14. Hazard and Risk

14.1 Risk Assessment Methodology

The major risks and hazards associated with the construction and operation at the Burnett River Dam are identified in this Section. The methodology employed in the study, the preliminary identification of hazards, an assessment of risks and the safe-guards to ensure risks are minimal and controlled are also discussed.

Note that this assessment is not dealing with occupational health and safety hazards, only those that affect the public or the environment. Occupational hazards at this site are similar to those of any construction or workplace site and need to be managed by sound workplace health and safety procedures.

The hazard and risk assessment involved the following:

- The identification of intended operations and the proposed design of the facilities (described in **Section 3**);
- The identification of hazards and potential operational problems using a modified form of a Hazard and Operability (HAZOP) study (referred to as a preliminary hazard analysis (PHA)) for the process of constructing a dam, in line with Queensland practice;
- a summary of these scenarios in the form of hazard review tables;
- the identification of possible causes and consequences of the hazards and their detection and protection mechanisms;
- a preliminary qualitative assessment of the major risks associated with each hazardous scenario;
- a preliminary qualitative assessment of the major risks from natural hazards and external risks to major infrastructure;
- a series of recommendations on the most appropriate safety management systems needed, in regard to key scenarios and potential impacts; and
- an outline of key items for an emergency response plan.

A preliminary hazard analysis was undertaken rather than a comprehensive study due to the preliminary nature of the design at this point in time. A quantitative and failure impact assessment should be conducted before the detailed design following ANCOLD guidelines.

The PHA identified the key events that might have an impact on surrounding land uses from the associated construction and transport activities. The study considered all relevant hazards, both minor and major, for all activities related to the proposed development.

ANCOLD determines Dam Hazard Categories on the basis of the consequences of failure of a particular dam and are given in **Table 14.1**. Categories of environmental effects have been included.

Table 14.1: ANCOLD Dam Hazard Impacts (Consequences)

HIGH	MEDIUM	LOW
Loss of life expected because of community or other significant developments downstream	No loss of life expected, but the possibility recognised. No urban development and no more than a small number of habitable structures downstream.	No loss of life expected.
Excessive economic loss such as serious damage to communities, industrial, commercial or agricultural land or facilities, important utilities, the dam itself or other storages downstream.	Appreciable economic loss, such as damage to limited land areas, secondary roads, minor railways, relatively important public utilities, the dam itself or other storages down stream.	Minimal economic loss, such as farm buildings; limited damage to agricultural land, , minor roads etc.
Repairs to dam not practicable. Dam essential for services.	Repairs to dam practicable or alternative sources of water/power supply available.	Repairs to dam practicable. Indirect losses not significant.
Substantial to irreversible reduction of a species/habitat of National or State significance with little prospect of recovery to pre-impact conditions.	Reduction of a species/habitat with regional significance.	Impacts to abundance of flora and fauna in the affected environment limited to a localised effect as species and habitat abundant in the region.

Source: Adaptation from ANCOLD 1994(a)

Risk criteria guidelines available from the NSW Department of Urban Affairs and Planning (HIPAP 4, 1990) and ANCOLD (b) were utilised as a guide only.

Each part of the operations was assessed to identify the hazards, their causes and consequences (or impact). The potential impact was assessed with regard to the public and the environment. The hazard detection and protection measures for each construction and operation activity are also described in the review tables. These measures are taken into account when the risk assessment is undertaken to determine the residual risk.

The assessment involves rating each hazard for the level of impact, exposure and frequency expressed as L for low, M for medium and H for high. The residual risk rating was determined using a risk calculator (shown in **Appendix E**) which combines the impact, exposure and frequency rating of the hazard.

The Impact category relates to the severity of the possible consequence (as shown in **Table 14.1**). The level of exposure relates to how often the receptor is exposed to the hazardous element. The frequency category is determined as follows:

- low if the hazard is expected to occur once every 100 years;
- medium if it could occur once every 10 years; and
- high if it could occur once every year.

Historical data were assessed, where available, to indicate the possible frequency of the hazardous events. Where the data were not available, the frequency was based on the experience of experts closely involved in the industry. Outlines of emergency planning and safety management systems as part of the overall risk management strategy are also addressed.

Definitions*

Risk: – The probability of an adverse event occurring. The likelihood of a dam failure occurring with adverse consequences (chance of failure to perform, or chance of harm are alternative definitions.

Hazard: - The potential loss of life, property or services

*ANCOLD Guidelines on Dam Safety Management, 1994

14.2 Construction Hazard Identification

The hazards during construction of the dam that have been identified are listed in **Table 14.2**. A discussion of these hazards is provided in this Section. A Risk Assessment of the main hazardous elements is provided in the **Section 14.4**.

