Gunns Limited

Bell Bay Pulp Mill Project

Preliminary Hazard Analysis

Final Report

July 2006

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1. Executive Summary

Gunns Limited (Gunns) plan to build a greenfield pulp mill for the production of bleached eucalyptus and pine kraft pulp at Bell Bay in northern Tasmania. As part of the pre engineering of the project, a Preliminary Hazard Analysis (PHA) must be conducted. The purpose of the PHA is to:

- consider all events which have the potential to result in offsite effects; and
- determine the need for a safety report under Major Hazard Facilities Regulations.

Analysis of on site risks has not been conducted as part of this PHA. A detailed risk assessment will be conducted as the design becomes more defined. A more detailed design allows a better understanding of the risks posed by the facility. Therefore a detailed risk assessment which will include on site risks will be carried out in the detailed design phase of the project.

For the purpose of this study, 'offsite effects' has been defined by GHD-Qest as:

- For explosion: overpressure of 7 kPa outside the facility boundary. An overpressure of 7 kPa causes shattering of glass windows and damage to internal partitions of buildings which can be repaired. There is a 10% likelihood of injury and no likelihood of fatalities;
- For fire: radiant heat level of 4.7 kW/m^2 outside the facility boundary. If a person is exposed to a heat flux of 4.7 kW/m^2 they will experience pain in 15 to 20 seconds, and second degree burns after 30 seconds exposure; and
- For toxic release: concentrations in the atmosphere exceeding ERPG 3. This is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

These criteria are consistent with the consequence criteria nominated by other Major Hazard Facilities Regulations.

A one day Hazard Identification workshop was conducted on Monday 29th August 2005. The focus of this workshop was to identify all hazards with the potential for off site effects. This workshop short listed several hazards involving dangerous substances for further analysis and consequence modelling. This modelling showed that none of the hazard scenarios have the potential to result in offsite effects.

Based on the HAZID workshop and the consequence modelling conducted, it can be concluded that there are no hazards which have offsite impacts. The controls in place adequately safeguard against offsite safety, asset and environmental consequences from hazards associated with dangerous substances.

A total of four actions were identified in the HAZID which will need to be incorporated into the design. The existing controls, in combination with these minor changes, adequately prevent a hazard involving dangerous substances from presenting an offsite risk.

At the time of writing, it is expected that the Major Hazard Facilities Regulations for Tasmania (Dangerous Substances (Safe Handling) Act 2005) will come into effect in March 2006. Handling of dangerous goods will need to comply with these Regulations. However, as the Regulations have not been passed at the time of writing, it is not possible to determine the need for a safety report or to classify the facility under Major Hazard Facility Regulations at this stage in time. A separate review will need to be conducted to classify the facility according to these Regulations. This report can be used as part of the review for Major Hazard Facility classification.

2. Background Information

2.1 Glossary Of Terms

HAZID	Hazard Identification
PHA	Preliminary Hazard Analysis
PHAST	Process Hazard Analysis Software Tool
ERPG	Emerging Response Planning Guideline
ESP	Electronic Suppression System

2.2 Introduction

Gunns Limited (Gunns) plan to build a greenfield pulp mill for the production of bleached eucalyptus and pine kraft pulp at Bell Bay in northern Tasmania. As part of the pre engineering of the project, a Preliminary Hazard Analysis (PHA) must be conducted. The purpose of the PHA is to:

- consider all events which have the potential to result in offsite effects; and
- determine the need for a safety report under major hazard facilities regulations.

This report details the analysis which has been conducted.

2.3 Process Description

The pulp mill is proposed to be situated adjacent to the existing wood chipping facilities. Initially both native and plantation trees will be used, though this is likely to change to plantation trees only during the life of the plant.

The wood chips will be treated in the fibre line, which will consist of three processes; cooking, bleaching and drying. The finished product from the fibre line will be pulp bales, ready for export.

To the extent possible, the mill will operate on a self sufficient basis for chemicals, and chemicals which are consumed in the process will be manufactured from raw products on site. All chemicals from the fibre line will be recycled. A chlor-alkali plant will manufacture chlorine for use in chlorine dioxide synthesis. The other raw products needed to produce chlorine dioxide (hydrochloric acid and sodium chlorate) will also be manufactured on site. There will also be an onsite oxygen plant to generate oxygen for use in the delignification and bleaching processes as well as to produce oxidised white liquor.

All water on site will be collected and treated to appropriate standards prior to discharge. Where possible, run off water will be recycled into the process. After treatment, effluent water is proposed to be pumped to a discharge point offshore.

Raw water for the process will be sourced from the existing Trevallyn Dam in the South Esk River. Gas for the process is proposed to be supplied by pipeline which will be taken off the pipeline supplying Bell Bay Thermal Hydro Station, which lies to the north of the proposed facilities. If gas is unavailable for the project, oil will be used.

The pulp mill will be a net supplier of electricity, and will supply electricity into the Tasmanian grid.

For a detailed process description, reference is made to the pre engineering report completed by Jaakko Pöyry [Ref 2].

2.4 Hazardous Chemicals

The dangerous substances proposed to be used on site are:

- Chlorine

  Chlorine gas is a respiratory irritant. Symptoms which may be caused by inhalation include headache, painful and difficult breathing, burning sensation of the chest, nausea and watering of the eyes. At concentrations of 1 ppm there will be slight symptoms after several hours of exposure. At 15 ppm there is throat irritation, levels of 40 ppm are dangerous for exposure duration of 1 ½ - 2 hours. At 1000 ppm it is fatal after a few breaths.

  Chlorine is manufactured in a chlor alkali plant on site. An electric current is passed through a brine solution, producing chlorine, hydrogen and a caustic solution. Chlorine is not proposed to be stored on site, as it will be immediately used in the manufacturing of chlorine dioxide.

- Sodium chlorate

  There are no exposure limits set for sodium chlorate solution. If sodium chlorate solution leaks and evaporates, solid sodium chlorate will remain. While not flammable in itself, it is a strong oxidising agent and will support combustion as it gives off oxygen as a product of decomposition. If a leak of sodium chlorate comes into contact with acid, chlorine dioxide gas will be liberated.

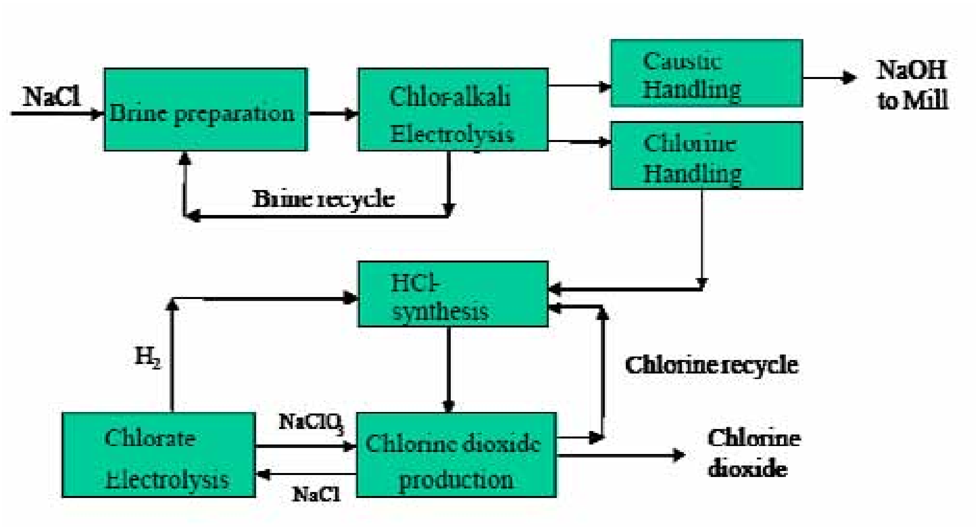
  Sodium chlorate solution is produced and stored on site. It is used as a raw product in the production of chlorine dioxide. As such it forms a part of the integrated chlorine dioxide plant.

