BVI CONSULTING ENGINEERS (PTY) LTD

PRE-FEASIBILITY STUDY FOR THE CONSTRUCTION OF A LPG STORAGE FACILITY AT THE OIL JETTY IN THE PORT OF SALDANHA

PRE-FEASIBILITY DESIGN HAZID STUDY AND QRA REPORT

Client: SFF

Prepared by independent Risk Specialist: M Knoetze

Approval

The following Signatories approve this Plan:

NAME	ROLE	SIGNATURE	DATE
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Revision History

REV	DATE	DESCRIPTION	AFFECTED PAGES	ORIGINATOR
A	13/08/2018	ISSUE FOR INTERNAL REVIEW	ALL	M Knoetze
B	14/08/2018	ISSUE FOR DISCUSSION	ALL	M Knoetze

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1. ABBREVIATIONS AND ACRONYMS

The following acronyms are applicable to this document:

ACRONYM	DESCRIPTION
BFD	Block Flow Diagram
BLEVE	Boiling Liquid Expanding Vapour Explosion
HAZID	Hazard Identification Study
HSE	Health, Safety and Environment
ISO	International Organization for Standardization
O&M	Operations and Maintenance
PFD	Process Flow Diagram
P&ID	Piping and Instrument Diagram
QRA	Qualitative Risk Assessment
SFF	Strategic Oil Fund

2. INTRODUCTION

A HAZard IDentifcation study (HAZID) and Qualitative Risk Assessment (QRA) is performed as part of the pre-feasibility study for the proposed SFF LPG Storage Facility in Saldanha.

A HAZID study is used as a tool with which to identify process related hazards on a high level based on the process flow diagrams for the proposed plant. The aim of the HAZID study is to identify, assess, and propose mitigation measures and/or recommendations for hazards identified early on in the project. The focus of the HAZID was specifically on the process related hazards associated with the design and construction of a LPG Storage Facility and the QRA complements the HAZID focusing on process related hazards. The HAZID also included the risks identified by the other design disciplines, i.e. Civil, Structural, Mechanical and Electrical and Instrumentation.

Any significant hazards identified that pose an intolerable level of risk to the project will be considered and actions included for this or the next phase of the design of the facility. Additional risk control measures are to be adopted to reduce the risk levels.

2.1. REFERENCES

The following documents are either:

a. Applicable Documents - applicable to the extent specified herein and thus forming part of this document. The applicability shall generally relate to, standards, qualification, etc.
b. Reference Documents / Drawings - where the information concerned has been fully extracted from the reference document and added to this document, or where the reference document contains information relevant to this document, or for information only.

2.2. APPLICABLE DOCUMENTS

Document Tile	**Number**	**Revision**
1. LPG Terminal Pre-feasibility Project SOW	TBC	0
2. LPG Pre-Feasibility Design Package	TBC	A

2.3. REFERENCE DOCUMENTS / DRAWINGS

Document Title	Number	Revision
3. **PFD – LPG Import/Export Terminal Information Sketch**	SSF-PFD-001	0
4. SFF Saldanha LPG Terminal Infrastructure Site Layout	33454-00-005-01-04	A
5. Shell International Report	SM/R/88/24	
6. Keeley and Prinja	RAS/06/04	

3. BACKGROUND

The HAZID and QRA will form part of the SFF LPG pre-feasibility study. This entails the study of an 8,000-metric ton LPG storage facility to be located at the existing SFF oil storage facility in Saldanha. The facility should consider the receipt of product via the existing oil jetty, storage of LPG and truck loading operations for a loading gantry to be located at the Saldanha oil terminal.

Figure 1 shows the port of Saldanha and the existing jetty to be used for receipt of LPG cargoes. The proposed LPG terminal infrastructure shall be combined into the existing operational oil jetty infrastructure. The LPG terminal shall be designed to receive and supply via cargo carrier, store 8,000 metric ton of LPG product in pressurized vessels.

A truck loading gantry shall be incorporated into the study; the truck loading gantry shall have a minimum of 2 bays. The final number of dispensing bays and configuration of the loading gantry for the truck loading shall be determined during the development of the design.

A rail loading facility and provision for cylinder filling will be not be considered in the study.

A weigh bridge shall track the weight of product entering and leaving the terminal. The terminal will also cater for single truck off-loading back to the terminal storage.

The loading of product will be achieved via the existing oil jetty which is located approximately 9 km away. The project will use the existing servitudes for the product lines which would be used to deliver product from the jetty to the terminal via a dedicated pipeline for this purpose.

It is anticipated that LPG vessels will be moored on the Langebaan side of the jetty and the pre-feasibility study will consider cargo receipt from this side of the jetty. The pre-feasibility study will consider the use of existing infrastructure that is available at the SFF terminal, these include, fire-fighting systems, electrical, control and instrumentation as well as operational staff required to run the facility.

The project scope does not include the further down line corporate customer and consumer distribution of the product.

The design of the facility will also provide an indication of further LPG storage potential for the site in case future expansion could be considered.

Figure 1: Port of Saldanha Bay

3.1. RISKS AND REQUIREMENTS ASSOCIATED WITH LPG INSTALLATIONS

3.1.1 BLEVE

It is generally accepted in the LPG Industry that 80% of the "Risk" of any installation is due to the possibility of fire engulfment, & radiated heat from a fire in close proximity. The resulting fire could lead to the catastrophic tank failure termed as a "BLEVE" (Boiling Liquid Expanding Vapour Explosion). It is here that the mounded vessel concept provides its greatest benefits as a "BLEVE" is not possible.

