RISK ASSESSMENT FOR THE DEVELOPMENT OF BULK LIQUID BERTH FOR HANDLING LNG AT KARAIKAL PORT

FINAL REPORT- REVISED AFTER PUBLIC HEARING

PROJECT CODE: 484061314

For

KARAIKAL PORT PRIVATE LIMITED (KPPL)
KARAIKAL

November 2016

INDOMER COASTAL HYDRAULICS (P) LTD.

(ISO 9001 : 2008 CERTIFIED AND NABET-QCI & CDC - MoST ACCREDITED)

63, GANDHI ROAD, ALWAR THIRUNAGAR, CHENNAI 600 087.
Tel: + 91 44 2486 2482 to 84 Fax: + 91 44 2486 2484
Web site: www.indomer.com, E-mail: ocean@indomer.com

TERRESTRIAL EIA & EMP

ADITYA ENVIRONMENTAL SERVICES PVT. LTD.
REG. OFFICE: 107, HIREN LIGHT INDUSTRIAL ESTATE,
MOGUL LANE, MAHIM, MUMBAI-16.
Tel: 24456473/24453998 Fax: 022 24459609
E-mail: adityaenviro@vsnl.com

RISK ASSESSMENT

ROOTS EHS ADVISORY
201, GOKULESH, 5 GOKULESH SOCIETY,
VASNA TAKAT NAKA, VADODARA,
GUJARAT - 390021

INDOMER COASTAL HYDRAULICS (P) LTD.
(ISO 9001 : 2008 CERTIFIED AND NABET-QCI ACCREDITED)
63, Gandhi Road, Alwar Thirunagar, Chennai 600 087.
Tel: + 91 44 2486 2482 to 84 Fax: + 91 44 2486 2484
Web site: www.indomer.com , E-mail: ocean@indomer.com

Client	:	Karaikal Port Private Limited, Karaikal.
Project Title	:	Risk Assessment for the development of bulk liquid berth for handling LNG at Karaikal Port.
Project Code	:	484061314
Abstract	:	Karaikal Port Private Limited (KPPL) is an all-weather Port developed by MARG Group on Build, Operate and Transfer format under Public Private Partnership in terms of the concession awarded by the Government of Puducherry. The Port is in operation since 2009 and it handled over 32 Million Tonnes of various cargoes including Liquid Petroleum. Presently KPPL is planning to set up a liquid cargo berth to handle LNG on the southern side of the Port basin. This report presents the details of the Risk Assessment and Disaster Management Plan of the development of Bulk liquid cargo berth for handling LNG adopting Floating Storage Regasification Unit (FSRU)/ Storage Unit (FSU).
Foreword	:	
Document type	:	Controlled
References	:	W.O. No: KPPL/SWO/04/2013 dt. 26.07.2013

Date	Report Type		Originator	Checked by	Approved by	Approver's sign
09.11.16	Revised final		V. Vaigaiarasi	Mr. K. Dharmalingam	Dr. P. Chandramohan	
09.07.15	Draft		A.P.Anu/G.Yogaraj	Mr. K. Dharmalingam	Dr. P. Chandramohan	
01.10.15	Final	√	A.P.Anu/G.Yogaraj	Mr. K. Dharmalingam	Dr. P. Chandramohan	

1	Project Code	:	484061314	Text pages	:	39
2	File location	:	2015 Projects/Nov 16/484. Karaikal Port	Tables	:	1
				Figures		-

CONTENT **Page**

LIST OF TABLES

Table

1. INTRODUCTION

Risk Assessment (RA) is a method that has proven its value as an all-round tool for improving the safety standards prevalent in every hazardous industry. With advancements in in-built and inherent safety systems, accidents rates have come down, but still persist at unacceptable levels for newer technology, new plants and chemical handling facilities. RA is a structured safety assessment tools designed for high hazard industries such as chemical, petrochemical, pesticides, pharmaceuticals, sea ports, etc., supplementing other safety systems tools such as HAZOP, safety audit, and regular incident analysis to identify the potential for incidents (near-misses, unsafe conditions) and to evaluate the necessary control measures.

1.1. Objectives of Risk Assessment

The objectives of RA can be summarized as follows:

- Assessing risk levels due to the operations of the facility
- Identification of the risk mitigation measures to bring the potential risk within acceptable range
- To suggest general safety improvement measures.
- To help generate maximum accident free mandays.
- To identify emergency scenarios and suggest mitigation measures.

The underlying basis of RA is simple in concept. It offers methods to answer the following five questions:

1. What are the risks?
2. What are the causes of risks?
3. What are the consequences of risks?
4. What is the probability of the risk causing events?
5. Whether the risk is at acceptable level ?

1.2. Philosophy behind Risk Assessment

Risk is the unwanted consequence of an event or series of events. Risk occurs when multiple risk causing factors occur at the same time causing an accident manifesting in an event like a fire or explosion. Certain risks are generally accepted as part of the industrial operations, while other low-frequency, high consequence risks attract statutory attention and are regarded unacceptable to local public.

The influence of various factors on the public perception of risk are summarised below.

Sr.	Factors influencing public perception	Descrip
1	Control	People are more willing to accept risks they impose upon themselves than to have risks imposed upon them.
2	Dread and scale of impact	Fear is greatest where the consequences of risks are likely to be catastrophic rather than spread over time.
3	Familiarity	People appear to be far more willing to accept risks that are familiar rather than new risks.
4	Timing	Risks are more acceptable if the risk consequences are immediate or short-term, rather than delayed consequences.
5	Social amplification & attenuation	Concerns are increased if media coverage or graphic depiction of events is there, reduced if there is economic hardship.
6	Trust	If public trusts policy makers, public trusts regulators or industry as being honest, admit mistakes and limitations and one who take into account different views, then public is more likely to place credibility in them.

Source: British Parliamentary Office of Science and Technology – "Safety in Numbers - Risk Assessment and Environment Protection"

The need for communicating acceptable risks is very important. Though setting acceptable criterion for use in Quantitative Risk Assessments may often lead to disagreement between parties, nevertheless sound techniques and methods have led to the definition of acceptable levels of risks taking into account the need of people to feel safe in their day-to-day activities.

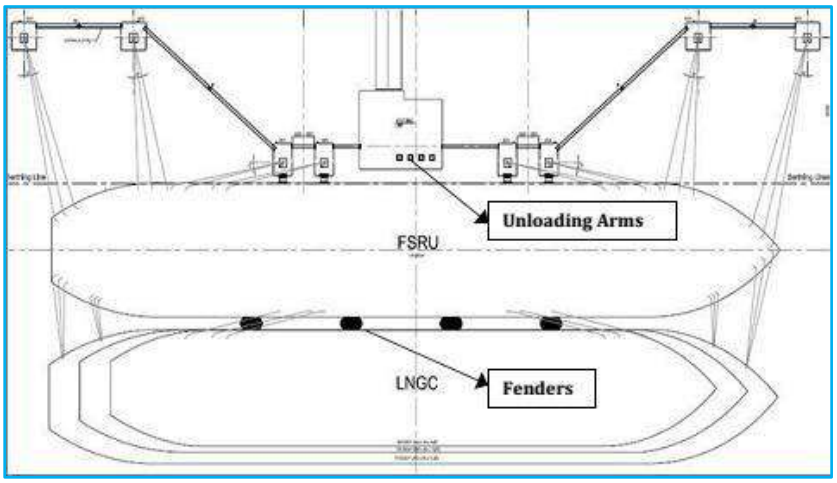
A RA should therefore, be seen as an important component of any or all on-going preventive actions aimed at minimising and thus hopefully, avoiding accidents.

Re-assessments should therefore follow at regular intervals, and/or after any changes that could alter the hazard, so contributing to the overall prevention programme and disaster management plan of the project.

1.3. Statutory Requirement, Coverage of the Risk Assessment

An LNG Terminal of 05 MMTPA capacity has been considered for the RA, with a Floating and Storage Unit and jetty deck based Regassification and Sendout Unit (FS-R-U). The RA covers operations of the Port within the battery limit of the proposed LNG terminal. As Loss of containment scenarios of LNG/natural gas and consequent hazards are possible only on the above-ground segment of the pipeline carrying NG within the Port battery limit, the RA includes the above-ground, Port-ward side of NG pipelines up to the Sectionalizing and Metering Station in the battery limit for the RA.

Schematic arrangement of the proposed jetty/FSU



and NG qualify as '*Hazardous*' by virtue of listing in the Schedule 1, Part I and/or II of the Manufacturing Storage and Handling of Hazardous Chemicals Rules, 1989 (amended 2000), (MSIHC Rules) therefore have been considered for consequence analysis for RA.

The Project *inter alia* attracts application and compliances under following statutes relevant to port and personnel safety:

i) Manufacture, Storage and Import of Hazardous Chemicals (Amended) Rules, 2000

ii) Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996

iii) Petroleum Act, 1934, Petroleum Rules, 2002

The RA also discusses risks due to vessel collision and grounding and risks due to fire and explosion of hazardous cargo in the vessels within the notified Port limit/administrative limit of the proposed Port.

The DMP covers emergency response of the Port during natural hazards and hazards due to release and compound consequences of hazardous chemicals. The RA is prepared to address the following two ToR points as issued by EAC:

i) ToR No. 4 – "Submit details of Risk Assessment, Disaster Management Plan including emergency evacuation during natural and man-made disaster like floods, cyclone, tsunami and earth quakes, etc.", and

ii) ToR No. 5 – "Submit details of safety aspects associated with handling of LNG vis-a-vis other cargo in other facilities within the port", and

iii) ToR No. 6 – "Submit details of storage and regasification, distribution network, etc. and vulnerability of human habitation vis-a-vis LNG associated risks"

1.4. Methodology of Risk Assessment

The risk is measured usually by various screening techniques that vary from one technique to another. No single risk measure is sufficient for conveying all the possibilities and combinations in process risks. The basic methodology adopted for risk assessment is generally based upon the nature of the hazard, the basic need for conduct of risk assessment and the information and resources available for such risk assessment.

Table 1.1. Possibility and severity of Risk

Probability of Occurrence	Severity of Occurrences			
	Major	Significant	Minor	Incidental
Frequent (Incident may occur on annual basis or more)				
Occasional (Incident may occur several times during facility life)				
Seldom (Incident may occur once during facility life)				
Unlikely (Given current practices and procedures, incident is not likely to occur at this facility)				

SEVERE	HIGH	MODERATE	LOW

The following illustrates the detailed philosophy of the classification of incidence severity.

MAJOR INCIDENTS:

- Personnel: Fatality or permanently disabling injury
- Community: One or more severe injuries
- Environmental: Event having serious on-site or off-site impact, results in off-site agency involvement and a major fine, serious negative public health or financial impacts, major local negative media coverage, international negative media coverage.
- Facility: Major or total destruction to process area(s)

SIGNIFICANT INCIDENTS:

- Personnel: One or more severe injury
- Community: One or more minor injuries
- Environmental: Event having significant on-site or off-site impact and requiring prompt agency and corporate notification, serious negative public impact or perception, significant local negative media coverage, a fire is likely.
- Facility: Major damage to process area(s)

MINOR INCIDENTS:

- Personnel: Single injury, not severe, possible lost time
- Community: Odour or noise complaint from public
- Environmental: Event results in agency reporting or consent violation, minor negative public impact or perception, little or no local media coverage, a fire is not likely
- Facility: Some equipment damage

INCIDENTAL INCIDENTS:

- Personnel: Minor or no injury, no lost time
- Community: No hazard to public, no public complaint
- Environmental: Environmental event with no agency involvement or consent violation, no negative public impact or perception
- Facility: Minimal equipment damage

Another RA method generally used for the classification of incidence and used for Risk Analysis is the NIOSH method. The NIOSH method gives in brief the methodology and the Hazard Risk Matrix to assess the risks posed by use of hazardous substances and operations.

Methodology of the NIOSH method is summarized as follows:

- List of all possible hazards that exist in the study area.
- Assessment of all the possible hazards that exist in the study area
- Selection of the identified hazards for consequence analysis
- Consequence analysis of the identified areas.

The Hazard Risk Matrix is a useful tool to accord a risk rating for each hazard identified in terms high, medium or low. The Hazard Risk Matrix is illustrated below. The terms *Hazard* refers to a situation that has damage potential, *Probability* is the likelihood that the particular hazard will lead to damage, *Severity* is an estimation of how serious will be the manifestation of the damage.