- Chlorine dioxide solution

  The concern with chlorine dioxide solution is the potential for chlorine gas and chlorine dioxide gases to be emitted from solution if a spill occurs. While chlorine dioxide gas is flammable, its toxic effects are worse than its flammable effects. Case reports show that exposures of 5 ppm chlorine dioxide are irritating. Regular exposure to levels of 0.1 ppm leads to respiratory irritation.

  Chlorine dioxide is manufactured on site in an integrated chlorine dioxide plant. Figure 2-1 below shows the process for chlorine dioxide preparation, and how it is linked with the chlorine plant and sodium chlorate electrolysis. Chlorine dioxide is used as a bleaching agent in the fibre line. It attacks the aromatic ring of the lignin but does not react with carbohydrates thus preserving pulp yield and giving superior pulp strength compared to other oxidants.

Figure 2-1 Integrated Chlorine Dioxide Plant



- Hydrogen Peroxide

  Exposure to hydrogen peroxide can occur by skin contact, inhalation of mist or ingestion. Ingestion of large quantities can be fatal. Prolonged exposure to skin may lead to irritation and burns, and exposure to eyes can cause blindness. It is a strong oxidising agent and when mixed with combustible materials it burns fiercely or may explode.

  Hydrogen peroxide is used in the bleaching plant, along with chlorine dioxide.

- LPG

  LPG is heavier than air and may accumulate in low lying areas (eg gutters, drains) where it can become a serious fire and explosion hazard. LPG is highly flammable and explosive. Pressurised containers may BLEVE in a fire situation. It will ignite on exposure to heat or ignition source and may also ignite on exposure to strong oxidising agent. Flashback may occur.

  LPG is used in various parts of the process, but mainly in the workshop as a fuel / heat source for miscellaneous equipment items in the workshop.

- Miscellaneous Chemicals

  A number of chemicals are used on site which are dangerous substances but are used in very small quantities. These chemicals are: acetylene, natural gas, nitrous oxide, hydrogen, methanol, turpentine, and red oil. The effects of these chemicals is not listed here, as they are present in such small quantities.

Table 2-1 below lists the inventories of each of dangerous substances which will be present on site. This is presented for the two cases of integrated chemical plant and merchant case. The quantities listed are the maximum capacities on site (sum of maximum storage and in process inventory)

Table 2-1 Dangerous Substances Present

	Integrated Chemical Plant	Merchant Case
Chemical	**Amount Present (tonnes)**	**Amount Present (tonnes)**
Chlorine	0.054	0.054
Chlorine dioxide solution	18	18
Sodium Chlorate	118	368
Liquid Oxygen	102	201
Acetylene	0.4	0.4
Natural Gas	1.1	1.1
LPG	9.7	9.7
Nitrous oxide	0.018	0.018
Hydrogen	0.00088	0.00088
Combustible liquids	38	38
Oxidising agents	60	60

2.5 Site Layout and Site Boundary

Figure 2-2 below shows the proposed site layout and the site boundaries.

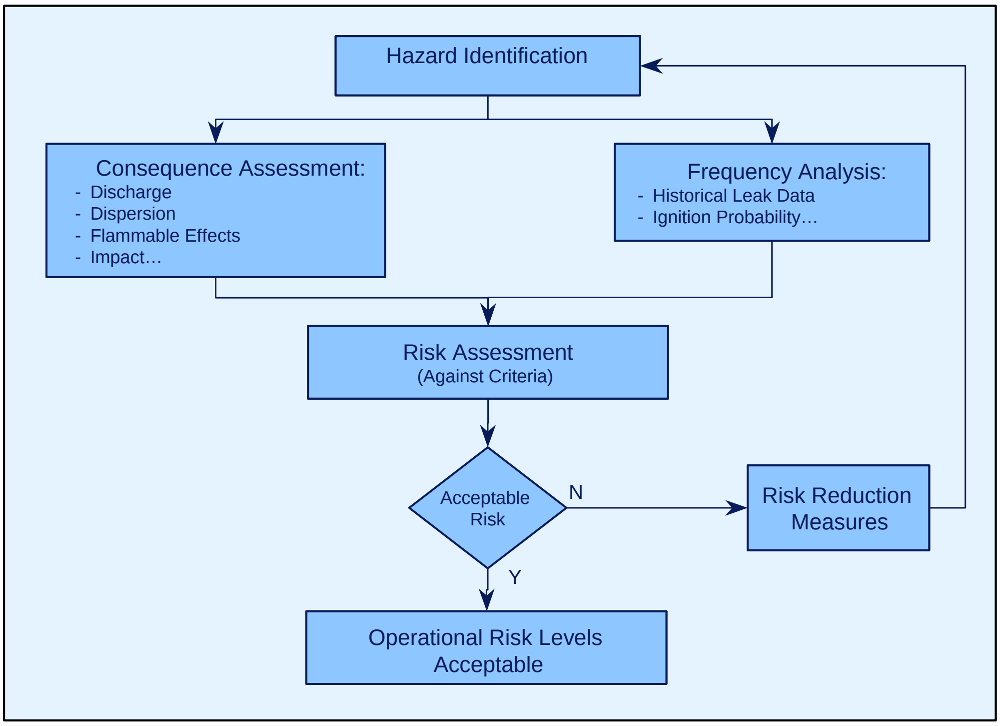
Figure 2-2 Site Layout, Showing Site Boundaries

The blue line in Figure 2-2 denotes the lease boundary for the pulp mill site. The East Tamar Highway runs through this lease boundary (the red line on Figure 2-2). The site boundary for off site risk effects has therefore been taken as the East Tamar Highway on the east side, and the lease boundary on the other sides.

3. Methodology

The methodology employed in this assessment is summarised in Figure 3.1 below. Each stage identified in the process is discussed in detail below.

Figure 3.1 Risk Assessment Process



This methodology is consistent with the following regulations and standards:

- Australian Risk Management Standard AS 4360:2004.
- Control of Major Hazard Facilities National Standard [NOHSC:1014 (2002)] and National Code of Practise [NOHSC:2016 (1996)].
- Dangerous Substances (Safe Handling) Act 2005. (This Act will be the Major Hazard Facilities Regulations for Tasmania. The Act has been passed but it is not expected that the regulations will be in place until late 2006 / early 2007.

3.1 Hazard Identification

The Hazard Analysis was conducted in a HAZID workshop conducted on 29th August 2005, at the Bell Bay Pulp Mill Project Office. During this workshop, the focus was on hazards involving dangerous substances which could result in off site impact; be it safety, asset or environmental. Hazards which were thought to have the potential for off site impact were carried forward for consequence analysis.

3.2 Consequence Analysis

The objectives of the consequence analysis are to:

- Determine relevant toxic and flammable inventories;
- Analyse a representative set of release cases; and
- Determine the consequences of each release with regards to their potential to cause offsite fatalities;

Release, dispersion, and subsequent fire, explosion and toxic effect calculations are performed using PHAST (Process Hazard Analysis Software Tool) commercial software package. The PHAST package models have been extensively validated and a description of the consequence models employed in PHAST is provided in Appendix C.

