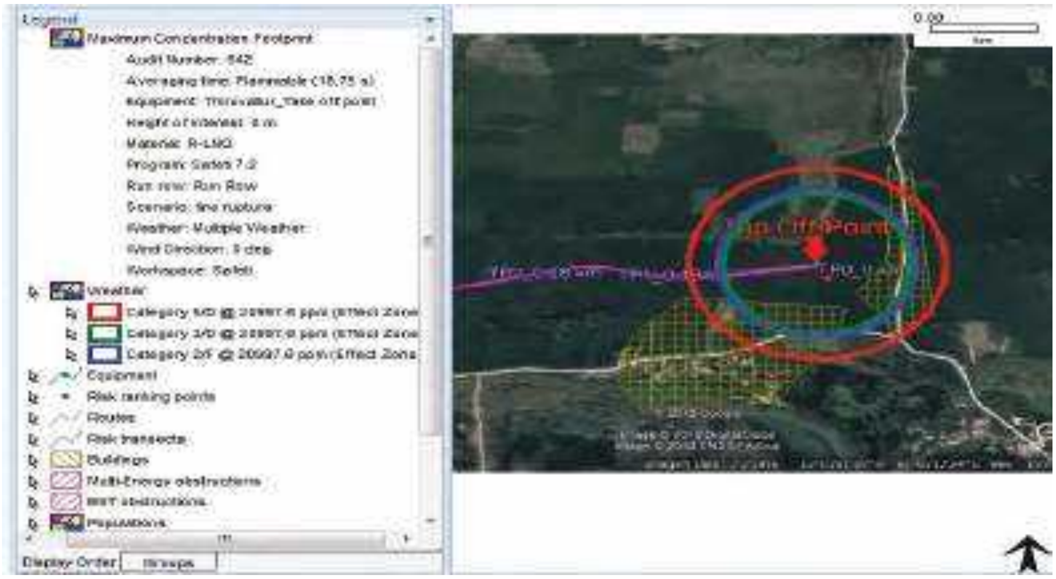

Figure 7.4: Maximum Concentration footprint graph for Worst Case Scenario for Thiruvallur