Hazard Risk Matrix

1. Hazard : _____

2. Potential Location : _____

_____

_____

_____

Probability	Severity		
	Low	Medium	High
Low			
Medium			
High			

Notes (if any)

3. Area in which potential location(s) exists:

4. Date:

2. VULNERABILITY PROFILE OF THE PORT

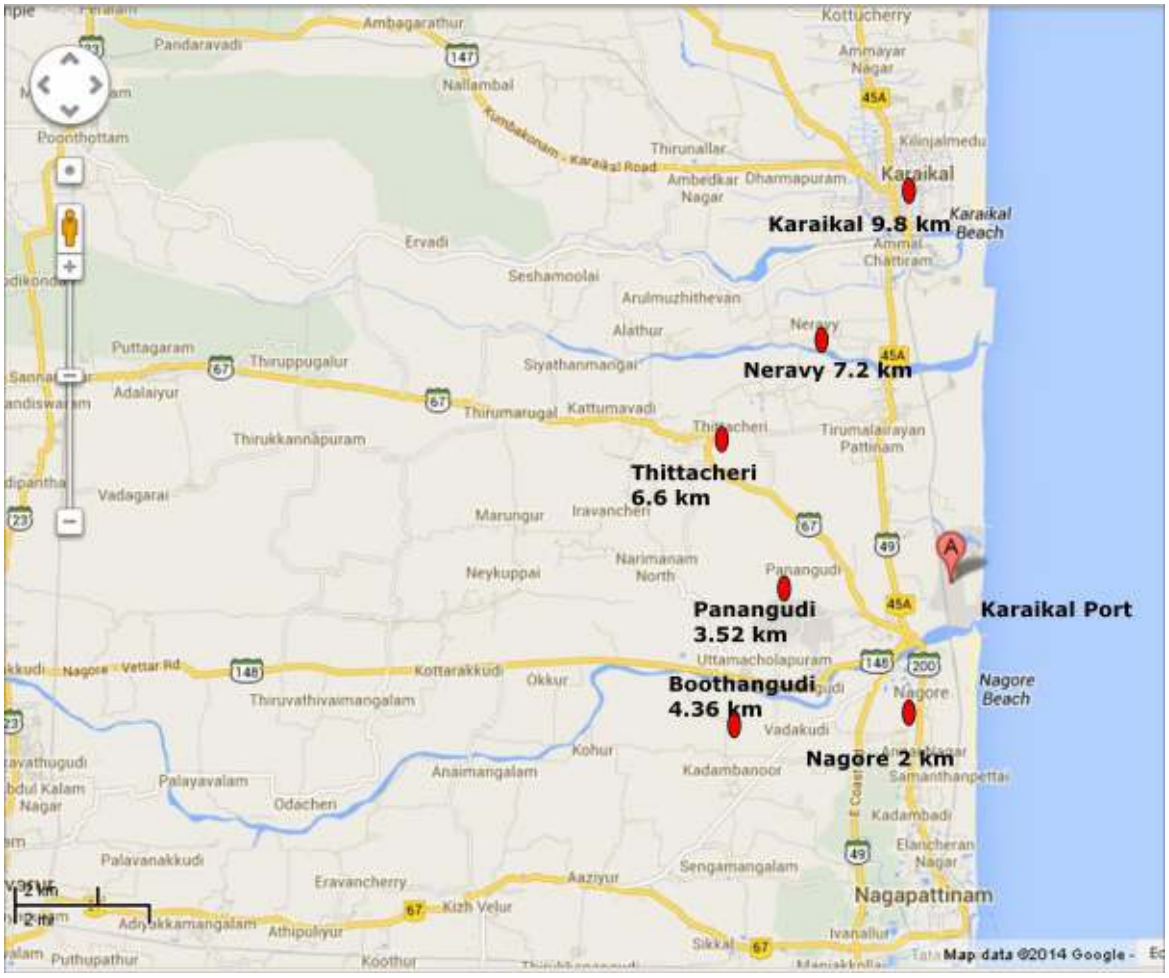
2.1. Project Site

The Port is located near Keezha Vanjore village, Karaikal, UT of Puducherry, about 10 km south from the Karaikal City. The Port site is bordered by Kaveri river in the south. Siting features of the Port are given below. General siting features within 10 km of the Port site is shown below.

Siting Features of the Port

Sr.	Feature	Distance, approx, (Km)	Direction
1	Karaikal City (Approx. centre of city to approx. centre of the Port)	9.8	N
2	Karaikal City (Approx. margin of city to margin of the Port)	7.7	N
3	Nagore Railway Station (Southern Railway – Chennai Madurai trunk route)	2.0	S
4	Tiruchirappali Civil Airport	138	W
5	Channai International Airport	298	N
6	NH 45A (Villupuram to Nagapattinam)	3.9	NW
7	NH 49 (Chennai to Nagapattinam)	1.5	W
8	NH 67 (Nagapattinam to Gundlupet)	2.1	W
9	SH 148 (Nagore to Vettur)	2.4	SW
10	Nagore town	2.6	S
11	Boothangudi village	4.4	SW
12	Panangudi village	3.5	W
13	Neravy village	7.3	NW
14	Pravadenar river	4.5	N
15	Vettar river	1.4	S
16	Abhirami Amman temple, Thirukadaiyur,	25	N
17	Lord Singaravelavar Temple, Sikkal	14	S
18	The Church of Basilica of Our Lady of Good Health, Velankanni	18 km	S
19	Nagore Dhargah	3.1	S
20	Indira Gandhi National Park and Wildlife Sanctuary	303	SW
21	Guindy National Park, Chennai	243	N
22	Vedanthangal Bird Sanctuary	186	N

General Siting Features of the Port



2.2. Site Meteorology

Meteorology of a site plays an important part in its natural hazard vulnerability and dispersal characteristics in case of loss of containment of any hazardous material. The consequences of released toxic or flammable material are largely dependent on the prevailing weather conditions. For the consequence analysis of major scenarios the most important meteorological parameters are wind speed, atmospheric stability and temperature as they directly affect the atmospheric dispersion of the escaping material. Rainfall does not have any direct bearing on the results of the consequence analysis; however, it can have beneficial effects by absorption/washout of released materials. Actual behaviour of any release would largely depend on prevailing weather condition at the time of release.

Climate

Karaikal has Tropical Dry and Wet climate according to Köppen-Geiger climate classification system. Karaikal experiences small daily range of temperature and moderate rainfall.

Rainfall

Karaikal has an annual average rainfall of about 126 cm, 68 percent of which occurs during October to December. The amount of rainfall during the south-west monsoon period is small, being less than 20 per cent of the annual. November is the rainiest month, accounting for about a third of the annual total.

Temperature

The level of temperatures in Karaikal is about the same as in Poducherry. December and January are the coolest months with the maximum temperature at about 28° C and the minimum at about 23°C. However, minimum temperature as low as 16°C have been recorded.

Humidity

The level of humidity and the pattern of cloudiness and surface winds are the same as in Poducherry. Although slight variations in the month wise occurrence of depressions and storms are noticeable, thunder-storms generally occur during April to November, particularly in April, September and October.

Wind

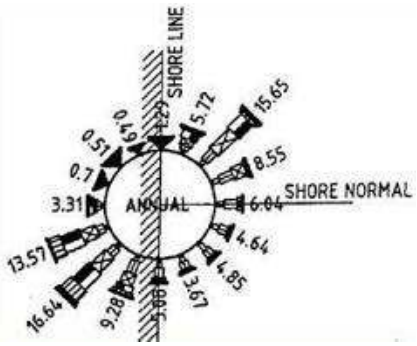
Average wind conditions at the Port are shown below.

Average Wind Conditions at Karaikal

Month	Direction	Avg. Speed (Km/hr)
January	N, NE	18.3
February	NE, E, SE	15.9
March	NE, E, SE	14.2
April	E, SE	13.8
May	S, SW, W	12.7
June	S, SW, W	12.8
July	S, SW	11.7
August	SE, S, SW, W	10.6
September	SE, S, SW, W	9.9
October	SW, W, NW, NE	8.9
November	N, NE, NW	13.8
December	N, NE	14.0

Wind direction is predominant from the West South-West direction during the south west monsoon and North-East direction during North East monsoon. Windrose of Karaikal is given below.

Annual Windrose of Karaikal



Karaikal experiences average wind velocity between 2.7 m/s to 4.2 m/s.

Atmospheric 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 emitted into it 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 will vary from time to time and from place to place. The atmosphere is said 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 such 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 nighttime sky cover have been identified as prime factors defining these stability categories. Table presented below indicates the various Pasquill stability classes.

Pasquill Stability Classes

Surface Wind Speed (m/s)	**Day time Solar Radiation**			**Night time Cloud Cover**		
	Strong	**Medium**	**Slight**	**Thin <3/8**	**Medium 3/8**	**Overcast >4/5**
< 2	A	A – B	B	-	-	D
2 - 3	A - B	B	C	E	F	D
3 – 5	B	B – C	C	D	E	D
5 – 6	C	C - D	D	D	D	D
> 6	C	D	D	D	E	D

Legend: A = Very unstable, B = Unstable, C = Moderately unstable, D = Neutral,
E = Moderately stable, F = stable

As the D Neutral and F Stable states of the atmospheres pose greatest hindrance to dispersal of any chemical by advection by natural atmospheric dynamic processes, these stability classes are assumed for consequence analysis for the purpose of conservativeness. Possibility of occurrence of stability class D Neutral, E Moderately stable and F Stable are rare at Karaikal owing to wind speeds generally being lesser than in 5-6 km/hr during day

time. Neutral to Stable atmospheric condition may be possible during night time in the monsoon months with overcast skies.

2.3. Vulnerability Profile of the Port

Following aspects of the Port may create threat to safety and wellbeing of the Port infrastructure and life of the people working in the Port and those residing in the vicinity of the Port. A qualitative scoping assessment of the hazards has been presented in Table below.

Vulnerability Profile of the Port

S. No.	Hazard	Cause	Effect	Mitigation
1	Earthquake	Geo-tectonic	Building and marine structure failures - Onsite effects, low casualty potential	a. Construction in accordance with applicable Codes b. DMP
2	Wildfire	Causative factor not present		
3	Tsunami	Geo-tectonic, Oceanographic	Marine structure failures, inundations, loss of hazardous cargo, offsite impacts, high casualty potential	a. Construction in accordance with applicable Codes b. DMP
4	Mud/landslide	Causative factor not present		
5	Dam failure	Causative factor not present		
6	Riverine Floods	Possibility of high flow in the rivers on north and south of the Port possible only in conjunction with Cyclone induced rainfall		
7	Cyclone	Meteorological	Blow away of structures, cargoes and secondary losses, low casualty potential	a. Construction in accordance with applicable Codes b. DMP
8	Flash Floods	Not likely		
9	Thunderstorm and lightening	Not likely		
10	Volcano	Causative factor not present		
11	Extreme weather conditions	Out of purview of Port Intervention		
12	Major Industrial accident/industrial disaster/nuclear disaster	Causative factor not present , out of purview of Port Intervention		
13	Fires (Casue and effect limited and localized to solid cargo handling sections of the existing Port operations)	Spot fire in coal stockpile	Localized effect, economic loss, no casualty potential	a. Sprinkling of water b. Fire fighting system c. SOP d. DMP

S. No.	Hazard	Cause	Effect	Mitigation
		Fire in POL/Hazardous cargo (due to pipeline failures)	Localized effect, economic loss, no casualty potential	a. Design engineering b. Fire fighting system c. SOP d. DMP
		Fire in bulker fuel	Localized effect, no casualty potential	a. SOP b. DMP
		Fire in Fertilizer/FRM	Localized effect, economic loss, no casualty potential	a. SOP b. DMP
14	Explosion	Dust explosion in coal	Localized effect	a. Design engineering b. SOP
15	Toxic release	Liquid Chemical cargo	Localized to medium spread (onsite) effect, casualty potential low	a. Design engineering b. SOP c. DMP
16	Terrorist/disruptive activity	Low likelihood		Port security

2.4. Vulnerability Profile of the Site with respect to Natural Disasters

Sea ports are vulnerable to natural hazards of ocean geo-tectonic and meteorological origins by being the first to bear their brunt. Ports absorb the forces of nature and act as shield for population immediately in their landward shadow, though facing losses due to damage of infrastructure and cargo, disrupted operations and other commercial losses.

Natural Hazard classification of the Project has been carried out in accordance with the Munich Re database of natural hazards. Munich Reinsurance Company Limited (Munich Re) is a leading International Reinsurer which has collected and analysed precise natural disaster data of about two centuries in addition to credible historic records of natural disasters for classification of the world into hazard proneness and exposure ratings. The authoritative database is used by insurance companies worldwide to assess natural hazard risks of projects in specific geographical locations and decide upon the insurance premium amount.

Following natural hazards relevant to the proposed Port have been ranked on the scale of respective severity for the Karaikal region:

A. Earthquake
B. Storm/Cyclone
C. Lightening
D. Flood
E. Tsunami

A. Earthquake

According to Munich Re Earthquake classification, Karaikal falls in the Zone 2 – MM VII which is rated medium. The location falls in earthquake zone II as per IS 1893.

The Port construction will take into account structural stability of the onshore and offshore structures so that they may withstand a high intensity earthquake during construction phase. Port structures will be designed in accordance with IS 1893: Part 1 2002 - Criteria for Earthquake Resistance Design of Structures. Construction activities will be based on technically evaluated and certified plans by established and authorised consultants. Action to be taken during an earthquake has been spelt out in Disaster Management Plan.

2.5. Disaster Management Plan for Storm and Tsunami

This section describes the possibility of occurrence of Cyclone and the related high wind speed, the expected storm surge along the coastal region due to the passage of Cyclone and also the impact in case of occurrence of Tsunami. The possible intensity of occurrence, impact on the coastal form and people, the risk assessment and the Disaster management plan are enumerated.

2.5.1. Storm surge

Occurrence of storm is a common phenomenon in Bay of Bengal during Northeast monsoon particularly in October and November. The region selected for the development is prone to cyclone and storm surges. Based on the data published by IMD in, '*The tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea-1877 to 2013*', ninety nine storms had occurred in the vicinity. The occurrence of cyclones is more frequent in the month of

November followed by October (Table 14.3). If a cyclone with an intensity of 180 kmph develops near the project region it will be followed by heavy wind and continuous rain, in such case the storm surge will be around 1.5 m. The rise in water level combined with high tide period and flood discharge due to heavy rain fall will flood the areas having elevation < 3 m MSL.

Storm surge and the associated effect during the storm

If a cyclone approaches the project region, it will be followed by heavy wind, incessant rain, coinciding with the high tide time, flooding from catchments and the storm surge causing the rise in water level on low lying areas and draining basins.