Table 14.2: Burnett River Dam Construction

Hazard or Event	Possible Causes	Possible Consequences	Detection/ Protection Measures
Spill of fuel or chemicals	Spill or leakage of fuel or lubricating oil	Short term degradation of river water quality	☐ Construction activities to operate to approved EMP ☐ Provide spill clean up kits and ☐ Provide means and guidelines for responsible disposal
Vehicle collision or highway congestion	Highway route for material delivery is inadequate or collision with other vehicle/obstacle	☐ Loss of life ☐ Loss of equipment ☐ Project disruption	☐ Development of a Traffic Management Plan ☐ Upgrade roads where needed
Wall collapse	Inadequate spillway design	Construction safety issue, project delay	☐ Ensure sound construction methodology and planning to sequence stages to match seasons ☐ Strict construction supervision and monitoring
Landslide	Inadequate excavation	Construction safety issue, project delay	Ensure excavate with stable slopes

Hazard or Event	Possible Causes	Possible Consequences	Detection/ Protection Measures
Failure of diversion works	Inadequate construction planning	Uncontrolled release but manageable	☐ Construct during low flow season ☐ sizing of coffer dams and diversion tunnels need to be optimised using the probability of flooding
Explosive accident in quarry or river bed	Inadequate supervision Poor signage and security	Fly-rock hitting nearby structure/personnel/public	☐ Do not set off explosive within 60 m of concrete structures ☐ Employ stringent Work Place Health and Safety practice ☐ Adequate signage and security to warn and protect the public
Major flood during construction resulting in 'wash out'	Unpredicted heavy rainfall event	Loss of coffer dam and abutments	☐ Construction timed to occur during dry season. ☐ Undertake weather monitoring. ☐ Construction activities phased to minimise potential 'wash out impacts'
Cyclonic activity leading to flood	Construction not complete	☐ Earthworks washed away, sudden release, poor quality water	☐ Concrete abutments constructed first that has no impact from flooding ☐ All construction occurs in dry season
Fire destruction of buildings or vegetation	Uncontrolled fire	Injury, loss of life	☐ Arrange fire events with Fire services ☐ Supply fire safety equipment

The major hazards resulting in the possible loss of life which ranks as a high impact / consequence, are summarised as follows:

1. Vehicle collision during material deliveries;
2. Explosive accident impacting on nearby residents/passers by; and
3. Uncontrolled fire from scrub burn-off impacting on the public.

Vehicle collisions generally occur due to road conditions or collisions with other vehicles/obstacles. To minimise the frequency of such an event a number of road and bridge upgrades and constructions are detailed in **Section 4**, summarised as follows:

- ☐ Mingo Crossing will be inundated by flood water – the intention to construct a replacement high level crossing has not been approved, to date;
- ☐ A section of the Gayndah/ Mt Perry Road, south of the river, will also be inundated – an alternative route has not been selected, to date;
- ☐ All construction vehicles accessing the site will use the Isis Highway. DMR has designated the Isis highway a 'B double' route which is suitable for heavy goods traffic; and
- ☐ The present gravel access road to the Dam site will be sealed and a strip of land at the eastern section will be purchased to provide a direct link to the Isis Highway.

Transport issues with regard to dangerous goods are discussed in the following Section.

Explosives will be needed to provide earth and rock fill for the dam wall from a nearby quarry. Explosives may also be needed in the river bed to remove the permeable strata if it is deemed to provide a significant risk to the dam safety (described later in **Section 14.3.1**). Explosive accidents are caused by inadequate supervision and/or inexperienced personnel leading to incorrect placement and detonation of explosives. Further, poor signage and inadequate security measures could increase the exposure of the public to a possible accident.

Some of the inundated land may need to be burnt off to avoid degrading the dam water quality. If the fire is not controlled adequately, then the fire could go out of control and pose a risk to the public.

14.2.1 Hazardous Substances

During the dam construction, some hazards are associated with substances being stored and used for motor vehicle operation, quarry operation and concrete etching.

Petroleum products will be stored on-site in accordance with Australian Standard, The Storage and Handling of Flammable and Combustible Liquids (AS 1940 – 1993). Explosive materials to be used for blasting will be stored in a secure and purpose built powder magazine. Handling and storage of explosives will be in accordance with AS 2187 – Part 1. A very small amount of hydrochloric acid (as shown in **Table 14.4**) will be used and consequently, does not pose a hazard to the public or to the environment.

Given the correct controls on these materials, there is negligible risk to nearby land uses or to the public.

All effects from incidents are expected to be contained within the site and within bunded areas. Contamination to site will be avoided by having concrete pads and strict spill clean-up procedures as well as contaminated storm-water isolation and on-site handling procedures.

Hazardous chemical storage, if properly bunded and maintained, only constitute occupational health and safety concerns for those involved in using these materials. These concerns will be reduced by having the necessary protective gear available and used when loading or transferring these substances.

Diesel fuel fires are indeed a possibility and are discussed in Section 14.6.2. The probability of such an event is low and is controlled by the type of spill, its extent and the presence of ignition sources. The fuel tank will be above ground to reduce the impact on soils and ground water.

14.2.1.1 Spill of Liquids on Site

A spill of liquid in the construction site could occur during any material handling process. If the spill is minor then it would be controlled through the use of spill kits which will be kept at appropriate locations on the site. The site will be designed so that spills that do occur are contained within localised bunded areas and sumps. The spilt liquid and materials will be contained in drums for storage before disposal to an appropriate landfill/waste management site.

14.2.1.2 Bunding Standards

The diesel tank should be bunded in concrete retention areas with impermeable floor and bund walls. The design of the bunding should meet the requirements in AS 1940. This will ensure that there will be no significant contamination to soils and surrounding areas.

14.2.1.3 Transport Accidents Remote From Site

Off-site transportation of materials to and the from the site could result in accidental release or exposure to hazardous materials. The hazards of transporting chemicals by road and handling chemicals off-site are described in **Table 14.3**.