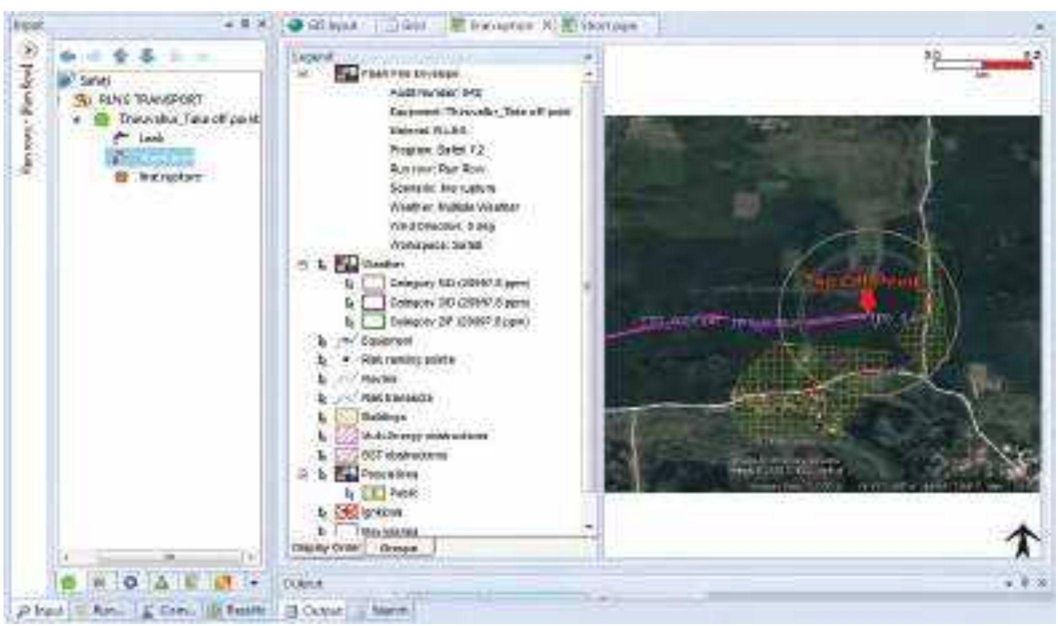

Figure 7.5: Flash fire envelope for Worst Case Scenario for Thiruvallur

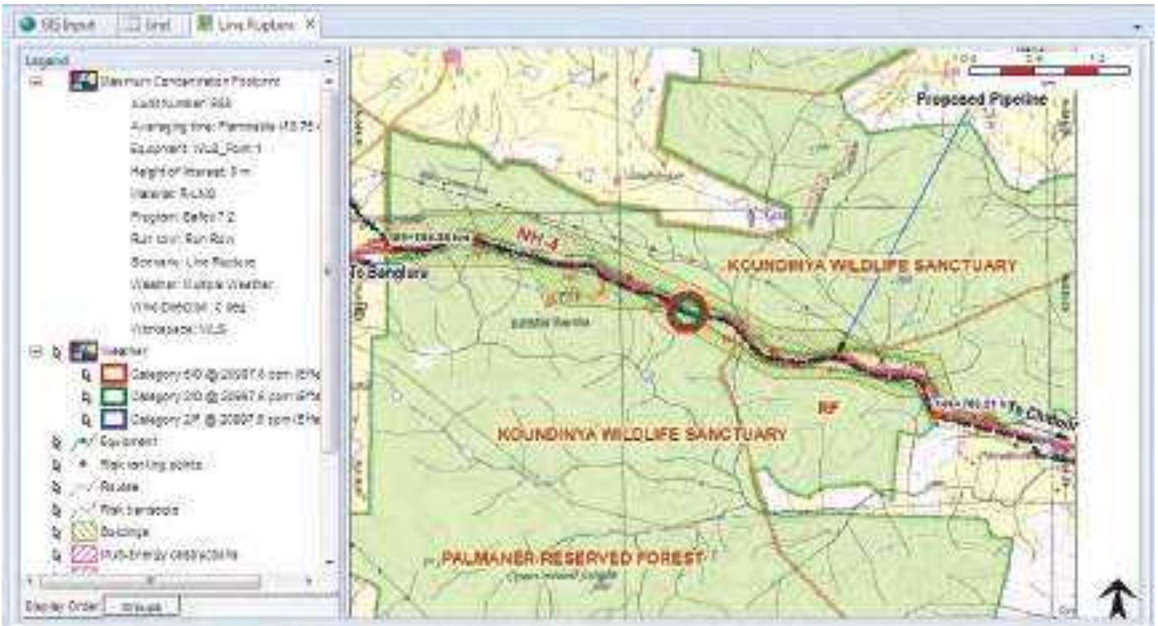

Figure 7.6: Maximum Cloud Footprint on Koundinya WLS

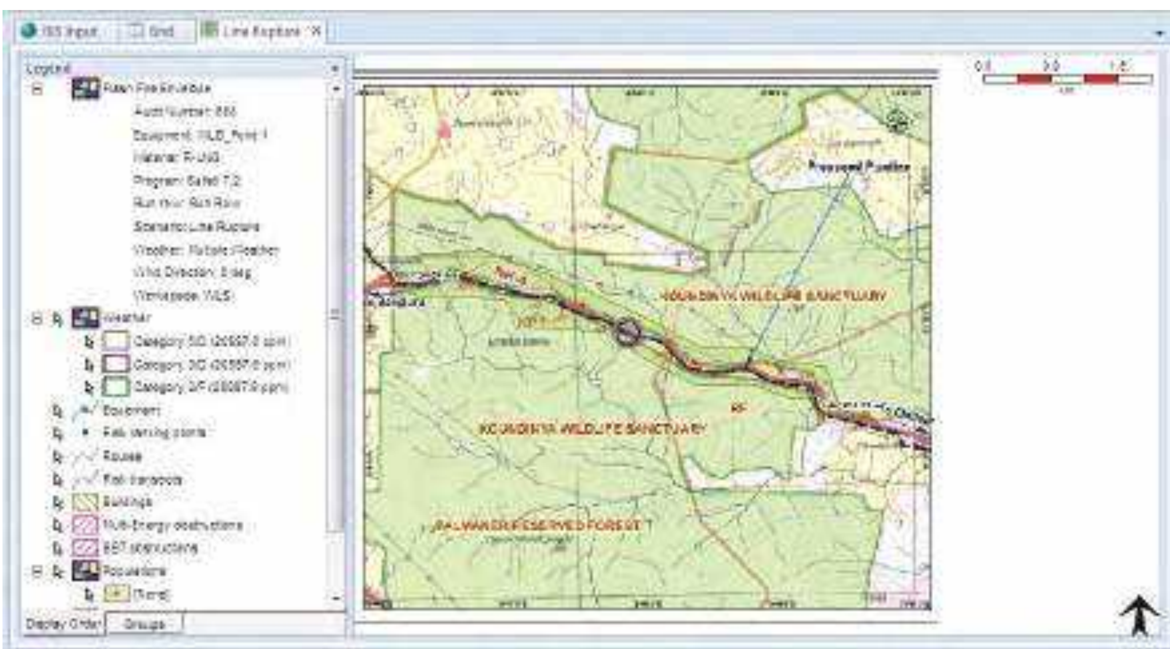

Figure 7.7: Flash Fire Envelope for Koundinya WLS

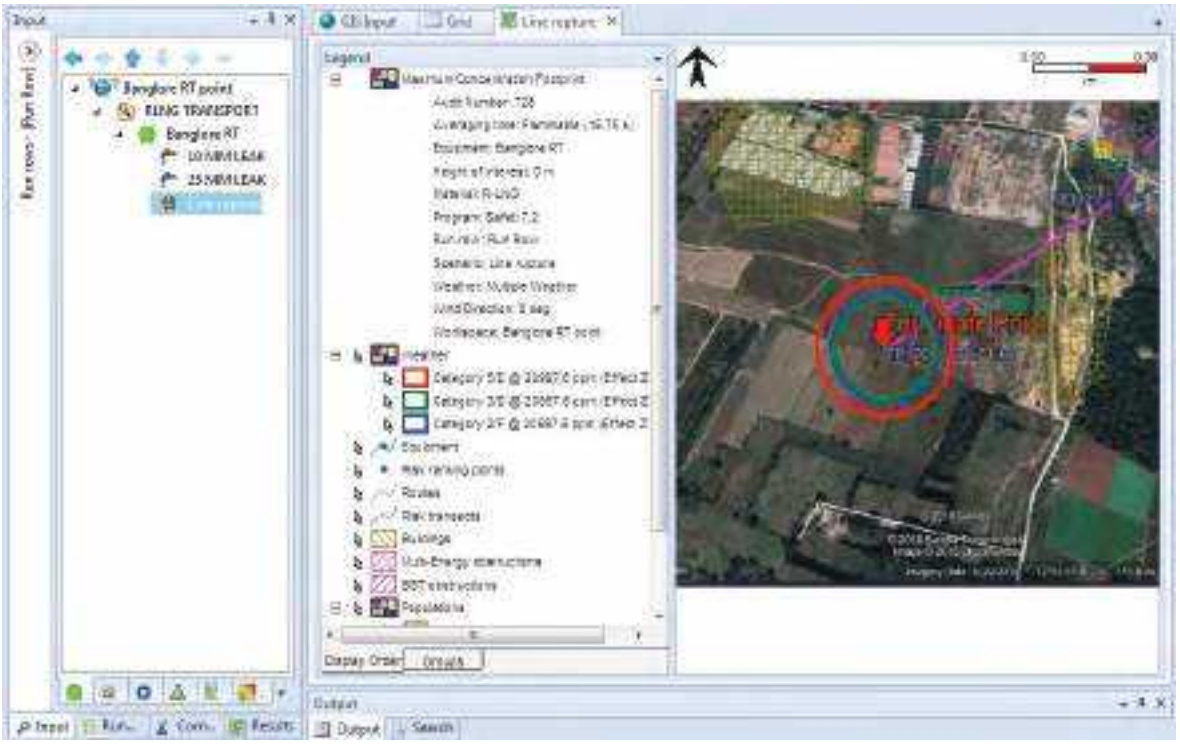

Figure 7.8: Maximum Concentration Cloud Footprint Bengaluru terminating point

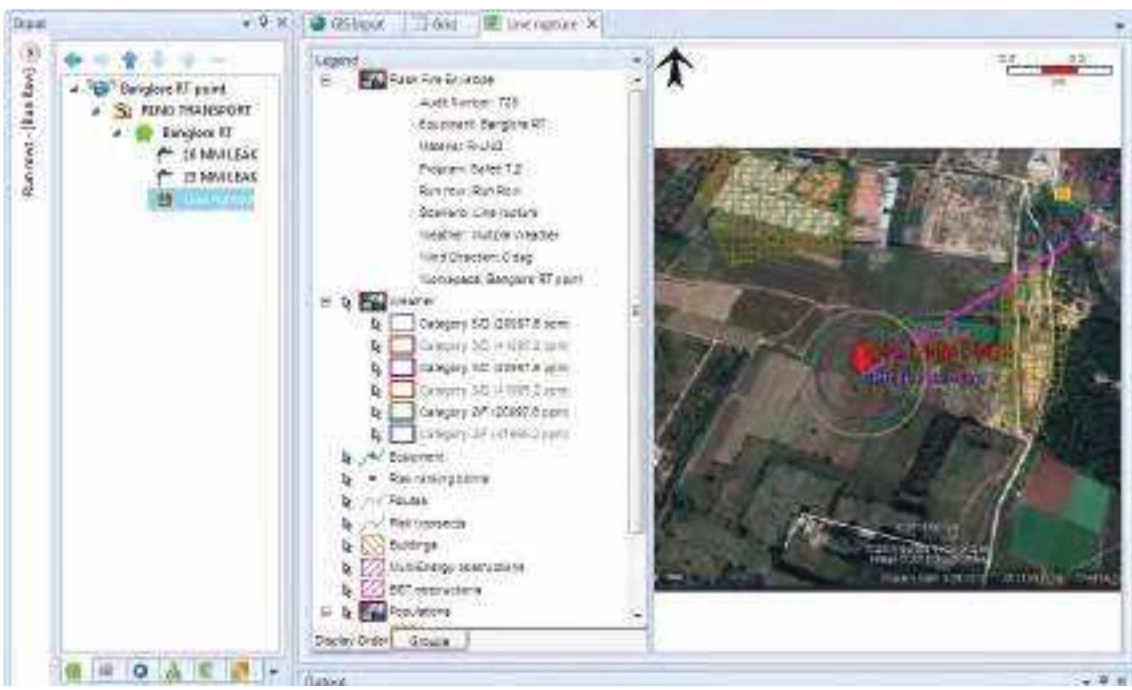

Figure7.9: Flash Fire Envelope Bengaluru Terminating Point

Computed Damage Distance Graphs for the TBPL(6"Spur Line)