The processes used to complete the analysis are;

- Discharge rate modelling;
- Dispersion modelling;
- Fire and explosion impact modelling; and
- Toxic impact modelling.

Hazards identified as having a potential off site impact are reviewed in detail and a consequence footprint is determined for them. These footprints are then overlaid onto the site layout and a conclusion can be made whether or not an offsite impact occurs. The consequences of interest are:

- For explosion: overpressure of 7 kPa outside the facility boundary. An overpressure of 7 kPa causes shattering of glass windows and damage to internal partitions of buildings which can be repaired. There is a 10% likelihood of injury and no likelihood of fatalities;
- For fire: radiant heat level of 4.7 kW/m^2 outside the facility boundary. If a person is exposed to a heat flux of 4.7 kW/m^2 they will experience pain in 15 to 20 seconds, and second degree burns after 30 seconds exposure; and
- For toxic release: concentrations in the atmosphere exceeding ERPG 3. This is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

It should be noted that these represent very conservative offsite consequence criteria. Exposure to these levels of consequences will not lead to fatalities. In all cases it could be reasonably assumed that a person will fully recover from the exposure at the levels as defined. These criteria are consistent with other consequence criteria nominated by other Major Hazard facilities Regulations.

3.3 Frequency Analysis

The objective of the frequency analysis is to determine the frequency of each of the hazardous events.

Where a potential hazard is identified as having consequences which extend beyond the site boundary, a frequency analysis is conducted to determine the magnitude of the risk associated with the potential hazard.

In this step, the role of passive controls in reducing the likelihood of the hazards are considered qualitatively.

The risk is the combination of the consequence and frequency assessment of the potential hazard.

3.4 Assessment of Results

Once the consequences from hazard scenarios with potential for offsite consequence have been determined, they need to be compared against risk criteria in order to determine if there is a meaningful offsite consequence or not. These risk criteria are normally published in guidelines. However, in Tasmania there are currently no guidelines that define offsite effects.

4. HAZID

4.1 HAZID Methodology

As part of the PHA, a hazard identification workshop was conducted. A HAZard IDentification (HAZID) workshop aims to systematically identify all hazards associated with a particular plant, process, area, activity etc. It is commonly carried out in a workshop in which an experienced facilitator leads the team through the HAZID process.

The steps followed in the HAZID process are summarised below:

1. Select system
2. Structured brainstorm of the system to identify hazards
   - use keywords to recover momentum if needed
3. For each identified hazard, document:
   - description;
   - impact;
   - outcome;
   - prevention measures.
4. If necessary, state the required action(s)
5. Repeat from step 1 for next system

The first step is to select a system for investigation. The systems chosen in this HAZID were each of the various processing areas. The possibility of an offsite effect from each of these materials was considered in turn.

The second step was to consider the hazards associated within each area. The focus in the HAZID was on dangerous substances materials, with the potential for offsite effects. Methods of losing containment of the material were discussed.

In step 3, a short description of the hazard is given, if required. This is to ensure that everyone in the room is thinking about the same hazard, and to avoid any confusion in the discussion. Only hazards with potential for offsite impact were discussed. Prevention measures for each of the outcomes were identified and documented.

If any deficiencies are found in the prevention measures, actions can be recorded to rectify them. Actions can also be used where new control measures, currently not in place, are thought of.

This process is then repeated for each of the systems / areas identified.

4.2 Attendance

A one day workshop was conducted at the Bell Bay Pulp Mill Project Office, Tasmania, on Monday 29th August 2005. The workshop was facilitated by GHD - Qest personnel, with the following project personnel in attendance:

Table 4-1 HAZID Attendance

Name	Position / Role	Company
Lawson Harding	Environmental Systems Coordinator	Gunns Ltd
Sven Lundgren	Engineering and Construction Manager	Gunns Ltd
Peter Ryder	Consultant	Jaakko Pöyry
Richard Fawkes	Environmental Manager	Gunns Ltd
Greg Stanford	Infrastructure Manager	Gunns Ltd
Steve Cooper	Facilitator	GHD - Qest
Chris Griffioen	Facilitator	GHD - Qest

The group comprised of participants with sufficient knowledge and experience in different disciplines of the project to ensure that the output of the workshop is soundly based.

The list of drawings used in the PHA are included in Appendix B.

4.3 HAZID Systems and Guidewords

The systems identified in the workshop are summarised in Table 4-2 below.

Table 4-2 Systems Identified

System No	System Description
1	Chemical plant
2	Fibre line, including chip storage and screening
3	Recovery; waste evaporators / power boiler / turbine / water treatment
4	Recausticising lime kiln
5	Effluent
6	Natural gas
7	Electrical substation / HV connections
8	Solid waste disposal
9	Water supply line and pipeline (including Trevallyn Dam)
10	Ocean outfall
11	Wharf

The guidewords used to prompt the team for hazards are shown below:

- Falls & Dropped Objects
- Electrical Upsets
- Collisions
- Structural Upsets
- Emissions
- Security
- Aggressive Releases
- Fires & Explosions
- Mechanical Upsets
- Emergency Services
- Natural Forces
- Flora & Fauna

4.4 Minutes

A complete set of the minutes is attached in Appendix A. A total of six actions were identified in the HAZID workshop. These are shown in Table 4-3 below.

Table 4-3 Actions identified in the HAZID Workshop

Action No	Area	Description	Responsible
1	Chemical plant	Model a chlorine release from the chemical plant to determine the maximum impact distance for the worst case chlorine release. Inventory is 60 kg, at just above atmospheric pressure.	Covered in this report
2	Chemical plant	Ensure spills from pipe bridges are contained and drained to effluent.	Gunns
3	Chemical plant	Model dispersion of worst case ClO_2 release. The worst case is vapourising from a pool after tank rupture (600 m^3 volume at 10 g/l). Also model release of 0.4 kg of ClO_2 vapour.	Covered in this report
4	Fibre Line, including chip storage and screening	Ensure design of screening plant avoids areas in which dust can build up, as dust presents a fire and explosion risk.	Gunns

Action No	Area	Description	Responsible
5	Electrical Substation / HV Connections	Ensure there is protection on site access road to protect power lines from damage from run away trucks / vehicles.	Gunns
6	Wharf	Provide adequate pumping capacity at the wharf to ensure that all products can be pumped to the chemical plant. The ship's pumps may not be sufficient.	Gunns

Two of these actions (1 and 3) were subjected to consequence modelling to determine offsite consequences for worst case events from loss of containment of chemicals. For all other dangerous substances as outlined in Section 2.4, the workshop was able to determine that there would be no offsite consequences from an accidental release of the substance, due to the control measures in place. A discussion of these controls is included in Section 5. The scenarios identified in the actions were short listed because the workshop group could not conclusively decide the same for these scenarios.

Three actions (2, 4 and 5) relate to reducing risk to on site personnel, and to ensure that events will not escalate to offsite events. The remaining action (6) is an operational concern relating to pump capacity on the wharf.

4.5 Consequences

Based on the consequence modelling conducted by GHD-Qest, the distance to ERPG-3 values for the chlorine and chlorine dioxide hazards short listed for further analysis are summarised in Table 4-4.

The weather conditions used to model these consequences is 1.5 m/s wind speed and stable atmosphere (stability class F). These represent weather conditions in which the scenarios will have the largest consequence footprint, ie, conservative weather conditions for consequence modelling.

