1. INTRODUCTION

1.1 SCOPE

The proposed Capacity Expansion Project of Cuddalore Port will have additional two Cargo Berths and so eventually enhanced cargo which will increase the vulnerability of the Port to natural and manmade hazards.

The scope and purpose of this report is to identify the main hazards to the existing Port and more precisely, the proposed additional infrastructures as capacity Expansion Project. The assessment on the likely hazards is made in order to achieve a state of preparedness, or implement mitigating actions, which will reduce the impact. A simple identification of the hazards would serve little purpose if they were not assessed and action taken on such assessment.

Any coastline and marine areas are vulnerable to natural disasters like cyclone, Storm, earth quake, Flood, Tsunami, rise in tides, etc. The proposed capacity expansion project will enhance the Port activities further with additional two cargo berths with required cargo handling systems.

Activities during construction pose little hazards, if any, due to **human error** and **failure of erection or construction equipments** leading to injury and health impairment.

This report delineated the location specific natural hazards and risk prone activities of the Port and drawn a detailed scheme for effective management to provide risk-free environment to Cargo management in the post project scenario.

The purpose of the study includes the following:

- To identify and assess those hazards and risks arising from their activities connected to the project that require management in order to comply with regulatory requirements, company policy and business requirements

- To eliminate or reduce to as low as reasonably practical in terms of risk to human health, risk of injury, risk of damage to plant, equipment and environment, business interruption or loss etc.

The scope of the QRA is given below:

- Identification of Hazards and Major Loss of Containment (LOC) events
- Calculation of physical effects of accidental scenarios, which includes frequency analysis for incident scenarios leading to hazards to people and facilities (flammable gas, fire, and smoke, explosion overpressure and toxic gas hazards) and consequence analysis for the identified hazards covering impact on people and potential escalation.
- Damage limits identification and quantification of the risks and contour mapping on the layouts.
- Individual risk quantification and contour mapping.
- Societal risk quantification and contour mapping
- Hazard mitigation recommendations based on QRA

1.2 RISK FACTORS AND ATTRIBUTES

The in-practice RA & RMP as the Port is an operating Port with 02 numbers of Cargo Berth require updating to address the proposed additional infrastructures and activities. The proposed project of Capacity Expansion with additional Berths and Cargo handling, the following risk prone situations are envisioned:

- Natural hazards
- Fire
- Human error in handling Cargo

These four are very likely events and with significant credibility to happen to lead an accident or an injury.

The project location is vulnerable to coastal extremes like Cyclone, Storm Surge, Earth Quake and including Tsunami. Hence, the following methodology was adopted for identifying and listing of risk scenarios.

IDENTIFICATION	MAIN HAZARDS
Assessment	Assessing the probability of an incident and its consequences
Prioritization	Assessing which hazards should be awarded priority consideration for mitigation/emergency planning
Mitigation	Considering the actions which could be taken to mitigate the effects of a potential incident. This will usually mean the preparation of an emergency plan or identifying existing plans which are relevant
Management Plan	Taking action as appropriate taking into account the processes set out above

There are several methods by which hazards can be assessed leading to a formal "Risk Assessment". However, many of the methods do not lend themselves readily to the type of hazards that are being considered here. The emergency management assessment is looking at hazards over which local authorities or indeed any other organizations have little or no control. In such cases, arrangements to reduce the impact on the community are necessary. Such hazards include severe weather, transport accidents, etc. Those activities or hazards over which there is an element of control, however small or remote have been assessed to determine any actions could be taken to mitigate the effects or likelihood of an incident.

The human error during cargo handling is a very credible cause for an accident which could lead to injuries and the impact is temporal and retrievable.

After identifying the study objectives and collection of data, the team identified the major consequences that are possible due to deviations from design and engineering intentions.

1.3 FACILITY DESCRIPTION

At present, Cuddalore Port is operating a wharf in the Uppanar water spread. The adjoining fishing Harbor is using the same Uppanar as its waterway. Hence, the proposed CEP is envisaged in Paravanar Water spread. Nevertheless, the required area for turning circle and approach channel for vessels are available in more compatible conditions in the proposed location for berth construction in the Paravanar River

The CEP was envisaged based on the location-specific coastal processes of project zone, the proposed Berths, Cargo handling facilities, modifications in the Breakwaters, Dredging and Dredged Spoil Management.

TNMB will optimally use natural character of coastline of the existing Cuddalore Port area and the proposed CEP is envisaged to ensure long term sustainability of Cuddalore Port, which eventually enhance the socio-economic status of the Cuddalore district.

1.4 CARGO BERTHS; TWO NUMBERS

The proposed additional Berths; Two Numbers are within the notified Port Limits and in the water spread of Paravanar. The proposed Berths will be 120 X 21 m each. The depth at the proposed berth area will be dredged for -10m.

A turning Circle for a diameter of 300m is proposed. The approach Channel is envisaged for 1500m with the width of about 60m and for a depth of -9m. This will facilitate the navigation of cap max ships and the Port activities in the post project scenario will essentially make it as All Weather Port.

1.5 EXTENSION OF BREAKWATERS

At present, one wharf (400 m) is under operation and it is in the Uppanar water spread. The proposed Berths are envisaged in the water spread of Paravanar with required turning circle and navigational facilities.

The new Berths are in different locations, but within the notified limits of the Port. The extension of North Breakwater is proposed for 210m and South Breakwater for 410m. The required modification and extension of the existing Breakwaters were planned and designed by IIT-M.

1.6 CARGO HANDLING FACILITIES

The Berths are envisaged as Multi-cargo handling facilities. At present, Cuddalore Port is permitted to handle fertilizers, bulk pharma and chemicals, Cereals, wood, etc. The proposed Berths are envisaged with cargo handling mechanical systems with loading and unloading winches and other ancillary equipment for transfer.