Mounded Installations can be found all over the world located in Oil Refineries, Import Terminals, Distribution Depots, and even residential districts.

History is on the side of mounded Installations with the earliest installations being constructed as long ago as 1959 in Harburg Germany, where 30 x 200m^3 tanks were installed using the materials and the limited availability of corrosion protective coating of the day. The installation was inspected every 5 years and no problems occurred (Refer to Ref [5]).

Inspection of newer installations is normally on a 10 year basis but in countries like France a 50 year inspection interval has been tabled as inspection reports dating from the early 1970's showed no deterioration.

The safety record of the LPG industry is generally good, but it has been blighted by some serious incidents. The worst was the 1984 Mexico City disaster, when LPG tanks at a storage complex ruptured and a BLEVE occurred followed by fire engulfment conditions. There was considerable loss of life.

If the LPG tanks were mounded with an adequate layer of sand and earth, the possibility of fire engulfment and a BLEVE would have been removed.

3.1.2 Catastrophic Failures and design requirements

The catastrophic failure of LPG vessels is a rare occurrence and has only ever happened on aboveground tanks with no mounded tank installations having experienced a BLEVE in the +50 years since their inception.

There were at least 25 large storage spheres world-wide subjected to fire impingement from 1955 to 1987, of which 12 were destroyed by BLEVE. The leading surveys in this area have been conducted by the UK Health & Safety Executive in 1988 with the following findings:

- The predicted BLEVE frequency of a selected 2000m^3 LPG Sphere on a refinery site was determined and the BLEVE frequency confirmed to be 9 x 10^{-7} per vessel year.
- The predicted BLEVE frequency of a selected 200m^3 LPG Horizontal Cylindrical Pressure Vessel on a distribution site was determined and the BLEVE frequency confirmed to be 9 x 10^{-6} per vessel year.

Although conducted in the UK, similar studies undertaken by leading Multinational Organisations on a global basis have arrived at similar predictions.

This survey was updated in 1992 and 2006 which gave a failure rate of 9.4 x 10^{-7} per vessel year. Taking this into account, and the generic failure rates used within Health Safety and Environment (HSE), the value of 9 x 10^{-6} continues to be used, Ref [6].

Outside external radiated heat source creating a BLEVE, there is the theoretical possibility of a catastrophic failure due to cold failure. The same reports indicated herein provide a cold failure rate of 2 x 10^{-6}.

It was also concluded that the mounding of LPG tanks gives protection from fire engulfment and significantly reduces the possibility of a BLEVE. The mounding or burying also changes the likelihood of the possible causes of cold failure. Where the LPG tank is fully mounded or completely buried, the BLEVE frequency is taken as zero. Partially mounded tanks or other tanks that have part of the surface exposed are assigned the standard BLEVE frequency.

The reduction in risk has provided for all International Standards dealing with mounded storage to provide for significantly reduced safety distances.

Mounded storage vessels represent a radical advancement in safety, and help towards ensuring that LPG industrial incidents are reduced significantly. Mounding vessels also reduce the land size and requires a lot less fire water. No reported BLEVE has been reported for mounded installations for more than 50 years.

It is important to not over prescribe requirements in the LPG design, especially since sufficient experience and evidence are available to make practical and sound safety considerations.

3.1.3 Water Requirements

The water related risks are reduced by mounding tanks. The volume of water saved by mounding LPG tanks is significant when considering the codes for aboveground tanks require 10 litre/min/m^2 of Tank Surface Area.

3.1.4 Corrosion Protection Requirements

Mounded tanks require protection against corrosion. Different systems are used, including reinforced bituminous wrapping and high strength epoxy coatings. Two complimenting systems are employed for the protection of the vessel, i.e. protective coating and cathodic protection.

Coatings are only as good as the preparation of the tank surface, and the quality of application. Strict quality control is employed to prepare and apply high level sub-terrain coating and on itself has proved to be a more than adequate protection. The 1959 Harburg Mounded Tank installation, mentioned in Section 3.1.1, had no Cathodic Protection only a coating of the day and after a 30 year inspection showed no sign of deterioration (Refer to Ref [6]).

However in all cases it is recommended that a professionally designed Cathodic Protection System accompanies the Coating System. The Cathodic Protection design is part of the geotechnical site investigation. Permanent Cathodic Protection is designed for a life of 30-50 years.

3.1.5 Process Transfer Lines

Worldwide, there are over 350,000 km of pipeline transporting petroleum refined-products, including LPG. Some refined-product pipelines carry LPG in batch form. However, there are only about 8000km of single-phase pipelines, of various diameters, that transport LPG (propane or butane) fluids.

Response to emergencies such as a rupture or leak in an LPG pipeline is thus critical and must ensure rapid action with respect to containment, control, elimination, and effective maintenance/repair.

Failure rates vary between 1 x 10^{-5} to 4 x 10^{-8} per meter/year for hole sizes from 3 mm to guillotine breaks for various line sizes.

