7.0 ADDITIONAL STUDIES

7.1 Continuous Risk Management:

The decision about the proposed project with respect to the safety aspect is made on the basis of risk management. Risk management includes Identification, Assessment, Mitigation and Disposition of Risk. Implementation of risk management ensures an integrated, inherent risk management approach throughout the life of the project.

The Risk Management Plan is developed during the project formulation phase to include project plan for execution during the implementation phase. A **prioritized** risk list is maintained with development of a **"Success Criteria"** which is clearly communicated to all levels of employees with the scope of the efforts so as to guide risk decisions. An Acceptable Risk Level (what level of risk is reasonable) is defined for the project to accept while implementing the project.

Risk is defined as; *"the combination of the probability (qualitative or quantitative) that a project will experience an undesired event and the consequences (impact) of the undesired event were it to occur".*

The principles of Risk Management involve the following methodology:

- IDENTIFICATION of Hazards
- ASSESSMENT of Risks and Existing Control Measures
- MANAGEMENT of Risk
  - Controlling the Risks through implementation of appropriate control measures,
  - Monitoring the control measures,
  - Review to evaluate their effectiveness,
- Communication of Risks & Controls,
- Documentation of the Risk Management process.

The steps involved in Continuous Risk Management vis-à-vis the component are summarized in the table given below:

Table No. 7.1

Continuous Risk Management Components and Steps

COMPONENTS		**STEPS**	
A.	Identify	1.	Identify the Hazards
B.	Analyze	2.	List Top Events or Incidents which will result when hazards are released and relate them to the hazards identified. [Decide who might be harmed & how].
		3.	Analyze and Assess the Risk – • List consequences which result from hazard being released. • Evaluate the Risk = Probability X Severity. [Qualitative Vs Quantitative]. • Rank the Risk - using the Risk Matrix & brainstorming techniques based on the probabilities of the Top Event occurring.
		4.	For all hazards and consequences which have been ranked as HIGH risks, IDENTIFY ALL THREATS or causes which can release the hazard to become a top event.
C.	Control	5.	Determine BARRIERS for each threat
		6.	Determine the RECOVERY MEASURES to reduce the impact of the Consequences due to the occurrence of the Top Event.
		7.	Identify ESCALATION FACTORS which will reduce the effectiveness or operation of the barriers or recovery measures and implement additional measures to compensate for these factors.
		8.	LINK Barriers and Recovery Measure controls to HSE Critical Activities which are part of Business Activities.
E.	Monitor	9.	Monitor People, Activity, Work zone & Process.
F.	Review	10.	Review the effectiveness of HIRARC. [Basis: Gap Analysis Vs. Accepted Criteria]. Decide on further action – Preventive/Corrective.
G.	Communicate	11	Communicate as required during each stage.
H.	Documents	12	Document the entire process.

7.1.1 Hazard Identification:

Hazard is defined as; "Source, situation, or act with a potential for harm in terms of human injury or ill health or a combination of these". It is an act or a condition in the workplace that has the potential to cause injury, illness, or death to a person and/or damage to company property, equipment and materials. Hazards may include flammability, explosive, corrosiveness, toxicity and hazards due to different activities.

Risk is defined as; "Combination of the likelihood of an occurrence of a hazardous event or exposure(s) and the severity of injury or ill health that may be caused by the event or exposure(s)".

Risk = Probability (likelihood of Occurrence) X Consequence (severity).

Hazard is the cause and Risk is the effect. Various techniques of predictive hazard evaluation and quantitative risk analysis suggest identification of hazard has very important role in estimation of probability of an undesired event and its consequences on the basis of risk quantification in terms of damage to personnel, property and environment.

Hazard identification is of prime significance for the quantification of risk and for cost-effective control of accidents in any industrial installation. There are many techniques for identification of hazard; such as Checklists, Walk through Surveys, Safety Audits, Past Records Review, Accident Investigation, Brainstorming, What If" analysis, HAZOP, Job Safety Analysis, Task Analysis, Fault Tree Analysis, Event Tree analysis, Index (Dow, Mond), Failure Mode and Effects Analysis (FMEA).