The proposed Cargo Mix is Coal, Cement, Fertilizers and Clean Cargo like containers. The net Cargo handling capacity of the proposed CEP is projected for **5.68 MTPA**.

The reclaimed area using dredged spoil will be used to establish storage facilities for the Cargo. All storage for Cargo will be in closed sheds, except for Coal. Coal will be stored in open yards with paved platform with well laid approach roads. TNMB is committed to phase out the use of open yards for storage by Silos in phased manner within the first five year of the CEP get commissioned.

TNMB is committed to incorporate semi or fully auto operated Cargo handling mechanical systems with the control of Instruments.

1.7 DREDGING & DISPOSAL

The Paravanar water spread has been surveyed for heavy silting over the several years. The proposed turning circle to facilitate vessel movements into the river and to make the proposed Berths operational, dredging is important.

Dredging is assessed based on the prevailing bathymetry and requirements for the size of vessel and cargo, it is assessed that **1.88 million Cubic Meter** of dredging is important and must for operating vessels in the proposed project expansion of Cuddalore Port.

The dredged spoil will be reused for reclaiming area within the Port limits to have storage Closed Sheds and Open Yards for the operation of the port. A part of the dredged material is envisaged for use towards erosion prevention on the leeside of the northern breakwaters

2. HAZARD AND RISK

2.1 GENERAL

Oil handling, natural or manmade, may have the potential to cause disruption, damage to property, or endanger life in and around the Port. The section will list the hazards in three categories, **Natural, Technological and Others**. A brief description of each hazard's characteristics will be given.

"A hazard is best viewed as a naturally occurring or human induced process or event which has the potential to create loss." The hazards covered in this section are ones viewed as most prominent to the Harbor and are not an exhaustive list of all known hazards. In this section each hazard will be viewed as a primary hazard. This chapter therefore provides the understanding of hazards in an attempt to increase the accuracy of the risk assessment.

2.2 NATURAL HAZARDS

Severe weather includes heavy rain, cyclone, and storm surge. These types of weather storms usually result in the disruptions to transportation routes, power and utility failure, immobilizing fishing activity. The India Meteorological Department (IMD) provides a certain amount of warning for these types of hazards and they rarely cause lengthy disruptions apart from in extreme cases when severe damage is caused to infrastructures.

Depression in the Bay of Bengal re0gion are most frequent in the South West monsoon and least so in the North East monsoon. Storms are least frequent from January to March and most frequent in the months of October and November. Storms are also as frequent in May and in August. Severe storms are most frequent in May and in October and November. During October, the entire region to the north of about Latitude of 8^0N is liable to be affected. This is one of the three months where storms are most likely to be severe. In the month of November, severe storms are more frequent and the whole region is likely to be affected. However, the Port location is historically not significantly affected by extreme weather conditions.

2.3 TECHNOLOGICAL HAZARDS

The Cargo handling, transfer, storage and loading/unloading are accident prone areas due to mechanical/electrical failure.

2.4. HUMAN ERROR

At times, human error cannot be ruled out which can result in major mishaps.

2.5. OTHER HAZARDS

Being a Port and has long history of operation and multi- Cargo handling facilities, including Oil and Chemicals, accident due to fire and gas leak are credible. The post project scenario of the Port must be reinforced with required systems to prevent, mitigate and manage such emergency situations out off accidents.

Fire, Terrorism or any public disorder will have no cause of any risk in the post project scenario.

3. QUANTITATIVE RISK ANALYSIS

3.1 GENERAL

Risk Analysis is proven valuable as a management tool in assessing the overall safety performance of the Chemical Process Industry. Although management systems such as engineering codes, checklists, and reviews by experienced engineers have provided substantial safety assurances, major incidents involving numerous casualties, injuries and significant damage can occur - as illustrated by recent world-scale catastrophes. Risk Analysis techniques provide advanced quantitative means to supplement other hazard identification, analysis, assessment, control and management methods to identify the potential for such incidents and to evaluate control strategies.

The underlying basis of Risk Analysis is simple in concept. It offers methods to answer the following four questions:

1. What can go wrong?
2. What are the causes?
3. What are the consequences?
4. How likely is it?

This study tries to quantify the risks to rank them accordingly based on their severity and probability. The report should be used to understand the significance of existing control measures and to follow the measures continuously. Wherever possible the additional risk control measures should be adopted to bring down the risk levels.

3.2 RISK CONCEPT

Risk in general is defined as a measure of potential economic loss or human injury in terms of the probability of the loss or injury occurring and magnitude of the loss or injury if it occurs. Risk thus comprises of two variables; magnitude of consequences and the probability of occurrence. The results of Risk Analysis are often reproduced as Individual and groups risks and are defined as below.

Individual Risk is the probability of death occurring as a result of accidents at a plant, installation or a transport route expressed as a function of the distance from such an activity.

It is the frequency at which an individual or an individual within a group may be expected to sustain a given level of harm (typically death) from the realization of specific hazards.

Such a risk actually exists only when a person is permanently at that spot (out of doors).

The exposure of an individual is related to

- The likelihood of occurrence of an event involving a release and Ignition of hydrocarbon,
- The vulnerability of the person to the event,
- The proportion of time the person will be exposed to the event (which is termed 'occupancy' in the QRA terminology).

The second definition of risk involves the concept of the summation of risk from events involving many fatalities within specific population groups. This definition is focused on the risk to society rather than to a specific individual and is termed **'Societal Risk'**. In relation to the process operations we can identify specific groups of people who work on or live close to the installation; for example communities living or working close to the plant.