LPG transfer pipelines can be both above ground or buried, the risk of liquid expansion in trapped dead liquid legs of the pipeline should always be considered. Buried pipelines offer a degree of protection in this regard as the product temperature is not significantly impacted by ambient conditions. Other considerations for above-ground or buried pipelines include the risk profile for the project and impacts of events such as sabotage or accidental pipeline collisions

4. HAZID AND RISK ASSESSMENT PRINCIPALS

The purpose of a HAZID study and QRA are to assess the potential hazards and risks to personnel (health and safety), hazards and risks that could have financial and commercial implications on the project and effect the environment and the community. This was done in respect to regulatory requirements, standard operating practices at the plant, hazardous events, operability and maintainability considerations.

In this study, the HAZID guide words (Refer Appendix A) were identified and selected based on the extent of their impact on the process and facility design and may be recommended for further study in subsequent phases, or referred to a HAZOP study.

With reference to the LPG facility, the following steps are to be taken in mitigating risks:

1) Identify the hazards of unwanted events;
2) Determine the effect and consequences for the health and safety of humans and the environment, as well as financial/commercial impacts;
3) Assess the risks in terms of probability and consequence to get to a risk value before any reduction measures have been implemented;
4) To demonstrate how the hazards and unacceptable risks can be eliminated (by an inherently safe design) or to demonstrate that safety measures can control the hazards to a safe and acceptable situation;
5) To identify actions to reduce unacceptable risks and determine the remaining risk and demonstrate that the risk has been reduced to an acceptable level or listed to be actioned to reduce the risk. This will be completed during the next phase of the design where more detailed information will assist to mitigate effectively.

4.1. PURPOSE OF THE HAZID AND QRA STUDY

HAZID is a technique utilized in the feasibility stages of a project for (early) identification of potential hazards and threats. Performing the HAZID at the earliest possible stage in the project enables fundamental decisions in the process design to be taken or confirmed. A HAZID does not preclude the need for further hazard assessment (unless deemed necessary by the HAZID team). Instead, it is a precursor to subsequent hazard analyses and risk assessments and is normally carried out during the earliest project phases. The HAZID should be implemented as soon as preliminary plot plans, environmental conditions, process flow diagrams and utility flow diagrams are available.

It is often likely that an HAZID is the first formal Health, Safety and Environment (HSE) related study for any new project. The major benefit of a HAZID is that the early identification and assessment of the process hazards provides essential input to project development decisions. This will lead to safer and more cost-effective design options being adopted with a minimum cost of change penalty.

4.2. HAZID AND QRA TOOLSETS

The objective of the HAZID study is to review facility design through an interactive session, during which the multidisciplinary team methodically 'brainstorms' the proposed facility design to identify possible hazards, assess the likely effects, identify the causes and propose recommendations, or mitigation measures, for consideration.

The HAZID is guided by guide words (Refer to Appendix A) and checklist of (Refer to Appendix B) and draws benefit from the HAZID team's experience.

A QRA further assesses the identified hazards and classifies the hazard or risk in terms consequence and probability based on the QRA risk matrix (Refer to Appendix C). Risks that pose an intolerable level of risk to the project are then mitigated by corrective action to reduce the technical, safety, environmental and financial risk to the project.

4.3. HAZID AND QRA TEAM

The team members should be selected for their knowledge of the technical and operational aspects of installations similar to the installation to be studied.

The HAZID/QRA team should consist of a team leader with general experience of hazard identification, a technical scribe, engineering and operational personnel relevant to areas of the installation being studied.

Typically the team should include, but not be limited to:

- A Team Leader (or Facilitator);
- A Project representative (Client);
- A Process representative (Design engineer);
- Other Discipline Design Engineers;
- Technical Client Representative (e.g. from current Terminal Operations and Maintenance);
- A Technical Secretary (Scribe);
- Other Technical specialist(s) (as required).

In order to keep manageable sessions, it is recommended to limit team composition to maximum 8-10 people around the table at any time.

5. METHODOLOGY

The LPG Storage Facility was divided in nodes or groups based on the Process Flow Diagram (PFD). A checklist or HAZID worksheet, with potential guidewords was provided as the tool where potential identified hazards are recorded. The guidewords were allocated based on whether the guide words were applicable to the plant as a whole or on a specific node.

The following HAZID and QRA methodology was established and followed:

- The Team Leader identified the ‘Plant’ or a ‘Node’ to be studied.
- The process description of the selected node was discussed and agreed by the team. This was provided by the Process (or Design) engineer.
- The HAZID team then systematically went through the relevant process guidewords provided in Appendix A. Only the three main modes of operation were considered.
- In each case the team analysed each guide word to determine if the guide word is relevant to the selected Node.
- The team identified any causes leading towards the specific guide word situation (e.g. unignited gas release).
- A brainstorming exercise was used to identify all the potential causes which could result in the potential development towards a given consequence.
- The team analysed the appropriate controls (systems or practices) that are / could be in place to prevent each cause.

This was recorded on the HAZID checklist and provided in Appendix D.

A QRA further assessed the identified hazards in terms of the hazard consequence and probability as follows.

- The hazards identified were qualitatively categorized as a Rare, Unlikely, Possible, Likely or Frequent event (1-5).

