Australia Pacific LNG Project

Volume 5: Attachments

Attachment 24: Adaptive Associated Water Management Plan – Gas Fields

Executive Summary

Sustainable resource management and development is a key driver of the Australia Pacific LNG project. The appropriate management of associated water is critical to the gas field development program as well as the long-term social, environmental and economic well-being of south central Queensland. Australia Pacific LNG is committed to a water management strategy which will encourage commercial and beneficial uses of associated water to deliver sustainable outcomes.

An Adaptive Associated Water Management Plan (AAWMP) has been developed, and herewith documented and provided, as a tool to assist with the long-term management of the associated water produced during the extraction process of coal seam gas. This plan will form part of the required environmental management plan for the expansion of the Australia Pacific LNG Coal Seam Gas (CSG) fields and will set out specific measures or goals to be achieved to maximise the beneficial use of associated water. This plan has been developed with reference to and prepared in accordance with the *Operational Policy – management of water produced in association with petroleum activities (associated water)* (Queensland Government, Environmental Protection Agency, December 2007) and the *Queensland Coal Seam Gas Water Management* (Queensland Government, Department of Infrastructure and Planning, May 2009).

The amount of associated water produced during gas extraction is difficult to predict and varies both with the location and stage of the production cycle. Likewise, the quality of the associated water is highly variable, but it frequently contains elevated quantities of salt and other contaminants. The quantity, timing and location of water demand are similarly anticipated to fluctuate, both in terms of the life of the project and seasonal conditions. The AAWMP therefore needs to be adaptive to reflect changing supply and demand conditions, whilst remaining sustainable addressing social, economic and environmental considerations.

Australia Pacific LNG has adopted an initial management regime for associated water management, known as the “Initial Case”. This case is to sustainably manage associated water, with readily applied existing technologies and customers, whilst Australia Pacific LNG optimises commercial and beneficial water use. An indicative program for development of these preferred options is in the order of three to five years; however Australia Pacific LNG considers the early implementation of these options to be beneficial socially, environmentally and economically.

A five step rational decision model was adopted for the appraisal and selection of the Initial Case associated water management options. The model was used to define the water management requirements, guide brainstorming and external investigative processes to develop management ideas, evaluate issues using two recognised management processes and result in the final associated water management Initial Case selection.

The selected management option was assessed using five internally selected criteria which focused primarily on regulatory approval requirements and achievable implementation within the Project schedule. Two management options were selected for the short-term management of treated water, whilst a single salt management option has been proposed. The concept design of an Initial Case for the management of associated water is as follows:

- A low pressure water gathering and transfer system delivering water to a series of central locations;
- Short-term storage ponds to facilitate initial water treatment and operational flexibility;

- Water treatment facilities to treat the water to a standard suitable for use in the respective management option;
- Australia Pacific LNG owned and operated agricultural use, complimented with negotiated water supply to existing agricultural ventures;
- Opportunistic discharge of high quality treated water to major watercourses as to cause minimum environmental impact considering seasonal and annual variations; and
- Brine evaporation ponds, to be encapsulated following end of use.

Key environmental risks associated with the Initial Case management approach were evaluated using the project agreed risk assessment framework. The assessment identified the following ten key risks:

1. Erosion from exposed areas resulting from clearing of agricultural land.
2. Contamination of water and soil environments from use of poor quality irrigation water.
3. Offsite surface drainage caused by irrigation.
4. Deep drainage caused by irrigation.
5. Change in geomorphology due to increased flow.
6. Localised erosion at watercourse discharge points.
7. Impacts to aquatic ecology from change in flow regime.
8. Impacts to aquatic ecology from inappropriate water quality discharge.
9. Contamination resulting from brine pond overflows.
10. Contamination resulting from brine pond seepage.

The above list of identified environmental risks was subsequently reduced to less serious rankings with the proposed implementation of appropriate mitigation measures in the assessment. The substantial reduction in risk was predominantly due to water treatment commitments and the assimilation of discharges to reflect existing flow regimes and the short-term time period. Efforts are being furthered to reduce or eliminate any environmental risks in relation to associated water. Australia Pacific LNG intends to adopt a continuous improvement approach in all aspects of associated water management.