Risk is a function of the probability *(likelihood)* of particular hazards arising and the potential impact which would result from these. Therefore, risk is the level of perceived exposure of people, services or processes to the effects of identified hazards. Risk assessments are part of everyday life. People, and what they value, are the essential point of reference and basis for all risk assessments.

3.3 POTENTIAL IMPACTS

The risk of each hazard has been calculated on two criteria - probability and consequences. Probability is the likelihood of a particular event occurring. Consequences are the expected number of lives lost, persons injured, scale of damage to property and disruption of essential services and economic activity resulting from the impact of a particular natural or manmade hazard. The probability and consequences of the hazards identified in the previous section were assessed on a scale 1-5. Very unlikely probability or very minimal consequences being rated at 1, with very likely probability and very severe consequences rated at 5. The probability and consequences are then multiplied to determine the risk category. The Risk Categories are illustrated in the **Table-3.1.**

Table 3.1 RISK CATEGORY

SEVERITY OF IMPACT/ CONSEQUENCES → LIKELIHOOD/ PROBABILITY↓	1 (Minimal)	2 (Slight)	3 (Moderate)	4 (Severe)	5 (Very severe)
1 (Very unlikely)	1	2	3	4	5
2 (Unlikely)	2	4	6	8	10
3 (Moderate)	3	6	9	12	15
4 (Likely)	4	8	12	16	20
5 (Very likely)	5	10	15	20	25

The level of risk is categorized based on the product of probability and consequence values. This is illustrated in the **Table-3.2.**

Table-3.2 LEVEL OF RISK CATEGORY

Very Low	Low	Moderate	High	Very high
1-2	3-6	7-12	13-19	20-25

3.4 RISK ASSESSMENT PROCEDURE

Hazard identification and risk assessment involves a series of steps as follows:

Step 1: Identification of the Hazard

Based upon consideration of factors such as the physical & chemical properties of the fluids being handled, the arrangement of equipment, operating & maintenance procedures and processing conditions, External hazards such as third-party interference, extreme environmental conditions, aircraft / helicopter crash should also be considered.

Step 2: Assessment of the Risk

Arising from the hazards and consideration of its tolerability to personnel, the facility and the environment, this involves the identification of initiating events, possible accident sequences, and likelihood of occurrence and assessment of the consequences. The acceptability of the estimated risk must then be judged based upon criteria appropriate to the particular situation.

Step 3: Elimination or Reduction of the Risk

Where this is deemed to be necessary, this involves identifying opportunities to reduce the likelihood and/or consequence of an accident.

Hazard Identification is a critical step in Risk Analysis. Many aids are available, including experience, engineering codes, checklists, detailed process knowledge, equipment failure experience, hazard index techniques, What-if Analysis, Hazard and Operability (HAZOP) Studies, Failure Mode and Effects Analysis (FMEA), and Preliminary Hazard Analysis (PHA). In this phase all potential incidents are identified and tabulated. Site visit and study of operations and documents like drawings, process write-up etc are used for hazard identification.

Assessment of Risks

The assessment of risks is based on the consequences and likelihood.

Consequence Estimation is the methodology used to determine the potential for damage or injury from specific incidents. A single incident (e.g. rupture of a pressurized flammable liquid tank) can have many distinct incident outcomes (e.g. Unconfined Vapor Cloud Explosion (UVCE), Boiling Liquid Expanding Vapor Explosion (BLEVE), flash fire.

Likelihood assessment is the methodology used to estimate the frequency or probability of occurrence of an incident. Estimates may be obtained from historical incident data on failure frequencies or from failure sequence models, such as fault trees and event trees. In this study the historical data developed by software models and those collected by CPR 18E – Committee for Prevention of Disasters, Netherlands are used.

Risk Assessment combines the consequences and likelihood of all incident outcomes from all selected incidents to provide a measure of risk. The risk of all selected incidents are individually estimated and summed to give an overall measure of risk.

Risk-reduction measures include those to prevent incidents (i.e. reduce the likelihood of occurrence) to control incidents (i.e. limit the extent & duration of a hazardous event) and to mitigate the effects (i.e. reduce the consequences). Preventive measures, such as using inherently safer designs and ensuring asset integrity, should be used wherever practicable.

In many cases, the measures to control and mitigate hazards and risks are simple and obvious and involve modifications to conform to standard practice. The general hierarchy of risk reducing measures is:

- Prevention (by distance or design)
- Detection (e.g. fire & gas, leak detection)
- Control (e.g. emergency shutdown & controlled depressurization)
- Mitigation (e.g. firefighting and passive fire protection)
- Emergency response (in case safety barriers fail)

3.5 RISK ANALYSIS METHODOLOGY

3.5.1 IDENTIFICATION OF HAZARDS & RELEASE SCENARIOS

A technique commonly used to generate an incident list is to consider potential leaks and major releases from fractures of all process pipelines and vessels. This compilation includes all pipe work and vessels in direct communication, as these may share a significant inventory that cannot be isolated in an emergency. The following data were collected to envisage scenarios:

* Composition of materials flowing through pipeline
* Flow rate of materials passing through pipelines
* Pipeline conditions (phase, temperature, pressure)
* Connecting piping and piping dimensions.

Accidental release of flammable liquids / gases and toxic gases can result in severe consequences. Delayed ignition of flammable gases can result in blast overpressures covering large areas. This may lead to extensive loss of life and property. In contrast, fires have localized consequences. Fires can be put out or contained in most cases; there are few mitigating actions one can take once a flammable gas or a vapor cloud gets released. Major accident hazards arise, therefore, consequent upon the release of flammable gases.