Table 14.3 Chemical Handling Off-site

Item	Hazard or Event	Possible Causes	Possible Consequences	Detection/ Protection Measures
RT-1	Road tanker	☐ run off road ☐ collision with other vehicle/obstacle	☐ Accident is minor with no spillage. ☐ Accident is serious and tank fails. ☐ Dangerous goods escape tanker and contaminate environment.	☐ All vehicles carry Hazchem Identification and responses for use by emergency personnel attending accident. ☐ Local roadways to the construction site will be adequate for bulk transport vehicles. ☐ Company emergency response plan will be developed to handle such incidents. ☐ Local emergency authorities would be made aware of traffic carrying dangerous good servicing the construction site. ☐ All tankers conform to the Australian Code for the Transport of Dangerous Goods by Road and Rail, and Australian Standard AS 2809.4-1986 road tank vehicles for dangerous goods.

If a tanker shell became damaged in an accident, the full contents of one tank compartment (5000-8500 litres) or greater (up to 20000 litres) could spill onto an off-site roadway, and escape into the soil profile or nearby waterway. The environmental damage caused by such a spill is dependent on the area in which the accident occurs. To control the damage that may occur, several measures will be put in place for transport operations. These measures include:

- dam owner to liaise with emergency services to develop an emergency plan to deal with tanker incidents off-site; number of road and bridge upgrades and constructions as detailed in **Section 4** and summarised in the previous Section;
- all vehicles to carry Hazchem Identification and response guidelines for use by emergency personnel attending the scene of the accident;
- tankers to incorporate internal valves on all outlets to prevent spills, in the event of vehicle damage; and
- all tankers to conform with the Australian Code for the Transport of Dangerous Goods by Road and Rail, and Australian Standard AS 2809.4.

The potential hazard of an accident occurring during diesel delivery is significant due to the potential loss of life.

The expected frequency of deliveries of hazardous materials that have the potential to spill is detailed in **Table 14.4**. The largest requirement for delivery of chemicals to the site is for diesel fuel oil.

Table 14.4: Delivery Frequency of Hazardous Goods During Construction Phase

Product	Annual Deliveries	Delivery Frequency
Diesel	$320m^3$	Weekly (April- November)
Hydrochloric Acid	220 litres	Single event

14.3 Operation Hazard Identification

The potential hazards associated with an operational dam are described in this Section. The potential hazards may be due to the following:

1. Dam failure;
2. Electrical Systems;
3. Fire Protection Systems;
4. Public Safety;
5. Flooding; and
6. Water quality.

A Risk Assessment of the main hazardous elements is provided in the following Section.

14.3.1 Dam Failure

Identified hazards due to dam failure are listed in **Table 14.5**.

Table 14.5: Dam Operation

Hazard or Event	Possible Causes	Possible Consequences	Detection/ Protection Measures
Water not released	Water release valve failure	☐ Failure to supply Environmental flow ☐ Failure to supply agricultural water ☐ Upstream flooding	Flow detection system
Internal water pressure build up within dam construction	☐ Inadequate design ☐ Poor construction	Water pressure causing structural failure and consequent, downstream flooding, loss of life	☐ Vertical drainage through the dam, ☐ Backup drainage device ☐ Rigorous construction supervision ☐ Use experienced engineers ☐ Perform core testing to determine concrete

Hazard or Event	Possible Causes	Possible Consequences	Detection/ Protection Measures
			strengths by a NATA accredited laboratory ☐ Rigorous quality control of material supply ☐ Regular monitoring of drain function ☐ Manual inspection of drains ☐ Design according to category of installation determined by Failure Impact assessment according to ANCOLD standards. ☐ Demonstrate to ANCOLD that designed to standards ☐ Obtain ANCOLD approval to proceed ☐ Submit construction reports to ANCOLD
Dam overtopping	PMF too low - resulting flood bigger than design parameters	Dam rim erosion, leading to dam failure, sudden release and loss of life	☐ Emergency action plans to cater for around 18 hours of inundation warning and include elaborate flood warning devices such as upstream level rainwater and gauges in order to increase warning time. ☐ PMF to be calculated for 1 in a million flood so error will result in a still insignificant probability ☐ Use guidelines on Selection of Acceptable Flood capacity for Dams, by ANCOLD ☐ Build emergency evacuation center above flood level
Spillway overtopping	☐ Spillway capacity under-designed ☐ Incorrect PMF	Dam rim erosion, leading to dam failure, sudden release and loss of life	☐ Design spillway capacity to take full PMF preferably based on river data else rainfall data and according to ANCOLD guidelines ☐ Ensure adequate data and/or best practice hydrological modelling
Water seepage beneath dam	Geology beneath dam contains permeable strata	Increase water flow down stream of dam	Construction to involve grouting to reduce seepage potential
Foundations eroding	☐ Inadequate design & construction of filters, piping, grouting and/or spillway. ☐ Significant flood	'Sunny day' failure leading to loss of life	☐ Use defensive design methods that are performed by experienced engineers ☐ Have backup filters ☐ Strict quality assurance of supplies, ☐ Strict supervision of construction performed by experienced engineers
Reservoir landslide	☐ Slope too steep ☐ Lack of stability ☐ Inadequate geotech investigation	Wall of water over top of dam, dam rim erodes, dam failure leading to loss of life	☐ Queensland soils generally do not have this problem ☐ Quality assurance performed on geotech investigations ☐ Ensure slopes are stable with rocks/vegetation
Gallery flood	Structural failure	Impacts on dam wall stability	Provide tolerance in design to allow for this possibility.
Sabotage	Public access to dam infrastructure	Dam collapse, failure, loss of life	Provide adequate security measures to inhibit public access
Cyclonic activity leading to flood	PMF too low	Dam overtopping leading to erosion, sudden release and loss of life	☐ Best practice hydrological modelling. ☐ Design structures to allow for wind loadings according to ANCOLD guidelines.