In addition, during the event of storm, high waves approach the coast and break. The heavy rainfall causing huge flood in the river as well as the opening of inland dams/reservoirs will cause stagnation of flow and inundation leading to killing people and damaging the coastal properties. For e.g., during the disastrous Cyclones like Andhra Pradesh Cyclone (November, 1977), Odisha Cyclone (November, 1999) and Rameswaram Cyclone (December, 1964),

thousands of people were killed and there was a huge damage to the coastal properties.

The characteristics of tropical disturbances and the maximum surge heights recorded along the east coast of India are given below:

Characteristics of Tropical disturbances

Tropical disturbances	Wind Speed	
	knots	kmph
Low pressure	< 17	< 31
Depression	17 – 27	32 – 50
Deep depression	28 – 33	51 – 60
Cyclonic storm	34 – 47	61 – 89
Severe cyclonic storm	48 – 63	90 – 119
Severe cyclonic storm with a core of hurricane winds	64 – 119	120 – 221
Super cyclones	≥ 120	≥ 222

Source: IMD, Pune.

2.5.2. Tsunami

Tsunami is a series of wave train generated in the ocean by a hydraulic impulsive force that vertically displaces the water column. Earthquakes, landslides, volcanic eruptions, explosions and even the impact of cosmic bodies taking place in the ocean can generate Tsunami waves with long periods (≈30 min), long wave length (≈ 100 km) with a high velocity of propagation (≈700 km/hr).

Tsunamis are shallow water waves which propagate with phase velocity equal to the square root of the product of the acceleration due to gravity and the water depth. For example, in the Pacific Ocean, where the typical water depth is about 4000 m, the Tsunami wave travels at about 700 km/hr. Because the rate at which the wave loses its energy is inversely related to its wave length, Tsunami not only propagates at high speed, but it can also travel great transoceanic distances with limited energy losses and reach different continents in shorter time i.e., the energy propagating with a Tsunami waves remain nearly constant.

Among the various factors causing the occurrence of Tsunami, the large vertical movements of the earth's crust is more predominant and it can occur at tectonic plate boundaries. The plates that interact along these boundaries are called faults. Around the margins of the faults, the denser oceanic plates slip under the continental plates in a process known as subduction. Such subduction earthquakes are particularly very effective in generating the devastating Tsunamis.

The energy flux due to Tsunami is proportional to its velocity of propagation and height and it remains nearly constant till it reaches the coast. Consequently, the velocity of propagation gets retarded when it enters shallower water and its height gets amplified. Because of this shoaling effect, the Tsunami that is imperceptible at deep ocean close to centimetre height may rise up to several metres near the coast called run up.

When Tsunami finally reaches the coast, the crest of the wave appears as rapidly risen water mass gushing into the coastline as a bore with a crashing velocity of 50 km/hr for more than

10 - 30 min. The trough of the wave will appear as the withdrawal of water mass with same speed back into the ocean swallowing everything on the land and dragging back into the ocean.

Possible intensity of Tsunami: In worst case, if a Tsunami occurs due to the movement of Andaman and Indonesian plate then there will be surging of Tsunami waves with a speed of > 60 kmph into the shore and the run-up will be > 4 m. The gushing of water will sweep and flood the areas having elevation < 3 m MSL.

The occurrence of a Tsunami along the Indian coast is an extremely rare event with a very low frequency of less than once in 500 years. No reliable historical records of occurrence of Tsunami events and their impact along the Indian coast are available because of its exceedingly rare nature.

One worst tsunami event was witnessed on 26th December 2004 along the Tamilnadu coast, and the water level rise due to this Tsunami along the coast near the project region was around 2.5 m. The backshore in the project region was low and flat and hence the runup of Tsunami has intruded to a longer distance till the East Coast Road.

From the records of tide gauge data during the 2004 tsunami event, the number of high tsunami waves at different places along the coast was observed to vary between 3 to 5 waves with an average period of nearly 2 hours. Eye witness accounts say that each high tsunami wave that approached the coast was like a solitary surging / tidal bore wave, and the rise in water level near the coast due to such surging wave existed only for a short duration of nearly 30 minutes.

2.6. Disaster Management Plan

Cyclone, Tsunami and Storm surge are the most destructive forces among the natural devastations. It causes instant disaster and burial of lives and destruction to entire coastal properties. The damage and loss can be minimized if appropriate preparedness plan is

formulated. The following statutory guidelines are recommended by National Disaster Management Authority (NDMA) to minimize the impact due to Cyclone, Tsunami and storm.

- Developing sand dunes along the coast with shrubs or Casuarina trees for stabilization of the sand dunes (Tsunami Mound).
- Raising the ground level (above the design water level) with natural beach sand so as to rehabilitate the coastal region.
- Development of coastal forest (green belt) by planting casuarinas and coconut trees along the coastline to cover minimum of about 500 m width of the beach.
- Adopting natural beach nourishment to create steep beach face.
- Creation of sandy ramps at close intervals along the coast.

In addition to the guidelines by NDMA, it is also necessary to adopt various preventive actions in the coastal region of the project site.

Preparedness Plan

The preparedness plan shall contain details about: i) warning that should be given ii) Protective measures to contain the effect of surging water level and iii) Other precautionary measures to be taken. The following measures are the key aspects in the preparedness plan.

i) Coordination with International and National Agencies
ii) Vigilant online monitoring
iii) Emergency Evacuation

2.6.1. Coordination with International and National Agencies

<u>International:</u> Following a series of Tsunamis that hit Japan and North America, an international Tsunami warning network was put in place in 1960s in regions around the Pacific Ocean. This network is administered by National Oceanic and Atmospheric Administration (NOAA), USA. NOAA comprises of hundreds of seismic stations worldwide, which can detect earthquakes that are precursors to Tsunami. This network also includes coastal tide gauges that detect local changes in sea level and sophisticated **DART Buoys** (Deep

Sea Assessment and Reporting of Tsunamis buoys) in the Pacific basin, capable of detecting even a centimetre change in water depths in ocean. DART was introduced in 2003. This system consists of a pressure sensor anchored to the sea floor and a surface transmitter. When potentially dangerous seismic activity is detected, the network of DART buoys will detect the small change in the sea level.

Tsunami waves do not induce high surface elevation in Deep Ocean and hence their presence is not felt in Deep Ocean until they reach the shallow water close to coast. If any small yet potentially significant sea level change is noted following a seismic activity, the data are transmitted acoustically to the surface buoys and relayed by satellites to the warning stations. Computer modelling converts the data into a prediction of potential damages for the use of the members of the network.

National: After the 2004 Tsunami affected the Indian sub continent, the following organizations are involved on watch and cautioning the government and public in the event of possibility of occurrence of Tsunami. As a part of Tsunami hazard mitigation, warning systems have been established in India by the coordination of the following organizations.

i) Indian National Centre for Ocean Information Services (INCOIS), Hyderabad.
ii) National Disaster Management Authority (NDMA), New Delhi.
iii) Indian Meteorological Department (IMD), New Delhi.
iv) National Institute of Ocean Technology (NIOT), Chennai.

The contact details of International and National agencies are given below:

Organization	Address	Email ID	Contact Number
INCOIS	Ocean Valley, Pragathi Nagar (BO), Nizampet (SO), Hyderabad - 500090	www.incois.gov.in	+91 - 40 - 23895002
NDMA	NDMA Bhavan, A-1 Satdarjang Enclave, New Delhi, DL 110029.	www.ndma.gov.in	+91 - 11 - 26701700
IMD	Mausam Bhavan, Lodi road, New Delhi, DL 110033.	www.imd.gov.in	+91- 11 - 24699216

NIOT	Velachery – Thambaram main Road, Narayanapuram, Pallikaranai, Chennai 600100.	www.niot.res.in	+91 - 44 - 66783300
NOAA	1401, Constitution Avenue, NW. Room 5128, Washington,USA. DC 20230	www.noaa.gov	-
Andaman Nicobar Administration	Andaman & Nicobar Administration o/o secretary (GA), Secretariat, Port Blair.	webmaster.and@nic.in	+91- 3192 - 236572

INCOIS in collaboration with NIOT has deployed DART buoys at 3 locations in the deep ocean along the fault plane of Andaman plate and Indonesian plate. The data transmission system has been effectively linked through satellite with 24 hours online monitoring at NIOT, Chennai.

The online monitoring is capable of raising alarm in case of instantaneous change in surface elevation exceeding centimetre which can be caused by the generation of Tsunami. IMD interacts with the above institutions and takes the responsibility of broadcasting the disaster through various Medias. In case of a Tsunami, the warning is usually broadcast based on the earthquake occurred in the nearby ocean. Irrespective of *definite occurrence* of Tsunami, the *possibility to occur* is also considered as equally vulnerable and accordingly the warning news is instantly flashed through Radios and TVs. The notification is followed by orders from the local Government Authorities on reinforcing evacuation, prohibition to enter the demarcated risky zone and mobilizing facilities for easier evacuation and augmenting medical facilities.

There are a variety of evacuation notification systems in case of Cyclone, Tsunami and Storm surge. They include sirens, weather radio, Emergency Alert System, Telephones, Emergency Weather Information Network etc. In each system, it should be noted that the application and message is consistent as well as continuous with repetition of messages with periodicity

at short time interval. It should be ensured that the warning reaches immediately to all people prone to the devastation.

2.6.2. Vigilant online monitoring

The time at which the cyclone, storm surge or Tsunami may reach the coast can be predicted with sufficient lead time. The destruction can be minimized if the coastal populations are warned and evacuated to elevated place and inland in time. Therefore keeping vigil on the warning is the very important aspect in protecting the lives.

PPGC should have an agreement with NIOT/INCOIS/IMD by enrolling themselves as the potential users. Live contact should be kept with the organizations indicated above to transmit the instant warning on occurrence of cyclone, Tsunami and storm surge. A vigilant team must be created and they should be deputed to the above organizations to attend the training programs and to understand the method of monitoring and the kind of emergency preparedness. The vigilant team must monitor the warning systems around the clock.

The vigilant team should have proper knowledge about the warning systems and should have attended the training programs conducted by the Tsunami warning centres. The training should be given periodically to update the system and methods of warning. The team should take the responsibility of giving immediate warning to the people in and around the power plant in case of Tsunami and they have to undertake the Emergency Preparedness Action. Safety drills should be conducted periodically.

Operational and emergency preparedness procedures should be planned meticulously in order to act on the warning and to disseminate it rapidly and effectively to the public.

2.6.3. Emergency Evacuation

Evacuation of people from risk areas is the first priority when early warning is received or the natural warning sign indicates the immediate arrival of cyclone, Tsunami wave or rise of storm surge.

Evacuation plan describes the time span available before and during the Tsunami or storm surge event. When facing local threat, evacuation procedures most possibly will have the character of a 'runaway effort' and people should not expect to receive much institutional support. The primary objective should be bringing as many people as possible out of the reach of the wave's impact to safe or 'relatively safe' areas. Therefore necessary steps have to be taken in advance to enable and support the community at risk to protect themselves at any time.

2.6.4. Mitigation against Tsunami and storm

Although the impact of Tsunami and storm is disastrous, the impact can be minimized by adopting the key components of mitigation measures. It was noticed during December 2004 Tsunami that the places located behind the highly elevated dunes, forest department planted Casuarina tress, dense plantations, Mangrove forests, offshore coral reefs, long salt pan heaps etc., were considerably protected. These areas experienced very low damage without causing death of the people. The kinematic energy of the Tsunami waves riding into the land gets dissipated due to these natural barriers. Thus the nature gives the scientific understanding of preparing the energy dissipating obstruction on the shore that can greatly protect the people and property against Tsunami.

The mitigation measures to be taken normally vary according to the local site conditions. Accordingly, in general case, the following mitigation measures are seen to be effective for the proposed project:

i) Bio Shield
ii) Construction of Tsunami mound
iii) Construction of Tsunami/Cyclone Shelter

Bio Shield

It is a general belief that natural formations such as coral reefs, grass beds, coastal vegetations such as mangroves, estuaries and deltas of river mouths and flood plains play an important role in dissipating the forces of Tsunami waves.

A bio-shield formed by planting a vegetation belt along coastlines would protect the region against coastal storms, cyclones and Tsunamis. The plantations could absorb the force of severe storms and Tsunamis, and it could act as a 'carbon sink' by absorbing emissions of the greenhouse gas. The coastal front comprises beaches, sand dunes, head lands, creeks/river, rocky cliffs. The coastal vegetation also has a very important role in stabilizing and trapping marine sediments and forming a protective buffer between the land and the sea.

Mangroves: Mangroves are often recognized as the best defenses against wind, waves and erosion by deflecting and absorbing much of the energy of winds hence, Forest department encourages afforestation of Mangroves. Because of planting suitable species of mangroves along the coastline, during 2004 Tsunami, the fishing hamlets

located on the leeward side of the Pitchavaram were totally safe without any traces of Tsunami. Therefore, Karaikal Port may explore the suitability of their location to plant mangroves in consultation with Forest department.

Planting of Casuarinas: *Casuarina equisetifolia* is the most popular farm forestry tree in the coastal lands of Mainland India. The Casuarinas planted along the east-coast protected the region from Cyclone in November, 1999. Planting Casuarinas along the coastal front would provide substantial protection to the project region from the impacts of storm surges and Tsunami. Hence the water level rise during a Tsunami or storm will not have any major impact in this region.

Transplanting vegetation will not prevent the natural process of erosion, but it will accelerate natural recovery after damage. Additional works are often necessary to increase the potential for success. Thatching and beach recycling will assist in the accretion of sand, and will provide minor protection from Tsunami waves and will reduce damage due to trampling. Once grasses are well established they may well become self-sustaining, although any storm erosion damage will need to be rapidly made good.

Construction of Tsunami Mounds

One of the natural methods of protecting the shore from the natural disasters like Tsunami and Storm surge is to construct Tsunami Mounds which will effectively help to dissipate the energy of Tsunami surge and protect the leeward side.