Table 4-4 Consequence Distance for Hazards Short Listed in the HAZID Workshop as Potentially Having Offsite Impact

Scenario	Distance to ERPG 3 (m)
Release of 60 kg of chlorine. (See action 1 in Table 4-3)	490
ClO_2 vapourising from pool after tank rupture. (See action 3 in Table 4-3)	200
Release of 0.4 kg of ClO_2. (See action 3 in Table 4-3)	350

The distance to the nearest site boundary from the proposed chemical plant is 500 metres. Therefore none of these scenarios has an offsite impact.

In addition to this, it was noted in the workshop that the transmission lines run through the site. If these lines become enveloped by gases or vapours emitted under any one of the scenarios described above, they will not be damaged. An explosion could potentially damage them. However, the workshop concluded that the open areas will adequately dissipate any explosion overpressure so that there will be no damage to the transmission lines. The potential for damage from flying debris was considered to be negligible.

4.6 Frequency Analysis

In the methodology it was stated that a frequency analysis is conducted if any of the potential hazards is identified as having consequences which extend beyond the site boundary. As none of the potential hazards have meaningful offsite consequences, as established in Section 4.5 above, a frequency analysis is not necessary.

5. Control Measures

In the HAZID, control measures were identified which it was expected would prevent an offsite hazard involving dangerous substance. The passive control measures in place are discussed below, with particular emphasis on how they will prevent the hazard from occurring. A full list of all the hazards and which controls act to prevent offsite consequences are included in the HAZID minutes, Appendix A.

5.1 Process Areas and Chemical Plant

The passive control measures discussed in this section relate to the chemical plant in general. Specific areas of the plant which contain dangerous substances but are not in the chemical plant are discussed separately.

- Collision Prevention

  Equipment which is located inside bunds cannot be impacted by vehicles. This is because vehicles cannot physically enter the bunds. By preventing vehicle access, the potential for vehicle collision resulting in leaks has been removed.

- Pipe Racks

  All pipe runs between processing areas are contained within pipe racks. Pipes in pipe racks are less susceptible to collision from moving equipment. Moreover, there are only site roads underneath pipe racks. As vehicle access to site is restricted, this reduces the probability of a vehicle striking the pipe rack by travelling underneath it.

  Pipes carrying chemicals along the jetty are placed away from vehicle movement areas on the jetty. This minimises the potential for impact with these pipelines. When not in use, these pipelines are drained. By draining them when not in use, the period during which a leak could potentially occur is limited to the times when chemicals are being pumped, which is very small.

- Bollards

  Bollards are used in areas where the protection of equipment from collision cannot be guaranteed by bunding or pipe racks. Bollards significantly reduce the potential for process equipment to be hit by a vehicle. This in turn significantly reduces the potential for a large leak from being hit by a vehicle.

- Plant layout – no lifting over equipment

  Dropping objects onto equipment items can result in large leaks, due to the energy contained in the fall. By designing the plant so that it is not necessary to lift over live equipment, this source of major leaks has been removed.

- Bunding / Spill Tanks.

  In the eventuality of a leak, bunding around process areas present the primary method for containment. Bunding is designed in accordance with industry best practise, ie, 110% of the volume of the largest vessel. Spills in a bund are diverted to spill tanks. This ensures that any spill from a vessel in the process area will be contained and will not leak into the environment. Small spills are recycled directly into the process.

The spill tanks contain conductivity meters. If the conductivity is too high, the spill is directed to the effluent treatment plant. Otherwise the spill is directed to the contaminated stormwater storage pond.

- Contaminated Stormwater Storage Pond

  This storage pond represents the secondary method for containment and treatment of spills from the process, and will be of sufficient size to accommodate normal rain and process water run off from process areas. There are two separate ponds; one for the pulp mill and one for the chemical plant. This ensures there can be no adverse chemical reaction in the storage pond. Water quality of the water in this pond is measured. If the water quality is adequate, the water is discharged to the settling and oil catchment pond, prior to being discharged to the river. If the water quality does not meet river discharge requirements, it is sent to effluent treatment.

- Effluent Treatment

  This represents the tertiary method for containing contaminated water. A bacterial process is used to treat effluent prior to it being pumped to a discharge location 4 km offshore. Water quality is monitored before the water is discharged.

- Dust Suppression Systems

  An electrostatic suppression system (ESP) operates in the stack to prevent dust particles from being released into the atmosphere. The design of these ESPs includes redundancy, so that it is possible to operate with some of them offline and still meet the requirements for dust control.

  In the event of power failure, the ESPs will continue to operate on back up power supply. Moreover, the plant will shut down due to the power failure, so no more dust will be produced.

  Emissions from the stack are continuously monitored to determine if there is any dust present. This provides continuous feedback on ESP performance.

5.2 Pipelines

Several pipelines supply the pulp mill with raw products, or remove effluent from the plant.

5.2.1 Gas pipeline

Gas is supplied from a tie in point in the gas pipeline feeding Bell Bay Thermal Power Station. A separate risk assessment workshop has been carried out on this pipeline [Ref 3]. This risk assessment was carried out in accordance with AS2885.1-1997. This Standard stipulates the number of physical and procedural controls required for a pipeline, as a function of the type of area it is in. The conclusion of this study was that 'assessment of [the] likely impacts or threats has produced mitigation measures compliant with AS 2885. Upon implementation, it would effectively minimise any likely impacts on the environment, human population and third party services, enabling the safe transport of gas to the Pulp Mill.' Risks associated with this pipeline were therefore not discussed in detail in this HAZID. On site risks associated with natural gas were discussed.

5.2.2 Supply Water Pipeline

The supply water pipeline provides water for the pulp mill from the Trevallyn Dam. The length of this pipeline is approximately 35 kilometres. As the water transported in this pipeline is clean (Trevallyn Dam is also used for recreational purposes), a leak from this pipeline does not present an environmental contamination issue. The main issue identified with this pipeline is the potential for a flood of water should a full bore rupture occur. This flood can potentially result in fatality, or erosion of the environment. The following passive control measures reduce the probability of a full bore rupture of the pipeline:

- Pipeline rated for pressure service. Internal water pressure will not rupture the pipeline as it will be designed for this pressure.
- Pipeline primarily buried. A collision with a vehicle or large mobile equipment is a high energy collision, with the potential to cause significant damage to the pipeline. As the pipeline will be buried for most of its length, the potential for impact on the pipeline from vehicles or other mobile equipment is significantly reduced. The potential for full bore rupture is therefore also significantly reduced.
- Large diameter pipeline. As the pipeline will be a large diameter pipeline it has a higher inherent strength than, say, a small diameter pipeline. The energy required for a full bore rupture is therefore increased. This significantly reduces the probability of the pipeline being impacted in any way with enough energy to result in a full bore rupture.

5.2.3 Effluent Pipeline

The effluent is pumped offsite, transported overland through a pipeline and discharged offshore into Bass Strait. Should the pipeline leak, the effluent which will be discharged into the environment will already have been treated and will meet the appropriate requirements for discharge. It has been treated on site and the purpose of the pipeline is to discharge the effluent into the ocean. A leak along the length of the pipeline will therefore not have any adverse environmental effects.

A preliminary risk assessment has been carried out on this pipeline [Ref 4]. Risks associated with this pipeline were therefore not discussed in detail in this HAZID workshop.

5.3 Transport risks

5.3.1 Road Transport

As most chemicals used in the bleaching process will be manufactured on site, the goods which will be transported to site are the raw chemicals used for the production of these chemicals. This amount of dangerous substances transported to the site will therefore be significantly lower than would otherwise have been the case if these chemicals were purchased from third party suppliers. Supply of chemicals to the site is outside the scope of the PHA.