Hazard or Event	Possible Causes	Possible Consequences	Detection/ Protection Measures
			☐ Develop Emergency Action Plans in conjunction with Emergency Departments.
Seismic activity leading to "water wall'	FSL 'weight' increases local seismic activity.	Erodes dam rim leading to overtopping, sudden release and loss of life	Design structural stability for expected seismic loads based on seismologist's assessment and according to ANCOLD guidelines.
Seismic activity resulting in liquefaction of permeable strata	Geology beneath dam contains permeable strata	Dam failure due to loss of support	☐ structural stability design to incorporate features to cater for the permeable strata ☐ remove permeable strata if needed

Based on the criteria outlined in **Table 14.1** the failure of the proposed Burnett River Dam is considered to have a high hazard ranking, due to:

- ☐ The likely impact and potential loss of life in populated areas downstream of the dam which include, the town of Wallaville and the City of Bundaberg as well as smaller hamlets and individual houses;
- ☐ Likely severe damage to the Bundaberg Water Supply Scheme, including loss of Walla Weir and the Ben Anderson Barrage
- ☐ Extensive flooding and associated damage of commercial and industrial properties along the coastal plain areas near the Burnett River
- ☐ Extensive flooding and associated damage to the Port of Bundaberg and vessels moored within the river at Bundaberg.
- ☐ Likely loss of bridges on major roads and railway lines including the Bruce Highway
- ☐ Extensive flooding and associated damage to irrigated crop areas and the sugar cane railway system.

The following operational dam failures have been identified:

- ☐ Sunny day failure – due to poor maintenance, design or construction faults, geotechnical slope stability;
- ☐ Seismic "uncontrollable" failure – earthquake;
- ☐ Hydrological – erosion of dam material, abutments/ foundations, destabilising the dam by hydraulic loads; and
- ☐ Miscellaneous – terrorism.

The main causes of dam failure are discussed further in the following Sections.

14.3.1.1 Hydrologic

Hydrologic overload risks for dams can be classified into three main groups as follows:

1. erosion of the material of the dam itself by overtopping, for which the design does not protect
2. destabilising of the dam by hydraulic loads that exceed the structural capacity of the dam, and
3. erosion of the abutments or foundations by overtopping flows to the extent that support for the dam is removed.

The result can be severe damage or failure. Embankment erosion and destabilisation tend to be progressive and irreversible once initiated, and failure of the dam is the typical outcome. Erosion is a problem for embankment dams while destabilisation and foundation/abutment erosion is typically associated with concrete dams. Foundation/abutment erosion occurs with embankment dams but is overshadowed by erosion of the embankment itself. (Ancold (b))

The Dam will be designed to a Probable Maximum Flood (PMF) level – there are recognised methods for determining this and are these are summarised in **Section 3.1.6**. The spillway will be designed to the FSL level. PMF will be calculated for a '1 in a million flood', so any error in the data or hydrological modelling will result in an insignificant probability of overtopping due to flood.

The cause of foundations eroding is generally due to inadequate design and construction. The clay core is protected by a series of filters that hold the clay within the wall structure. To ensure the foundations do not erode the following measures will be taken:

- Use defensive design methods that are performed by experienced engineers;
- Have backup filters;
- Strict quality assurance of supplies;
- Strict supervision of construction performed by experienced engineers.

Hydrologic risks also arise without overload. These involve limited damage to dam and spillway structures, and threats to downstream life and property due to large floods routed through the spillway or over the dam. There may be threats to upstream life and property due to high surcharge levels.

Cyclonic activity within the region is a possibility which would result in extra stresses on the dam wall loadings. Hence, the structures will be designed to allow for these wind loadings.

14.3.1.2 Seismic

Dams are designed to with stand seismic activity (earthquake). Many dams have been subjected to strong seismic loads. Damage has been common, but very few dams have failed. In contrast, hydrologic risks have been the cause of earlier dam failures.

The main risks to dams from earthquake are:

- cracking with loss of section strength (mainly concrete dams).
- cracking with potential for internal erosion (embankment dams).
- sliding of foundation (mainly concrete dams).
- sliding of the dam material (mainly embankment dams).
- liquefaction of foundations (mainly embankment dams).
- liquefaction of dam material (certain types of embankment dams such as hydraulic fill or tailings dams).
- landslide induced wave that results in overtopping (mainly concrete gravity dams and embankment dams).
- cracking or collapse of ancillary structures such as outlet towers, bridges.

The result can be failure or severe damage, there have been only a few failures recorded worldwide.

The risk of dam failure due to seismic activity is increased with the presence of the permeable strata below the river surface. This strata will liquefy during any seismic activity thus, reducing the support that the earth provides to the dam wall. Reducing the support to the dam wall will place extra loads on the wall structure. To ensure failure due to seismic activity is minimised the following measures will be taken:

- structural stability designed to incorporate features to cater for the permeable strata; and/or
- remove permeable strata.

The frequency of seismic activity is increased with the additional weight of the water on the earth surface. To ensure this event is adequately taken into account with the dam design, the expected seismic loads will be based on a seismologist's assessment.

14.3.1.3 Static

Approximately two thirds of all dam failures are caused by piping or slope instability which are referred to as static causes. All other failures, such as those due to outlet conduit leaks, overturning or sliding that are not associated with floods or earthquakes, are included in this category.