- The consequences were categorized as Low, Minor, Moderate, Major or Critical (1-5).
- This is plotted on a risk matrix as shown in Appendix C.
- The risk was then rated from the matrix as Low, Medium or High. For a Low risk improvement of corrective action may be considered. For Medium or tolerable risks corrective action are recommended and High or intolerable risks, corrective action is required to mitigate the risk.
- The risk rating was noted on the checklist.
- Corrective action and responsible person was noted on the checklist and if further investigation is needed the risk is parked for action.

6. SELECTION OF NODES

The following nodes were selected from the PFD (refer Ref [3]), as provided in Figure 2:

Plant Node: This node includes the entire plant area and hazard initiators that effect the entire plant were considered;

Node 1: This node includes the line from the oil jetty to and including the storage vessels;

Node 2: This node includes the lines from the storage vessels to including the road tanker loading gantries;

Node 3: This node includes all the evacuation lines and equipment.

Only the main operating modes were considered in the HAZID and QRA. These included the following:

- LPG import/export transfer;
- LPG road tanker single or multiple gantry loading operations;
- LPG pipeline liquid evacuation and vapour recovery with return to storage tank.

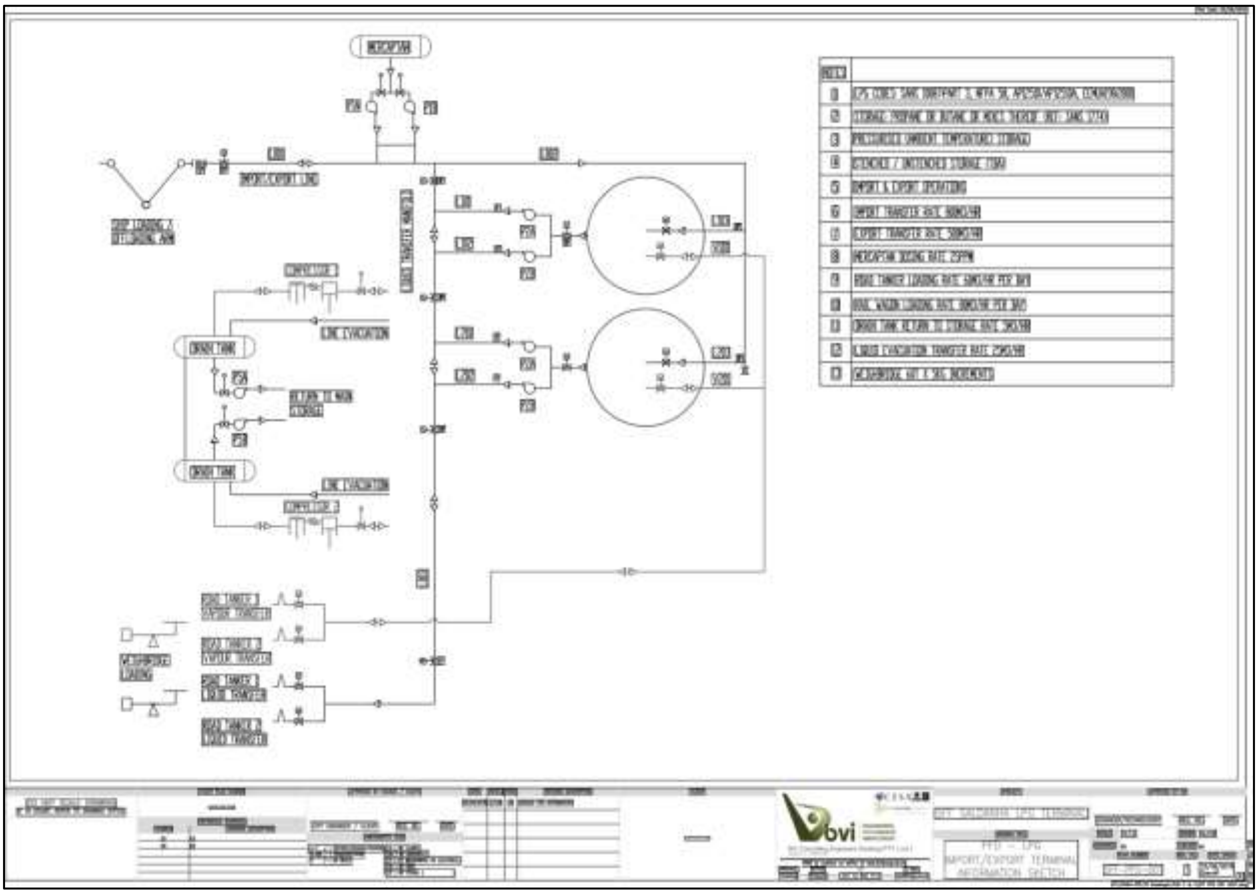

Figure 2: SSF LPG Terminal PFD

7. HAZID AND QRA RESULTS

7.1. ATTENDEES

The following table provides the attendees of the session.

Table 1 HAZID ATTENDANCE LIST

Name	Designation	Initials
Chiraag Gokaldas	BVi System Process Engineer and Scribe	CG
Ferdi Smith	BVi Civil Engineer	FS
Fanie Stanton	BVi Mechanical Engineer	FSt
Johan Havenga	BVi Electrical, I&C Engineer	JH
Marius Knoetze	Session Facilitator	MK
Mbuso Xaba	SFF Client Representative - Project Manager	MX
Simphiwe Dlalisa	SFF Client Representative - Operations	SD
Stanley Read	BVi Structural Engineer	SR
Tilana De Meillon	BVi Project Manager	TdM

7.2. ACTION ITEMS, RISKS RATED MEDIUM AND HIGH

The following hazards were identified with a risk rating of Medium and High and any further action required identified.