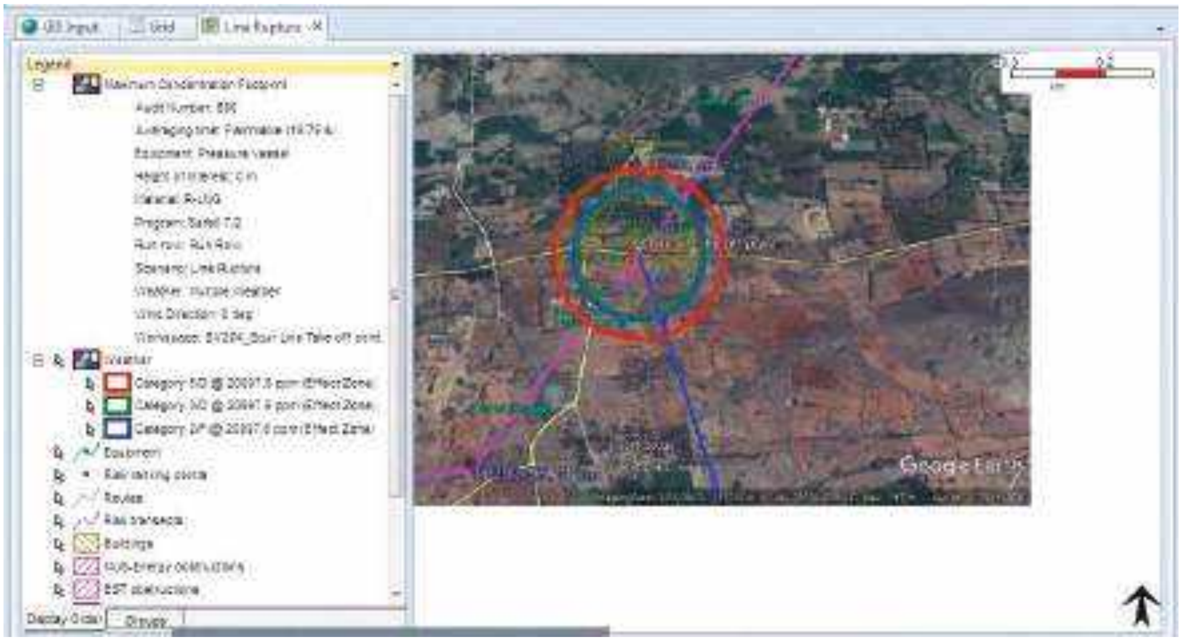

Figure 7.10: Maximum Cloud Foot print at Chitoor

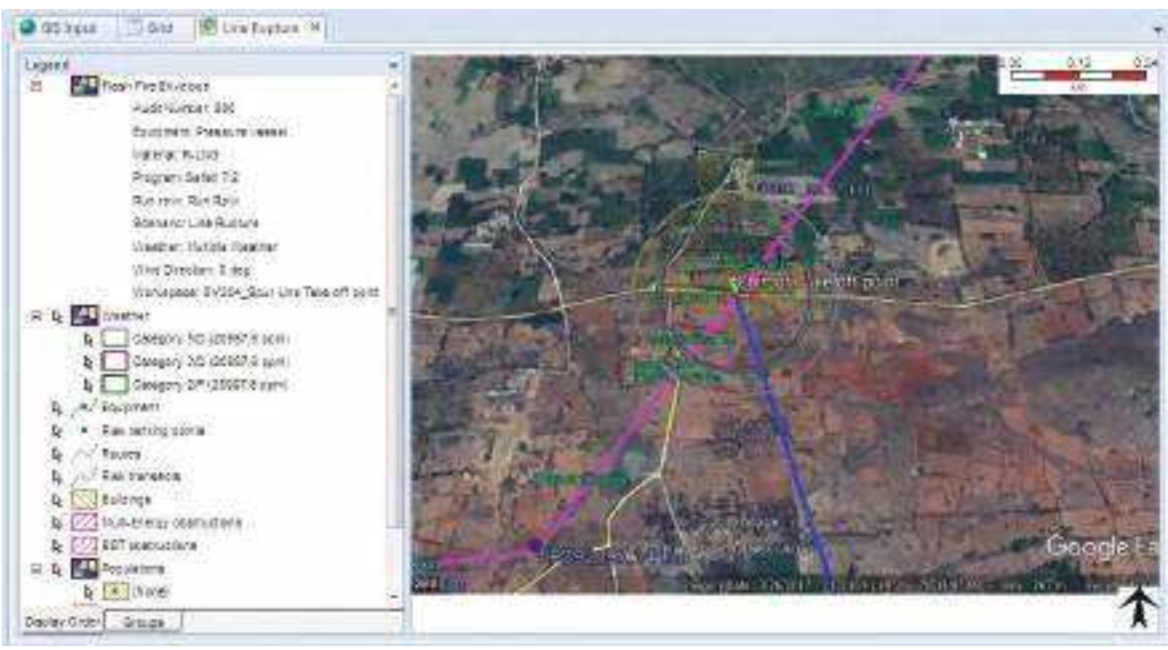

Figure 7.11: Flash Fire envelope for Chittoor

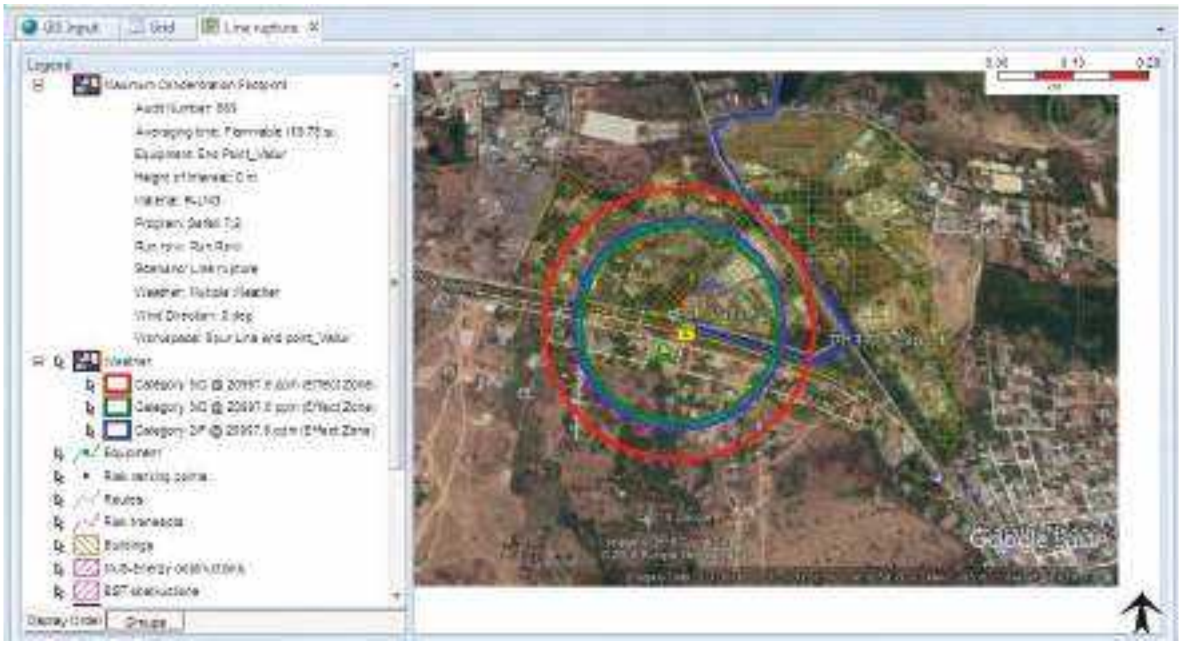

Figure 7.12: Maximum Concentration Cloud Footprint Vellore, Spur Pipeline

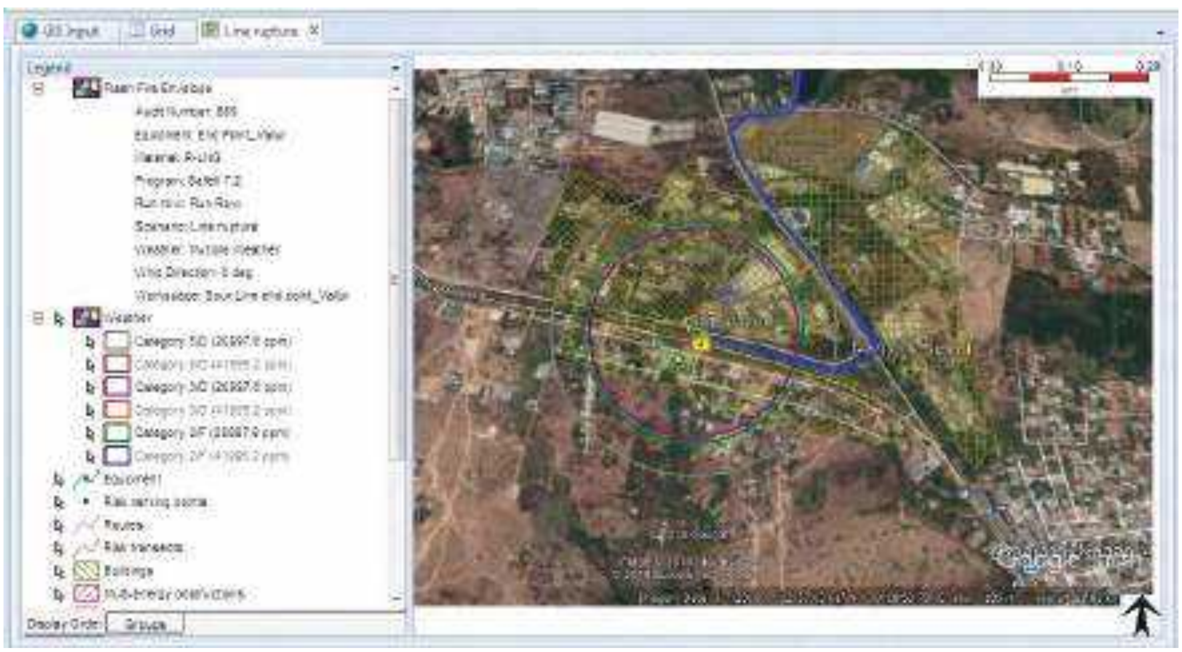

Figure 7.13: Flash Fire Envelope for Vellore, Spur Pipeline

7.14 RISK ANALYSIS

7.14.1 Risk Analysis Methodology

The RA methodology applied in this study is based on The Centre for Chemical Process Safety (CCPS, 2000) guidelines. A systematic approach has been made in the analysis of what can go wrong at the site. The normal conditions of operation of the system are defined and then the following questions asked.

- What can go wrong?
- What will be the consequences?
- How often?
- What is the significance of the resulting risk?

Risk is quantified in terms of probability of occurrence of fire i.e. fire frequency. The probability of occurrence of credible and worst-case scenarios are used with recourse to standard databases as discussed in the previous sections of the chapter. The damage caused due to spillage and release from leak from Pipelines and Pump for Gas from TBPL Pipeline the depends on:

- Probability of failure of Pipeline
- Length, diameter and thickness of pipeline
- Probability that the ignition source is available

Risk results obtained by using the data from various international guidelines for Transportation by pipelines and Pumps are discussed in the report. Frequency Analysis and Consequence Analysis is the next main step in the risk assessment process after Hazard Identification and Maximum credible accident analysis is done. Risk assessment is the process of comparing the results of the risk analysis with defined criteria. Depending on results and the criteria used, the assessment can indicate if the risks are broadly acceptable (low risks), intolerable (high risks) or somewhere in between these limits. The assessment should be used to provide guidance on managing risks achieved through the development of recommendations. Risk management is an ongoing process of managing risks through implementation of risk reduction measures, monitoring and analysing risk.