Solid waste is transported by road to the solid waste disposal area. For this road transportation, the following passive control measures were identified:

- Road design. The road at the turn offs to both the pulp mill and solid waste disposal areas has a slip lane and passing lane. This enables heavy vehicles to safely gather speed before merging with traffic.
- Existing heavy vehicle route. The route from the pulp mill to the solid waste site is an existing heavy truck route. The number of vehicles hauling solid waste will only fractionally add to the existing heavy trucks using this route. The risk increase from solid waste haulage is therefore negligible.
- While in transit, the solid waste loads are covered with tarpaulin to prevent dust from blowing off.

5.3.2 Sea Transport

The pulp will be shipped for export from a dedicated wharf. Currently the wood chips are shipped from a wharf at the wood chipping facilities. When shipping pulp bales, the number of shipping movements required will actually be lower than the current shipping levels. The risks associated with shipping will therefore be less than the current levels.

The potential exists for a pulp bale to be dropped into the river during loading. While a pulp bale would be unlikely to create adverse environmental effects if dropped into the river, the wharf is proposed to be designed with low concrete or wooden edges to prevent vehicles and bales from falling of the wharf.

The potential exists for a pulp bale to be dropped into the river during loading. The following control measures prevent or mitigate against this event:

- Design of wharf with low concrete or wooden edges to prevent vehicles falling of the wharf.
- A pulp bale presents no adverse environmental effects if dropped into the river.

5.4 Solid Waste

Solid waste is stored in the solid waste disposal area. This is located on the opposite side of the East Tamar Highway to the plant. Safeguards for the offsite risks associated with transporting the solid waste from the plant to this location are discussed in section 5.3.1. In the solid waste disposal area itself, the following control measures are in place:

- The landfill area is sealed with a clay lining. This minimises the potential for any liquid run off or leachate from entering the ground water.
- Leachate from the solid waste area is pumped back to the plant for treatment in the effluent treatment plant. The pipeline which carries the leachate runs through a conduit where it crosses the West Tamar Highway. This prevents accidental collision in case of a traffic accident or car running of the side of the Highway at this location.
- Ground water in the vicinity of the solid waste dump is monitored frequently. If any leachate is leaking into the ground water system, this will be observed in these readings.
- Once a particular disposal cell is full, it is capped and revegetated. The capping minimises the potential for run off water to become contaminated. Even at this stage, the area is still clay lined.

5.5 Separation Distance

The separation distance between the process area and the nearest site boundary is 500 metres. Based on the consequence modelling described in Section 4 and given the control measures for other potential hazards described in this Section, this large distance should ensure that the effects of a hazardous incident at the pulp mill site dissipate to below the criteria established in Section 3.4.

Moreover, the population immediately beyond the site boundary is a transient population. Commuters on the East Tamar Highway will only be present for several minutes. People fishing on the river or walking through the forest in the buffer zone will also only be temporarily present in the vicinity of the pulp mill site. The population at risk immediately beyond the site boundary is therefore not a vulnerable population. It is one which is moving through rather than staying in a place where they could potentially be exposed to hazardous substances emitted from the pulp mill site in the event of an incident.

6. Conclusions / Recommendations

Based on the HAZID workshop and the consequence modelling conducted by GHD-Qest, it can be concluded that there are no hazards which have offsite impacts. The controls in place adequately safeguard against offsite safety, asset and environmental consequences from hazards associated with dangerous substances.

Three actions were identified in the HAZID which will need to be incorporated into the design. These are:

- Ensure spills from pipe bridges are contained and drained to effluent.
- Ensure the screening plant is designed to avoid areas in which dust can build up, as dust presents a fire and explosion risk.
- Ensure there is protection on site access road to protect power lines from damage from run away trucks / vehicles.

The proposed control measures outlined in Section 5, in combination with these three minor changes, adequately prevent a hazard involving dangerous substances from presenting an offsite risk.

In addition to this, one operational action was identified:

- Provide adequate pumping capacity at the wharf to ensure that all products can be pumped to the chemical plant. The ship's pumps may not be sufficient.

At the time of writing, it is expected that the Major Hazard Facilities Regulations for Tasmania (Dangerous Substances (Safe Handling) Act 2005) will come into effect in March 2006. Handling of dangerous goods will need to comply with these Regulations. However, as the Regulations have not been passed at the time of writing, it is not possible to determine the need for a safety report or to classify the facility under Major Hazard Facility Regulations at this stage in time. A separate review will need to be conducted to classify the facility according to these Regulations. This report can be used as part of the review for Major Hazard Facility classification.

7. References

1. Resource Planning and Development Commission, Proposed Bleached Kraft Pulp Mill in Northern Tasmania by Gunns Limited, Draft Scope Guidelines for the Integrated Impact Statement (IIS), April 2005.
2. Jaakko Pöyry, Pre Engineering for the New Pulp Mill, Report completed for Gunns Limited, Bell Bay Pulp Mill Project, Tasmania, June 15 2005. Report No 16B0104-E0001.
3. Gas Pipeline Risk Assessment, See IIS section 7.8.6 and 7.9.6.
4. Effluent Pipeline Design Basis Reports, Doc no. HPG]005-EP-DBD, Rev D, Appendix D – Preliminary Risk Assessment.
5. Australian Risk Management Standard AS 4360:2004.
6. Control of Major Hazard Facilities National Standard [NOHSC:1014 (2002)] and National Code of Practise [NOHSC:2016 (1996)].
7. Dangerous Substances (Safe Handling) Bill 2005 - draft.

Appendix A

HAZID Minutes

Date	29 August 2005	Job Number	3117480	System ID	1
Description	Chemical Plant				

ID	Cause	Consequence	Safeguards	Action	Resp.
1.1	Corrosion of chlorine piping / equipment. Collision with chlorine equipment / piping.	Chlorine leak.	60 kg inventory at just above atmospheric pressure. Separation distance: approx 500 m to highway easement, 2 km to township, several hundred metres to goods train line. No storage of chlorine. Prevailing wind is north west. Chlorine alarms; chlorine equipment is inside buildings. Emergency response plans will be developed in conjunction with Bell Bay mutual aid group. Materials of construction suitable for wet chlorine. Piping location designed to prevent vehicle impact. Layout designed to ensure no lifting over equipment. Restricted vehicle access to chemical plant areas.	Model a chlorine release from the chemical plant to determine the maximum impact distance for the worst case chlorine release. Inventory is 60 km, at just above atmospheric pressure.	

ID	Cause	Consequence	Safeguards	Action	Resp.
1.2	Catastrophic ClO_2 tank failure. Impact with pipe bridge. Contact of ClO_2 with organic material (results in rapid decomposition)	Chlorine dioxide leak; chlorine dioxide will vapourise out of solution.	Maximum concentration in liquid is 10 g/l. Bunding around tank area. Spray leak with sodium sulfite (converts ClO_2 to HCl) (as part of emergency response). Piping location designed to prevent vehicle impact: Piping in pipe bridge along road. Only site road underneath pipe bridge, minimises potential for collision with pipe bridge. Pressure switches on piping in pipe bridge, pump will be switched off, only contents of pipe line will leak. Won't reach flammable concentrations of ClO_2 off a spill. Rapid decomposition will be contained within the reactor, ie, local effects only. Layout designed to ensure no lifting over equipment. Restricted vehicle access to chemical plant areas.	Ensure spills from pipe bridges are contained and drained to effluent. Model dispersion of worst case ClO_2 release. The worst case is vapourising from a pool after tank rupture (600 m3 volume at 10 g/l). Also model release of 0.4 kg of ClO_2 vapour.	
1.3	Loss of containment of acid HCl, sulphuric acid, eg tank or piping failure.	Hydrochloric acid leak, 32% concentration. 98% Sulphuric acid	Acid areas bunded, and drains to emergency effluent storage tank. Piping location designed to prevent vehicle impact: Piping in pipe bridge along road. Restricted vehicle access to chemical plant areas. Layout designed to ensure no lifting over equipment.		