3.5.2 FACTORS FOR IDENTIFICATION OF HAZARDS

In any installation, main hazard arises due to loss of containment during handling of cargo. To formulate a structured approach to identification of hazards, an understanding of contributory factors is essential.

Blast over Pressures

Blast Overpressures depend upon the reactivity class of material and the amount of gas between two explosive limits. For example fuel gas once released and not ignited immediately is expected to give rise to a gas cloud. These gases in general have medium reactivity and in case of confinement of the gas cloud, on delayed ignition may result in an explosion and overpressures.

Operating Parameters

Potential gas release for the same material depends significantly on the operating conditions.

The gases are likely to operate at atmospheric temperature (and hence high pressures). This operating range is enough to release a large amount of gas in case of a leak / rupture, therefore the pipeline leaks and ruptures need to be considered in the risk analysis calculations.

Inventory

Inventory Analysis is commonly used in understanding the relative hazards and short listing of release scenarios. Inventory plays an important role in regard to the potential hazard. Larger the inventory of a vessel or a system, larger the quantity of potential release, A practice commonly used to generate an incident list is to consider potential leaks and major releases from fractures of pipelines and vessels containing sizable inventories.

Range of Incidents

Both the complexity of study and the number of incident outcome cases are affected by the range of initiating events and incidents covered. This not only reflects the inclusion of accidents and / or non-accident-initiated events, but also the size of those events. For instance studies may evaluate one or more of the following:

- catastrophic failure of container
- large hole (large continuous release)
- smaller holes (continuous release)
- leaks at fittings or valves (small continuous release)
- "Popping" of relief valves (short duration limited release).

In general, quantitative studies do not include very small continuous releases or short duration small releases if past experience or preliminary consequence modeling shows that such releases do not contribute to the overall risk levels.

Selection of Initiating Events and Incidents

The selection of initiating events and incidents should take into account the goals or objectives of the study and the data requirements. The data requirements increase significantly when non -accident - initiated events are included and when the number of release size increase. While the potential range of release sizes is tremendous, groupings are both appropriate and necessitated by data restrictions. The main reasons for including release sizes other than the catastrophic are to reduce the conservatism in an analysis and to better understand the relative contributions to risk of small versus large releases.

As per CPR 18 E guidelines only the Loss of Containment (LOC) s which is basically the release scenarios contributing to the individual and/ or societal risk are included in the QRA. LOCs of the installation are included only if two conditions are fulfilled:

- Frequency of occurrence is equal to or greater than 10^{-8} and
- Lethal damage (1% probability) occurs outside the establishment's boundary or the transport route.

The above definition includes the Maximum Credible Accident Scenarios (with a potential to cause one fatality within the operating period of 10^{-6} years)

There may be number of accidents that may occur quite frequently, but due to proper control measures or fewer quantities of chemicals released, they are controlled effectively. A few examples are a leak from a gasket, pump or valve, release of a chemical from a vent or relief valve, and fire in a pump due to overheating. These accidents generally are controlled before they escalate by using control systems and monitoring devices – used because such piping and equipment are known to sometimes fail or malfunction, leading to problems.

On the other hand, there are less problematic areas / units that are generally ignore or not given due attention. Such LOCs are identified by studying the facilities and Event Tree Analysis etc. and accidents with less consequence are ignored. Some of the critical worst case scenarios identified by the Hazard Identification study are also assessed as per the guidelines of Environment Protection Agency.

3.6 TYPES OF OUTCOME EVENTS

In this section of the report we describe the probabilities associated with the sequence of occurrences which must take place for the incident scenarios to produce hazardous effects and the modeling of their effects.

Considering the present case the outcomes expected are

- Jet fires
- Vapor Cloud Explosion (VCE)
- Late Pool Fire

3.6.1 JET FIRES

Jet fire occurs when a pressurized release (of a flammable gas or vapour) is ignited by any source. They tend to be localized in effect and are mainly of concern in establishing the potential for domino effects and employee safety zones rather than for community risks.

The jet fire model is based on the radiant fraction of total combustion energy, which is assumed to arise from a point slowly along the jet flame path. The jet dispersion model gives the jet flame length.

3.6.2 VAPOR CLOUD EXPLOSION (VCE) AND FLASH FIRE (FF)

Vapor cloud explosion is the result of flammable materials in the atmosphere, a subsequent dispersion phase, and after some delay an ignition of the vapor cloud. Turbulence is the governing factor in blast generation, which could intensify combustion to the level that will result in an explosion. Obstacles in the path of vapor cloud or when the cloud finds a confined area, as under the bullets, often create turbulence. Insignificant level of confinement will result in a flash fire. The VCE will result in overpressures.

It may be noted that VCEs have been responsible for very serious accidents involving severe property damage and loss of lives. Substances like LPG can cause VCEs if they are released in huge quantities in short span of time.

3.6.3 POOL FIRES

This represents a situation when flammable liquid spillage like crude, HSD etc forms a pool over a liquid or solid surface and gets ignited.

Early pool fire was caused when the steady state is reached between the outflow of flammable material from the container and complete combustion of the flammable material when the ignition source is available. Late pool fires are associated with the difference between the release of material and the complete combustion of the material simultaneously. Late pool fires are common when large quantity of flammable material is released within short time.

These outcome events are then further analyzed in the Risk estimation procedure.

3.7 CONSEQUENCE CALCULATIONS

In consequence analysis, use is made of a number of calculation models to estimate the physical effects of an accident (spill of hazardous material) and to predict the damage (lethality, injury, material destruction) of the effects.

Accidental release of flammable liquids / gases can result in severe consequences. Immediate ignition of the pressurized chemical will result in a jet flame. Delayed ignition of flammable vapors can result in blast overpressures covering large areas. This may lead to extensive loss of life and property. In contrast, fires have localized consequences. Fires can be put out or contained in most cases; there are few mitigating actions one can take once a vapour cloud gets released.