Table 2 ACTION ITEMS

Item	Hazardous Event	Action/ Recommendation	Responsible
1	Aircraft Impact	Check legal compliance with aircraft warning lights and include in following phases of design.	SFF, next design phase
2	Seismic Event	Consult standards to confirm requirements. Obtain area specific seismic data to confirm level of risk and any specific additional design measures to be taken	SFF, next design phase
16	Access and Egress Normal/ICOE	Consider additional lanes for entrance or emergency exit Check requirements and investigate if this will be a problem. Consider pedestrian gates. Consider locked entrance from truck side to storage side for deliveries and environmental.	FS, updated for the pre-feasibility design pack.
36	Explosion on node 1	None, Safeguard mitigations in place are adequate.	N/A

58	Explosion on node 2	Consider additional fire protection during next phase.	SFF, next design phase
59	Fire on node 2/3	Consider additional fire protection for the parking areas during next phase. Consider bypass road next to gantries if trucks need to pass.	SFF, next design phase
80	Explosion on node 3	Consider additional fire protection during next phase. Consider location of drain tanks.	SFF, next design phase

8. CONCLUSIONS AND RECOMMENDATIONS

The HAZID and QRA methodology was confirmed and accepted by the team.

The guide words were considered complete. No additional items was identified under the guide word category “Other” but participants need to consider any new hazards identified in the next phase of the design when HAZOPS, LOPA, FMICA is to be performed.

The HAZID and QRA were completed during an interactive session, the checklist completed and met the expectations of all team participants. The HAZID considered process risks and included the risks identified by the other design disciplines, i.e. Civil, Structural, Mechanical and Electrical and Instrumentation. Client representatives represented the current operational oil fuel facility and jetty, in order to identify any risks from the LPG facility that might impact the oil fuel facility and vice versa.

The risks were identified and suitable actions identified for mitigating risks as appropriate. The list of action items that required attention from the assigned people must be monitored by the project manager during this and the next phases of the design.

9. APPENDIX A: HAZID GUIDEWORDS

The following guide words were used during the HAZID and QRA.

Node	**Hazardous Event**
Off Site Initiators	
Plant	Aircraft Impact
Plant	Seismic Event
Plant	Subsidence (Land slip)
Plant	Abnormal Rainfall
Plant	Very Low Temperature
Plant	Very High Temperature
Plant	Flooding
Plant	Gale Force Winds
Plant	Lightning Strike
Plant	Outside Vehicle Impact
Plant	Offsite Explosion
Plant	Offsite Fire
Plant	Offsite Missile
Plant	Offsite Pipe Rapture
Plant	Procurement Hazards
Site Initiators	
Plant	Access and Egress Normal/ICOE
Plant	Security
Plant	Sabotage
Plant	Spillages
Management Failure	
Plant	Containment degraded
Plant	Corrosion
Plant	Cyclic Loads
Plant	Inadequate Materials
Plant	Inadequate Specifications
Plant	Chemical Attack
Plant	Hidden Defect of Containment
Plant	Failure to Detect Dangerous Situations
Loss of Service	
Plant	Loss of Electricity
Plant	Loss of Fire Water
Plant	Loss of Cooling Water
Plant	Loss of Nitrogen
Plant	Loss of Compressed Air
Plant	**Other**

Onsite Initiators	
Node	Vehicle/vessel Impact
Node	Explosion
Node	Fire
Node	Flooding
Node	Missile
Node	Pipe Rapture
Node	Loss of Containment
Node	Temperature outside Limit
Node	Pressure outside Limit
Node	Under Pressure
Node	Spillages, leaks, (Product, oil etc.)
Operator Error	
Node	System Opened
Node	Filled when not closed
Node	System Overfill
Node	Excess Load
Node	Incorrect Alarm Response
Node	Incorrect Valve Action (pull-away)
Management Failure	
Node	Failure of Process Controls
Node	Safety System Degraded
Node	Control System Degraded
Node	Build Up of Static Electricity
Node	**Other**

10. APPENDIX B: HAZID AND QRA CHECKLIST TEMPLATE

The following checklist template was used during the HAZID and QRA.

ID	Node	Hazordouos Event	Possible Y/N	Cause, Reason for N/a	Potential Consequence and Effect	Fin & Comm	Enviro / Rep/Commun	Personnel H&S	Safeguard Mitigation in Place	Severity 1-5*	Likelihood or Frequency 1-5*	Risk Rating L/M/H	Recommendations /Action	Responsibility
		Off Site Initiators												
		Aircraft Impact												
		Seizmic Event												
		Subsidence (Land slip)												
		Abnormal Rainfall												
		Very Low Temperature												
		Very High Temperature												
		Flooding												
		Gale Force Winds												
		Lightning Strike												
		Outside Vehicle Impact												

11. APPENDIX C: QRA RISK MATRIX

The following QRA risk matrix was used during the HAZID and QRA.