7.14.2 Failure Frequencies and Ignition Probability

Generic leak frequency data published by International Association of Oil and gas Producers (OGP) are used in this QRA study. An extract from OGP Risk assessment data directory-report no.434 (March-2010) used in present study is reported in the table below-

Table 7.19: Failure Frequencies by OGP Data

Equipment overall failure frequency (per year)						
Equipment Name	Minor Leak	Medium Leak		Major Leak	Full bore Rupture	Total
	[3mm]	[10mm]	[25mm]	[100mm]	[>100mm]	
Process Pipe <2”	9.00E-05	3.80E-05	2.70E-05			1.6 E-4
Process Pipe <6”	4.10E-05	1.70E-05	7.40E-06	7.60E-06		7.3 E-5
Process Pipe <12”	3.70.E-05	1.60E-05	6.70E-06	1.40E-06	5.90E-06	6.7 E-5
Process Pipe 18”	3.6E-05	1.5E-05	6.5E-06	1.4E-06	5.9E-06	6.5E-05
Flanges<2”	4.40E-05	1.80E-05	1.50E-05			7.7 E-5
Flanges<6”	6.50E-05	2.60E-05	1.10E-05	8.50E-06		1.1 E-4
Flanges<12”	9.60E-05	3.90E-05	1.60E-05	3.20E-06	7.00E-06	1.6 E-4
Manual Valves<2”	4.40 E-05	2.30E-05	2.10E-05			8.8 E-5
Manual Valves<6”	6.60E-05	3.40E-05	1.80E-05	1.10E-05		1.3 E-4
Manual Valves<12”	8.40E-05	4.30E-05	2.30E-05	6.30E-06	7.80E-06	1.6 E-4
Actuated Valves<2”	4.20E-04	1.80E-04	1.10E-04			7.1 E-4
Actuated Valves<6”	3.60E-04	1.50E-04	6.60E-05	3.30E-05		6.1 E-4
Actuated Valves<12”	3.30 E-04	1.40E-04	6.00E-05	1.30E-05	1.80E-05	5.6 E-4
Instrument Connections	3.50E-04	1.50E-04	6.50E-05			5.7 E-4
Pumps-Centrifugal	5.10E-03	1.80E-03	5.90E-04	1.40E-04		7.6 E-3

7.14.3 Probability of Immediate Ignition and Individual and Societal Risk Assessment Criteria

For the frequency assessment, it is necessary to estimate the probability of ignition if a leak occurs. Frequency analysis involves the estimation of the likelihood of hazards occurring. Risk analysis provides numerical outputs of the various forms of risk, which are required. Ignition of a released material due to leak may occur either at the point of leak or at some distance from it. The cause of ignition may be the leak itself (e.g., a leak may generate static electricity) or an ignition source, which then gives a spark and ignites the leak.

Individual Risk

The Individual Risk (IR) level is more specifically defined as the Individual Risk Per Annum (IRPA), which is the calculated annual risk loading to a specific individual or group of individuals. Clearly this depends on the amount of time in a year that the individual spends in different risk areas. The individual risk calculation takes account of the fact that people move from one place to another.

When calculating individual risk from major accident scenarios, it is normal to take account of protection by buildings. Individual risk is typically depicted as contour plots on overall plot plan of a facility, the risk level falling off rapidly as one move away from the source of the leak / epicentre of potential explosions. General Procedure for calculation of Individual Risk contours is presented in Fig. 15

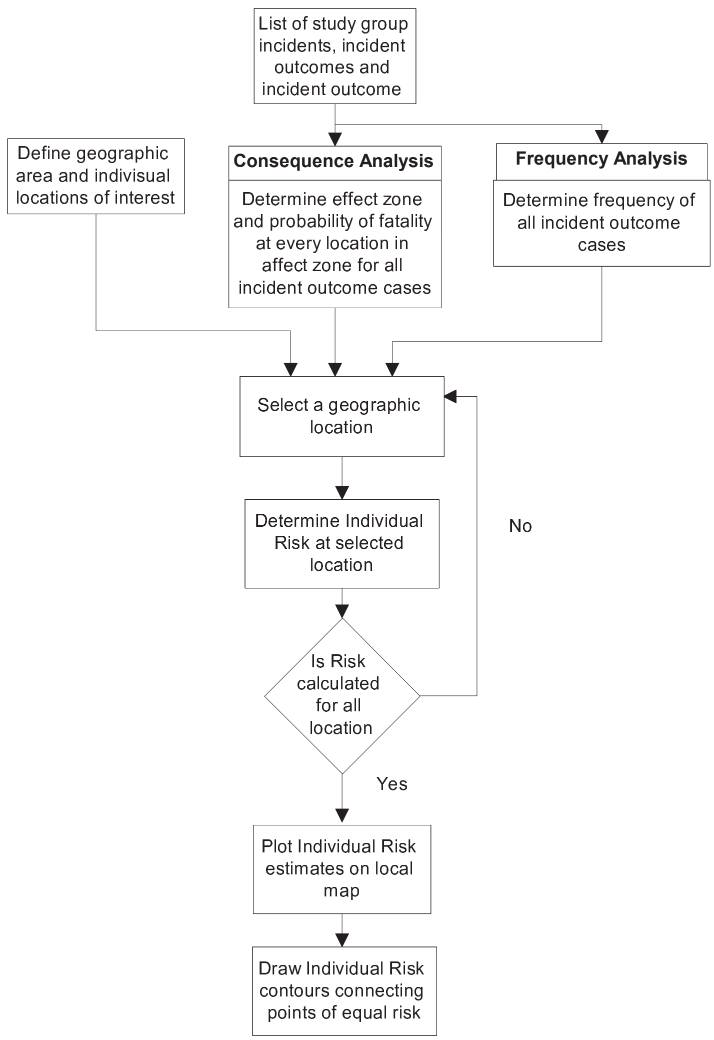

Figure 7.14: General procedure for calculation of Individual risk contours

7.14.4 Location Specific Individual Risk (LSIR)

The highest location-specific individual risk (LSIR) contour in terminal is of <10-7 per year which is within the ALARP region.

The maximum LSIR in the unit are listed in Table below:

Table 7.20: Maximum Location specific Individual Risk of TBPL

S. No.	Unit	Maximum LSIR
1.	Thiruvallur Take off point (SV 201)	3.714E-006
2.	Chittoor SV 206+TOP	4.317E-006
3.	Bengaluru RT	6.784 E-006
4.	Vellore	5.561 E-006
5.	Main Pipeline near Koundinya Wild Life Sanctuary	1.21 E-006

7.14.5 Individual Specific Individual Risk (ISIR)

Individual risk to worker at station/terminal calculated as a person who is standing at that point 365 days a year and 24 hours a day. The people in plant are expected to work in 8 hours shift as well general shift. The actual risk to a person “Individual Specific Individual Risk” (ISIR) would be far less after accounting the time fraction a person spent at location.

ISIR Area = LSIR X (8/24) (8 hours shift) x (Time spend by an individual / 8 hours)

The comparison of maximum individual risk with risk acceptability criteria is given in Table below-

Table 7.21: Maximum Individual specific Individual Risk of TBPL Pipeline

S. No.	**Location**	**Maximum ISIR**
1.	Thiruvallur Take off point (SV 201)	1.238E-006
2.	Chittor SV 206+TOP	1.439E-006
3.	Bengaluru RT	2.2613E-006
4.	Vellore	1.8536E-006
5.	Main Pipeline near Wild Life Sanctuaries	0.403E-006

Societal Risk

Societal risk is used in risk assessment (RA) studies and is depicted on a cumulative graph called an F/N curve. The horizontal axis is the number of potential fatalities, N. The vertical axis is the frequency per year that N or more potential fatalities could occur, F. This risk indicator is used by authorities as a measure for the social disruption in case of large accidents.

It is normal to take account of protection by buildings, and people's response. For large toxic release models, alarm and evacuation can be included. Because it is a cumulative curve, the curve always drops away with increasing N. Normally the F/N curve has a lower frequency cut-off at one in a billion (1 $x10^{-9}$ /yr). Regulators often split the graph into different regions, so that different actions have to be undertaken depending on where the F/N curve falls. Sometimes a maximum limit is placed on N (number of fatalities) possible for any event.