The calculations can roughly be divided in three major groups:

a) Determination of the source strength parameters;

b) Determination of the consequential effects;

c) Determination of the damage or damage distances.

The basic physical effect models consist of the following.

3.7.1 Source Strength Parameters

- Calculation of the outflow of liquid vapors or gas out of a vessel or a pipe, in case of rupture. Also two-phase outflow can be calculated.
- Calculation, in case of liquid outflow, of the instantaneous flash evaporation and of the dimensions of the remaining liquid pool.
- Calculation of the evaporation rate, as a function of volatility of the material, pool dimensions and wind velocity.
- Source strength equals pump capacities, etc. in some cases.

3.7.2 Consequential Effects

- Dispersion of gaseous material in the atmosphere as a function of source strength, relative density of the gas, weather conditions and topographical situation of the surrounding area.
- Intensity of heat radiation [in kW/ m^2] due to a fire or a BLEVE, as a function of the distance to the source.
- Energy of vapor cloud explosions [in N/m^2], as a function of the distance to the distance of the exploding cloud.
- Concentration of gaseous material in the atmosphere, due to the dispersion of evaporated chemical. The latter can be either explosive or toxic.

It may be obvious, that the types of models that must be used in a specific risk study strongly depend upon the type of material involved:

- Gas, vapor, liquid, solid?
- Inflammable, explosive, toxic, toxic combustion products?
- Stored at high/low temperatures or pressure?
- Controlled outflow (pump capacity) or catastrophic failure?

The basic physical effect models consist of the following:

3.8 SELECTION OF DAMAGE CRITERIA

The damage criteria give the relation between the extents of the physical effects (exposure) and the effect of consequences. For assessing the effects on human beings consequences are expressed in terms of injuries and the effects on equipment / property in terms of monetary loss. The effect of consequences for release of toxic substances or fire can be categorized as

- Damage caused by heat radiation on material and people
- Damage caused by explosion on structure and people

In Consequence Analysis studies, in principle three types of exposure to hazardous effects are distinguished:

1. Heat radiation due to fires. In this study, the concern is that of Jet fires and flash fires.
2. Explosions

The knowledge about these relations depends strongly on the nature of the exposure. Following are the criteria selected for damage estimation:

Heat Radiation

The effect of fire on a human being is in the form of burns. There are three categories of burn such as first degree, second degree and third-degree burns. The consequences caused by exposure to heat radiation are a function of:

- The radiation energy onto the human body [kW/m^2];
- The exposure duration [sec];
- The protection of the skin tissue (clothed or naked body).

The limits for 1% of the exposed people to be killed due to heat radiation, and for second-degree burns are given in the table below:

Damages to Human Life Due to Heat Radiation

Exposure Duration	Radiation energy (1% lethality, kW/m^2	Radiation energy for 2^{nd} degree burns, kW/m^2	Radiation energy for first degree burns, kW/m^2
10 Sec	21.2	16	12.5
30 Sec	9.3	7.0	4.0

Effects Due To Incident Radiation Intensity

INCIDENT RADIATION – kW/m^2	TYPE OF DAMAGE
0.7	Equivalent to Solar Radiation
1.6	No discomfort for long exposure
4.0	Sufficient to cause pain within 20 sec. Blistering of skin (first degree burns are likely)
9.5	Pain threshold reached after 8 sec. second degree burns after 20 sec.
12.5	Minimum energy required for piloted ignition of wood, melting plastic tubing's etc.

The actual results would be less severe due to the various assumptions made in the models arising out of the flame geometry, emissivity, angle of incidence, view factor and others. The radioactive output of the flame would be dependent upon the fire size, extent of mixing with air and the flame temperature. Some fraction of the radiation is absorbed by carbon dioxide and water vapor in the intervening atmosphere. Finally the incident flux at an observer location would depend upon the radiation view factor, which is a function of the distance from the flame surface, the observer's orientation and the flame geometry.

Assumptions (As per the guidelines of CPR 18 E Purple Books)

- The lethality of a jet fire is assumed to be 100% for the people who are caught in the flame. Outside the flame area, the lethality depends on the heat radiation distances.
- For the flash fires lethality is taken as 100% for all the people caught outdoors and for 10% who are indoors within the flammable cloud. No fatality has been assumed outside the flash fire area.

Explosion

In case of vapor cloud explosion, two physical effects may occur:

- A flash fire over the whole length of the explosive gas cloud;
- A blast wave, with typical peak overpressures circular around ignition source.

For the blast wave, the lethality criterion is based on:

A peak overpressure of 0.1 bars will cause serious damage to 10% of the housing/structures.

Falling fragments will kill one of each eight persons in the destroyed buildings.

The following damage criteria may be distinguished with respect to the peak overpressures resulting from a blast wave:

Damage Due To Overpressures

Peak Overpressure	Damage Type	Description
0.30 bar	Heavy Damage	Major damage to plant equipment structure
0.10 bar	Moderate Damage	Repairable damage to plant equipment & structure
0.03 bar	Significant Damage	Shattering of glass
0.01 bar	Minor Damage	Crack in glass

Assumptions (As per the guidelines of CPR 18 E Purple Books)

- Overpressure more than 0.3 bar corresponds approximately with 50% lethality.
- An overpressure above 0.2 bars would result in 10% fatalities.
- An overpressure less than 0.1 bars would not cause any fatalities to the public.
- 100% lethality is assumed for all people who are present within the cloud proper.