The following hazards are identified which are having a potential for leading to a disaster or emergency situation.

Table No. 7.2
Hazard Identification

Sl. No.	Hazard	Predictable Hazard Scenario	Impact
1.	HFO Storage Tanks Area in Alumina Refinery [12,000 KL]	Pool fire/fire ball may occur due to rupture in the tank and subsequent release and instantaneous ignition.	Fire may propagate to the nearby area.
2.	LDO Storage Tanks Area in CPP [100 KL]	Pool fire/fire ball may occur due to rupture in the tank and subsequent release and instantaneous ignition.	Fire may propagate to the nearby area.
3.	LDO & HFO Storage Tanks Area in CPP [LDO 100 KL &HFO 150 KL]	Pool fire/fire ball may occur due to rupture in the tank (LDO/HFO) and subsequent release and instantaneous ignition creating a catastrophic effect.	Fire may propagate to the nearby area.

7.1.2 Analysis of Identified Hazard and Risk Assessment:

Risk evaluation is carried out in three steps using several Risk Assessment techniques.

(A) Preliminary Hazard Analysis
(B) Risk Assessment and Ranking
(C) Threat Identification for High Ranked Risks

The individual steps followed are explained as below:

(A) Preliminary Hazard Analysis :

A **Preliminary Hazard Analysis** is carried out initially to identify the major hazards associated with the project. The top events or incidents which would result when the hazards are released are listed against the hazard identified. This is already covered under section 7.1.1. at Table No. 7.1.

The consequences w.r.t. respective hazards are listed. This is also covered under section 7.1.1. at Table No. 7.1. This is followed by the **Consequence Analysis with evaluation of the consequences** to qualify these hazards as credible hazard / most credible hazards**. This is explained as below.**

Case-1: Fire on HFO Storage Tank in Alumina Refinery, Capacity 12,000 KL :

Fire Hazard in FO Storage Tank is considered as Most Credible Hazard Scenario because of the following reasons;

HFO is a flammable liquid having flash point of >62°C and auto ignition temperature of 220-300°C and explosive limit of lower value 0.6% & upper value 7.5% by volume in air. So, it is susceptible to fire hazard. Whenever HFO catches fire it shall manifest in the form of pool fire. Taking into consideration of the metrological data of the area, one time storage quantity of HFO and its physical and chemical property, it is considered credible Hazard scenario.

Storage details	Significant heat level Kw/m^2	Experienced at distance in Mtrs.			Indication
		Summer	Rainy	Winter	
HFO 12000 KL	4.5	137.8	121.3	123.0	Causes pain if unable cove the body within 20 seconds. However blistering of the skin (2nd degree burn) is likely caused with no lethality.
	12.5	25.2	15.1	20.5	Minimum energy required for melting of plastic
	37.5	2.5	2.4	2.8	Sufficient to cause damage to the equipment.

Case-2:Fire on LDO Storage Tank in CPP, Capacity 100 KL :

Fire Hazard in LDO Storage Tank is considered as Most Credible Hazard Scenario because of the following reasons;

LDO is a flammable liquid as per schedule-1, Part-II (b) (v) having flash point of > 52°C and auto ignition temperature of 257°C and explosive limit of lower value 0.6% & upper value 4.7% by volume in air. Fire classification as per OSHA, it comes under category Flammability-2 (Moderate). So, it is susceptible to fire hazard. Whenever LDO catches fire it shall manifest in the form of pool fire. Taking into consideration of the metrological data of the area, one time storage quantity of LDO and its physical and chemical property, it is considered credible Hazard scenario.