This type of curve is normal for plant type hazardous installations where a large group of people could be affected and their location is well established (housing estates, schools etc) relative to the event location (the plant). For pipelines however, because there is no single location for an event and the population affected varies along the pipeline route, this curve is not normally generated unless a large group of people can be affected over a reasonable distance. Calculated Societal Risk for TBPL Pipeline is coming in the range of 1 $x10^{-8}$ /yr 1 $x10^{-9}$ /yr). AVG YEAR . General Procedure for calculation of Societal Risk F/N curves is presented in Fig. 16

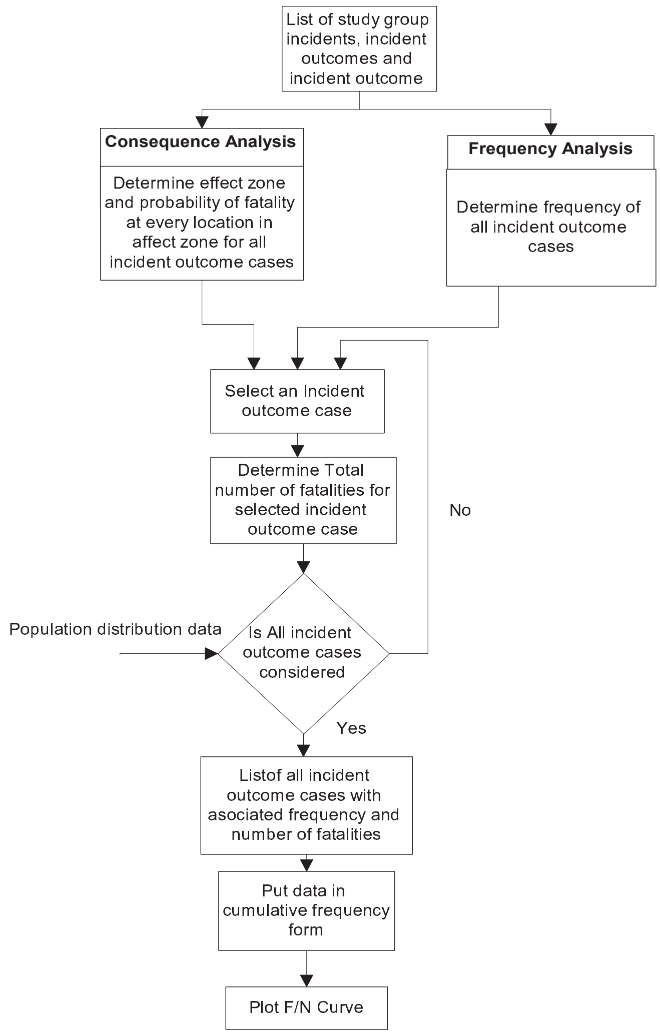

Figure 7.15: General procedure for calculation of societal risk F/N curve

Thus, Assessment for Individual and Societal Risk is done in accordance with HSE UK review report "*An independent review of HSE methodology for assessing societal risk*" Prepared by the Institution of Chemical Engineers for the Interdepartmental Task Group on Societal Risk, January 2006.

Figure 7.16: Graph Risk Contour showing overall Worst-case scenario for TBPL (Main + Spur Line)

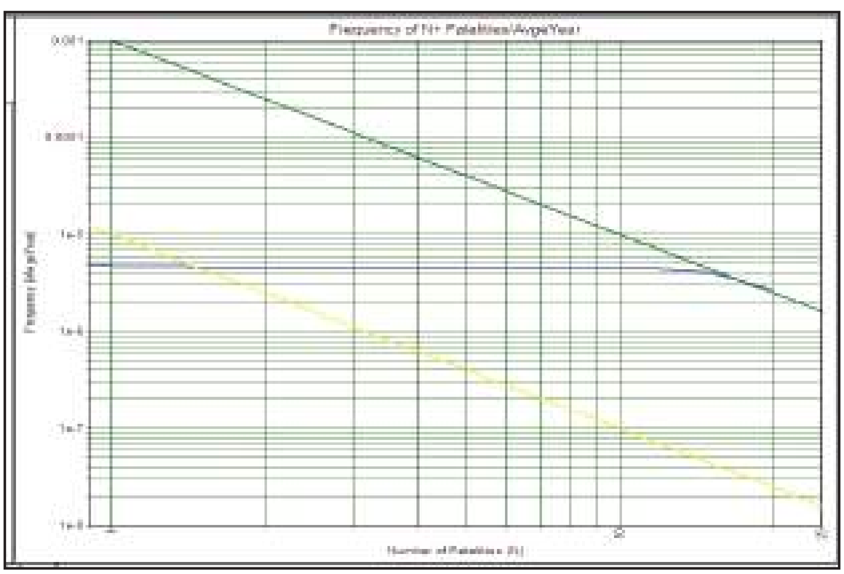

Figure 7.17: Graph showing overall F/N Curve for TBPL, Mainline

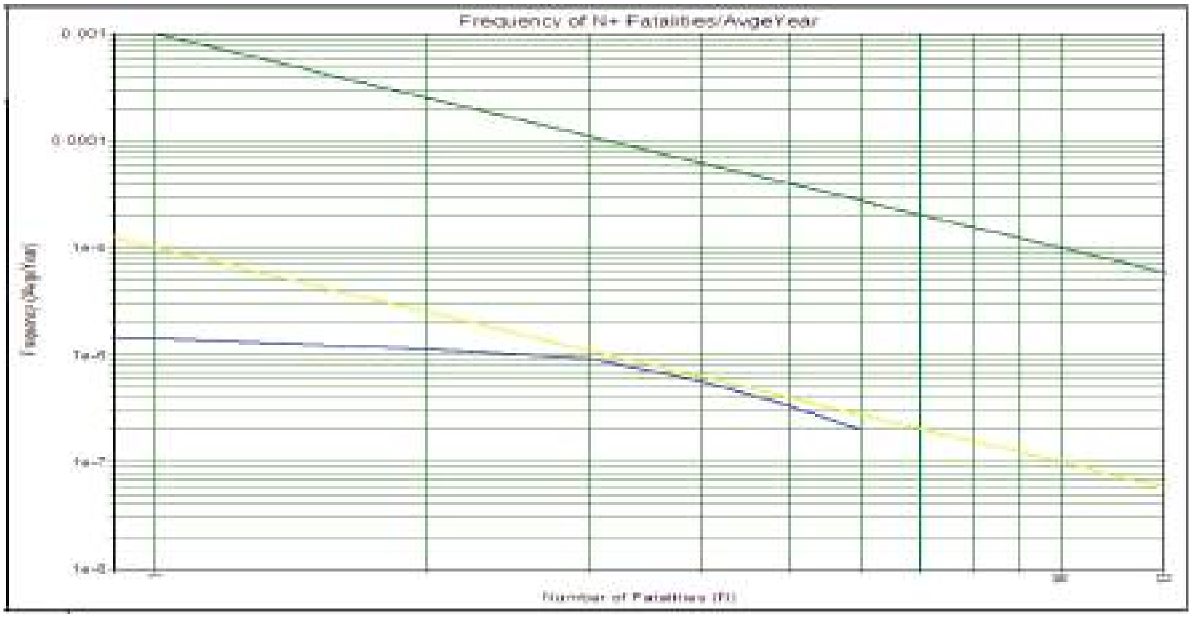

Figure7.18: Graph showing overall F/N Curve for TBPL, Spur Line

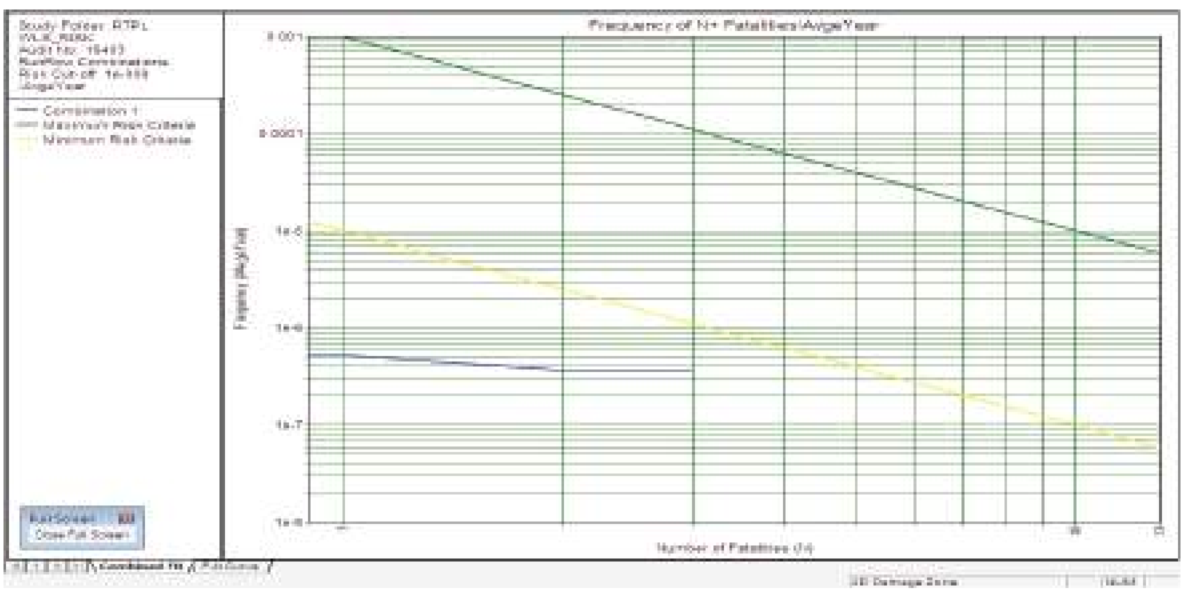

Figure 7.19: Graph showing overall F/N Curve for Pipeline Passing Through Koundinya Wild Life Sanctuary

7.15 The ALARP Principle

Societal Risk Contours were generated by PHAST RISK the ALARP (As Low As is Reasonably Practicable) principle seeks to answer the question "What is an acceptable risk?" The definition may be found in the basis for judgment used in British law that one should be as safe as is reasonably practicable. Reasonably practicable is defined as implying "that a computation must be made in which the quantum of risk is placed on scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time, or trouble) is placed on the other, and that, if it be shown that there is a gross disproportion between them – risk being insignificant in relation to the sacrifice – the defendants discharge the onus upon them" The ALARP details are represented in the Figure below-