In order to protect the project region against Tsunami destruction, it is proposed to construct Tsunami Mounds along the low lying coastal belt of < 3 m MSL. The top level of the mound can be raised to 5 m above the existing ground level. The mound can be constructed as 75 m long with 50 m gap in between. The mounds can be constructed 100 m on the landward side from the HTL.

The mounds can be constructed with beach sand or any inland native sediments/rocks. The mounds should be erected without felling trees if they exist in this region. It is very important that the Tsunami Mounds are constructed in a way that will not affect the existing trees along the coastal front.

The faces of the mounds can be planted with dune creeper like *Ipomea pes-caprae, Avicennia sp*. Also Casuarina trees can be planted in between and within the mounds. Coconut trees can also be planted which will add protection against Tsunami and also cyclone. Planting the dune creeper is very essential to minimize the wind drift of the sand from the mounds.

Tsunami/Cyclone shelter

The warning and disaster evacuation system is the most important element in ensuring the public's safety. Suitable shelter must be constructed in order to evacuate the people in case of emergency.

The time of arrival provides only a limited time for people to move safely to the shelter. Two Cyclone shelters per cluster must be provided along the region of port. After the warning/siren is given, the government authorities will start the evacuation and the people living in the interior area will have to be moved to the Cyclone shelter built along the coastal stretch.

The location of the shelter must be chosen such that it is easily accessible for workers in industries and for the public living in the vicinity. Maintenance of these shelters and the access roads and keeping them in good condition throughout the year to its functional requirements is very important.

The shelter should be equipped with water supply, toilets, first aid centre, Generators, ration storing rooms and minimum cooking facility**.** The shelters should be designed to bear the workers in the industry and the people living in the vicinity. The stairway should be wide enough (>3 m) for the rushing people to climb the top without confusion and struggle. It should have an elevated handrail with proper light and ventilation. There should not be any windows on the seaward side to avoid the entry of water due to rising Tsunami wave. But enough windows and other ventilation measures must be provided on the leeward side of shelters.

Escape routes: The availability of safety zones that can be used as evacuation sites within walking distance must be inspected. People can be evacuated to hills over ten metres in elevation or the deep inland (>1 km) out of coastal inundation. Good elevated roads should be laid along the escape route to safe places which can be waded even during flooding.

Emergency alarm from Government Institutions

Karaikal Port should jointly make understanding with NIOT/INCOIS/NDMA and a communication link should be established through satellite or GPRS. In case of emergency if warning is given at the above mentioned institutions, they can instantly activate the alarm at the industries through satellite/GPRS and give caution to the vigilant team so that they can immediately start the rescue operation.

3. ASSESSMENT OF RISKS IN HANDLING LNG

3.1. Risks due to Handling of LNG

A 05 MMTPA LNG import terminal is proposed in the Phase III development of the Port. The Terminal will have mandate comprising LNG unloading, LNG storage, LNG re-gassification into natural gas, and natural gas send out into country's gas grid. Salient features of the Terminal are discussed in **Chapter 4**. The Terminal will be a jetty-moored FSU based LNG import facility driven by the following considerations:

- low capital investment,
- very low land requirement,
- quick set up in event of early joining of gas JV partner and favourable gas procurement contract

3.2. Identification of Hazards – Loss of Containment of LNG

LNG as pure material and under confinement is non-combustible due to low temperatures and being too rich to support combustion. All fire related risks of LNG are associated with natural gas produced due to vaporization of LNG.

3.2.1. Property of LNG

LNG is imported and stored as a cryogenic liquid. LNG contains methane between 80% - 95%, remaining ethane, less than 1% of propane, with helium, nitrogen and carbon dioxide in traces (relative composition varying depending on the gas field of origin). Properties of LNG are as follows.

- LNG Density: 424.49 kg/m^3 (lighter than water)
- LNG boiling point: -161° C
- Natural gas has a density of 0.8 kg/m^3, at 20 ^{o}C under one bar pressure
- Flammability limits
- Lower Flammability Limit (LFL): 5%,
- Upper Flammability Limit (UFL): 15%

- 1 m3 LNG = 600 m3 of gas at 20°C

LNG as a cryogenic liquid is a relatively safe material to handle under insulated containment. LNG when in open and under conditions of heat ingress from ambient or conductive sources vaporises into natural gas which is flammable in a narrow range of concentration. Properties of LNG that have safety implications include auto-ignition temperature, low temperature, heat of vaporisation, flammability limits, heat transfer rate of boiling liquid and specific gravity. The average auto ignition temperature of pure methane at atmospheric pressure is 537 ^{0}C, which is quite high, and rare to be encountered in typical normal storage and handling conditions. The lower and upper flammability limit of methane in air is 5% & 15% by volume. Methane being a light and buoyant gas disperses (both by advection and diffusion) rapidly under normal atmospheric conditions and dilutes beyond 5% within few meters of the point of release with a vapour cloud incapable to sustain ignition. LNG under confinement cannot ignite.

3.2.2 Handling of LNG in the Terminal

LNG will be unloaded from the LNG carrier to the FSRU at the rate of 710 m^3/hour by a 170,000 m^3 LNG carrier (and upto 850 m^3/hr for a 267,000 m^3 LNG carrier) and will depending on the vessel size and distance of the vessel to the shore. In order to maintain a positive pressure, some of the vapour generated in the storage tank will be returned to the LNG vessel during unloading operations. The boil-off gas generated due to heat leak will be passed through BOG compressor (used to increase the pressure of boil off gas) and recondensor where LNG will be injected to liquefy the boiloff gas. If there is not enough LNG send-out to absorb the boil off vapour then the vapour will be compressed to pipeline pressure, or flared or vented.

The submerged pumps provided in each tank will pump will the LNG to the recondensor and from recondensor, a high pressure (HP) pump will boost the pressure to send to the vapourisers. The regasification process includes several vapourisers laid out in parallel to gradually increase the temperature to convert from the liquid to gas.

The regasified natural gas will be metered at a metering station at the terminal. The gas will be delivered to the national gas grid pipeline operated by GAIL through high pressure feed pipelines; the pressure in the feed pipeline will be achieved through multi-staged high head send out pumps.

3.2.3. Identification of Hazard Scenarios and Consequence Analysis

The RA of the FS-R-U is based on the following identified release scenarios from possible hazardous sources listed below.

The consequence analysis has been carried out for Pasquill and Gifford atmospheric stability class 'D – neutral' and 'F – stable'.

Identification of Hazard Scenarios

Sr.	Failure Case	Failure Mode Type	Consequence
1	25 mm leak in 16" DCMA LNG unloading arm or LNG STS Cryogenic Hose of the FSU	Loss of holdup of one arm, LNG drained into concrete impoundment basin, evaporative dissemination, vapour cloud meeting with a source of ignition after one minute	Pool fire (**Scenario 01** - stability class D, **Scenario 02** - stability class F). As the site of release is not a congested area, formation of ignitable vapour cloud followed by UVCE is not possible.
2	25 mm leak (flange or pipeline length) on 48' diameter insulated LNG berth-to-tank transfer pipeline operating at 08 Bar-g.	Loss of 40% holdup of pipeline for the first 10 minutes until intervened, LNG drained on ground/water, evaporative dissemination, vapour cloud meeting with a source of ignition after five minutes	Pool fire (**Scenario 3** - stability class D, **Scenario 04** - stability class F). UVCE is not supported for typical, open-to-air FS-R-U setup – not congested setting. Application override – congested setting assumed. UVCE (**Scenario 5**, - Stability class D, **Scenario 6**, - Stability class F)
3	25 mm leak on LNG LP pump header (flange or	Loss of holdup of 80 m line, LNG drained into concrete impoundment basin, evaporative dissemination,	Pool fire (**Scenario 07** - stability class D, **Scenario 08** - stability class F).

	pipeline length) 20“ diameter LNG pipeline operating at 12 Bar-g.	vapour cloud meeting with a source of ignition after five minute	UVCE is not supported for typical, open-to-air LNG terminal – not congested setting. Application override – congested setting assumed. UVCE (**Scenario 09**, - Stability class D, **Scenario 10**, - Stability class F)
4	5 mm leak on exposed 26” NG send out pipeline (pipeline length) operating at 90 Bar-g.	NG jet leak meeting a source of ignition,	Jet fire (**Scenario 11**, - Stability class D, **Scenario 12**, - Stability class F)

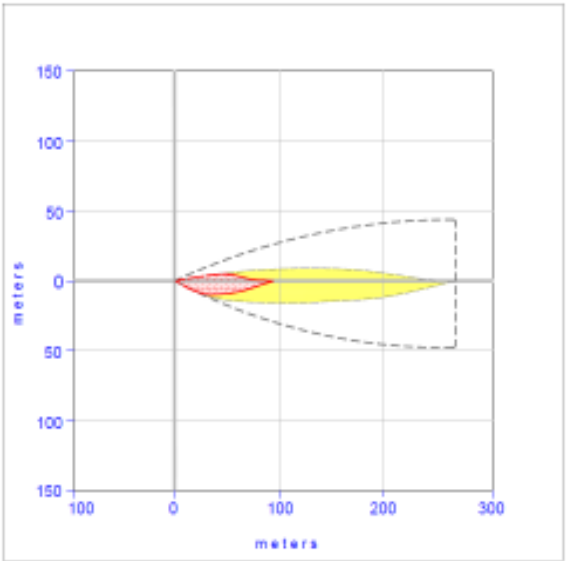
Quantity of LNG spill leaked from the terminal pipelines will comprise be full or part holdup of the pipeline. This may range from about 15 kl (from a 16” DCMA/LNG STS cryogenic hose collected in an impoundment basin/over concrete deck of the unloading platform or on the steel deck of the FSU) to several hundred kl (from the 48’ diameter insulated LNG berth-to-tank transfer pipeline). Spill of such size will generate NG vapours in quantities larger than what can sustain flash fire.

As the terminal will be an open-to-air facility with lack of congestion and high air exchange rates (owing of large wind fetch of the sea), possibility of concentration of NG vapours in pockets leading to a UVCE is not likely. However congested conditions have been assumed in the model and UVCE scenario have been run.

Since the LNG tanks on the FSU will store LNG under normal pressure under refrigerated condition, BLEVE on the tanks is ruled out.

Scenarios of Jet fire are possible on pipelines/sections under high pressure, which have been modelled for NG send out pipeline.

Scenario 01 – 25 mm leak in 16" DCMA unloading arm/LNG STS Cryogenic hose of the FSU, pool fire, Stability Class D

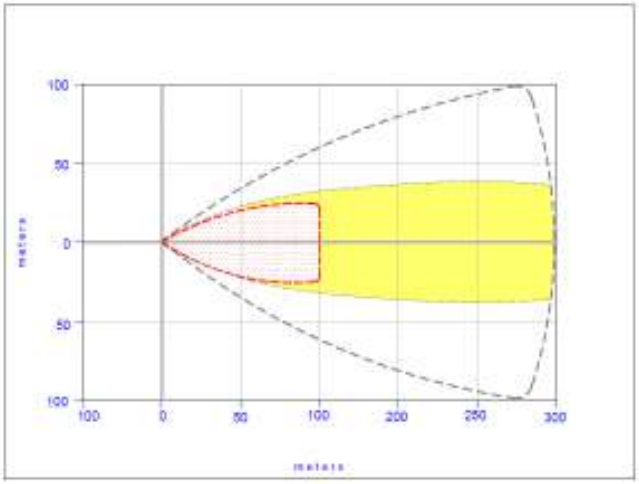


Thermal radiation from pool fire

Red : 83 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 274 meters --- (5000 ppm = 10% LEL)

Scenario 02 – 25 mm leak in 16" DCMA unloading arm, pool fire, Stability Class F

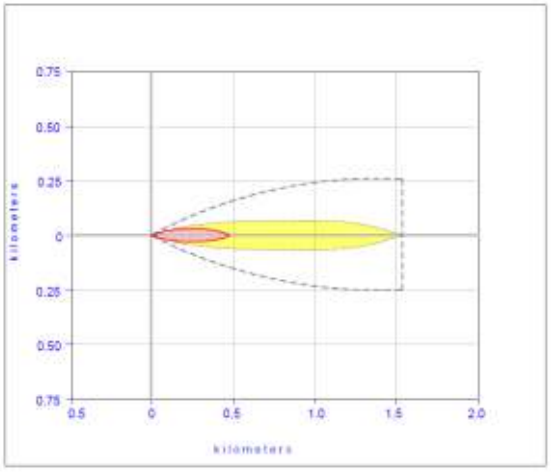


Thermal radiation from pool fire

Red : 101 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 299 meters --- (5000 ppm = 10% LEL)

Scenario 03 – 25 mm leak in 48” LNG Ship to Tank pipeline, pool fire, Stability Class D

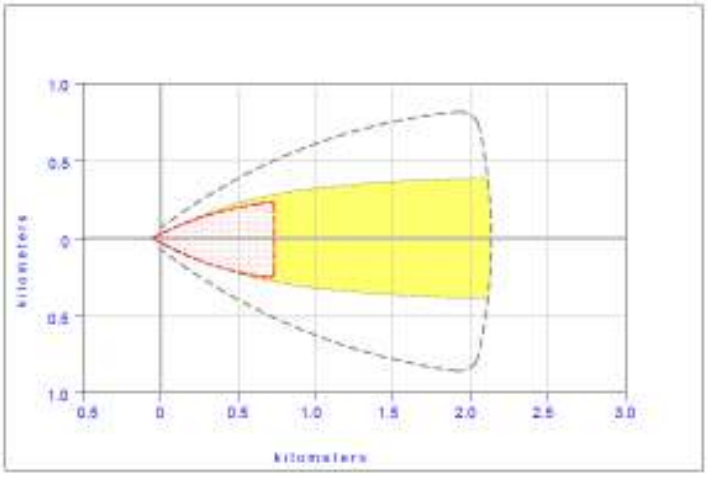


Thermal radiation from pool fire

Red : 453 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 1.6 kilometers --- (5000 ppm = 10% LEL)