				CONSEQUENCE/SEVERITY				
			Financial/ Commercial	R0 - R100 000	R100 000 - R1M	R1M - R10M	R10M - R100M	> R 100M
			Environmental/ Reputation/ Community	Limited environmental damage/Local complaints	Minor environmental effects/Minor adverse local and media complaints	Moderate short-term effects, no harm to ecosystem/ Attention from media and heightened concern from local community	Serious medium term environmental effects/ Significant adverse national media/public attention	Very serious long term environmental impairment/ Serious public Or media outcry (international)
			Personnel H&S	Minor Injury	Minor injury requiring hospitalization	Moderate injury or occupational illness	Single fatality and/or severe irreversible disability to 1 person	Multiple fatalities or significant irreversible effects to persons
				Low	Minor	Moderate	Major	Critical
				1	2	3	4	5
LIKELIHOOD / FREQUENCY	Continually Experienced	Frequent	5	M	H	H	H	H
	Occurs often	Likely	4	M	M	H	H	H
	Occurs several times	Possible	3	L	M	M	H	H
	Unlikely to occur	Unlikely	2	L	L	M	M	H
	Extremely unlikely	Rare	1	L	L	L	M	M

RISK CLASSIFICATION

H	Intolerable level of risk - action must be taken
M	Tolerable risk - corrective action recommended
L	Low risk - improvements may be considered

Figure 3: QRA Risk Matrix

12. APPENDIX D: HAZID & QRA CHECKLIST WITH RESULTS

The HAZID and QRA completed checklist is given below.

ID	Node	Hazardous Event	Possible Y/N	Cause, Reason for No	Potential Consequence and Effect	Fin & Comm	Enviro / Rep/Commun	Personnel H&S	Safeguard Mitigation in Place	Severity 1-5*	Likelihood or Frequency 1-5*	Risk Rating L/M/H	Recommendations /Action	Responsibility
		Off Site Initiators												
1	Plant	Aircraft Impact	Y		Loss of life, loss of product, environmental impacts, financial impacts,	1	1	1	National key point - no fly zone. Aircraft warning lights on Jetty	5	1	M	Check legal compliance with aircraft warning lights and include in following phases of design	Next design phase
2	Plant	Seismic Event	Y		Loss of life, loss of product, environmental impacts, financial impacts,	1	1	1	C&I system to cater for loss of product and pressure drop in vessel. Area is low seismic zone.	5	1	M	Detailed seismic data to be obtained during following phase of project and assessment of potential additional measures to be taken in this subsequent phase	Next design phase
3	Plant	Subsidence (Land slip)	Y		Loss of life, loss of product, environmental impacts, financial impacts,	1	1	1	Design covers piling and suitable civils for anticipated site conditions	3	1	L	Conduct Geotechnical studies for next phase	Next design phase
4	Plant	Abnormal Rainfall	Y	Droughts or Floods.	No identified consequences				Considered in the design					
5	Plant	Very Low Temperature	N	Low temperatures not less than -5°C					Casting of concrete to be mitigated due to temperatures					
6	Plant	Very High Temperature	Y		Pressure increase in dead legs of piping.		1		Casting of concrete to be mitigated due to temperatures	1	1	L	Pipe expansion to be included in next design phase. Prevent dead legs of piping as far as possible	Next design phase
7	Plant	Flooding	N	Low risk for Tsunami, Fire water is pumped in.									There has been evidence of freak waves in the West Coast at 3mamsl. Koeberg design basis was for 5mamsl and terrace built for 8mamsl, with no problem experienced to date. As the Saldanha jetty is protected and the height of the jetty is already at least 5mamsl, the risk should be extremely low of any tsunami impacts. Confirm Tsunami risk	PM
8	Plant	Gale Force Winds (Dust)	Y		Tank structures suitably designed for max wind gusts.	1		1	Coupling for oil tankers are only allowed at wind speeds below 43 knots. TNPA will have similar restriction. Vessel berthing restrictions	1	3	L		
9	Plant	Lightning Strike	Y		Equipment damage, fire	1	1	1	Exiting design in accordance with guidelines and standards	3	1	L		
10	Plant	Outside Vehicle/Vessel Impact	N	Not possible for vehicles from road, Not possible for jetty as fenders on jetty support VLCC										
11	Plant	Offsite Explosion	Y		Damage to equipment, loss of services (power, fire water etc.), Loss of production, demurrage, injuries	1	1	1	Backup power supply for safe shut-down Limited fire water requirements Operations halted Adjacent operations have their own safeguards	3	1	L		
12	Plant	Offsite Fire	Y		Damage to equipment, loss of services (power, fire water etc.), Loss of production, demurrage, injuries. Jetty - fire on jetty or adjacent vessel	1	1	1	Operational procedures to maintain firebreak Design in accordance with code and standard Current design mitigates fire propagation on the facility due to paved areas	3	1	L	Allow for a fire break around the LPG site and indicate on the Layout	Ferdi
13	Plant	Offsite Missile	Y		Damage to equipment, not to mound. Loss of life, injury	1	1	1	Operations halted	2	1	L		
14	Plant	Offsite Pipe Rupture	Y		None - no impacts on LPG pipeline or facility. Possible stop in operation	1	0	0	Operations halted	1	1	L		
15	Plant	Procurement Hazards	N	Sampling and BOL									Surveyors survey every cargo to confirm specs of the LPG before it is accepted. Don't want hydrogen cracks because of off-spec LPG.	