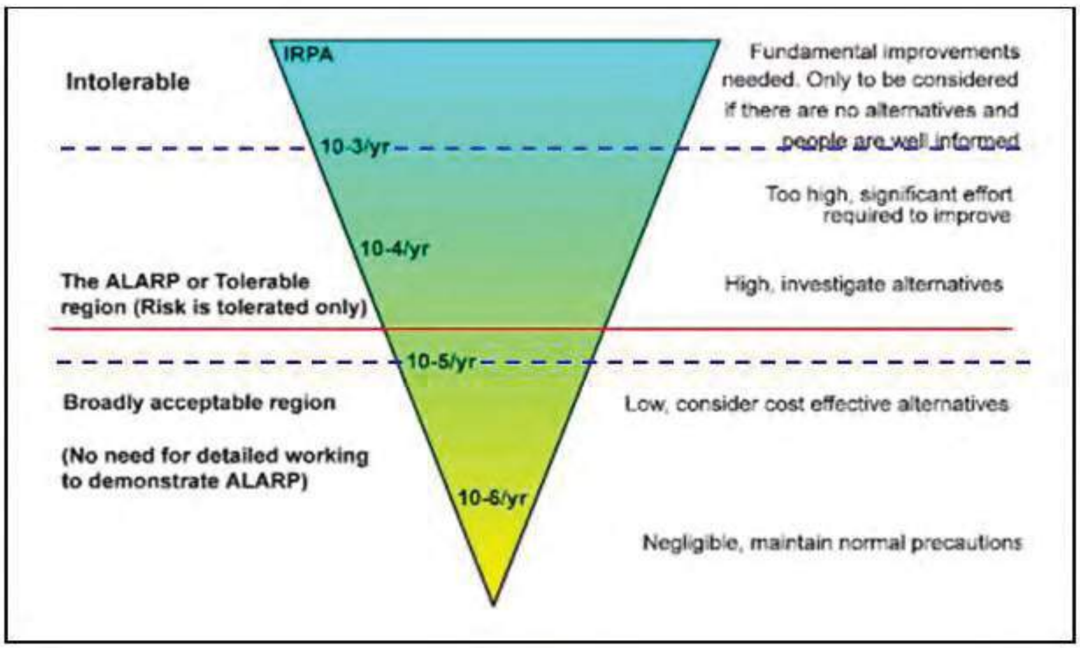

Figure7.20: ALARP Detail

7.16 ALARP Summary of TBPL Pipeline

ALARP summary & comparison of Individual risk with acceptability criteria. The objective of this RA study is to assess the risk levels at Proposed TBPL (Main Line & Spur) pipeline with reference to the defined risk acceptability criteria and recommend measures to reduce the risk level to as low as reasonably practicable ALARP).

ISO Contour suggest that Calculated risk Falls in the acceptable region of ALARP Summary The comparison of maximum individual risk with the risk acceptability criteria is shown in Figure below-

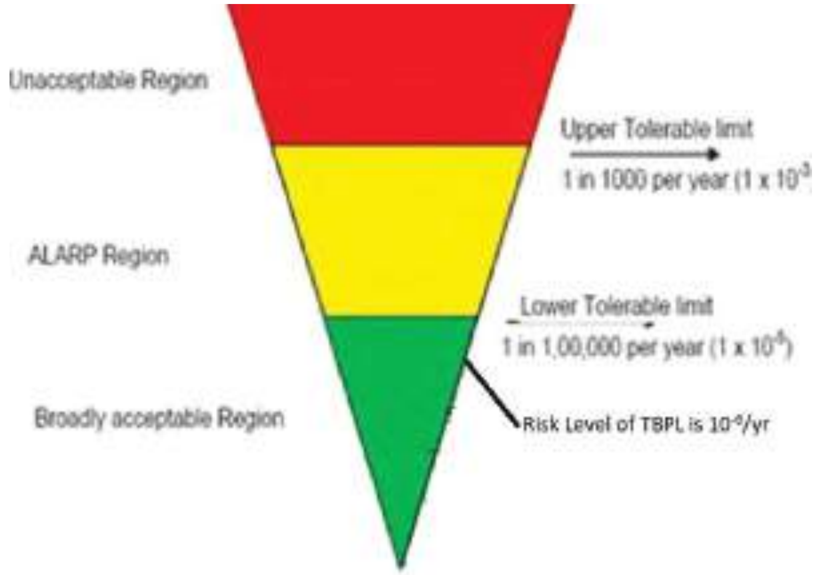

Figure7.21: Individual risk at IOCL TBPL Pipeline

7.17Risk Acceptance Criteria

The level of risk in this study is quantified with an express purpose of comparing against typical acceptable risks. The acceptable risk levels can change with time and place. Although there are differences between the legislation adopted in the various countries, there appears to be broad consensus on the tolerability of risk. The majority of the countries would accept risk levels for the public around 10^{-5}/yr whilst the more stringent countries would set the tolerability level at 10^{-6}/yr.

Table 7.22: Acceptable Risk Criteria of various countries

Authority and Application	**Maximum tolerable risk (per year)**	**Negligible risk (per year)**
VROM, the Netherlands (New)	1×10^{-6}	1×10^{-8}
VROM, the Netherlands (Existing)	1×10^{-5}	1×10^{-8}
HSE, UK (Existing hazardous industries)	1×10^{-4}	1×10^{-6}
HSE, UK (Nuclear power station)	1×10^{-5}	1×10^{-6}
HSE, UK (Substance transport)	1×10^{-4}	1×10^{-6}

Authority and Application	Maximum tolerable risk (per year)	Negligible risk (per year)
HSE, UK (New Housing near plants)	3×10^{-5}	3×10^{-7}
Hong Kong Government (new plants)	1×10^{-5}	Not Used

7.18 Detailed guidelines available from various countries have been presented below:

United Kingdom

In the UK the "Control of Major Accident Hazards" (COMAH) regulations are in line with the latest EU "Seveso-2" Directive. The regulations do not formally require risk assessment, but the guidance notes make clear that in some circumstances quantification will help or could be asked for by the UK regulator - the Health and Safety Executive (HSE) - and this is often done in practice.

To advise planning authorities on developments around industrial installations, the UK HSE has been developing risk acceptance criteria over the years. A comprehensive treatment of the subject of tolerability of risk was given in a report titled "Reducing Risks Protecting People". The report repeated the concept and criteria as argued by the Royal Society in 1983. It accepted the concept of tolerable Individual Risk as being the dividing line between what is just tolerable and intolerable and set the upper tolerable limit for workforce fatalities at 10^{-3}/yr (1 in a thousand) for workers and 10^{-4}/yr (1 in 10 thousand) for members of the public. A level at which risks might be broadly acceptable but not altogether negligible was set at 10^{-6}/yr (1 in a million). The region in between would be controlled by the ALARP concept.

ALARP can be demonstrated in a variety of ways, depending on the severity of the worst-case scenario. These are expressed in HSE guidance to Inspectors Consultation Draft September 2002.

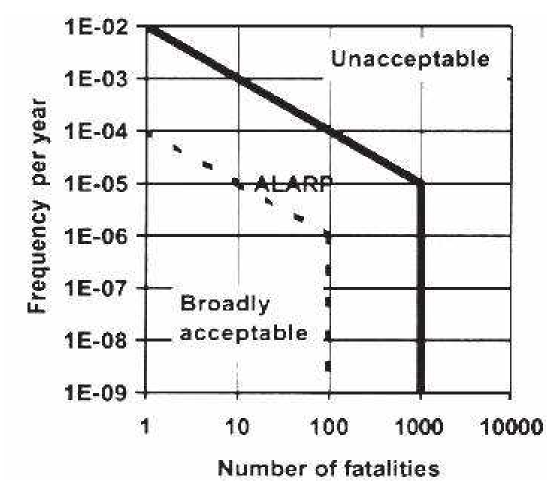

Figure 7.22: United Kingdom Societal Risk Guidelines (risk to workforce and public)

Unlike the Netherlands (see below), the potential workforce fatalities are included in the F/N curve.

Canada: Major Industrial Accidents Council of Canada (MIACC)

The MIACC recommend individual risk levels for use in respect to hazardous substances risk from all sources, i.e. there is no need to distinguish between risk from a fixed facility at which hazardous substances may be found, or a pipeline or a transportation corridor. The acceptability levels are equally applicable. With these considerations in mind, the guidelines for acceptable levels of risk are given in Table indicates acceptable Individual risks for designated land zones.