Scenario 04 – 25 mm leak in 48” LNG Ship to Tank pipeline, pool fire, Stability Class F

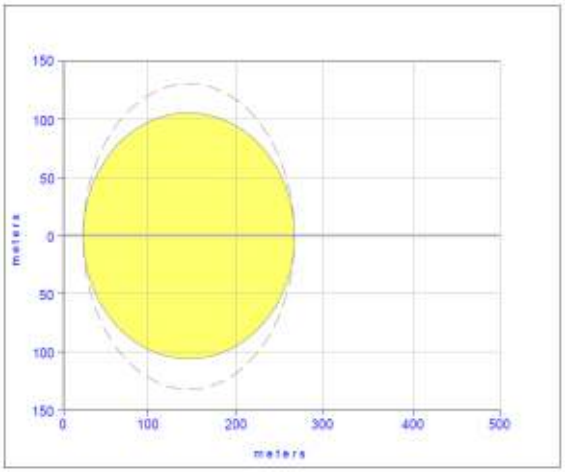


Thermal radiation from pool fire

Red : 730 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 2.1 kilometers --- (5000 ppm = 10% LEL)

Scenario 05 – 25 mm leak in 48" LNG Ship to Tank pipeline, UVCE, Stability Class D



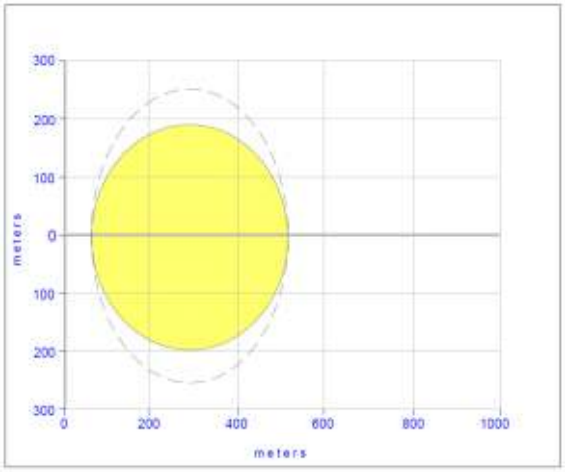
Blast overpressure

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 257 meters --- (1.0 psi = shatters glass)

Scenario 06 – 25 mm leak in 48" LNG Ship to Tank pipeline, UVCE, Stability Class F



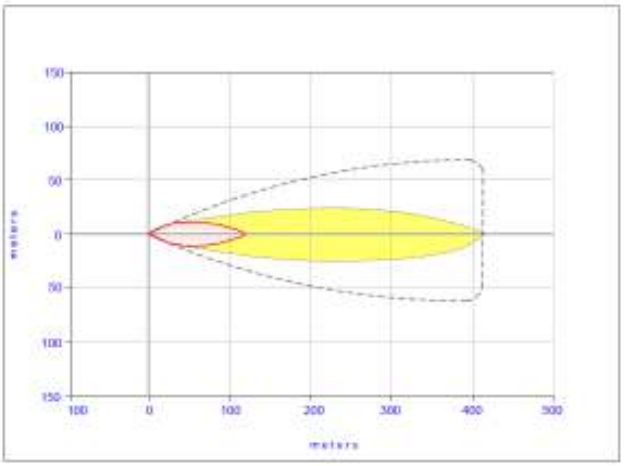
Blast overpressure

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 455 meters --- (1.0 psi = shatters glass)

Scenario 07 – 25 mm leak in 20” LNG LP Pump line, pool fire, Stability Class D

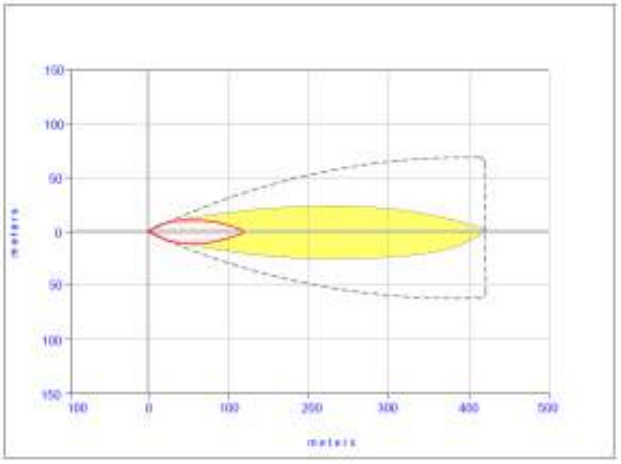


Thermal radiation from pool fire

Red : 125 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 434 meters --- (5000 ppm = 10% LEL)

Scenario 08 – 25 mm leak in 20” LNG LP Pump line, pool fire, Stability Class F

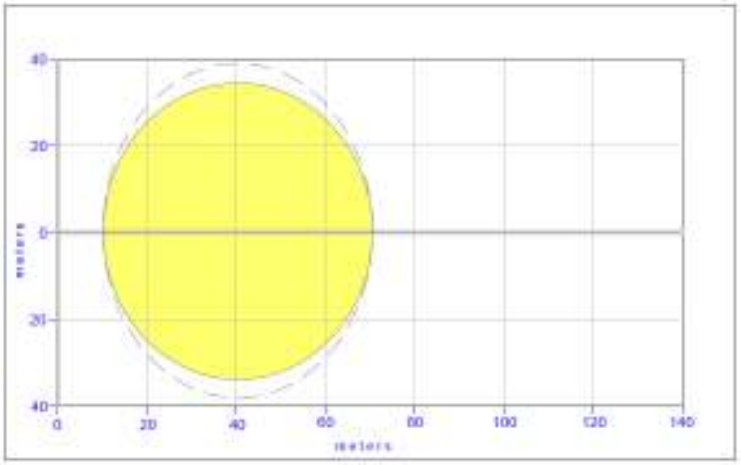


Thermal radiation from pool fire

Red : 167 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 522 meters --- (5000 ppm = 10% LEL)

Scenario 09 – 25 mm leak in 20" LNG LP Pump line, UVCE, Stability Class D



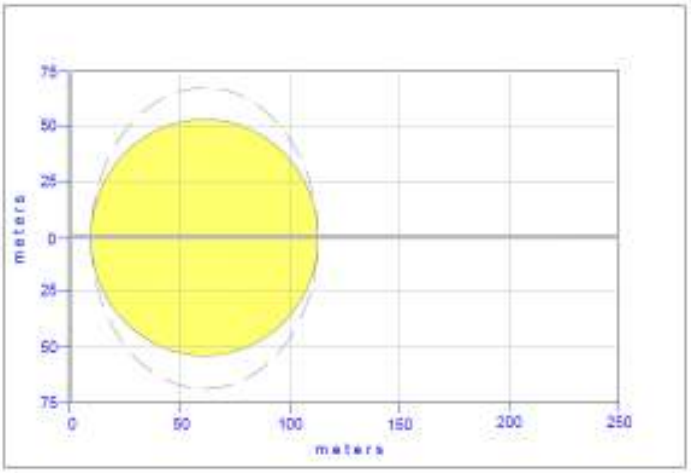
Blast overpressure

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 72 meters --- (1.0 psi = shatters glass)

Scenario 10 – 25 mm leak in 20" LNG LP Pump line, UVCE, Stability Class F



Blast overpressure

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 111 meters --- (1.0 psi = shatters glass)

Scenario 11 – 1 cm leak in 26" NG send out line, jet fire, Stability Class D

Max Flame Length: 1 meter

Max Burn Rate: 69.6 kilograms/min

Total Amount Burned: 230 kilograms

Thermal radiation from jet fire

Red : less than 10 meters (10.9 yards) -- (10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: less than 10 meters (10.9 yards) -- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

Yellow: less than 10 meters (10.9 yards) -- (2.0 kW/(sq m) = pain within 60 sec)

Scenario 12 – 1 cm leak in 26" NG send out line, jet fire, Stability Class F

Max Flame Length: 1 meter

Max Burn Rate: 71.4 kilograms/min

Total Amount Burned: 236 kilograms

Thermal radiation from jet fire

Red : less than 10 meters (10.9 yards) -- (10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: less than 10 meters (10.9 yards) -- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

Yellow: less than 10 meters (10.9 yards) -- (2.0 kW/(sq m) = pain within 60 sec)

Consequence distances for the scenarios for Stability Class D and F are given below.

Sr.	Scenario	Consequence	Stability Class D	Stability Class F
1	01 and 02 – 25 mm leak in 16" DCMA unloading arm/LNG unloading arm or LNG STS Cryogenic Hose of the FSU	Pool fire	60% of LEL = Flame pocket – 83 m	60% of LEL = Flame pocket – 101 m
2	03 and 04 – 25 mm leak in 48" LNG Ship to Tank pipeline	Poo, fire	60% of LEL = Flame pocket – 453 m	60% of LEL = Flame pocket – 730 m
3	05 and 06 – 25 mm leak in 48" LNG Ship to Tank pipeline	UVCE	Blast overpressure 1.0 psi = shatters glass – 275 m	Blast overpressure 1.0 psi = shatters glass – 455 m

4	07 and 08 – 25 mm leak in 20" LP LNG line	Pool fire	60% of LEL = Flame pocket – 125 m	60% of LEL = Flame pocket – 167 m
5	09 and 10 – 25 mm leak in 20" LP LNG line	UVCE	Blast overpressure 1.0 psi = shatters glass – 72 m	Blast overpressure 1.0 psi = shatters glass – 111 m

3.3. Failure Frequency associated with Loss of Containment

Quantitative risk is a product of failure frequency and consequence of the scenario. Failure frequencies of plant elements in the LNG terminal are given below.

Sr.	Plant component	Failure Frequency per year
1.	16"unoading arm, 25 mm hole	5.0 E -7
2.	48" unloading header, 25 mm hole	2.5 E -7
3.	20" LP Pump header, 25 mm hole	6.0 E -7
4	26" send out heder, 25 mm hole	5.0 E -7

It may be observed from the above failure frequency data that the likelihood of an incidence occurring in the 40 years assumed lifetime of the LNG terminal is extremely rare.

3.4. Risks due to Vessel Collision and Grounding

Vessel collision or grounding, onboard fire, explosion etc. are the consequences which may threaten integrity of the vessel, can endanger cargos on the vessel involved in the incident and may result in release of cargo in the sea. Vessel collision and grounding are more frequent and often result from out of control vessel movement.

The frequency of vessel collision is governed by the frequency of vessel encounter and the probability of collision given an encounter. From the records of accidents maintained at several major ports worldwide it has been considered that collision frequency is proportional to the square of the traffic density and is directly proportional to the number of encounters. Casualty statistics maintained at UK ports indicate that collisions involving vessels account for 7% of all accidents and represent 0.024 for every 1000 vessel

movements. Accident figures for India would be still lower considering lack of congestion in Indian ports.

The proposed all weather Port at Karaikal has a channel extending from the fairway from natural depths of 20.0 m or more so that the vessels of any other Port do not intermingle, thus eliminating ship interactions. The channel has been designed following PIANK Guideline (which considers safety as the primary requirement for selection of the channel width. Tug assistance will be provided in the channel and basin for safe manoeuvring and berthing.

Not all ship accidents result in spills. International Tank Owners Pollution Federation Limited (ITOPFL) has maintained a database of oil spills from tankers and other ships. Spills are categorized by size (< 7 t, 7 -700 t and> 700 t). Information is held for about 10000 accidents. Their data-base indicates that the vast majority of spills (83%) fall in the smallest category (< 7 t) and < 3% of accidents result in large spills. Hence, the probability of a large spill occurring along this coastal area is low.

Bulk release of liquid/refrigerated cargo can also result if a tanker goes aground rupturing cargo holds. The data-base of ITOPFL reveals that 34.4% and 28.9% of large spills (> 700 t) have occurred due to groundings and collisions respectively. Channel length and its width are the major factors controlling grounding in inshore waters. The ships are vulnerable to grounding in long and narrow channels particularly those which have several bends. From grounding incidents at several ports it has been considered that the channel length to width ratio gives a good indicting probability of encountering a grounding obstruction. Thus, the grounding frequency increases with increasing length of the channel and decreases with increasing width for a given length. The grounding frequency may therefore be expressed as:

$$GF = K \times L/W$$

Where G = grounding frequency

L = channel length

W = effective channel width

K = constant (normally taken as 1×10^{-5} per movement).

Hence, depending on frequency of ship movement the grounding probability increases or decreases. In case of the Karikal Port, there will be no bends in the navigation channel and it will be dredged and maintained at (-) 19.0 m CD, practically eliminating grounding incidences inside the Port waters. In addition – "no movement of any other ship in the channel while LNG vessel is moving in the channel" - will be observe as an operational protocol thus practically eliminating LNG vessel interaction with any other vessel in the Port. All LNG transfer will be carried out under a tug at disposal.

4. DISASTER MANAGEMENT PLAN

4.1. Introduction

Emergency/disaster is an undesirable occurrence of events of such magnitude and nature that adversely affect operations, cause loss of human lives and property as well as damage to the environment. Coastal infrastructure is vulnerable to various kinds of natural and manmade disasters. Examples of natural disaster are flood, cyclone, tsunami, earthquake, lightning, etc., and manmade disasters are like major fire, explosion, sudden heavy leakage of toxic/poisonous gases, civil war, nuclear attacks, terrorist activities, sabotage, etc. It is impossible to forecast the time and nature of disaster, which might strike a common user infrastructure. An effective disaster management plan helps to minimize the losses in terms of human lives, assets and environmental damage and resumes working condition as soon as possible.