3.9 PROBABILITIES

3.9.1 Failure / Accident Probabilities

The failure data is taken from CPR 18E –Guidelines for Quantitative Risk Assessment, developed by the Committee for the Prevention of Disasters, Netherlands.

3.9.2 Weather Probabilities

The data provided by the TPT and the actual monitoring data were taken for this project

More details on the wind speed and direction are provided in Chapter 3 of this report.

Wind velocity

The minimum and maximum wind velocities are 2.1 and 2.7m/s respectively.

Stability Class

In a QRA, representative weather classes have to be used, covering the stability conditions if stable, neutral and unstable, and low and high wind speeds. In terms of Pasqual classes, the following weather classes may be covered:

Stability class	Wind speed (1)
B	Medium
D	Low
D	Medium
D	High
E	Medium
F	Low

Low wind speed corresponds with 1-2 m/s

Medium wind speed corresponds to 3-5 m/s

High wind speed corresponds to 8-9 m/s

The Annual mean air temperature is around 29.21^{O}C. The maximum and minimum temperatures were 40 deg C and 23deg C.

Annual mean % humidity is 73 %

3.9.3 Ignition Probabilities

For gas releases from the gas distribution system, where a large percentage of rupture events may be due to third party damage, a relatively high probability of immediate ignition is generally used. This is supported by the data given below:

Data Source	Probability of Ignition	
U.K. Gas (Townsend, 1986)	Leaks Ruptures	0.1 0.5
U.S. Gas (Jones, 1986)	All sizes Ruptures	0.16 0.26
European Gas (European Gas pipeline incident data group, 1988)	Pinholes / cracks Holes Ruptures < 16” Ruptures >= 16” All sizes	0.02 0.03 0.05 0.35 0.03

These figures represent the total chance of ignition, not just immediate ignition. Immediate and delayed ignition probabilities are also specified in the Cox, Ang and Lees Model.

Delayed ignition takes other factors into account. Delayed ignition probabilities can also be determined as a function of the cloud area or the location. In general as the size of the cloud increases, the probability of delayed ignition decreases. This is due to the likelihood that the cloud has already encountered an ignition source and ignited before dispersing over a larger area (i.e. the cloud reaches an ignition source relatively close to the point of origin).

For this study the ignition probabilities have been modified to suit the existing site conditions. The ignition probabilities inside enclosed areas will be much higher than the open areas. It is because of the fact that there will be much more activities taking place and the possibility of ignition increases.

In this study the following probabilities were taken as per CPR 18 E

Operating probability : 0.5

Ignition probability : 0.9

3.10 EXPOSURE TO NATURAL HAZARDS

3.10.1 Extreme Weather (Cyclone/Storm/Storm Surge)

In this report, severe weather includes heavy rain, cyclone, and storm surge. These types of weather storms usually result in the disruptions to transportation routes, power and utility failure, immobilizing fishing activity. The India Meteorological Department (IMD) provides a certain amount of warning for these types of hazards and they rarely cause lengthy disruptions apart from in extreme cases when severe damage is caused to infrastructures.

Depression in the Bay of Bengal region are most frequent in the South West monsoon and least so in the North East monsoon. Storms are least frequent from January to March and most frequent in the months of October and November. Storms are also as frequent in May and in August. Severe storms are most frequent in May and in October and November. During October, the entire region to the north of about Latitude of 8^0N is liable to be affected. This is one of the three months where storms are most likely to be severe. In the month of November, severe storms are more frequent and the whole region is likely to be affected. However, during the past 30 years, as furnished by Indian Meteorological Department, only 3 cyclones have crossed the coast near Karaikkal which is about 40 km to south of Poombuhar.

The effect of extreme weather would most likely be a disruption of vital services such as water, sewer, power and transportation; damage to and disruption of emergency response facilities, resources and systems. As per the Vulnerability atlas of cyclone frequency and wind hazard map, Poombuhar falls in the **Very High Damage Risk Zone-B (Figure-3.1).** Hence, a "worst case scenario" would affect the port and also the entire community to a significant level.

3.10.2 Coastal Erosion

Coastal erosion is the gradual removal of sediments (including beach sand and topsoil) in coastal areas due to wave and tidal action. Wind, wave and tidal action can impact large portions of the shoreline, including beaches and small cliff areas. Erosion may cause damage to roadways, residences, and other structures, and it may also lead to a loss of vegetation. The impacts of erosion on coastal areas are generally gradual, although dramatic coastal erosion may occur following a storm or flood event.

The present project is Engineered Structures Viz., **Rubble Mound Seawall (RMS), Groynes and Training Walls**. The proposed structures are essentially to prevent such erosion and to protect the shoreline.

3.10.3 Flooding

Floods constitute one of the most potentially serious hazards facing the District. Flooding occurs when abnormally high-water levels overtop the natural or artificial banks of a river or other watercourse. The harbour is situated near the estuary of the river Cauvery. The District is potentially at risk from riverine or fluvial flooding which can result from either long duration of rainfall causing watercourse to rise above their normal level (usually winter scenario) or short intense rainfall events causing the watercourse to rise rapidly due to overland flow (typically a summer scenario). The magnitude of flooding is influenced by the following factors, precipitation amount, intensity and distribution, soil moisture, seasonal variation in vegetation and infiltration capacity of the ground surface – influenced by the degree of urbanisation. The inundation caused by riverine or fluvial flooding may vary from a few hours to many days.

The **Cauvery River confluence** with sea has been addressed in the proposed project to reduce this kind of natural hazards by incorporating **Training Walls**. This project is envisaged with Training Walls at the bar mouth of river Cauvery to regulate flood line and flow regime so that the vulnerability of erosion is reduced.

Training Walls are also to have **extended Groynes** into sea to regulate the flow regime and to prevent erosion or accretion.