The effect of significant heat radiation level of 4.5 Kw /m^2, 12.5 Kw/m^2 and 37.5 Kw/m^2 for different season in case of fire on LDO storage tank as assessed through modeling in different season as per modeling is given in table below;

Storage details	Significant heat level Kw/m^2	Experienced at distance in Mtrs.			Indication
		Summer	Rainy	Winter	
HFO 12000 KL	4.5	4.5	5	5	Causes pain if unable cove the body within 20 seconds. However blistering of the skin (2nd degree burn) is likely caused with no lethality.
	12.5	2.5	3	2.5	Minimum energy required for melting of plastic
	37.5	1.5	2	2	Sufficient to cause damage to the equipment.

Case-3:Fire on LDO & HFO Storage Tank in CPP, Capacity LDO 100 KL & HFO 150 KL :

LDO is a flammable liquid as per schedule-1, Part-II (b) (v) having flash point of > 52°C and auto ignition temperature of 257°C and explosive limit of lower value 0.6% & upper value 4.7% by volume in air and HFO is a flammable liquid having flash point of >62°C and auto ignition temperature of 220-300°C and explosive limit of lower value 0.6% & upper value 7.5% by volume in air.

Since LDO/HFO has flammable properties, the major release scenario is fire in LDO/HFO storage tank. Worst-case scenarios of catastrophic failure of tanks and fire on the liquid pool have been considered for the consequence analysis. The maximum hazard distance of significant heat radiation level of secondary damage corresponding to pool fire in different season is given in the table given below.

Storage details	Significant heat level Kw/m^2	Experienced at distance in Mtrs.			Indication
		Summer	Rainy	Winter	
LDO (100 KL) & HFO (150 KL)	4.5	6	5	5	Causes pain if unable cove the body within 20 seconds. However blistering of the skin (2nd degree burn) is likely caused with no lethality.
	12.5	4	3	3	Minimum energy required for melting of plastic
	37.5	3	2	2	Sufficient to cause damage to the equipment.

Risk Evaluation and Ranking :

The Risk is evaluated by multiplication of Probabilistic Factor(determined above) and Severity Factor(determined through consequence analysis). The Risk Ranking is done in a 5 X 5 matrix. This is mentioned as below in Table No. 7.3 which is self-explanatory.

The standardized 5 X 5 Risk Matrix followed is depicted below at **Figure No. 7.1**.

Figure No. 7.1
Risk Matrix

The ratings of consequences w.r.t People, Assets & Environment are as follows:

Table No. 7.3
Ratings of Consequences w.r.t People, Assets & Environment

Sl. No.	Damage to People	Damage to Assets	Damage to Environment
0	No Injury or damage to health	Zero Damage	Zero Effect – No Environmental damage. Mo change in Environment. No financial consequences.
1	Slight injury or health effects (including first aid case and medical treatment case) – Not affecting work performance or causing disability.	Slight Damage – No disruption to operation	Slight Effect – Local Environmental damage. Within the fence and within systems. Negligible financial consequences
2	Minor Injury or health effects (Lost Time Injury) – Affecting work performance, such as restriction to work activities (Restricted Workday Case) or a need to take a few days to fully reconvert (Lost Workday Case). Limited health effects are reversible e.g. Skin, irritation, food poisoning.	Minor Damage – Brief disruption	Minor Effect – Contamination Damage sufficiently large to attack the environment. Single exceedance of statutory or prescribed criterion. Single complaint. No permanent effect on the environment.
3	Major Injury or health effects	Local Damage	Localised Effect – Limited loss of

	(including Permanent Partial Disability) – Affecting work performance in the longer term, such as prolonged absence from work. Irreversible health damage without loss of life e.g. Noise included hearing loss, chronic back injuries.	– Partial shutdown	discharges of known toxicity. Repeated exceedance of statutory or prescribed limit. Affecting neighbourhood.
4	Single Fatality – From accident or occupational illness (Poisoning, cancer).	Major Damage – Partial operation loss	Major Effect – Severe Environmental Damage. The company is required to take extensive measures to restore the contaminated environment to its original state. Extended exceedance of statutory or prescribed limits.
5	Multiple fatalities – From accident or occupational illness (Poisoning, cancer).	Extensive Damage – Substantial or total loss of operations	Massive Effect – Persistent severe Environmental damage or severe nuisance extending over a large area. In term or commercial or recreational use of nature conservancy, a major economic loss for the company. Constant, high exceedance of statutory or prescribed limits.