		Site Initiators												
16	Plant	Access and Egress Normal/ICOE	Y		Blockage of entrance exit to terminal Inability to evacuate Inability to get fire fighting equipment onto site			1	2 lanes, dedicated entrance and exit	3	2	M	Consider additional lanes for entrance or emergency exit Check requirements and investigate if this will be a problem. Consider pedestrian gates. Consider locked entrance from truck side to storage side for deliveries and environmental	Ferdi
17	Plant	Security	Y		Intentional/ unintentional damage to plant Injury or fatality	1	1	1	Road tanker loading is separated from storage limiting impacts Security provisions to be put in place with procedures	1	1	L	Consider physical security requirements in next phase	Next Phase
18	Plant	Sabotage	See item 17											
19	Plant	Spillages (Ablutions, workshop, mess)	N	Was not considered a real possibility - nades will be addressed Typical safeguards to be included - operator training									Consider oil-water separators for run off	
		Management Failure												
20	Plant	Containment degraded	Y		Loss of Containment Loss of Production Environmental Impacts Safety Risk	1	1	1	Quality Control Specifications, 100 % NDE to be conducted. Testing and Commissioning. Hydrostatic Pressure Test during construction. Maintenance and inspections Certification Gas detectors	4	1	M	Vessel quality control will be rigorous to ensure that there is very low risk of any repairs due to poor welding, 100% NDT testing.	
21	Plant	Corrosion (internal and external)	Y	See 20					Active cathodic protection on the jetty and at the terminal					
22	Plant	Cyclic Loads	N	See 20										
23	Plant	Inadequate Materials	Y	See 20										
24	Plant	Inadequate Specifications	N	See 20										
25	Plant	Chemical Attack	N	See 20										
26	Plant	Hidden Defect of Containment	Y	See 20										
27	Plant	Failure to Detect Dangerous Situations	Y	Failure of equipment, control systems, operational procedures, risk assessments, cameras, security personnel, etc.	Failure of equipment, environmental impacts, Loss of product, injury	1	1	1	Training and certification of operators, C&I design safeguards - redundancy on power supply Leak detectors Emergency shut-down systems Security - Operators	to be addressed in later phase	to be addressed in later phase		To consider when HAZOPS, LOPA, FMICA is performed at later stage of project	
		Loss of Service												
28	Plant	Loss of Electricity	Y	Refer to previous item (11-12)	Power failure Fire on site Sabotage	1	1	1	Failure modes Safe shut-down backup power included Safe shut-down procedures	2	2	L		
29	Plant	Loss of Fire Water	Y	Refer to previous item (11-12)	Reliance on adjacent facilities Leak in supply line Failure of pumps Halting of operations	1	1	1	Locally receive fire water Design caters for low fire water requirements Operations halted Ring Feed Backup diesel pumps on SF terminal side Multiple reservoirs	3	1	L		
30	Plant	Loss of Cooling Water	N/A											
31	Plant	Loss of Nitrogen	N/A											
32	Plant	Loss of Compressed Air	N/A	LPG facility will only use electrically actuated equipment									Confirmed no compressed air requirements.	
33	Plant	**Other**												
		Onsite Initiators												
34	Node 1	Vehicle/vessel Impact	See item 10											
35	Node 1	Oil, waste spillage from vessel	Y		Environmental Impacts		1		Existing safeguards - OPC on standby, Booms to contain spillage	3	1	L	To be addressed in EMP	
36	Node 1	Explosion	Y		Possible leakage , sparks, explosion on vessel Vessel collisions	1	1	1	Insulating flange connection on jetty Earthing of piping and equipment Vessel earthing TNPA manage ship navigation in port	5	1	M	None, Safeguard Mitigation in Place are adequate.	
37	Node 1	Fire	Y		Same as above									
38	Node 1	Flooding	N	Not possible, run off and process drain will be included - see item										