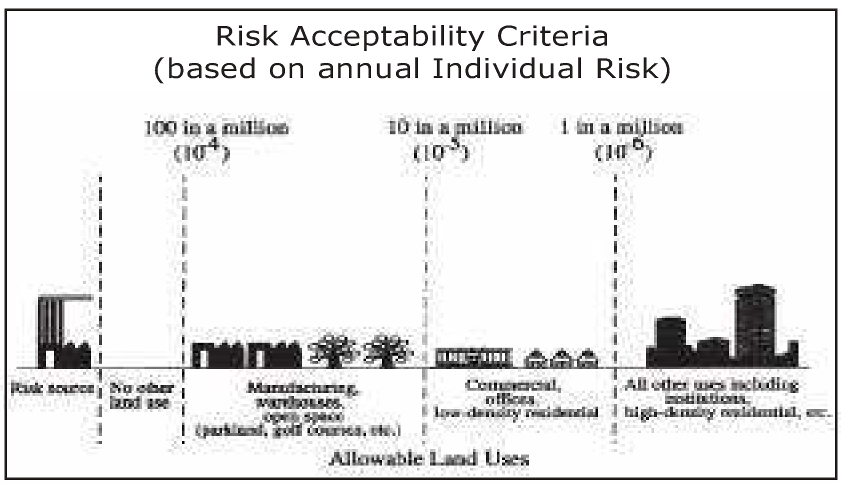

Figure 7.23:

Table 7.23: Land use and Industrial Risk According to MIACC

Location (based on risk level)	Possible land uses
From risk source to 1 in 10,000 (10^{-4}) risk contour:	No other land uses except the source facility, pipeline or corridor
1 in 10,000 to 1 in 100,000 (10^{-4} to 10^{-5}) risk contours:	uses involving continuous access and the presence of limited numbers of people bút easy evacuation, e.g. open space (parks, golf courses, conservation areas, trails, excluding recreation facilities such ás arenas), warehouses, manufacturing plants
1 in100,000 to 1 in 1,000,000 (10^{-5} to 10^{-6}) risk contours	Uses involving continuous access but easy evacuation, e.g., commercial uses, low-densily residential areas, offices

Beyond the 1 in 1,000,000 (10^{-6}) risk contour	All other land uses without restriction including institutional uses, high-density residential areas, etc.

Malaysia

The criteria used by the Department of Environment (DOE) for existing facilities are outlined below for residential and industrial areas:

- Residential 1 x 10^{-6} fatalities / person / year
- Industrial 1 x 10^{-5} fatalities / person / year

In words, the acceptability criteria are as follows: the risk of death to persons in a residential area must not exceed 1 chance in a million per person per year and the risk of death to persons in a nearby industrial area must not exceed 1 chance in 100,000 per person per year.

If the quantified individual risk compares favourably with the acceptability criteria, then it is deemed acceptable. If not, the components of the overall risk are re-examined to determine where risk mitigation measures can be implemented cost effectively. Risk evaluation must also be conducted taking into account the fact that hazard analysis and consequence assessment only gives an estimation of risks from a facility.

Australia

The Western Australia (WA) Department of Planning has adopted risk criteria for hazardous installations. They are based on risk contours and can be summarized as follows:

- A risk level in residential zones of one in a million per year (1 x 10^{-6}/yr) or less, is so small as to be acceptable to the WA EPA (Environmental Protection Agency);
- A risk level in "sensitive developments", such as hospitals, schools, child care facilities and aged care housing developments, of between one half and one in a million per year (5 x 10^{-7} and 1 x 10^{-6}/yr) is so small as to be acceptable to the WAEPA;
- Risk levels from industrial facilities should not exceed a target of fifty in a million per year (1 in 20,000) at the site boundary for each individual industry, and the cumulative risk level imposed upon an industry should not exceed a target of one hundred in a million per year (1 in 10,000);
- A risk for any non-industrial activity, located in buffer zones between industrial and residential zones, of Ten in a million per year or lower is so small as to be acceptable to the WA EPA;
- A risk level for commercial developments, including offices, retail centres and showrooms located in buffer zones between industrial facilities and residential zones, of five in a million per year or less, is so small as to be acceptable to the WA EPA.

The Netherlands

The policy statement approved by the Dutch Parliament states the following criteria for existing facilities. The risk is unacceptable if the 10^{-6}/yr risk contours affect residential areas or the F/N curve is above 10 fatalities with a frequency of 10^{-5}/yr with a slope of -2. This is illustrated in Fig. 25: Below the criteria, the ALARP, "As Low as Reasonably Practicable", principle should be used.

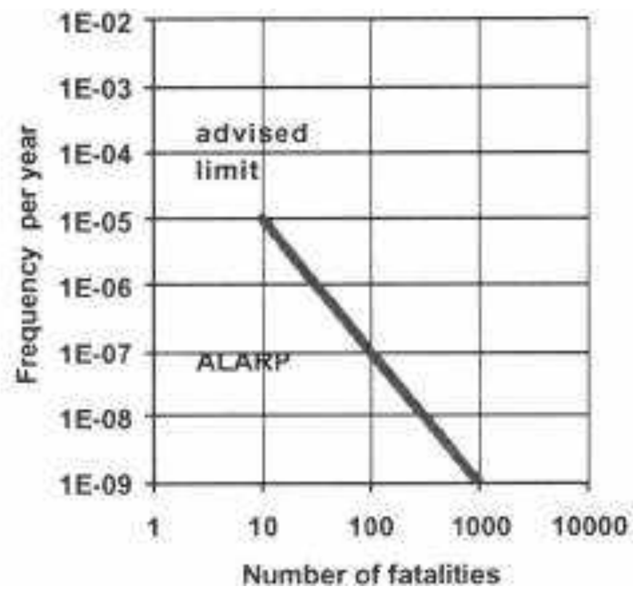

Figure 7.24: Netherlands Societal Risk Guidelines (risk to public only)

All Dutch installations should meet the criteria for new facilities by the year 2005. For the Societal Risk it should be emphasised that the exposure or "presence" factor of population used for calculating the F/N curve during the day is 0.7 and 1 during night. Also the assumption is made that being indoors gives protection where the fraction of people being indoors is 0.93 during daytime and 0.99 during night time.

Hong Kong Government Criteria

The Hong Kong government has published "Interim Risk Guidelines for Potential Hazardous Installations". The guideline covers new installations and expansion of existing installations and also controls the development of land around installations. It should be pointed out that although these are described as "guidelines" they are very strictly applied in practice. They are seen as necessary because of the special circumstances of Hong Kong, where there is a dense population in close proximity to industrial facilities, and are mainly used for land-use planning decisions. Societal risk guidelines are shown in Fig. 27 and set forth two criteria;A risk contour of 10^{-5}/yr for fatality as an upper limit of tolerability.

The maximum F/N curve exceeds the line through the point of 10 fatalities at a frequency of 10^{-4}/yr with a slope of -1. No event at any frequency should take place which causes more than 1000 deaths.

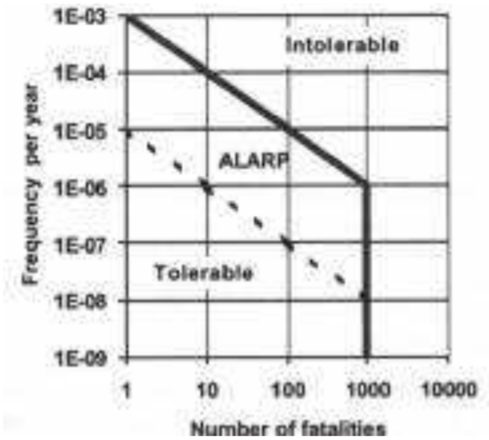

Figure 7.25: Hong Kong Societal Risk Guidelines (risk to public only)

The Hong Kong regulators scrutinize each risk assessment closely and insist on the use of consistent methodology from case to case.

7.19 RECOMMENDATIONS

Risk Mitigation Measures

Risk Assessment study has been carried out for proposed facilities of TBPL (Main & Spur Line) Pipeline project of IOCL. The Fire & Explosion were computed for the identification of vulnerable sections. Maximum Credible Accident (MCA) analysis for the visualised release scenarios of hazardous chemicals was also carried out. Risk mitigation measures have been recommended based on computation of indices and MCA analysis. General as well as specific recommendations are presented in the subsequent sections. References are taken from NFPA, OISD Standard 116,117,118,244 and Cameo Chemicals Directory.

General Mitigation Measures

Damage distances for the worst case could affect nearby facilities within the terminal/stations and some minimal direct effect on nearby hutments is possible. Due care should be the road is close by and hence close co-ordination with administration is important. As such, the traffic is moderate and no cause of major concern.

Ensure that combustible flammable material is not placed near the Critical instrument of the Station/terminal. These could include oil filled cloth, wooden supports, oil buckets etc. these must be put away and the areas kept permanently clean and free from any combustibles. Secondary fires probability would be greatly reduced as a result of these simple but effective measures.

Gas detector should be provided to the pump house as per OISD standards.

As per the OISD standards proper lighting arrangements and CCTV should be provided.

Safety Aspects for Pipeline

1. The pipeline will be physically patrolled by walk-through and drive through survey to ensure that there is no encroachment on the pipeline right of way. Moreover, during day to day operational and maintenance activities, company employees should be aware of all activities occurring around the pipeline and report such activities to the appropriate authorities.
2. Pipeline appurtenances like valves and meters should be painted to prevent atmospheric corrosion.
3. Pipeline marker signs should be placed where the pipeline crosses rivers, highways and major crossings. Line of sight of markers should be maintained
4. Nearby population along the pipeline route should be made aware of the safety precautions, to be taken in the event of any mishap due to pipeline.