3.10.4 Earthquake

An earthquake is the sudden motion or trembling in the earth caused by an abrupt release of slowly accumulating strain. This sudden release results in ground shaking, surface faulting, and/or ground failures.

The Indian subcontinent has a history of devastating earthquakes. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approximately 47 mm/year. Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. A World Bank & United Nations report shows estimates that around 200 million city dwellers in India will be exposed to storms and earthquakes by 2050. The latest version of seismic zoning map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone II, III, IV and V) unlike its previous version which consisted of five or six zones for the country. According to the present zoning map, Zone V expects the highest level of seismicity whereas Zone II is associated with the lowest level of seismicity. The latest seismic zoning map released by the India Meteorological Department website is shown in the the proposed fishing harbour falls in the **Zone II.**

As per the National Disaster Management Authority of India, the Geographical areas which fall under seismic zones III, IV and V, which are vulnerable to potential impact of earthquakes, landslides, rock falls or mudflows. Though the harbour comes in the Zone II, the risks involved due to earth quake cannot be ruled out.

3.10.5 Tsunami

Tsunami is a series of travelling ocean waves of great length and long period usually generated by submarine geophysical displacement. May or may not be preceded by an earthquake.

Tsunamis are also generated by volcanic eruptions and submarine landslides, nuclear explosions, and even due to impact or fall of large size meteorites, asteroids, and comets from outer space. Tsunami genic zones that threaten the Indian Coast have been identified by considering the historical tsunamis, earthquakes, their magnitudes, location of the area relative to a fault, and also by tsunami modelling. Both the east and west coasts of India and the island regions are likely to be affected by tsunamis from the five potential source regions, viz., the Andaman-Nicobar- Sumatra island arc, Indo-Burmese zone, Nascent Boundary (in the central Indian Ocean), Chagos archipelago and the Makran subduction zone.

Tsunami 2004, which heavily affected the project location, is the reason for proposing the SPS. Hence, the proposed project will reduce the risk or hazard out of this attribute.

4. CONSEQUENCE ANALYSIS

4.1 SCENARIO SELECTION

Hazard impact assessment is nothing but the consequences of an effect or disaster. The consequences of the various hazards are analyzed and presented. In order to understand the severity of the hazard or accident, it is necessary to know its impacts. In this section, the report seeks to know the various consequences of disasters that would need Mitigation strategies to minimize the property damage and or fatalities.

This section documents the consequence-distance calculations, which have been computed for the accident release scenarios considered.

In Risk Analysis studies contributions from low frequency - high outcome effect as well as high frequency - low outcome events are distinguished; the objective of the study is emergency planning, hence only holistic & conservative assumptions are used for obvious reasons. Hence though the outcomes may look pessimistic, the planning for emergency concept should be borne in mind whilst interpreting the results.

4.2 ACCIDENT SCENARIOS

As large number of failure cases can lead to the same type of consequences, representative failure cases are selected for this analysis. The failure cases are based on conservative assumptions and engineering judgment. Typically, failure models are considered for 100% pipe diameter/ catastrophic rupture of vessels for rupture and 10% leak (Hole Size Max 50mm) based on the guidelines of CPR 18 E.

4.3 SCENARIOS DUE TO Flammable RELEASE

Events considered for heat radiation effects are:

- Vapor Cloud Explosion
- Jet Fires
- Late Pool Fires

Flammable materials and air can burn if the concentration is in the flammable range. A deflagration of the flammable vapor cloud can only be initiated and propagated if the concentration is in this flammable range. But unconfined vapour cloud explosion (UVCE) is possible on delayed ignition of vapor cloud on sufficient dilution with air. Such Vapor Cloud Explosions are generally associated with sudden release of huge quantities of gas. In case of release of small quantities of flammable gases Flash Fire or Vapor Cloud Explosions may occur.

4.3.1 Fire Effects

This will arise due to leak / rupture of oil/gas line/vessels. Immediate ignition of the released vapor leads to jet fire; else the vapor gets diluted easily below LFL concentration due to initial turbulence created by high momentum. This vapor cloud may either get dispersed or a vapor cloud explosion may take place due to delayed ignition. It was envisaged that the operating personnel would close the valves immediately from the safe location preventing the further release of the Oil.

A significant number of large losses over $10,000,000 have been caused by piping leaks or piping failures leading to fires and explosions. Several large losses were due to corrosion issues or metallurgy issues. Weather related incidents played a major role in two of the large losses each of which exceeded over $ 200,000,000. Incidents occurring during start up or shut down continue to cause significant dollar losses.

4.3.1.1 Jet Fires

Leak / rupture of Flammable material transfer lines can result in jet fire on immediate ignition. The various consequence results for jet fire scenarios obtained by using the QRA software PHAST version 6.51 for wind velocities 6.26 m/s(D class) and 15.62 m/s(D class) are given below for analysis:

4.3.1.2 Combustible Fires

In addition to the flammable chemicals the port plans to use the ordinary combustible materials like coal, sulphur, rock phosphate, copper concentrate, edible oil, phosphoric acid, edible oil etc. These chemicals leaks cannot be mathematically modeled as they are not flammable materials. The following scenarios are modeled in a semi quantitative manner envisaging fires involving the above combustible materials:

1. Fire of Coal Conveyor

The matrix using likelihood of such fires and their envisaged impact based on the quantity of materials stored and their past experience is discussed in the subsequent paragraphs:

Frequency Estimation

The frequency estimation or likelihood of an event occurrence is estimated on the likelihood scale as described below,