ID	Cause	Consequence	Safeguards	Action	Resp.
1.4	Loss of containment of caustic	35% at chor-alkili plant, 46% if purchased.	Caustic in bunded areas. Bunds also prevent vehicle access. Unloading area is bunded (if brought in by trucks); wharf will drain back to effluent storm water settlement pond (if brought in by ship). Layout designed to ensure no lifting over equipment.		
1.5	Loss of containment of hydrogen	Leak of hydrogen, potential for fire	Maximum inventory of 2 kg. No storage on site; generated in process.		
1.6	Loss of containment of oxygen	Leak of oxygen; oxygen rich environment which supports combustion. (200 tonnes on site; liquefied oxygen)	Oxygen plant designed to Australian Standards. No flammable or combustible material near oxygen; closest is vegetation. No ignition sources (eg correct IP ratings on electrical equipment, hazardous zones according to Australian Standards). Restricted vehicle access to chemical plant areas. Layout designed to ensure no lifting over equipment.		

ID	Cause	Consequence	Safeguards	Action	Resp.
1.7	Loss of containment of sodium chlorate.	Leak of sodium chlorate	Both liquid and crystal chlorate. Leaks contained inside dump tank before draining to emergency effluent storage pond. Sodium chlorate areas are all indoors, with exception of storage areas. Restricted vehicle access to chemical plant areas. Layout designed to ensure no lifting over equipment.		
1.8	Sodium hypochlorite	Byproduct of chemical plant	Piping inside pipe racks. Leaks contained inside dump tank before draining to emergency effluent storage pond. Restricted vehicle access to chemical plant areas. Layout designed to ensure no lifting over equipment.		
1.9	Miscellaneous	LOC from chemicals such as flocculants.	Hazardous goods storage. Minimum amount used; several kilograms per year.		

Date	29 August 2005	Job Number	3117480	System ID	2
Description	Fibre Line, including chip storage and screening				

ID	Cause	Consequence	Safeguards	Action	Resp.
2.1	Peroxide	Peroxide leak; oxidising reactions from spill.	Leaks from storage tank contained within dedicated bund. Bunded delivery and storage areas. Control of vehicles in area. Pipe leaks contained within fibre line spill tank. 25 mm line through process; minimum inventory.		
2.2	Chip storage and screening	Potential for fire in chip storage or on conveyors. Dust in screening.	Sprinkling system on conveyor. Covered conveyor. Chips are stored in open silos. Fire break easement underneath overhead conveyor. Power line easement acts as a fire break. Ring main around mill site with fire hydrants / monitors at regular spacings.	Ensure design of screening plant avoids areas in which dust can build up, as dust presents a fire and explosion risk.	

ID	Cause	Consequence	Safeguards	Action	Resp.
2.3	Catastrophic rupture of tanks or towers	Digester and impregnation vessel are under pressure; hot caustic leak. Oxygen Delignification reactors (2 of).	Complete fibre line is bunded. Digesters at 8 – 10 bar. DCS control of process. Maintenance crane on top of digester only used when mill is shut for maintenance. Small spills from unbleached area are collected to a spill tank and fed back to process. Small spills from bleached area are collected to a dedicated spill tank and fed back to process. Large spills are collected in fibre line bunded area and go to emergency pond, and from there to effluent treatment.		
2.4	Miscellaneous chemicals	Leak of chemical	Any spill contained within fibre line bunded area. Small amounts of miscellaneous chemicals.		

Date	29 August 2005	Job Number	3117480	System ID	3
Description	Recovery: Waste Evaporators / Power Boiler / Turbine / Water Treatment				

ID	Cause	Consequence	Safeguards	Action	Resp.
3.1	Loss of containment of black liquor	Black liquor spill	Black liquor contained in dedicated bund for recovery and evaporation. Spills collected in spill tank and fed back to the process. Large spills collected in emergency basin.		
3.2	Failure of electrostatic precipitators (ESPs) / recovery boiler / power boiler	Release of particulates through stack.	Prevailing weather conditions will generally disperse particulates rapidly. Boiler reduced load or shut down, to reduce load on ESPs. ESP redundancy. Monitors in stack, downstream of ESPs.		
3.3	Smelt explosion	Molten salt / steam explosion. Major down time.	Explosion internal to boiler. Recovery boiler made with 'weak corner'. Emergency shut down procedures for boilers.		
3.4	Power failure	Shut down of ESPs, potential for large emissions for short period of time.	Back up power supply (UPS) which comes on automatically. Power source from Gunns turbine and from grid.		

ID	Cause	Consequence	Safeguards	Action	Resp.
3.5	Incinerator	Non condensable gases (NCGs), odour.	Triple redundancy: recovery boiler, incinerator and torch. Incinerator is down stream of recovery boiler burner, which burns NCG's, ie, NCG burner in recovery boiler needs to fail. Torch downstream of incinerator. If torch fails as well, NCG's released through stack.		
3.6	Loss of containment of methanol, turpentine or heavy fuel oil.	Localised spill contained, potential fire	Low volumes of flammable products turpentine / methanol Storage tanks bunded Ignition sources minimised No lifting over tanks Protection from vehicle impacts Appropriate fire fighting measures		
3.7	Loss of containment of soap	Localised spill contained	Low volumes of product Soap burnt in recovery boiler Soap stays in process Soap storage area bunded		
3.8	Miscellaneous chemicals Loss of containment of acetylene, small dangerous goods	Localised fire	Stored in minimal quantities Any spill contained within bunded area.		
3.9	Light plane impacts structure	Localised release	Navigational warning lights on high structures Plant would shut down if impacted by airplane		

Date	29 August 2005	Job Number	3117480	System ID	4
Description	Recausticising Lime Kiln				

ID	Cause	Consequence	Safeguards	Action	Resp.
4.1	Loss of containment of green or white liquor	Green or white liquor spill.	Green and white liquor contained in dedicated bund for recovery and evaporation. Spills collected in spill tank and fed back to the process. Large spills collected in emergency basin.		
4.2	Failure of ESPs (electrostatic precipitators)	Release of particulates through stack.	Prevailing weather conditions will generally disperse particulates rapidly. Kiln reduced load or shut down. ESP redundancy. Monitors in stack, downstream of ESPs.		
4.3	Natural gas release	Potential for fire or explosion. Localised fire and explosion.	Fire break around regulator station. Controlled shut down on loss of gas to prevent dust or other emissions.		
4.4	Release of burnt lime	Burnt lime trucked in.	Licensed transporters. Transported and stored as a solid powder.		
4.5	Loss of containment of sulphamic or phosphoric acid	Acid fuming	Small quantity stored on site when required (normally not stored) Used infrequently for cleaning Localised bunding		

Date	29 August 2005	Job Number	3117480	System ID	5
Description	Effluent				

ID	Cause	Consequence	Safeguards	Action	Resp.
5.1	Storm water	Large amount of water to storm water pond	Collected in spill tanks in process areas. Conductivity meters in spill tanks. If conductivity high, sent to effluent treatment. Size of storm water pond is suitable for normal run off from process areas. Clean storm water (of roofs etc) drained directly to river. Potentially contaminated storm water treated in contaminated storm water storage pond. Separate contaminated water storage ponds for pulp mill and chemical plant. Analysis of water prior to final discharge into river.		