The cause of these kind of failures is primarily due to poor design and/ or construction. To ensure Sunny-day failure is minimised the following measures will be taken:

- Vertical drainage through the dam will be installed;
- Backup drainage devices will be used;
- Regular monitoring of drain function;
- Manual inspection of drains;

- Rigorous construction supervision provided by experienced engineers;
- Perform core testing to determine concrete strengths by a NATA accredited laboratory;
- Rigorous quality control of supplied material;
- Design according to category of installation determined by Failure Impact assessment according to ANCOLD standards.

A land slump within the impoundment area could result in a wall of water overtopping the dam wall. However, Queensland soils generally do not pose such a problem. To ensure this is so, a quality assured geotechnical survey will be conducted and taken into account during any excavation. Slopes that are at risk of eroding will be appropriately stabilised and maintained. Also, levels within the storage will not change rapidly. Therefore, erosion around the edge of the inundation area is not considered to be a significant problem.

14.3.2 Electrical Systems

The electrical and control systems that may be used on the site were reviewed. The control system does not in itself constitute a significant risk and so is not discussed here. It is primarily used to control risks and help mitigate effects.

The major hazards are restricted to the site and involve the potential for fire from short circuiting and electrical leakages. Uncontrolled water release would also be possible from power grid supply failures. These hazards are insignificant.

Specific details of these systems are still to be developed as the detailed design stage proceeds.

14.3.3 Fire Protection System

The hazards associated with a fire protection system are restricted to the dam gallery. Therefore, this type of hazard does not pose a risk to the public or environment.

14.3.4 Public Safety

Visitor access to the dam wall will be restricted. The wall will be fenced to prevent access and vehicle access will be restricted to the entire site. Access to the impoundment will generally be restricted as it is surrounded by private land.

Drowning and falling accidents are a potential risk where the public can access to the dam wall and impoundment area.

14.3.5 Flooding

Flooding in the impoundment area may result in adjacent properties being inundated. The probability of this happening is not changed by the dam. However, the consequence changes because different lands will be subject to flooding. Although, flood levels will rise more slowly thus, providing more warning.

Following dam construction, the risk of minor flooding downstream of the dam will be reduced. In the event of a major flood, there will be greater warning of floods and a time delay to flood peaks. Hence, the impact of flooding following dam construction is deemed to be not hazardous.

14.3.6 Water Quality

The identified hazards due to water quality, are listed in **Table 14.6**. The river water quality refers not only to changes in the levels of toxins in and temperature of the water but also to river depth and flows as well as the number of living species within the river.

Table 14.6: River Quality

Hazard or Event	Possible Causes	Possible Consequences	Detection/ Protection Measures
Cold Water Release	Water released from the 'cold' lower water strata	Affects downstream ecology	☐ Multi-level off-take points ☐ Monitor downstream temperature ☐ Log water release levels
Algae blooms in dam waters	Low water flow and increase in temperature	Toxic algae can reduce water quality	☐ Develop an Algae bloom action plan. ☐ Recreational activities in dam waters will be restricted ☐ Inspection of algae levels in dam ☐ During bloom, monitor toxins downstream
Changes to current downstream river ecology	Water release flows and schedules do not mimic current environmental conditions Barrier to passage of aquatic life	Reduction of current populations due to: reproductive and life cycle ecology altering from changes in spawning and migration queues; barrier impacts on migratory species so do not complete life cycle.	☐ Install fish lock ☐ Mimic environmental flows with release patterns ☐ Maintain downstream riffle areas ☐ Survey for macro-invertebrates and other relevant indicator species' population ☐ Log water release flows and schedules ☐ Review schedules after survey
Changes river ecology to lake ecology	Reservoir changes water depth, flows, temperatures, plant and bed habitat	Displacement of species, loss of shallow habitat including riffles resulting in reduction in numbers of native turtles and lungfish	☐ Maintain downstream riffle areas ☐ Determine status of vulnerable species ☐ Determine if possible to relocate vulnerable species ☐ Continue to monitor numbers of these species

In the event that 'cold water' was constantly released from the dam, the downstream ecology will be moderately affected. This consequence will be reduced with the provision of a multi-level off-take system. This will allow the release of ambient river water temperature. To assist with monitoring this impact, the downstream river temperature will be measured.

A major algae bloom could change the quality of water released to the extent that it causes incremental reductions in downstream ecology and impacts on other water users. This consequence is restricted to a local area and so has a low impact. However, algae blooms are a widespread problem in Queensland and needs to be taken into account in regard to the management of the water supply. Measures that will be employed to reduce the hazard are to develop an algae bloom action plan that will identify what can be done and when it should be done. Further, recreational activities in the dam waters will be restricted to reduce contamination to the water.

The schedule of the downstream flows, if significantly different to current environmental flows, can impact on spawning and migration queues which would alter reproductive and life cycle ecology. The presence of the dam wall also poses a significant barrier to migratory organisms. The consequence could be a reduction in current aquatic populations that are significant to the region. Therefore, the impact of this consequence on the downstream river ecology was rated as medium. The impact will be reduced to low with proper management of releases. The impact is also reduced by installing a fish transfer system, however, the barrier for migratory fish movement will still be significant.

The replacement of shallow riverine habitats with a deep, lake-like habitat will result in a significant change in community structure. The loss of riffle habitats is likely to significantly impact on populations of Lungfish. While these species are not currently listed as "Threatened", they are likely to be nominated or listed and can be disadvantaged by water infrastructure development, particularly in the impounded reaches. The loss of this habitat and reduction in abundance of these species is rated as being of regional and, possibly, of State or National significance. Because of this rating, the short term impact will be high. However, mitigation measures described in Section 11 indicate that the medium to long term impact will be medium to low.