7.20Proposed Safety System for TBPL (Main Spur Line)

Sectionalizing Valve Stations can be operated by local and / or remote operation through local control panel or pipeline SCADA system. Initial System Capacity would be developed based on initial requirement and available gas source and shall be augmented in phases synchronize with increase of demand and augmentation of sources.

Cathodic Protection

The underground pipeline shall be protected against corrosion to ensure its continued safe operation. Cathodic protection is an Electro Chemical Process for eliminating or mitigating corrosion of buried steel pipe and other metallic structures. It is not possible to lay the complete pipeline at a time, hence temporary Cathodic Protection will be provided for the laid portion of the pipeline. After complete erection of entire pipeline, Permanent Cathodic Protection system will be used.

The pipeline would be externally coated with a high quality three layered Polyethylene (PE) coating and provided with cathodic protection to ensure corrosion protection. Following specifications will establish the minimum requirements for detailed design of TCP & PC system and equipment.

Electrical System Requirement

The following Electrical equipment / system are envisaged in this project:

- Grid Power Source (with UPS backup) with Transformer Rectifier Unit (TRU)
- [AC Input DC Output] or CP Power Supply Module(CPPSM) [DC input DC Output].
- Anodes - for Temporary Cathodic Protection [TCP] Mg/Zn.
- Anodes - for Impressed Current Cathodic Protection (ICCP) for
- Permanent Cathodic Protection Mixed Metal Oxide [MMO] Single or String Anodes.
- Cables
- Polarization Cell [Solid state decoupling device]
- Half Cell Reference Copper Sulphate Electrodes - Permanent type
- Test Lead Points (TLP) A, B, C, D, E, DMV, DAC Type
- Insulation Mono Blocks
- Grounding Cell
- Junction Boxes [AJB & CJB]
- Surge Diverters
- Automatic [P-S-P] Recording Computerized Data loggers with Reading facility

7.21 Metering and Gas Quality Monitoring

Custody transfer metering Custody transfer flow metering will be provided before the gas is transferred to the end users. These metering stations will be identified as and when the Gas Transfer Agreement (GTA) with the end users is signed. The custody transfer metering system is based on AGA or equivalent standards. Flow meters along with flow computers will be considered for despatch stations and receiving station. The flow computers are connected with measurement device & pressure and temperature correcting equipment.

Flow computer shall calculate standard flow rate, Energy Flow Rate, super compressibility, calorific values etc. Metering system supplier will supply flow computer along with all required hardware's and software's, which will be installed in the field or metering panel depending upon the configuration. A gas chromatograph is located before the receiving station for the gas coming from various sources.For control room mounted Metering panel will have flow computer, printer, power supply unit, Barriers isolators, repeaters, other panel accessories etc. as required.

Gas Chromatographs

Gas Quality and composition may be measured by on line gas chromatographs. This chromatographs can be installed at either metering skids or any other suitable locations. The gas chromatographs provide an indication of gas gross heating value, specific gravity, and gas composition for use in calculating the energy flow in flow computers.

Supervisory Control And Data Acquisition (Scada) System

Pipeline process parameters will be monitor and controlled from SCADA system consisting of Dual Master control Station (MCS). SCADA system is envisaged to ensure effective and reliable control, management and supervision of the pipeline & the pipeline process parameters. The SCADA system shall accommodate remote control functions for actuated valves. SCADA System shall also accommodate data storage and trending for selected parameters. Control functions for actuated valves shall also be made available at local control panel installed at the stations. An emergency control room or redundant MCS is provided for use in the event of failure of the primary Master Control Room.

7.22 TELECOMMUNICATION SYSTEM

The proposed TCP/IP based telecommunication system / network will be comprised of the following:

- Optical Fiber based SDH Communications System (STM-1 expandable to STM-4), where SDH (STM-1) will form the backbone. The flat ring based on dual optical fibre pair, shall be formed with all the stations on gas pipeline. These STM-1 nodes will be configured as ADM-node. The
- ring is based on a sequential network topology with a redundant path. The proposed system will use the latest technological advancements in SDH networks such as Virtual Concatenation (VCAT) and Link Capacity Adjustment Scheme (LCAS). The equipment shall be upgradeable to STM-4 without any changes in the backplane.
- Direct dialling facility between the stations will be provided. The integration of these voice circuits will be made with new EPABX on the network.

- Optical Fiber Communication System: Provision of Voice communication at the stations through ordinary, digital and weather proof phones.

7.23 FIRE & GAS DETECTION SYSTEM

A fire detection system will be installed in rooms like electrical room, control room, battery room of the different stations along the pipeline network. Each system will consist of two different detection loops comprising of smoke detectors. The smoke detectors will be of ionization type in the first loop and optical type in the other for timely detection of fire.
Smoke detectors will be installed above the false ceiling in order to sense fire occurring in the electrical wiring and fittings etc. Since the smoke detectors above the false ceiling will not be visible, "these detectors will be fitted with remote Response Indicators located below the false ceiling, which will glow in the event of actuation of these detectors. On the alarming, two red flashlights located in the Control Room and in the guard room in sites and two hooter one inside and other outside will be actuated at the same time. A break glass unit will be installed at the exit door, outer side of the different rooms of the local control station for manual actuation of the fire alarm. Break glass unit(s) will be installed in the plant along the escape ways. When a detector will be in alarm condition, the information will be sent to the central unit and the same signal will be sent to SCADA through signal repeater, which will be supplied by Fire Detection system supplier. The alarm situation of the detector will remain on the detector itself and on the central unit until a separate manual reset device is activated on the central unit. An indicating LED will permit the direct identification of the detector that is the cause of alarm. The main control panel will derive its power from a 230V AC UPS, which will be converted to DC by the rectifier circuit inside the panel. The control panel will provide the required power to the sensors and accessories and will monitor the zonal circuits for open and short circuit faults as also various other parameters of the system. The control panel will also be provided with a secondary power source comprising two nos. of Maintenance free batteries, which automatically takes over the system in the event of AC power failure to the panel. Contacts used in intrinsically safe circuit will be gold plated. All electronic circuits used in the system will be free from the effects of any RF interference.
Fire detection panel will be wall mounted. Size of the panel as per the vendor standard. Fire detection system will be suitably hooked up with C02/FM 200 for auto/manual flooding in control room, electrical room battery room etc.

Gas Detection System

The system will consist of detection loops with gas detectors and their control units. Minimum two nos. open path and point gas detectors of IR absorption type will be provided for each GOOA, pig launcher/ receiver terminals, SV stations for hazardous area. The low and high gas concentrations and a failure/default state will be detected and signalized by the control unit. Entire single will be repeated through repeater/ relay and connected to RTU for providing the information to SCADA.

Gas detection system will consist of point detectors and one control unit.

Point gas detectors will be considered for metering station, filter, Pressure control valve system and tap-off node, SV and Despatch and receiving station. Point gas detectors will be "IR" type. Gas detection panel will be wall mounted. Size of the panel shall be as per the vendor standard.

7.24 APPROACH TO DISASTER MANAGEMENT PLAN

Several agencies of the Government, both at the Central and State levels, such as the Directorate of Explosives, the Inspectorate of Factories and Port and Transport Authorities are entrusted with the responsibility of ensuring safe handling and management of hazardous chemicals under acts and rules made for the purpose. In spite of these measures, the possibility of accidents cannot be ruled out. Human errors and mechanical, electrical, instrumental or system failures have, on occasions, led to severe disasters. Accidents occurred at Bhopal, Mexico and other parts of the world have made people concerned with the dangers of chemical accidents. Occurrence of such accidents makes it essential that the Central and State Governments as well as the local authorities are fully prepared to mitigate the sufferings and meet the eventualities resulting from any unfortunate occurrence of chemical accidents in our country. Disaster Management Plan (DMP) can be extended for the proposed facility also for TBPL.

Objectives

The worst case scenario for this facility will be of the Flammable material release. The maximum Fire effect can be controlled with the precautionary measures like Hydrant system, Fire extinguishers, Protective and use of water. Emergency planning plays important role to tackle the emergency due to the accidental release of Hazardous Materials. DMP delineates an approach to detail organizational responsibilities, actions, reporting requirements and support resources available to ensure effective and timely management of emergencies associated to production and operations in the site. DMP has been prepared with the following objectives after the due consideration of effective distances computed in consequence analysis of chapter 3.

1. Ensure safety of people, protect the environment and safeguard commercial considerations
2. Immediate response to emergency scene with effective communication network and organized procedures
3. Obtain early warning of emergency conditions so as to prevent impact on personnel, assets and environment
4. Safeguard personnel to prevent injuries or loss of life by protecting personnel from the hazard and evacuating personnel from an installation when necessary
5. Minimize the impact of the event on the installation and the environment, by:

Minimizing the hazard as far as possible

Minimizing the potential for escalation

Minimizing leak or rupture scenarios

To provide guidance to help stack holders take appropriate action to prevent accidents involving hazardous substances and to mitigate adverse effects of accidents that do nevertheless occur. Following figure shows effect of loss of containment from the process