39	Node 1	Missile		See item 13										
40	Node 1	Pipe Rupture		See item 14										
41	Node 1	Loss of Containment	Y		Loading arm connections PRV's Drain valves	1	1	1	Gas detectors Pressure monitoring of line Maintenance of Loading arm and other equipment Line inspections Operation	2	2	L		
42	Node 1	Temperature outside Limit		See item 6					PRV's on dead legs					
43	Node 1	Pressure outside Limit	Y		Over pressure in tanks, loss of product,	1	1	1	PRV's on dead legs and tanks	2	1	L	Check PSV and Vessel design pressure and relief pressure	Chiraag/ Fanie/ Marc
44	Node 1	Under Pressure	N/A	Only applicable to node 3										
45	Node 1	Spillages, leaks (Product, Mercaptan etc.)		See previous item, Loss of containment										
		Operator Error												
46	Node 1	System Opened	Y	Operator error Non compliance Sabotage	Loss of product Environmental impact Safety	1	1	1	Procedures Interlocks on values Supervision Training	2	2	L		
47	Node 1	Filled when not closed	See loss of containment and 46											
48	Node 1	System Overfill	N	Limit on the ships pumps, will prevent overfilling HH limits on the receiving vessels will shut of supply valves										
49	Node 1	Excess Load	N/A											
50	Node 1	Incorrect Alarm Response	Y		Incorrect mitigating actions from operator, Loss of product, Safety, Equipment damage, Environmental	1	1	1	Emergency responses are totally automated, HH levels, Fire Case, Operator training	1	1	L	Consider in next phase of design	
51	Node 1	Incorrect Valve Action (pullaway)	Y	See above (50)					Operator training, procedures					
		Management Failure												
52	Node 1	Failure of Process Controls	Y		Loss of product, Safety, Equipment damage, Environmental	1	1	1	ESD backup to the Operations system, failsafe system	1	1	L		
53	Node 1	Safety System Degraded	Y		Same as above	1			ESD will fail to a safe state, required redundancy	1	1	L		
54	Node 1	Control System Degraded	Y		See item 54									
55	Node 1	Build Up of Static Electricity	Y						Comprehensive earthing system, earthing between vessel and jetty connection	3	1	L		
56	Node 1	Other	N	None identified										
		Onsite Initiators												
57	Node 2	Vehicle/vessel Impact	Y	Vehicle	Loss of product Environmental impact Safety, equipment damage	1	1	1	Trucks are loaded from below and cannot collide with this. Barriers for the weighbridges. No risk of mound impact and higher than loading area. Piping systems will run on racks, overhead, Traffic management on site	1	1	L	EMS system to be implemed. no reversing, only one directional trafic. There is a likelihood for minor incidents but the structures should be well protected to ensure minimum terminal equipment impacts, only gantry equipment is exposed and the structures are suitably designed in respect to impact protection.	
58	Node 2	Explosion	Y		Possible leakage , sparks, truck BLEVEE	1	1	1	Deluge fire system, fire distinguishers. Support from Municipal fire department.	5	1	M	Consider additional fire protection during next phase.	TdM, next design phase
59	Node 2	Fire	Y		Possible leakage , sparks, truck explosion	1	1	1	Deluge fire system, fire distinguishers. Support from Municipal fire department. Through lane for trucks.	5	1	M	Consider additional fire protection for the parking areas during next phase. Consider bypass road next to gantries if trucks need to pass	TdM, next design phase
60	Node 2	Flooding		Same as 38										
61	Node 2	Missile		Same as 39										
62	Node 2	Pipe Rupture		Same as 40										
63	Node 2	Loss of Containment	Y	Same as 41	Loss of containment on the road tankers		1		Monitoring the weight, gas detectors	1	1	L		
64	Node 2	Temperature outside Limit		Same as 42										
65	Node 2	Pressure outside Limit		Same as 43										
66	Node 2	Under Pressure		Same as 44										
67	Node 2	Spillages (Pumps, Trucks)		Same as 45										

		Operator Error												
68	Node 2	System Opened		Same as 46										
69	Node 2	Filled when not closed		Same as 47										
70	Node 2	System Overfill		Same as 48	Overfill of Road Tanker via weighbridge	1			Monitor setpoint on weighbridge, automatic stop if reached.	1	1	L		
71	Node 2	Excess Load		Same as 49					Weighbridges spec'd for maximum loads					
72	Node 2	Incorrect Alarm Response		Same as 50					High pressure and decoupling alarms, etc.					
73	Node 2	Incorrect Valve Action (pullaway)		Same as 51										
		Management Failure												
74	Node 2	Failure of Process Controls		Same as 52										
75	Node 2	Safety System Degraded		Same as 53										
76	Node 2	Control System Degraded		Same as 54										
77	Node 2	Build Up of Static Electricity		Same as 55										
78	Node 2	Other		Same as 56										
		Onsite Initiators												
79	Node 3	Vehicle/vessel Impact	Y	During maintenance , Vehicle impact on drain system	Loss of product, Safety, Environmental	1	1	1	Cold system - shut down prior to maintenance Controlled activity Consider barriers where appropriate	1	1	L	To be considered in next phase	
80	Node 3	Explosion	Y		Possible leakage , sparks, drain tank BLEVE	1	1	1	Support from Municipal fire department.	5	1	M	Consider additional fire protection during next phase. Consider location of drain tanks	
81	Node 3	Fire	See item 59											
82	Node 3	Flooding	See item 60											
83	Node 3	Missile	See item 61											
84	Node 3	Pipe Rupture	See item 62										The risk is extremely low, any significant rupture would be detected prior to the draining operation	
85	Node 3	Loss of Containment	See item 63											
86	Node 3	Temperature outside Limit	See item 64											
87	Node 3	Pressure outside Limit	See item 65						Compressors will have set points, drain tank PRVs					
88	Node 3	Under Pressure	No	Compressor Suction causes vacuum in vessel	Vessel design specs								Consider this once equipment spec is decided in next phase	
89	Node 3	Spillages (Compressor etc.)	See Item 66										Consider when equipment is spec'd, perhaps add bund or absorbers	
		Operator Error												
90	Node 3	System Opened	See item 46											
91	Node 3	Filled when not closed	N/A											
92	Node 3	System Overfill	N/A											
93	Node 3	Excess Load	See item 49											
94	Node 3	Incorrect Alarm Response	See item 50											
95	Node 3	Incorrect Valve Action	See item 51											
		Management Failure												
96	Node 3	Failure of Process Controls	See item 52											
97	Node 3	Safety System Degraded	See item 53											
98	Node 3	Control System Degraded	See item 54											
99	Node 3	Build Up of Static Electricity	See item 55											
100	Node 3	Other												