14.4 Risk Assessment

To assess the risks posed by the construction and operation of the dam, the major credible hazards (as identified above) were individually examined and each was assigned a value for frequency, exposure and impact. The major hazards have an impact of "High" as they resulted in possible fatalities or a significant incremental reduction in the number of a species. In determining the resultant risk levels, mitigation and control measures were taken into account, even if these were only identified as being applied at the time of design, construction or operation. It is expected that the approval to construct and operate the dam would be dependent on these conditions being met.

The table below (**Table 14.7**) lists the credible hazards and the assessed values for the various inputs and the resultant individual risk level based on using the risk calculator. To allow for frequencies less than 1 in 100 years, an additional frequency category was used as low-low (LL).

The standard approach has been taken in relation to acceptability of risks, as follows:

- HIGH This level of risk is not tolerable. Additional or alternative mitigation strategies to be implemented to reduce risk to lower level;
- MEDIUM This level of risk is acceptable provided all possible efforts have been made to reduce risk where those efforts have a positive cost benefit ratio (apply the principles of ALARP – As Low As Reasonably Practical); and
- LOW This level of risk acceptable with normal management procedures.

Table 14.7: Major Credible Hazards

Hazard or Event	ID	Frequency	Exposure	Impact	Residual Risk
Vehicle Collision	C1	L	L	H	L
Serious Diesel Tanker Accident	C4	L	L	H	L
Accident from explosives	C2	M	L	H	M
Uncontrolled fire	C3	M	L	H	M
Internal Water Pressure	O1	L	M-H	H	M
Dam overtopping	O2	LL	M-H	H	M
Spillway overtopping	O3	LL	M-H	H	M
Foundation Eroding	O4	L	M-H	H	M
Reservoir Landslide	O5	LL	M-H	H	M
Sabotage	O6	LL	M-H	H	M
Cyclonic Activity	O7	LL	M-H	H	M
Seismic activity, water wall	O8	LL	M-H	H	M
Seismic activity, permeable strata	O9	L	M-H	H	M
Public safety	O10	L	L	H	L
Reduction in number of species in reservoir area	O11	M	M	H	M

Each of the hazards in the above table has been assigned a number (C1 for construction hazards and O1 for operational hazards) and these numbers are cross- referenced in the text below for ease of understanding.

14.4.1 Construction

Off-site transport accidents have the potential to occur but that is low. Most of the transport occurs along major roadways (described in Section 4, Impacts on Infrastructure). The increased exposure of the public to this hazard due to the dam construction is low and the frequency of such an event occurring is low (C1). Therefore, this event is not a likely scenario for this proposed development.

There is a potential for the uncontrolled release of fly-rock from the quarry or river bed. However, correct management procedures that ensure the following:

- explosions are carried out by qualified and experienced personnel;
- stringent Work Place Health and Safety practices are applied; and
- Adequate signage and security to warn and protect the public;

results in the residual risk being moderate (C2).

The hazard due to uncontrolled fire (C3) is minimised by the following:

- conducting the burn-offs with supervision by local fire authority; and
- minimise the need for burn-off's by transporting as much plant debris off-site as possible for use as garden mulch.

The potential for a diesel transport accident to occur is low (C4). Most of the road tanker transport occurs along major roadways (described in Section 4, Impacts on Infrastructure). An accident involving a road tanker would most likely require a second vehicle to collide with the tanker. Tanker drivers are trained to such a level, and are sufficiently experienced that single vehicle accidents do not regularly occur.

The increased exposure of the public to a diesel transport hazard is low and the frequency of such an event occurring is low. Therefore, this event is not a likely scenario for this proposed development.

All of the hazards that have been identified due to the dam construction result in a low or medium residual risk which is acceptable.

14.4.2 Operations

The main hazardous events involved with operating the Burnett River Dam are due to dam failure and public safety.

The essential cause of dam failure is due to hydrological and static reasons. The frequencies of these failures based on historic data are provided in **Table 14.8**.

Table 14.8: Prior Frequencies of Failure Based on Historic Data

		Frequency per dam-year
Earth, Rockfill		
	Piping	6.3×10^{-5}
	Slope Stability	1.1×10^{-5}
	Piping outlet works	5.9×10^{-6}
	Foundation and miscellaneous failure modes	4.7×10^{-5}
Concrete		
	Foundation/abutment	5.1×10^{-4}
	Structure distress	1.7×10^{-4}
	Miscellaneous failure modes	8.4×10^{-5}

Source: ANCOLD (b)

The residual risk to the public of dam failure (O1 to O9) depends primarily on the rating of exposure. The duration of exposure of an individual living in Bundaberg to a consequent water wall caused by a dam failure would be rare to occasional due to the possibility of being able to evacuate. The rare to occasional categories result in the residual risk being low to medium, respectively. However, for residents close to the dam, the exposure would be occasional which results in a residual risk of moderate (high end of moderate range). Because of the relative inaccuracy of this preliminary hazard and risk assessment, and the fact that the risk levels in some areas are close to the limits of tolerability, it is considered essential that a quantitative risk assessment be undertaken as part of the design process to confirm the risks are in fact acceptable and that all efforts have been applied to reduce the risks to ALARP.