The probability or likelihood of occurrence of a top event w.r.t. identified hazard is rated as per following table.

Table No. 7.4
Probability Rating

Probability Rating	Probability of Occurrence (cost & schedule)	Probability of Occurrence (performance)	Safety Probability of Occurrence
1	0< – 20%	0< – 4%	10^{-6} P > 10^{-1} >_ P
2	21% – 40%	5% – 14%	10^{-1} >_ P >_ 10^{-2}
3	41% – 60%	15% – 30%	10^{-2} >_ P >_ 10^{-3}
4	61% – 80%	31% – 50%	10^{-3} >_ P >_ 10^{-6}
5	81% – >99%	51% – >99%	10^{-6} >_ P

The Risk Acceptability Criteria followed is depicted below at **Table No. 7.5**.

Table No. 7.5
Risk Acceptability Criteria

Risk Score	Risk Level	Acceptability of Risk	Recommended Actions
<4	Low Risk	Acceptable	No additional risk control measures required. To continue to monitor to ensure risk do not escalate to higher level.
4 - 12	Medium Risk	Moderately Acceptable	Acceptable to carry out the work activity; however, task need to be reviewed to bring risk level to As Low As Reasonably Practicable [ALARP]. Interim control measures such as administrative controls can be implemented. Supervisory oversight required.
>12	High Risk	Not Acceptable	Job must not be carried out until risk level is brought to at least medium risk level. Risk controls should not be overly dependent on personal protective equipment. Controls measures should focus on Elimination, substitution and engineering controls. Immediate Management intervention required to ensure risk being brought down to at least medium level before work can be commenced.

The Risk Assessment is carried out and summarized in the following **Table No. 7.6**

Table No. 7.6
Risk Assessment

<table>
<tr><th>Sl. No.</th><th>Hazard</th><th>Predicted Hazard Scenario</th><th>Impact Evaluation</th><th>Consequence Scoring</th><th>Likelihood Scoring</th><th>Risk Evaluation</th></tr>
<tr><td>1.</td><td>HFO Storage Tanks Area in Alumina Refinery [12,000 KL].
➢ Flash point of >62°C.
➢ Auto ignition temperature of 220-300°C.
➢ Explosive limit of lower value 0.6% & upper value 7.5% by volume in air.</td><td>Poor fire/fire ball may occur due to rupture in the tank and subsequent release and instantaneous ignition.

Fire may propagate to the nearby area.</td><td><table><tr><th rowspan="2">Significant heat level Kw/m²</th><th colspan="3">Impact distance (in m).</th></tr><tr><th>Summer</th><th>Rainy</th><th>Winter</th></tr><tr><td>4.5</td><td>137.8</td><td>121.3</td><td>123.0</td></tr><tr><td>12.5</td><td>25.2</td><td>15.1</td><td>20.5</td></tr><tr><td>37.5</td><td>2.5</td><td>2.4</td><td>2.8</td></tr></table></td><td>4</td><td>4</td><td>16</td></tr>
<tr><td>2.</td><td>LDO Storage Tanks Area in CPP [100 KL].</td><td>Poor fire/fire ball may occur due to rupture in the tank and subsequent</td><td><table><tr><th rowspan="2">Significant heat</th><th colspan="3">Impact distance (in m)</th></tr><tr><th>Su</th><th>Ra</th><th>Wint</th></tr></table></td><td>3</td><td>3</td><td>9</td></tr>
</table>

<table>
<tr>
<td></td>
<td>➢ Flash point of > 52°C.
➢ Auto ignition temperature of 257°C.
➢ Explosive limit of lower value 0.6% & upper value 4.7% by volume in air.</td>
<td>release and instantaneous ignition.