Disaster Management Plan (DMP) forms an integral part of any risk assessment and management exercise; any realistic DMP can only be made after proper risk assessment study of the activities and the facilities provided in the installation. Correct assessment and evaluation of the potential hazards, advance meticulous planning for prevention and control, training of personnel, mock drills and liaison with outside services available can minimize losses to the facility's assets, rapidly contain the damage effects and effectively rehabilitate the damage areas.

4.2. Location of the Port, Surrounding Areas and Population

The LNG FS-R-U berth is proposed beyond 1.5 km from the boundary of Port, separated by the Port basin and southern breakwater. In an event of fire on the berth or on the pipeline corridor between the Pump House and the liquid berths only Port personnel present within 50 to 100 m of the of the point of release will be effected. These persons will be trained to quick leave the site of incidence and let the Port Fire and Safety Department personnel take charge of the situation. No incidence in the Port has likelihood of offsite consequences.

4.3. Approaches to Disaster Management Plan

Modern approach to disaster management involves the following two steps:

- Risk Identification
- Risk Evaluation

Risk identification entails:

- Identification of hazardous events in the installation, which can cause loss of capital equipment, loss of operation, threatens health and safety of employees, threatens public health and damage to the environment

- Identification of risk important processes and areas to determine effective risk reduction measures

Risk evaluation involves calculation of damage potential of the identified hazards with damage distances, which is then termed as consequence analysis as well as estimation of frequencies of the events.

A hazardous area with different hazard scenarios and their damage potential with respect to fire has already been mentioned in Consequence Analysis chapter. However, failure rate of different hazard scenarios has been discussed broadly based on data available for similar incidents outside India.

Probability of any hazardous incident and the consequent damage also depends on:

- Wind speed
- Wind direction
- Atmospheric stability
- Source of ignition and also
- Presence of Port assets & population exposed in the direction of wind.

Action plan depends largely on results of risk assessment data and may include one or more of the following:

- Plan for preventive as well as predictive maintenance
- Augment facilities for safety, fire fighting, medical (both equipment and manpower) as per requirements of risk analysis
- Evolve emergency handling procedure both onsite and offsite
- Practice mock drill for ascertaining preparedness for tackling hazards/emergencies at any time of the day

4.4. General Nature of the Hazard

Operation of the Port involves two types of cargoes which may pose operational hazards: bulk solid cargo, mainly coal and Fertilizer/FRM, and liquid cargoes including POLs and chemicals. Coal and Fertilizer/FRM cargoes have moderate to low fire hazard potential localized to the site of storage. Incidences of fires in these cargoes can be easily avoided and controlled if recommended practice for their handling is followed.

Incidences of pool fire are possible in events of loss of inventory from the Port pipeline which is laid above grade. While vapors evaporating from a pool of low-vapor pressure hydrocarbons and chemicals may be explosive under conditions of congestion, owing to low level of ambient confinement and high wind conditions, explosions are not possible in the Port.

Any small fire in the Port near the POL and chemical pipelines, if not extinguished immediately, can cause large scale damage and may have a cascading effect. Hence, liquid berths and pipelines require:

- A quick responsive containment and control system requiring well planned safety and fire fighting system
- Well organized trained manpower to handle the process equipment & systems safely

- Well trained personnel to handle safety and fire fighting equipment to extinguish fire inside the installation promptly as well as tackle any type of emergency

4.5. Designated Hazardous Areas of the Port

Depending on the kind of operation, hazardous area within the battery limit of the Port may be subdivided into the following sections:

Activities	Place
a) Pumping of POL and chemical	Pump house
b) Pipeline conveying above grade	Pipeline corridor
c) Ship shore transfer	Liquid berths

Since some of the POL products are highly inflammable and explosive, fire hazard exists in all these areas. However, risk varies due to varying inventory of the material and operations involved.

The risk potential of the above areas has been discussed in the **Chapter 22** as in Consequence Analysis. The maximum credible hazard scenarios are found to be gasket failure, mechanical seal failure of pumps, loading arm failure on the liquid berths and small bore pipe line failure, etc.

Apart from the above, fire cannot be ruled out in substation & MCC as well as in other places from short circuiting and also secondary fire from nearby industries.

However, major accident may occur in the Port and call for emergency/disaster.

4.6. Disaster Preventive and Pre-Emptive Measures

After identification and assessment of disaster potential the next step in disaster management plan is to formulate and practice the preventive measures. Proper preventive and pre-emptive measures can reduce the disaster potential to a minimum.

Preventive and pre-emptive measures are taken from the design stage itself. Preventive measures which are to be taken during design stage:

- Layout of the Pump House, pipeline corridor and liquid berths with sufficient safety distances
- Avoidance of low lying areas, which facilitate accumulation vapors of flammable material
- Use of proper material of construction for equipment and piping
- Use of SRVs & Pop-off valves of proper size and capacity
- Use of automatic as well as manual isolation valves at proper places
- Proper instrumentation with interlock, trip and alarm system
- Installation of vapor and heat detectors, and fire water system (sprinkler, hydrants, deluge valves, etc.) at proper places to detect release of flammable inventory and taking necessary automatic/manual action

Apart from the above precautions in the design stage, procurement of equipment are to be done strictly as per specification/code and fabrication/erection of the equipment are to be done under supervision of competent and experienced personnel. Some of the preventive & pre-emptive measures, which are to be taken during operational life are as follows:

a) Safety Measures

Following safety tips should always be borne in mind while working in the Port to avoid emergency & hazardous situation.

- Follow specified procedures and instructions for start-up, shut down and any maintenance work
- Follow permit to work system
- Identify correctly the part of the pipeline in which work is to be done
- Isolate the part, machine properly on which work is to be done
- Release pressure from the part of the pipeline on which work is to be done

- Remove flammable liquid/gases thoroughly on which work is to be done
- Use non sparking tools

b) Port Inspection

Apart from planned inspection, checks and tests should be carried out to reduce failure probability of containments.

- Pump house and pipeline during both their construction and operational life
- Pressure relief valves to avoid fail danger situation. The safety relief valves connected with pumps and piping should be checked and calibrated at regular intervals according to specification
- Critical trips, interlocks, & other instruments should be checked regularly to avoid fail danger situation
- Vapor detection, heat detection & fire fighting system should be checked regularly to ensure proper functioning for avoiding emergency situation
- Lightning protection system

c) Performance or Condition Monitoring

A systematic monitoring of performance or condition should be carried out especially for pumps and associated equipment, which may be responsible for serious accidents/disaster in case the defined limits are crossed.

- Vibration, speed & torque measurements for pumps, etc.
- Thickness and other flaw measurements in metals of pipelines, etc.

Many types of non-destructive testing/condition monitoring techniques are available. X-ray radiography, acoustic emission testing, magnetic particle testing, eddy current inspection techniques etc. are used for detection of flaws and progression of cracks in metals. The above condition monitoring techniques should be applied regularly by internal/external agencies. Immediate corrective measures should be taken if any flaws are detected.

d) Preventive Maintenance

A schedule for preventive maintenance for moving machineries like pumps, compressors, etc. should be prepared based on experience in other similar operations as well as instruction of the suppliers. The schedule should be followed strictly during operation as well as planned shut down period.

e) Entry of Personnel

Entry of unauthorized personnel will be strictly prohibited inside the Port liquid cargo battery limit. The persons entering the liquid cargo area will not carry matches, lighters, Mobiles, Cameras etc. and hot work will not be permitted except in designated areas with utmost precaution.

4.7. Disaster Control/Response Plan

Disaster may arrive without any warning, unexpectedly in spite of all precautions & preventive measures taken. However, an efficient control/response plan can minimize the losses in terms of property, human lives and damage to the environment can be the minimum.

4.7.1. Objectives of the Plan

The plan should be developed to make best possible use of the resources at the command of the Port as well as outside resources available like State Fire Services, Police, Civil Defence, Hospitals, Civil Administration, neighbouring institution and industries.

It is not possible for the Port to face a disaster single handed and calls for use of all available resources in the surrounding area. Advance meticulous planning minimizes chaos and confusion, which normally occur in such a situation and reduce the response time of Disaster Management Organization.

The objectives of Disaster Management Plan are:

- To contain and control the incident
- To rescue the victim and treat them suitably in quickest possible time
- To safeguard other personnel and evacuate them to safer places
- To identify personnel affected/dead
- To give immediate warning signal to the people in the surrounding areas in case such situation arising
- To inform relatives of the casualties
- To provide authoritative information to news media and others
- To safeguard important records & information about the organization
- To preserve damaged records & equipment needed as evidence for any subsequent enquiry
- To rehabilitate the affected areas
- To restore the facilities to normal working condition at the earliest

4.7.2. Components of the DMP

An onsite emergency is one, which is having negligible effects outside the Port premises and can primarily be controlled by internal facilities and resources available. Some help may be required from external agencies or local authorities. All the consequence footprint of the scenarios identified in the Consequence Analysis chapter indicates that the effects of the incidences will be well within the boundary, which can be mitigated by following the Onsite DMP.

An offsite emergency will affect the neighbouring areas and population outside the Port premises and would require substantial contribution from local authorities and institutions like police, civil defence, state hospital and civil administration in addition to state fire services. Offsite DMP will be needed in case of natural disaster of large magnitude such as tsunami and cyclone.

4.7.3. Onsite Emergency as Statutory Requirement

The requirement of an Onsite DMP with detailed disaster control measures was embodied for the first time in section 41B (4) of the Factories (Amendment) Act, 1987. The requirement is applicable to Ports handling flammable cargo per the First Schedule of the Act, item 29 entitled "Highly Flammable Liquids and Gases".

Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989, (amended) under Sections 6, 8 and 25 of the Environment (Protection) Act, 1986 concurrently provides the requirement of an Onsite Emergency Plan by the occupier of accident hazard site, under rule 13, sub-rule 1.

4.7.4. Emergency Control Philosophy

The principal strategy of emergency control at the proposed Port is prevention of the identified major hazards. Since hazards can occur only in the event of loss of containment, one of the key objectives of detail engineering, construction, commissioning and operating of the Port is total and consistent quality assurance.

The second control strategy adopted for potential emergencies is surveillance of handling and storage of hazardous substances.

Yet another control measure adopted is early detection of any accidental leak of hydrocarbon and other flammable vapors by gas detectors and by trained and vigilant operating staff and activation of well-structured, resourced and rehearsed emergency plan to intercept the incident with speed and ensure safety of employees, assets, public and environment as a matter of priority.

4.7.5 Content of the Onsite DMP

Information to be provided by any MAH installation or an Isolated Storage has been prescribed in schedule 11 of the MSIHC Rules. This DMP has been prepared, in so far as is practicable, in accordance with the guidelines stipulated in the Rules.

Details that need to be furnished in the Onsite DMP per schedule 11 of MSIHC Rule, 1989 are:

- Name and address of the person furnishing the information
- Key personnel of the Organization and responsibilities assigned to them in case of an emergency
- Outside Organization if involved in assisting during an onsite emergency:
  - Type of accidents
  - Responsibility assigned.
- Details of liaison arrangement between the Organizations
- Information on the preliminary hazard analysis:
  - Type of accidents
  - System elements or events that can lead to a major accident.
  - Hazards
  - Safety relevant components
- Details about the site:
  - Location of dangerous substances
  - Seat of key personnel
  - Emergency control room
- Description of hazardous chemicals at Port site:
  - Chemicals (quantities and toxicological data)
  - Transformation if any, which could occur
  - Purity of hazardous chemicals
- Likely dangers to the Port
- Enumerate effects of -
  - Stress and strain caused during normal operation

- Fire and explosion inside the Port and effect, if any, of fire and explosion out side

- Details regarding
  - Warning, alarm, safety and security systems
  - Alarm and hazard control plans in the line with disaster control and hazard control planning, ensuring the necessary technical and organizational precautions
  - Reliable measuring instruments, control units and servicing of such equipments
  - Precautions in designing of the foundations and load bearing parts of the building
  - Continuous surveillance of operations
  - Maintenance and repair work according to the generally recognized rules of good engineering practices
- Details of communication facilities available during emergency and those required for an offsite emergency
- Details of fire fighting and other facilities available and those required for an offsite emergency
- Details of first aid and hospital services available and its adequacy

An outline of these details is provided in the pages following under the headings stated above, in so far as the headings apply to the proposed Port.