The hazard associated with public access (O10) to the dam reservoir resulting in drowning would have a low frequency. Rare exposure of the public to the reservoir and who are at risk of drowning results in the residual risk being low and therefore, acceptable.

The major environmental hazard posed by the reservoir over the length of the river is assessed as follows:

- moderate frequency with regard to the numbers of species that are affected;
- the exposure would be medium as only the species within the impounded reaches would be affected;
- the impact was previously defined as high; therefore,
- the residual risk to the environment is medium.

However, this assessment is based on a preliminary analysis and further work is required to assess the turtles and lungfish as to the level of rarity and endangerment. Based on this work, the need for establishing a manmade natural environment further upstream or downstream to resettle these species would be determined. The results of this study may reduce the impact to medium and residual risk to low. Also, to ensure the impact upon these species is absolutely warranted, careful consideration of alternatives to the dam that will increase crop yield must be undertaken.

14.5 Risk Summary

The analysis of the hazards indicates that off-site risks to the public and to the environment are moderate, with some risk levels being at the top end of the moderate range. In terms of this preliminary risk assessment, it is considered that the risk levels are tolerable, but every effort must be made to both reduce and confirm the risk levels.

The major risks are summarised as follows:

Construction	**- Off-site transport accidents**
Low risk	- Transport route upgrade.
Construction	**- uncontrolled release of fly-rock**
Medium risk	- explosions are carried out by qualified and experienced personnel; - Stringent Work Place Health and Safety practice applied; and - Adequate signage and security to warn and protect the public
Construction	**- uncontrolled fire**
Medium risk	- conducting the burn-offs with supervision by local fire authority; and - minimise the need for burn-off's by transporting as much plant debris off-site as possible for use as garden mulch.

All of the hazards that have been identified due to the dam construction result in either a low or medium residual risk.

Dam Operation	**– dam failure**
Moderate risk	– all features of design and construction to follow ANCOLD guidelines which dictates that a Failure Risk Assessment must be performed.
Dam Operation	**– public safety**
Low risk	– provide adequate signage to ensure public are aware of the dangers of recreation in and around reservoirs.
Dam Operation	**– reduction in river species**
Moderate risk	- perform ecological survey of possible threatened species – careful consideration of alternatives to the dam that will increase crop yield.

14.6 Community Safeguards

It is vitally important that the impact of the proposed dam have minimal impact on the local communities around Bundaberg. The community safeguards will be implemented through a, 'safety in depth' or 'defence in depth' approach where there exists a layered approach to public and environmental impacts. These safeguard layers come in two principal forms:

- the design of processes to, 'best engineering practice' standard; and
- the implementation of safety management systems and emergency planning appropriate for the hazards involved in the operations.

Many of the design issues, related to the Dam, have been discussed in the hazard review in the previous Sections which outlined the detection and protection mechanisms that should be in place.

Using the "defence in depth" approach the 'inner layer' deals with the actual engineering designs and these are usually often dictated by Australian Standards and industry codes of practice as specified by Ancold. The outer layers of the approach can include:

- continuous regulation and control via DCS or equivalent such as SCADA;
- alarm systems on the DCS or SCADA;
- fire detection and suppression systems;
- local and site emergency procedures; and
- off-site emergency procedures.

All of these items need to be in place where the hazards dictate.

14.6.1 Safety Management Systems

The safety management system adopts an integrated approach to risk management of the dam construction and operations, recognising the hazards at all points in the operations and how these are controlled.

The safety management system will comprise many of the 'defence in depth' layers but should also include the following:

- strict review of modification and design procedures;
- policies for managing change (new technology, new procedures);
- assessment of human factors in the design and operation;
- training programs for operators;
- internal standards and codes of practice;
- process and equipment integrity including preventative maintenance and procedures;
- documentation and propagation of process knowledge to operators and engineers;
- accident investigation procedures;
- enhancement of safety knowledge and its dissemination to staff;
- high quality risk and compliance auditing; and
- clear statements of risk management objectives and goals.

These issues will be addressed by the operating company as the Project progresses.

14.6.2 Emergency Planning

Emergency planning represents the outer layers of the 'defence in depth' approach to community safeguards. Any emergency planning must be based on the following components:

- an analysis of the key incidents likely to take place for each operational area;
- an assessment of the degree of impact likely to occur;
- an assessment of what constitutes 'an emergency' for the particular operation;
- an on-site plan to handle incidents;
- an off-site plan with reference to emergency services needed;
- communication, emergency responsibilities, control centre establishment;
- post emergency procedures, including recovery, debriefing and review of plan; and
- test the plan under emergency-like conditions.

General guidance for preparing emergency plans can be obtained from the Queensland Government, Department of Emergency Services. In particular, the recent Australian-New Zealand code of practice for emergency planning will form the basis for the detailed development of the plans covering the individual areas.

The final detailed plans should be developed by the operating company as the detailed engineering design takes shape. This might involve local emergency services such as police, fire brigade and state emergency services personnel as well as the local emergency response groups.