ID	Cause	Consequence	Safeguards	Action	Resp.
5.2	Large process spill	Contamination of storm water pond	Collected in spill tanks in process areas. Conductivity meters in spill tanks. If conductivity high, sent to effluent treatment. Conductivity and pH meters in contaminated storm water treatment ponds. Potentially contaminated storm water treated in contaminated storm water storage pond. Separate contaminated water storage ponds for pulp mill and chemical plant. Analysis of water prior to final discharge into river.		
5.3	Loss of air to aeration pond (eg power failure)	Smell from aeration pond Several hours before smells get too bad.	Three air blowers - Only one required for operation Shut down plant. Turbo blowers on back up power supply.		
5.4	Chemical in aeration pond	Microbes poisoned Efficiency decreases	Plant collection of spillages in emergency spill basin Equalisation basin has 12 hours retention Liquor fed to aeration pond in a controlled manner Expert control systems.		
5.5	Miscellaneous chemicals	Leak of chemical	Any spill contained within bunded area. Small amounts of miscellaneous chemicals.		

Date	29 August 2005	Job Number	3117480	System ID	6
Description	Natural Gas				

ID	Cause	Consequence	Safeguards	Action	Resp.
6.1	Loss of containment of natural gas from piping Natural gas used in recovery boiler, incinerator, power boiler lime kiln	Localised fire and explosion	Pressure regulated down from 8100 kPa to 700kPa. Gas detectors in process areas Piping located in common pipe rack Line sizes 150mm up to regulator, then 250mm on site. Separation distance to boundary eliminates offsite effects		
6.2	Loss of containment of natural gas from pipeline / regulator station	Fire and explosion	Pipeline risk assessment completed on inlet line (See IIS Para 7.8.6 and 7.9.6)		

Date	29 August 2005	Job Number	3117480	System ID	7
Description	Electrical Substation / HV Connections				

ID	Cause	Consequence	Safeguards	Action	Resp.
7.1	Short circuit in sub station	Localised fire	Separation distance around sub station in the event of fire Fire suppression system in sub station		
7.2	Incorrect connection to Tasmanian electrical grid	Loss of power supply	System stability study on connection to the Tasmanian electrical grid. Reflects security of supply issues.		
7.3	Damaged transmission line Impact by truck	Loss of power supply	Easement underneath power lines Adequate separation distance between trees and power lines (30m from easement edge) Dedicated access way parallel to access site Embankment / cuttings separate powerlines and road Site speed limits	Ensure there is protection on site access road to protect power lines from damage from run away trucks / vehicles	

Date	29 August 2005	Job Number	3117480	System ID	8
Description	Solid Waste Disposal				

ID	Cause	Consequence	Safeguards	Action	Resp.
8.1	Rainfall and other infiltration (water run off)	Leaching into ground and surface water	Sealed off collection system Tip site lined with clay, capped and revegetated Monitoring of leachate from closed and open cells (volume and quality) Leachate pumped back to effluent treatment plant Monitoring of ground water		
8.2	Leachate pipeline return	Leaching into ground and surface water	Pipeline above ground Conduit protecting pipelines under roadway Regular pipeline inspections Low environmental harm from leachate (high pH)		
8.3	Transportation of solid waste to landfill	Interaction with road traffic	Passing lane on highway Existing heavy truck route Transportation of 8 trucks / day Slip lanes on access road		
8.4	Dried solid waste produces fine particulates	Dust generation	Trucks covered with tarps to prevent dust spreading		

Date	29 August 2005	Job Number	3117480	System ID	9
Description	Water Supply and Pipeline (Trevallayn Dam)				

ID	Cause	Consequence	Safeguards	Action	Resp.
9.1	Damaged water pipeline	Potential flooding issues to local areas	Pipeline primarily buried Pipeline rated for pressure service Large diameter pipeline		
9.2	High suction pressure	Suction of objects into pipeline (people / objects)	Grill on suction line Large diameter equates to low approach velocity		
9.3	Vandalism of equipment	Interaction with pumping station	Pumping station in a secure location Regular inspection on equipment items		
9.4	Rupture of dam wall	Loss of water, flooding of highway	Earth and rock constructed dam Regular inspections of dam		

Date	29 August 2005	Job Number	3117480	System ID	10
Description	Ocean Outfall				

ID	Cause	Consequence	Safeguards	Action	Resp.
10.1	Damaged treated effluent pipeline on land	Potential flooding issues to local areas on land	Pipeline follows low level ground contours, minimises pumping head required Buried pipeline Minimal pressure in lines reduces consequences in the event of damage AS2885 risk workshop conducted on the pipeline (see IIS Para 7.8.6 and 7.9.3) No toxicological issues with the treated effluent		
10.2	Damaged treated effluent pipeline on sea bed (struck by object / anchor)	Compromises operating parameters No operating issues No identified environmental issues with treated effluent	Buried pipeline to 1.4 km offshore, then on sea bed for 1.4km AS2885 risk workshop conducted on the pipeline (see IIS Para 7.8.6 and 7.9.3) No toxicological issues with the treated effluent Treated effluent pipeline located between Basslink and gas pipeline Published location on sea charts		

Date	29 August 2005	Job Number	3117480	System ID	11
Description	Wharf				

ID	Cause	Consequence	Safeguards	Action	Resp.
11.1	Loading ships Truck drives off wharf into the river	None identified	No environmental impact from loading pulp to ship. Less shipping movements in channel from construction of new pulp mill wharf compared to current traffic levels Barriers along wharf causeway		
11.2	Unloading	Chemical spill on wharf deck	Dry break couplings for caustic Dedicated drainage area to capture spills on wharf Piping protected from vehicle impacts Less shipping movements in channel after construction of new pulp mill wharf compared to current traffic levels Bell Bay mutual aid emergency response	Provide adequate pumping capacity at the wharf to ensure that all products can be pumped to the chemical plant. The ship's pumps may not be sufficient.	

ID	Cause	Consequence	Safeguards	Action	Resp.
11.3	Ship collision	Ship impacts wharf Oil spill into river	Local pilot docks ships Tugboat present to assist in Wharf pipe lines cleaned and emptied after use Less shipping movements in channel after construction of new pulp mill wharf compared to current traffic levels Bell Bay mutual aid emergency response		

Appendix B

Drawings used in the PHA

The following drawings were used in the PHA:

Layout Drawings

Title	No	Date
Mill site layout, Bell Bay site	16B0101-10002	Preliminary 06.06.2005 / PeT
Mill site layout, Bell Bay site	16B0101-10001	Preliminary 06.06.2005 / PeT

P&ID's

Title	No	Date
Wood Preparation Alternative 1	16B0104-02001	2.3.2005
Cooking	16B0104-02002	4.2.2005
Screening / Pre-Oxygen Washing	16B0104-02003	22.2.2005
Oxygen Delignification	16B0104-02004	28.2.2005
Bleaching	16B0104-02005	1.3.2005
Oxygen Plant	16B0104-02006	25.4.2005
Stock System	16B0104-02007	24.2.2005
Stock System and Bleached Stock Cleaning 1 and 2	16B0104-02008	1.3.2005
Drying Machine – Wet End and Water System 1	16B0104-02009	7.3.2005
Cutting and Baling 1 and 2	16B0104-02010	2.3.2005
Dryer Heat Recovery and Condensate System 1 and 2	16B0104-02011	10.3.2005
Evaporation Plant	16B0104-02012	24.1.2005
Recovery Boiler	16B0104-02013	26.1.2005
Power Boiler	16B0104-02014	21.3.2005
Feedwater Plant Water Demineralizing	16B0104-02015	3.2.2005
Condensate and Feedwater	16B0104-02016	9.2.2005
Turbogenerator and Steam Distribution	16B0104-02017	3.2.2005
Recausticizing	16B0104-02018	7.2.2005
Lime Kiln	16B0104-02019	8.2.2005