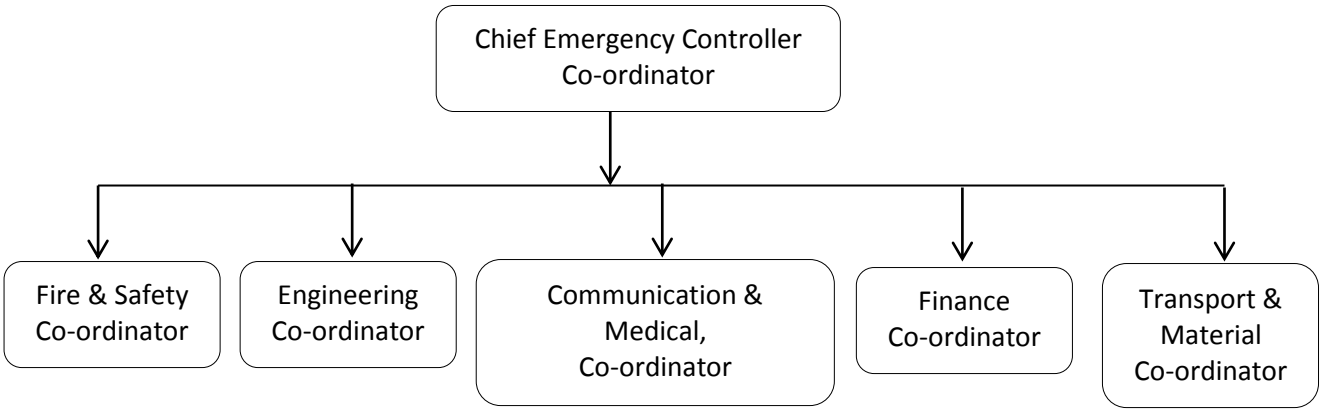
4.7.6. Key Personnel of the Port and Responsibilities in the Event of an Emergency

It is to be understood that the first few minutes after the start of an incident are most vital in prevention of escalation. Therefore the personnel available at the site on round-the-clock basis will play an important role. Some of them will be the identified “Key Persons”. Since the liquid berths and Pump House are to be operated by highly skilled officers/operators with the help of “Port In-Charge/Dy. Port Manager”, in the emergency he will also act as “Chief Controller” for incidence and he will nominate different “Emergency Coordinators” to control emergency situation.

The role of various coordinators is to assess the situation from time-to-time, take appropriate decisions in consultation with the “Chief Controller” and to provide timely resources to the

"Key Persons" to fight the emergency. "Key Persons" as far as is possible are available during shift on a round the clock basis. An organogram of the officers at the liquid cargo operations during emergency is presented below.

Organization Chart for Onsite Emergency Management Team



Key Personnel

The senior most officer present in the Port at the time of the incident will be the designated the "Chief Emergency Controller". Duties and responsibilities of "Chief Controller: and other "Coordinators" are as follows:

He will report at the "Emergency Control Centre" and will assume overall responsibility of the works and its personnel. His duties will be:

i) To assess the magnitude of the situation and decide whether a major emergency exists or is likely to develop, requiring external assistance. To inform District Emergency Chief (i.e. District Collector)

ii) To exercise direct operational control over areas in the Port other than those affected

iii) Assess the magnitude of the situation and decide if staff needs to be evacuated from the assembly points to identified safe places

iv) To continuously review and direct shutting down of Port sections and operations in consultation with the other key personnel

v) To liaise with senior officials of Police, Fire Brigade, Medical and local administration, and pass on information on possible effects on the surrounding areas, outside the factory premises

vi) To liaise with various coordinators to ensure casualties are receiving adequate attention and traffic control movement within the work is well regulated

vii) To arrange for a log of the emergency to be maintained in the Emergency Control Centre

viii) To release authorized information to press through the Media Coordinator

ix) To control rehabilitation of the affected persons and the affected areas after the emergency

a. Fire and Safety Coordinator

The main responsibilities of Fire and Safety Coordinator will be:

i) To immediately take charge of all fire fighting operations upon sounding of the alarm

ii) To guide the fire fighting team and provide logistics support for effectively combating the fire

iii) To barricade the area at appropriate locations in order to prevent the movement of vehicular traffic

iv) To operate the Mutual Aid Scheme and call for additional external help in fire fighting

v) To organize relieving groups for fire fighting

vi) To inform the Chief controller and give “All Clear” signal when the fire emergency is over

b. Engineering Coordinator

i) Responsibilities of Engineering Coordinator will be:

ii) To liaise with Chief Controller and various other Coordinators

iii) To stop/regulate all operations within the Port

iv) To switch off main Instrument Control Panel

v) To stop all engineering works and instruct contractors and their employees to leave the area

vi) To assess the water level in the fire water reservoir and supply engineering tools, fire-fighting materials and equipments to various Coordinators

vii) To start all pumps to replenish water and switch on the fire engine for

a. hot standby

viii) To liaise with transport Coordinator to arrange for external water supply and fuel for generators/engines

ix) To attend mechanical fault/failure of fire water pump and facilities

x) To assess situation in consultation with Chief Controller and if required, start/provide electric supply to certain areas/points

c. Communication and Medical Coordinator

Duties and responsibilities of the Communication and Medical Coordinator will be:

i) To liaise with Chief Controller and various other Coordinator

ii) To take over entire communication system (external as well as internal)

iii) To arrange to distribute Walky-Talkie/ VHF sets to various other Coordinator

iv) To inform police, fire brigade, civil authorities, hospitals & request for speedy help

v) To arrange for vehicles/ambulance for evacuation and causalities

vi) To set and activate first aid centre and arrange to mobilize medical team

vii) Arrange to procure required drugs & appliances

viii) Arrange to transfer causalities to other hospitals/first aid centre

ix) To maintain a register for causalities (type of injury, number, hospitalization, etc)

x) To inform families of the causalities

d. Finance Coordinator

The Asst. Manager (Finance) or his nominee:

i) Release finances (Cash/Cheques, etc.) as directed by the Chief Controller

ii) Assist Material Coordinator in enactment of emergency procurement procedures and by deputing his staff

iii) To liaise with Insurance Company personnel

e. Transport and Materials Coordinator

Duties & Responsibilities will be:

i) To liaise with Chief Controller and other Coordinators

ii) To arrange issue of materials from warehouse round-the-clock during the emergency period

iii) To arrange emergency procurements from local dealers or from neighbouring industries

iv) To arrange transportation of materials from warehouse to the site in consultation with other Coordinators

v) To arrange for police help for control of traffic & public outside the affected area of the Port

vi) To arrange for entry for authorized personnel/vehicles only

vii) To mobilise necessary vehicles as required by various Coordinators

viii) To arrange for regulating the traffic inside the Port area

ix) To arrange to evacuate all unnecessary personnel from the Port and arrange for vehicles/ambulance for evacuation and casualties

x) To control and disperse crowd from the scene of fire

xi) To mobilize all the fire fighting spare equipment/ refills/hosepipes/trolleys etc. form the neighbouring units, if required

xii) To monitor stock of all fire fighting equipments and replenish them as and when required

4.7.7. Safety Hardware recommended in the Port

The designated hazardous areas of the liquid cargo handling facility in the Port will be served by a number of sensitive flammable gas detectors, hooked to alarm in the Marine Control Room. The detectors will be strategically located to detect presence of flammable vapor cloud. The detectors will be supplemented by manually operated break-glass type fire alarm call points linked to electric sirens and a centralized and manned alarm annunciator panel.

All strategic areas, especially the Pump House shall be fitted with 'quartz heat-bulb' actuated medium velocity water sprinkler systems supported by fire fighting water pumps. An extensive network of pressurized fire hydrant system set up in accordance with OISD 144 standard shall been installed to fight fire anywhere within Port and to cool pipelines and structures to ensure their safety during an incident, involving incidence of dangerous heat flux. Adequate onsite manpower shall be suitably trained and equipped to carry out fire fighting operation efficiently.

A number of diverse fire fighting media such as DCP, CO_2 Fire extinguishers, etc. will be strategically located in various parts of the Port in suitable dispenser sizes.

Foam or any other equivalent substance will be used in adequate measure to cut down evaporation from a flammable liquid pool and thus inhibit fire and formation of a flammable gas cloud.

The design of the complete fire protection system is as per OISD norms.

a. Emergency Annunciation

Warning alarm, safety and security systems will be installed in the Port. One 3 km range Electric Siren will be installed on the roof of the Marine Control Room to announce the onset of an emergency.

The alarm will have facility to be triggered manually after activation of anyone of the break-in glass type fire-alarm call points, geographically located throughout the plant both in hazardous as well as in non-hazardous areas. Sirens can also be energized as and when a gas leak is detected.

Flammable vapor alarm will be set to activate by scanning network of vapor detectors spread near the liquid handling area in the Port site to detect presence of flammable vapor at 50 % of the LEL level. The audio-visual alarm will come on in control room alarm annunciator panel. Auto-sprinkler alarm will be provided in the Pump Room as well as in the MCR if any auto-sprinkler is activated through operation of heat fuse by a fire.

b. Communication Facilities to be provided for Emergency

- One 3.0 km range Electric Siren to announce nature of emergency
- An Interport paging system in non-flame proof areas and as well as in flame proof areas will be provided for normal and emergency announcements and communication with master control in the MCR
- For inter-location communications requisite number of P&T telephones will be provided including tie lines and hot lines for communication with district emergency services, authorities, hospitals, etc.
- The interport paging and public address system will have the following features-
    - All call with answer back
    - Group call with answer back
    - Interfacing with walkie talkies
    - Field call stations
- Walkie Talkies and mobile phones will be deployed for mobile-to-mobile and mobile-to-stationary communication
- A broad communication diagram outlining interactions between various role players will be set up and rehearsed

4.8. Details of First Aid and Hospital services available

Fully stocked first aid boxes shall be placed in the Port at strategic locations. A visiting medical practitioner will be made available on a part time basis during day. He will be available on call and round-the-clock for emergency duty. The onsite medical center will be equipped with facilities for treatment of mechanical injuries, burn injuries and electric shock. An ambulance will be available in the Port round-the-clock. Details of important/prominent medical facilities available in Karaikal with their contact numbers is given below.

Emergency contact number

Department	Contact number
FIRE & SAFETY OFFICE	04365 256614/95000 94245
DSS PUMP HOUSE	87545 96257
MEDICAL CENTER	04365 256534/95001 21771
PORT SECURITY OFFICE	04365 256617/9566680077
VECHILE RETRIEVAL	9600192851
PORT OPERATION CENTER	04365 256612 / 9566000700
CARGO OPERATION – 24 X 7 Hrs	96770 52433/9566159588
MECHNICAL – 24 X 7 Hrs	95001 25252
ELECTERICAL - 24 X 7 Hrs	95001 25244
RAILWAY -24 X 7 Hrs	95000 93414
PFSO	97909 60448
DY.PFSO	96000 45039
HEAD FIRE & SAFETY	98409 02445
HEAD SECURITY	87545 96248

HOSPITALS / CASUALTY POLICE STATIONS

G.H KARAIKAL	04368 222593
SUGAM PRIYA Hospital	04368 224040
ANSARI HOSPITAL – NGT	04368 224349
COASTALPOLICE	04368 224750
KARAIKAL POLICE	04368 222437/222402
T.R.PATTINAM P.S	04368 233014/233480

FIRE STATIONS

KARAIKAL	230101/227112
NAGAPATTINAM	04365 242101/221101
ONGC – NERAVY	04368 2 3 8 8 9 0
CPCL	04365 2 5 6 4 2 0
ONGC – NARIMANAM	04365 2 3 5 1 6 7

COAST GUARD

KARAIKAL	04368 226500
PUDUCHERRY	04132 602498
CHENNAI	044 23460403

INDIAN NAVY

NAGAPATTINAM	04365242534

***BOMB SQUAD** (to be contacted through Karaikal police station)*

KARAIKAL POLICE	04368 2 2 2 4 3 7 / 2 2 2 4 0 2

4.9. Personal Protective Equipment

The following PPEs and other emergency handling equipment will be stocked in the MCR to be issued to the trained Key Personnel during an emergency.

- Fire proximity suit
- Fire entry suit
- Self contained Breathing Apparatus with one spare cylinder (30 minutes)
- Water gel blanket
- Safety helmet.
- Rubber hand gloves for use in electrical jobs
- Power tool
- Resuscitator

The quantities available will be sufficient to meet the needs of emergency handling personnel.

4.10. Rehearsal and Testing

'Fire Drills' will be arranged periodically to test out the laid down system and facilities. The emergency handlers will also "act out" their individual roles in accordance with the emergency procedures laid down to demonstrate that the entire emergency response system can perform efficiently and accurately. Mock drills for emergency will be conducted twice a year.

4.11. Emergency Plan for Natural Disasters

Due to its location, the Port is exposed to natural disasters of cyclones and tsunami in greater measures than any other natural disaster. Both the disasters give a short to very short notice, have potential to cause sudden and widespread damage to the Port infrastructure and the population beyond it, and make recover efforts difficult due to total collapse of administrative and welfare machinery.

It is essential for DMPs of a Port to have special provision for meeting with the challenges of cyclones and tsunamis. Since they do not give a long lead warning, pre-meditate and pre-rehearsed action between the first intimation and the onset of the event becomes crucial for

effectiveness. Since both events involve mass evacuation and widespread public notice, DMPs for cyclone and tsunami can ill-afford to be complicated.

a. Emergency measures during a Cyclone

IMD usually gives a 24 to 36 hours early warning on the onset of cyclone right from the time a depression starts forming in the Bay of Bengal. Aided by weather satellite, path of a cyclone can be traced almost in real time. The path of the cyclone can be reliably predicted and early warning/alerts can be given 10 to 12 hours prior to the hit of the cyclone. The details of actions to be taken before, during and after a cyclone by the Port authorities are given below.