Table 14.9: Emergency Plan Elements

Event	Level of emergency	Emergency services required	Resources needed	Organisational aspects	Damage control actions
Bush fire on site during clearing or construction	□ Site wide □ Potential external alert	□ Site fire fighting team □ Town fire crew or country fire authority	Fire fighting truck and water tankers	□ Evacuation of affected workers □ Roll call	□ Fire containment □ Shutdown of affected works
Bulk diesel fuel fire	Local, site and external	Site fire fighting crew	□ Fire fighting □ Fire suppressants	□ Evacuation notice □ Communication to fire and recovery crews	□ Evacuate from local area □ Fire spread control □ Adjacent cooling of tanks and/or structures
Vehicle collision	Local/site	□ Ambulance □ Police □ Fire crew	□ Rescue □ Fire fighting capability □ Fuel containment materials	□ Spill Management plan	□ Contain fuel spillages □ Control ignition sources
Earthquake	□ Site wide □ Potential external alert	Emergency response teams	□ Spill containment materials □ Rescue	□ Spill Management plan □ Evacuation notice □ Communication	□ Evacuate from site □ Shutdown all operations □ Contain fuel spillages □ Control ignition sources
Cyclone/Flood	□ Site wide □ Potential external alert	Emergency response teams	Rescue	□ Emergency Response Plan □ Evacuation notice □ Communication	□ Evacuate from site □ Shutdown all construction activities □ Contain fuel spillages □ Control ignition sources
Falls and impact incidents	Local	□ Ambulance □ Paramedics □ Rescue	Site rescue equipment	□ Evacuation □ Communication □ MSDS's at hospital	□ Stabilise □ Isolate source of incident

14.6.3 Emergency Action Plan

An Emergency Action Plan (EAP) or Dam Safety Emergency Plan must be developed for the dam, this should include:

- □ identification of emergency conditions which could endanger the integrity of the dam
- □ dam operation procedures to follow in the event that such emergency conditions are identified
- □ warning systems for downstream communities
- □ Notification listing or flowchart – identifying responsibility for notification, the order of notification and who is to be notified.
- □ Roles and responsibilities – of the dam owner, operator and dam personnel
- □ Area map – showing the access routes to the storage during fair and adverse weather conditions, including distance and travel times.
- □ A drawing of the Storage Catchment Area
- □ Emergency Events and Actions List
  - – detailing typical problems, problem characteristics and when/ what to check for during inspections
- □ A dam failure inundation map – this should identify: downstream inhabited areas subject to danger, inundated areas, a narrative description of areas affected by the dam break
- □ Any other charts, rating tables, considered by the dam owners as necessary.

14.7 Commitments

The major potential hazards from the dam operations were identified to be due to dam failure and a reduction in aquatic species in the inundation area.

The Burnett River Dam is deemed to be a referable dam and as such will require a Failure Impact Assessment Study prior to undertaking detailed design.

The following general recommendations are made, based on the preliminary hazard review:

- Perform ecological survey of possible threatened species;
- Careful consideration of alternatives to the dam;
- Undertake a Failure Impact Assessment Study according to ANCOLD guidelines;
- Safety management systems for all of the operations will be established in line with current guidelines as published by ANCOLD (b);
- Emergency planning will be implemented in line with recent Queensland and Australian Emergency Planning Guidelines Codes of Practice;
- An Emergency Plan detailing each potential hazardous scenario on the site, including evacuation plans and emergency response needs to be documented prior to the Dam's commissioning;
- All storages of bulk liquids needs to be adequately bunded to contain a maximum possible spillage and designed according to Australian Standards;
- A dangerous goods manifest would need to be prepared for the construction site. The manifest would show the location of all chemicals (hazardous and non-hazardous) on site and emergency spill equipment; and
- An Environmental Management System based on the ISO 14001 series should be developed for the site to ensure the continued improvement of environmental performance of the dam operation.

14.7.1 Dam Safety

The recommendations specific to ensuring that the dam is constructed and operated safely, are summarised in this Section.

14.7.1.1 Design

The following recommendations are made with respect to design of the proposed Burnett River Dam:
- Regional and site geology must be investigated in detail to allow foundations to be designed to support the dam wall and control seepage
- Spillway size and level should be determined so that the dam will not overtop in the Probable Maximum Flood event
- Suitable materials for dam construction must be identified
- Design must take into consideration the load and strengths of construction materials to ensure that dam wall integrity is maintained in the long term and that seepage is controlled
- Outlet works should allow rapid drawdown of the dam in the event of loss of integrity of the dam wall
- Instrumentation should be included to allow adequate monitoring during construction and operation
- A quantitative Risk Assessment is carried out according to ANCOLD (b); including HAZOP analysis of the operating elements associated with the release mechanisms.

14.7.1.2 Construction and Filling

The following recommendations are made with respect to construction of the proposed Burnett River Dam:

- Actual conditions must be checked against design assumptions and specifications and amendment of the design made as appropriate
- Detailed records including as built drawings of all stages of construction must be maintained
- Detailed records must be kept during the initial reservoir filling stage
- Design report with associated data must be prepared.

14.7.1.3 Operations and Maintenance

An Operations and Maintenance manual must be prepared for the dam. This should include procedures for:

- operating the dam under normal conditions;
- coordination with other flow regulating structures within the catchment;
- maintaining environmental flows;
- operating the dam under adverse and worst case scenario conditions;
- coordinating with emergency response and counter disaster agencies;
- flood warning ;
- maintaining the dam wall, associated structures and associated equipment in accordance with the designer's operating criteria;
- a program for surveillance and monitoring of the dam and all associated structures and equipment to allow for early detection of faults and deficiencies;
- recording and reporting of routine and non-routine surveillance;
- remedial action in the event of faults or deficiencies being identified by surveillance; and
- periodic review, at five yearly intervals or when changes or other circumstances dictate.

The manual must be written such that persons unfamiliar with the dam can operate it properly. This is particularly important in an emergency situation.