Likelihood of occurrence	General Definition	Recurrence frequency for routine operations	Frequency
Very Unlikely (A)	A freak combination of factors would be required for an incident to occur	Over One hundred years	Less than 1/10,000
Possible (B)	Could happen when additional factors are present but otherwise unlikely to occur	Between ten and en years	Between 1/1- and 1/1000
Very Likely (C)	A Continuous Emission or an incident that is very likely to occur	Under One Month	Greater than 1/10

Severity Class

The Hazard Severity is described as below:

	Hazard Severity			
		Negligible (1)	**Moderate(2)**	**Very High(3)**
Impact	Injury	None	Serious injury causing long term disability	One or more fatalities
	Recovery Time	Almost Immediate	One Week	One year
	Business Interruption	None	Less Than One Week	More Than One Week
Legal & Policy	Reporting requirements	None	Must be reported to authorities	Must be reported immediately to several authorities
Reputation	Public Concern	None	Significant Local Concern	Major international concern

The hazard evaluation matrix is developed based on the judgment of the risk assessment expert considering the passive protection measures

The Hazard evaluation significance matrix is represented as below,

HAZARD EVALUATION SIGNIFICANCE MATRIX

	Hazard Severity			
Likelihood of Occurrence		Negligible (1)	Moderate(2)	Very High(3)
	Very Unlikely(A)	Low	Low	Medium
	Possible(B)	Low	Medium	Medium
	Very Likely(C)	Low	Medium	High

Based on the above matrix the following hazard class is arrived at for various fire scenarios:

S.No	Scenario	Consequence	Likelihood	Hazard Severity
1.	Fire of Coal Conveyor	Fire Hazard, Damage to environment	Possible (B)	Medium

From the above matrix it may be noted that fires due to Coal, Sulphur and Edible Oils fall under medium category.

4.4 RISK CONTROL MEASURES

4.4.1 Risk Control measures which are in place

- The pipelines and equipment selection is based on the relevant standards.
- Trained people are employed for the job
- Fire Fighting facilities are available as per OISD 156
- Dedicated Fire Station is available

4.4.2 Additional Risk Control Measures Suggested

- Periodical inspection and maintenance of pipelines as per the ASME/ other relevant standards like API to be carried out.
- Corrosion protection system to be provided for pipelines and be monitored periodically
- Leak detection and control system to be provided.
- Pressure and flow transmitters with alarms to be provided for the pipelines.
- Pipeline over pressure protection systems like PSV auto tipping of pumps etc., to be provided.
- Periodical testing of pipelines may be carried out.
- Instruments like Pressure switches and gauges to be periodically inspected and calibrated.
- Onsite Emergency Plan to be developed and mock drills to be conducted once in six months to ensure better preparedness.
- Suitable kind of Leak arresting kits & PPEs to be made available to tackle the emergency situations in a efficient manner.

References

- Guidelines for Quantitative Risk Assessment CPR 18 E (Purple book), Committee for the Prevention of Disasters, Netherlands
- Guidelines for Hazard Evaluation Procedures, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, 1992.

5. CONCLUSION

5.1 GENERAL

The proposed Capacity Expansion of Cuddalore Port is in respect of establishing additional two berths with required dredging for vessel navigation inside the port limits and within the existing break waters.

There are already 02 numbers of Berths/Jetties are in operation and Cuddalore Port is handling varied Cargo namely, Thermal Coal, Copper Concentrate, Phosphate, Chemicals, construction materials like Cement, Wood, etc., and Containers.

At present, the net Cargo handling exceeds 0.37 MTPA during 2012-13 and poised to have an incremental increase for 5.68 MTPA.

The maritime transport of cargo and demand for thermal coal to cater the demand of increasing Thermal Power Plants in the hinterland are increasing in multifold. The Cuddalore Port, with its proximity to International sea route, established coastal structures and existing infrastructures for cargo handling and storage, is proposing the proposed capacity expansion after having studied the project feasibility and environmental compatibility.

These two Berths will handle specifically bulk cargo of Thermal Coal and Copper Concentrate. The cargo handling capacity is assessed for **5.68 MTPA**.

The proposed project also envisaged dredging for **1.88 Million Cubic Meter.**

The dredged sediment will be used to reclaim land by dumping along the shoreline on both North and Southern side of the Break waters, to form additional stretches of land for providing infrastructures like road and cargo evacuation systems. Special designs of dykes as revetment with **geo synthetic material** will be used to prevent any leach of materials from the proposed dump into sea.

The risk and accident prone areas and situations were characterized and measures to prevent and manage, if occurred were presented.

Port will strengthen the existing Emergency Management Plans (offsite and on site) in compliance to the requirements of the post project scenario.

The Port shall address the following for required compliance:

- ✓ Compliance to all Legal Systems of MoEF&CC, especially with respect to **CRZ Notification, 2011**.
- ✓ Coordination with District and state level committees on Disaster Management.
- ✓ Awareness Campaign for the local Fisherman community.
- ✓ Coordination with Crisis Groups in Local/District/State level as per **Rules on Emergency Planning Preparedness and Response for Chemical Accidents, 1996.**
- ➢ Construction of Buildings and other off shore structures as per the respective BIS Codes and Standards with Fire Safety systems in place.

5.2 CONCLUSION

Cuddalore Port Trust is committed to evaluate new Corporate Environmental Policy to have all PPP operators with their respective responsibilities to have the proposed Capacity Expansion with sustainability and environmentally compatible.

In the absence oil as cargo, Cuddalore Port will be having the least risk factor. Cuddalore Port is committed to develop and honor Environmental Policies and Programs with exclusive teams for Berths/cargo under the Chairman as the chief of the Cell.

Cuddalore Port will address all requirements for ISO 14 000 for Environmental Management Systems to ensure safe and environmental friendly operations in the port for its continued development to cater the demand of country's maritime transport.