Fire may propagate to the nearby area.</td>
<td>
<table>
<tr><th>level Kw/m^2</th><th>mmer</th><th>in y</th><th>er</th></tr>
<tr><td>4.5</td><td>4.5</td><td>5</td><td>5</td></tr>
<tr><td>12.5</td><td>2.5</td><td>3</td><td>2.5</td></tr>
<tr><td>37.5</td><td>1.5</td><td>2</td><td>2</td></tr>
</table>
</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>LDO & HFO Storage Tanks Area in CPP [100 KL / 150 KL].
➢ LDO Flash point of > 52°C.
➢ Auto ignition temperature of 257°C.
➢ Explosive limit of lower value 0.6% & upper value 4.7% by volume in air.
➢ HFO Flash point of >62°C.
➢ Auto ignition temperature of 220-300°C.
➢ Explosive limit of lower value 0.6% & upper value 7.5% by volume in air.</td>
<td>Poor fire/fire ball may occur due to rupture in the tank (LDO/HFO) and subsequent release and instantaneous ignition creating a catastrophic effect.

Fire may propagate to the nearby area.</td>
<td>
<table>
<tr><th rowspan="2">Significant heat level Kw/m^2</th><th colspan="3">Impact distance (in m)</th></tr>
<tr><th>Summer</th><th>Rainy</th><th>Winter</th></tr>
<tr><td>4.5</td><td>6</td><td>5</td><td>5</td></tr>
<tr><td>12.5</td><td>4</td><td>3</td><td>3</td></tr>
<tr><td>37.5</td><td>3</td><td>2</td><td>2</td></tr>
</table>
</td>
<td>3

4</td>
<td>3

3</td>
<td>9

12</td>
</tr>
</table>

Risk Ranking:

Rank 1:HFO Storage Tanks Area in Alumina Refinery [2 X 6000 KL]: Rank Score -16

Rank 2: HFO Storage Tank in Tank Farm Area in CPP [1 X 150 KL]: Rank Score -12

Rank 3: LDO Storage Tank in Tank Farm Area in CPP [1 X100 KL]: Rank Score -10

Rank 4: LDO Storage Tank Area in CPP [1 X 100 KL]: Rank Score -9

(B) Threat Identification for High Ranked Risks:

The **threats or causes** associated with the High as well as Medium Ranked Risks are identified as mention in the following table:

Table No. 7.7
Identification of Threat

Risk Rank	Hazard	Risk Scoring	Consequence	Probability	Threat
1	Storage of HFO in Alumina Refinery [12,000 KL].	16	Poor fire/fire ball may occur due to rupture in the tank and subsequent release and instantaneous ignition.	High	• Rupture in the tank • Subsequent release • Instantaneous ignition.
2	Storage of HFO in CPP [150 KL].	12	Poor fire/fire ball may occur due to rupture in the tank (LDO/HFO) and subsequent release and instantaneous ignition creating a catastrophic effect.	Medium	• Rupture in the tank • Subsequent release • Instantaneous ignition creating a catastrophic effect
3	Storage of LDO in CPP [100 KL].	9	Poor fire/fire ball may occur due to rupture in the tank and subsequent release and instantaneous ignition.	Medium	• Rupture in the tank • Subsequent release • Instantaneous ignition.
4	Storage of LDO in CPP [100 KL].	9	Poor fire/fire ball may occur due to rupture in the tank and subsequent release and instantaneous ignition.	Medium	• Rupture in the tank • Subsequent release • Instantaneous ignition.

7.1.3 Control Measures:

The risk information is translated into planning decisions and mitigating actions (both present & future) so as to control of risk through implementation of appropriate control measures. The following four steps were following for formulation of control measures.

(A) Determination of BARRIERS for each threat.
(B) Determination of RECOVERY measures to reduce the impact of consequences due to occurrence of Top Event.
(C) Identification of ESCALATION FACTORS which will reduce the effectiveness or operation of barriers or recovery measures and implement additional measures to compensate for this factor.
(D) Linking the Barriers and Recovery Measures to HSE Critical Activities.