Sr.	Action	Responsibility
	A. Actions before the	
1	The MCR will depute a Nodal Person to be on standby for receiving cyclone alert messages from the DG Shipping, DG Lighthouse and Lightships, Maritime Department of the state and Distt. Collector, as also from AIR and DD news telecasts and keep the MCR In-charge abreast of the situation.	MCR In-charge
2	The Port In-charge will start taking Cyclone Action 12 hours before the forecast time of hit. He will issue cyclone warning in the Port by asking the Nodal Person to play out warning on the Port paging channel, and individual call to all the HODs including Port security at the gate complex to be on high alert for further instructions.	Port In-charge Nodal Person in MCR.
3	The Port In-charge will order implementation of Port shutdown and evacuation 8 hours before the time of hit. Following actions will be taken: a. Entry to the Port will be stopped. All cargo trucks will be told to leave the Port premises in a coordinated manner assisted by the Traffic In-charge of the Port. b. Cargo handling operation on the Port backup (bulk cargo area and on the berths) will be stopped. All machinery will be folded back, retracted, fixed, moored and close-secured.	Port In-charge Transport and Materials Coordinator, Port Security Dry Cargo Department

Sr.	Action	Responsibility
	c. All material handling on the berths will be stopped. Outriggers of the cranes will be lifted and secured, booms and hoists retracted and secured in position, and the cranes to be locked and tide down with tie down hooks provided on the berths.	Dry Cargo Department
	d. All vessels berthed on the Port will be unmoored and set to sail to the anchorage area assisted by tugs.	MCR Traffic and VTMS Incharge, Tug masters
	e. All liquid cargo transfer on the liquid berths will be stopped. The loading arms will be unclamped, drained, folded and secured into vertical position. Liquid vessels will be given first right to sail.	Dry Cargo Department
	f. All tugs and other Port flotilla will be securely moored to the berths in the best wave shadow part of the berths.	Tug masters. Harbour masters.
	g. All loose material stored on the Port will be covered by tarpaulin and secured on the ground through grommets to the hooks provided on the edges of the hard stands.	Transport and Materials Coordinator
	h. All vehicles and material movers will be parked on the landward side of wind obstructing structures such as ware houses and buildings. Vehicles will be closed, locked down with their parking breaks on.	Transport and Materials Coordinator
	i. The ventilators of the covered godowns will be opened to provide cross movement of cyclonic winds.	Transport and Materials Coordinator
	j. Port In-charge will ask the HOD through the Nodal Person to relieve all the employees on duty except few who will be needed for final shutdown.	Port In-charge, Nodal Person, HODs.
	k. A jeep with battery power loudspeakers will be pressed to announce Cyclone Warning in local language on the nearby area.	Transport and Materials Coordinator
4	The Port In-charge will order complete evacuation of Port including the HODs 4 hours before the time of hit. Following actions will be taken:	Port In-charge, Nodal Person
	a. Security patrol party will announce evacuation in all the buildings by megaphone announcements.	Port security
	b. The MCR will be closed down systematically with all antennae lowered and secured, all equipment closed and powered off. All vessels at the anchorage will be asked to switch to VHS and UVHS channels as primary communication and maintain radio silence unless absolutely essential. MCR Communication will be put to roving mode. Communications will be handed over to the radio officer in the City office outside and away form the Port.	Port In-charge, MCR In-charge
	c. Port closure and security arrangements will be briefly	

Sr.	Action	Responsibility
	communicated to the District Crisis Group Centre by the Port In-charge through the hotline.	Port In-charge
	B. Actions during the Cyclone	
1	Port In-charge will be in contact with the Port personnel and District Crisis Group Centre on need basis through his VHS radio set from his residence or City office.	Port In-charge
	C. Actions after the Cyclone	
1	Port In-charge will order assembly of all HODs at his residence or in the Port city office after winds velocities have come down below 50 km/hr.	Port In-charge, HODs
2	Port In-charge will inspect damage in the Port personally along with relevant HODs and verbally instruct corrective and remedial measures to be taken. Following actions will be taken: a. The MCR will be reopened and all communication and navigation equipment restarted, calibrated and synchronised. b. Vessel stationed at anchored will be supplied with necessary supplies and spared if required by Port supply and pilot boats. Any medical causality will be rescued and hospitalized if necessary. c. All debris and wasted material spilled due to wind and rain will be collected, checked for contamination, and disposed off in a well designed pit in the Port premises. d. Damage to structural work of the Port, namely the cranes and other tall material handling structures (conveyor galleries, watch towers, building glasses) will be inspected and necessary repairs and cleaning will be undertaken. Structures whose stability is under question will be cordoned off till they are inspected in detail and cleared for general use. e. Water supply will be tested for portability, and other sanitary services resumed after suitable inspection. Water accumulated due to heavy rains will be drained and area dried, sprayed with disinfectant, etc. f. Status of Port will be communicated to the District Crisis Group Centre by the Port In-charge through the hotline	Port In-charge, HODs MCR In-charge Harbour master Transport and Materials Coordinator Engineering department Communications and Medical Coordinator Port In-charge.
1	After the Port housekeeping has been brought to order, all machineries will be sequentially tested. Port operations will be resumed with dry cargo handling vessels to be berthed first, followed by containers and liquid cargoes vessels.	Port In-charge.
2	Port medical, logistics, communication and personnel facilities will be suitably extended to the Crisis Group Centre Team the leadership of the Distt. Collector for any further relief work as desired by the local and distt. administration.	Port In-charge.

b. Emergency measures during a Tsunami

Early warning for a tsunami can be as short as one hour. Tsunami can be predicted by a network of seismic detection centers installed by the bordering nations after the December 2004 tsunami, as well as deep sea telemetered buoys placed by the MoES. Tsunami warning will be communicated to the Port MCR by the District Crisis Group Centre by telephone/emergency hotline.

Rapid action after the alert is critical to effective tsunami response. Unlike cyclone, tsunami is not accompanied by tell-tale disturbed weather and high winds, therefore Port must effectively communicate and elicit urgent action in this regard. The actions to be taken before, during and after a cyclone by the Port authorities are presented below.

Sr.	Action	Responsibility
	A. Actions before the Tsunami	
1	The MCR will initiate high–intensity emergency tsunami warning through all communications channel including Port paging channel, and individual call to all the HODs, including Port security at the gate complex with clear instruction to shut down all operations possible within 20 minutes, and move as far as possible from the sea front using any means of transportation available, including running away.	MCR In-charge
2	The MCR In-charge will carry out the following under standing authorization of the Port In-charge. Following actions will be taken: a. Entry to the Port will be stopped. All trucks and visitors will be driven away from the Port using one empty truck without creating any unnecessary traffic and congesting the roads/Port gate(s). b. All cargo handling operation on the Port and backup will be stopped immediately. All machinery will be folded back, retracted, fixed, moored and close-secured. Outriggers of the cranes will be lifted and secured, booms and hoists retracted and secured in position, and the cranes to be locked and tide down with tie down hooks provided on the berths. c. Mooring ropes of all vessels berthed on the Port will be slackened. Vessels will be asked to be on full power for any during-tsunami power assists. Tugs will be pressed to turn and send off any inbound vessel in the channel. All vessels in the anchorage will be communicated tsunami alert. All tugs and other Port flotilla will be securely moored to the berths in the best wave shadow part of the berths. d. All vehicles and material movers will be parked on the landward side of wave obstructing structures such as ware houses and	MCR In-charge Port Security Dry Cargo Department MCR Traffic and VTMS In-charge, Harbour master, Tug masters

Sr.	Action	Responsibility
	buildings. Vehicles will be closed, locked down with their parking breaks on.	Dry Cargo Department
	e. All HODs will ensure rapid and complete evacuation of the Port.	
	f. MCR will be manned and operational with essential staff for communication and coordination.	HODs.
	g. Decision on electrical shut down will be taken by the MCR In-charge after consultation with the Port In-charge depending on the size of the Tsunami waves predicted and communicated.	

B. Actions after Tsunami		
1	Port In-charge will resume office within minutes of waves subsiding to below deck height. He will inspect damage in the Port personally along with relevant HODs and verbally instruct corrective and remedial measures to be taken. Following actions will be taken: a. Vessels at the berths will be immediately attended for evacuation of any medical emergency. b. All debris and wasted material floated over dye to wave hit will be collected, checked for contamination, and disposed off in a well designed pit in the Port premises. c. Damage to civil and structural work of the Port, namely the berths, cranes, etc. will be inspected and necessary repairs and cleaning will be undertaken. Structures whose stability is under question will be cordoned off till they are inspected in detail and cleared for general use. d. Water supply will be tested for portability, and other sanitary services resumed after suitable inspection. Water accumulated due to wave hit will be drained and area dried, sprayed with disinfectant, etc. e. Status of Port will be communicated to the District Crisis Group Centre by the Port In-charge through the hotline	Port In-charge, HODs MCR In-charge, Harbour master, Tug masters, Communication and Medical Coordinator Dry Cargo Department Engineering department Communications and Medical Coordinator Port In-charge
2	After the Port housekeeping has been brought to order, all machineries will be sequentially tested. Port operations will be resumed after starting the unloading and stacking equipment.	Port In-charge.
3	Port medical, logistics, communication and personnel facilities will be suitably extended to the Crisis Group Centre Team the leadership of the Distt. Collector for any further relief work as desired by the local and distt. Administration.	Port In-charge.

Offsite action will be carried out in coordination with external agencies, whose responsibilities are listed as follows:

- Police
- Fire Brigade
- Medical Services
- Technical Agencies
- Rehabilitation Agencies
- Electricity Board

Responsibilities of the Services

I. Police

- To control traffic & mob by cordoning off the area

- Arrange for evacuation of people on advice from the Site Controller/District Collector
- Broadcast/communicate through public address systems to the community on advise from the District/Sub Collector
- Inform relatives about details of injured and casualties

II. Fire Brigade

- Fighting fire & preventing its spread
- Rescue & salvage operation

III. Medical/Ambulance

- First Aid to the injured persons
- Shifting critically injured patients to the hospitals
- Providing medical treatment

IV. Technical/Statutory Bodies

(Constitutes Factory Inspectorate, Pollution Control Board, Technical Experts from Industries)

- Provide all technical information to the emergency services, as required
- Investigate the cause of the disaster

V. Rehabilitation

- Arrange for evacuation of persons to nominated rescue centre and arrange for their food, medical and hygienic requirements
- Coordinating with the Insurance Companies for prompt disbursement of compensation to the affected persons
- Maintain communication channels of nearby industries like telephone, telex etc. in perfect working condition

VI. Electricity Board

- To regulate/re-connect the power supply to the Port if specifically asked for by the Port

4.12. Conclusion

4.12.1. Failure Frequency associated with Loss of Containment

Quantitative risk is a function of failure frequency of an equipment and consequence of the scenario. A moderate consequence with extremely rare frequency of occurrence may pose only minor risk to the facility in its operative lifetime. Failure frequencies of plant elements in the LNG terminal are given below.

Sr.	Plant component	Failure Frequency per year
1	16”unoading arm, 25 mm hole	5.0 E -7
2	48” unloading header, 25 mm hole	2.5 E -7
3	20” LP Pump header, 25 mm hole	6.0 E -7
4	26” send out heder, 25 mm hole	5.0 E -7

It may be observed from the above failure frequency data that the likelihood of an incidence occurring in the 40 years assumed lifetime of the LNG terminal is extremely rare.

4.12.2. Consequence Analysis findings – interpretation in the context of the proposed LNG Terminal

LNG industry has been among the safest in the petroleum and chemical sector with comparatively miniscule number of incidences in comparison with the total number of operational LNG facilities, number of shipments through seas, on roads and by pipelines. The strong safety record of the LNG industry is a result of several factors.

The industry has technically and operationally matured to ensure safe and secure operation.

Physical and chemical properties of LNG are such that risks and hazards are well understood and incorporated into technology and operations.

Standards, codes and regulations that apply to the LNG industry further ensure safety.

Safety in the LNG industry is ensured by four elements that provide multiple layers of protection both for the safety of LNG industry workers and the safety of communities that surround LNG facilities.

Primary containment is the first and most important requirement for containing the LNG product. This first layer of protection involves the use of appropriate materials for LNG facilities as well as proper engineering design of storage tanks onshore and on LNG ships and elsewhere.

Secondary containment ensures that if leak or spills occur at the onshore LNG facility, the LNG can be fully contained and isolated from the public.

Safeguard system offers a third layer of protection. The goal is to minimize the frequency and size of LNG releases both onshore and offshore and prevent harm from potential associated hazards, such as fire. For this level of safety protection, LNG operations use technologies such as high level alarms and multiple back-up safety systems which include Emergency Shutdown (ESD) systems. ESD systems can identify problems and shut off operations in the event certain specified fault conditions or equipment failures occur, and which are designed to prevent or limit significantly the amount of LNG and LNG vapour that could be released. Fire and gas detection and fire fighting systems all combine to limit effects if there is a release. The LNG facility or ship operator then takes action by establishing necessary operating procedures, training, emergency response systems and regular maintenance to protect people, property and the environment from any release.

Finally, LNG facility designs are required by regulation to maintain separation distance to separate land-based facilities from communities and other public areas. Safety zones are also required around LNG ships.

The physical and chemical properties of LNG necessitate these safety measures. LNG is odourless, non-toxic, non-corrosive and less dense than water. LNG vapours (primarily methane) are harder to ignite than other types of flammable liquid fuels. Above

approximately -1100C LNG vapour is lighter than air. If LNG spills on the ground or on water and the resulting flammable mixture of vapour and air does not encounter an ignition source, it will warm, rise and dissipate into the atmosphere.

There is a very low probability of release of LNG during normal industry operations due to the safety systems that are in place.

Shore based installations are characterized with high wind speeds and warm climate due to the land and sea breeze, and heat sink phenomenon of the ocean. This type of climate will ensure quick dispersion of any LNG spillage beyond its LFL of 5%.

Being in the temperate region, due to generally strong solar insolation, atmospheric stability is generally from A to D which ensures greater ambient mixing and rapid dispersion of flammable vapours. Stability Class F occurs for short duration in overcast skies with less than 2 m/s wind speed, which is an unlikely condition for Karaikal. However, consequence analysis is carried out for conservative dispersion scenarios under atmospheric dispersion condition of 'D – Neutral' and 'F – Stable'.

Intervention time upon any release, chance of the flammable cloud meeting with a source of ignition and total quantity under burn are equally important while perception of risk of the proposed terminal. In the modelled release scenarios serious risk may arise only due to escalation of the incidence, which is taken care in the operation philosophy and design of the facility per most stringent design codes for the industry.