Integrated Chemical Plant Brine Treatement and C/A Plant Sheet 2	16B0104-02020	14.3.2005
Integrated Chemical Plant Chlorated and ClO2 Plant	16B0104-02021	11.3.2005
Integrated Chemical Plant HCl Plant	16B0104-02022	11.3.2005
Purchased Chemicals Handling	16B0104-02023	21.2.2005
Water Treatment	16B0104-02024	16.2.2005
Stormwater Treatment	16B0104-02025	10.2.2005 (Revised 31/5/2005)
Effluent Treatment	16B0104-02026	17.2.2005
Odorous Gas Handling	16B0104-02027	9.2.2005
Mill Compressed Air Station	16B0104-02028	8.3.2005
Natural Gas 0.2Mpa 20°C	16B0104-02029	18.4.2005
MeOH Liquefaction Turpentine	16B0104-02030	4.5.2005
Effluent Pipe	16B0104-02031	4.5.2005
Heavy FeulFuel Oil	16B0104-02032	13.5.2005
Integrated Chemical Plant Effluent System	16B0104-02033	18.5.2005
Process Orientation Diagram Pulp Mill	16B0104-02034	18.5.205
Process Orientation Diagram Integrated Chemical Plant	16B0104-02035	23.5.2005
Spill Collection	16B0104-02036	30.5.2005

Appendix C

PHAST Consequence Models

PHAST Consequence Models

A part of the risk assessment process involves generating consequences for the release events identified. The steps involved in determining consequences are:

- Determine discharge conditions;
- Based on discharge conditions, determine the types of events which will occur (eg jet fire, pool fire, toxic release etc);
- Calculate the consequences;

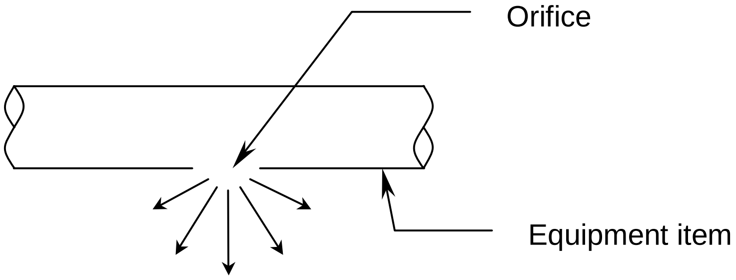
The consequences are calculated using empirically derived models. This Appendix discusses basic concepts and theory behind the various consequence models used in the analysis. The models discussed are:

- Discharge modelling
- Dispersion
- Flammable Effects
  - Jet Fire
  - Pool Fire
  - Multi Energy Explosion
  - BLEVE Flammable Effects

Discharge Modelling

If there is a hole in a pipeline, vessel, flange or other piece of process equipment, the fluid inside will be released through the opening, provided the process pressure is higher than ambient pressure. The properties of the fluid upon exiting the hole play a large role in determining consequences, eg, is it vapour or liquid, velocity of release etc. Figure B-1 shows a typical scenario.

Figure B-1 Typical Discharge



The discharge can be considered to have two stages, the first is expansion from initial storage conditions to orifice conditions, the second from orifice conditions to ambient conditions.

The conditions at the orifice are calculated by assuming isentropic expansion, ie, entropy before release = entropy at orifice. This allows enthalpy and specific volume at the orifice to be calculated.

The equations for mass flow rate and discharge velocity are then given by:

$$\dot{m} = C_d A_o \rho_o \sqrt{-2(H_0 - H_i)}$$

Where C_d = Discharge coefficients

A_o = Area of the orifice

ρ_o = density of the material in the orifice

H_o = Enthalpy at the orifice

H_i = Enthalpy at initial storage conditions

And $u_0 = C_d \sqrt{(-2(H_0 - H_i)}$

The discharge parameters passed forward to the dispersion model are as follows:

- release height (m);
- thermodynamic data: release temperature (single phase) or liquid mass fraction (two-phase), initial drop size;
- other data:
  - for instantaneous release: mass of released pollutant (kg), expansion energy (J)
  - for continuous release: release angle (degrees), rate of release (kg/s), release velocity (m/s), release duration (s).

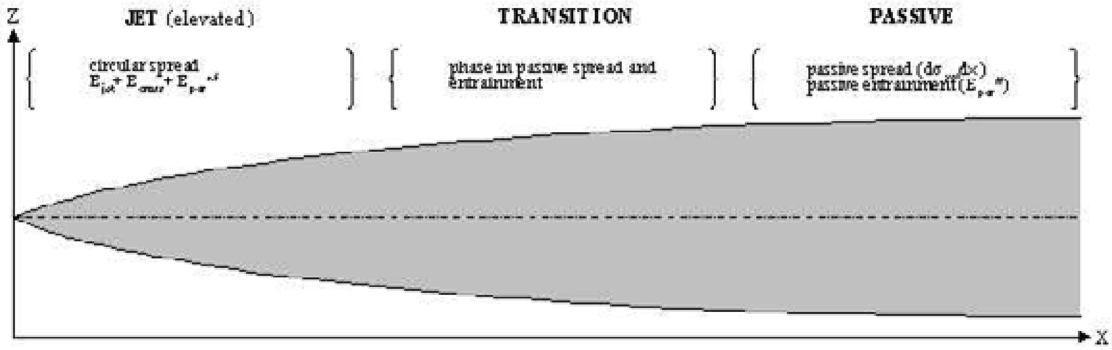
Dispersion

When a leak occurs, the material will be released into the atmosphere. Upon being released it will start to disperse and dilute into the surrounding atmosphere. The concentration of interest is related to flammable and toxic limits for flammable and toxic substances respectively. The model used to determine extent of release is described below, along with some of the key input parameters.

Dispersion modelling utilises the Unified Dispersion Model. This models the dispersion following a ground level or elevated two phase unpressurised or pressurised release. It allows for continuous, instantaneous, constant finite duration and general time varying releases. It includes a unified model for jet, heavy and passive two phase dispersion including possible droplet rain out, pool spreading and re-evaporation.

For a continuous, pressurised release, the material is released as a jet, ie, high momentum release. The jet eventually loses momentum and disperses as a passive cloud. Figure B-2 below shows a typical release and the various phases involved.

Figure B-2 Jet Dispersion



The cloud is diluted by air entrainment until it eventually reaches the lower limit of concern. During the jet phase, the cloud is turbulent and much air is entrained. In the passive phase, less air is potentially entrained, and it occurs via a different mechanism to the turbulent jet phase. The calculation of the plume therefore depends on many factors, the key parameters being:

- Material released, specifically molecular weight;
- Discharge conditions including phase(s) of release, velocity etc;
- Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds).

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	Chris Griffioen	M Thomson	M Thomson#	C Griffioen	C Griffioen #	3/10/05
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1	Chris Griffioen	S Cooper	S Cooper#	C Griffioen	C Griffioen#	23/02/06
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