In light of this, efforts are also continuing to find alternative beneficial uses for associated water management. Key milestones/dates have been established to ensure beneficial re-use options are implemented during the transitional period. The beneficial re-use options under consideration and investigation are industry use, potable water supply, agriculture, reinjection, innovative technologies and salt management.

It is proposed that this stand-alone AAWMP be regularly updated as stakeholder negotiations progress, operations expand, water markets mature and technology improves. This document is intended for use in establishing a strategic planning framework promoting active responses to regulatory change and outcomes of stakeholder engagement. The initial draft of this document outlines regulatory requirements and existing conditions setting the scene for the initial and further development of associated water management options.

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1. Introduction

1.1 Background

Australia Pacific LNG is a 50:50 coal seam gas (CSG) to liquefied natural gas (LNG) joint venture between Origin Energy and Conoco Phillips. The Australia Pacific LNG project proposes to supply CSG from the Walloons gas fields in south central Queensland to a LNG plant located on Curtis Island, near Gladstone, on the central Queensland coast.

CSG is predominantly methane stored within coal seams by adsorption to the surface of coal particles. In the Walloons coal seam, pressure from the surrounding body of water keeps the gas adsorbed as a thin film on the surface of the coal. Hence to extract the CSG, the water pressure needs to be reduced by transferring the associated water to the surface. Moreover transfer of water can be managed to modify the gas pressure, thereby optimising the rate of gas production.

The amount of associated water produced during the CSG extraction is difficult to predict and varies both with the location and stage of the production cycle. Likewise, the quality of the associated water is highly variable, but it frequently contains elevated quantities of salt and other contaminants. Inappropriate management of CSG associated water can potentially result in environmental harm. Beneficial uses for such large quantities of both treated and untreated water in this region are limited.

It is acknowledged that the treatment, use and disposal of associated water present a challenge for the Project, whilst simultaneously opening a number of options for beneficial water usage.

1.2 Objectives of the Plan

The aim of the Adaptive Associated Water Management Plan (AAWMP) is to provide a tool to assist with the long-term management of associated water. This plan will form part of the required environmental management plan (EMP) for the expansion of the CSG fields and will set out specific measures or goals to be achieved to maximise the beneficial use of associated water and ensure any potential impacts have been mitigated. The plan will set up a strategic management framework and will be based on a number of key objectives including:

- Provide a transparent document outlining Australia Pacific LNG's philosophy and approach
- Demonstrate adherence to regulatory policy
- Document the risks and challenges in relation to associated water management
- Provide a strategic management tool adaptive to changes in:
  - Source water quantity and quality
  - Demand location and volume
  - Technology
  - Environmental receptors/constraints
  - Community concerns, and regulatory requirements
- Allow for continual improvement and the implementation of good practice management of associated water

1.3 Terms of Reference

Table 1.1 summarises the Terms of Reference (ToR) for the Australia Pacific LNG Project Environmental Impact Statement (EIS, December 2009), as they apply to the management of associated water. The table sets out each specific ToR requirement and where it has been addressed in this report. All ToR requirements are sourced from Section 2.4.1.1 of the ToR, page 44.

Table 1.1 Terms of reference - associated water management

Term of Requirement	AAWMP Reference
The approach to be adopted for the management of associated water should be detailed.	Section 5
The discussion should outline the beneficial water use options considered for the project and set out a justification for the selection of the preferred option (s).	Section 6.1
The justification should have regard to the issues identified in the EPA Operational Policy '*Management of water produced in association with petroleum activity (associated water)*' and the DIP Policy '*Queensland Coal Seam Gas Water Management Policy'*.	Section 2
The operation of the water treatment plants should be described, and the volumes and characteristics of treated water and waste water streams specified.	Section 4 & 6.2
Process charts should be provided to illustrate the treatment processes.	Section 6.2.3
The discussion should also indicate how the management approach: • meets regulatory considerations • deals with water quality variations and other environmental constraints • incorporates the risk management framework agreed with the Queensland Department of Environment and Resource Management (DERM) and other local stakeholders • deals with the disposal of residual saline waste materials	Section 8
The EIS should provide an Associated Water Management Plan that will form part of the required Environmental Management Plan for the expansion of the CSG fields.	Section 7.3
The plan should set out specific measures or goals to be achieved to maximise the beneficial reuse of associated water and minimise the generation or emission of potential contaminants to the receiving environment. Such plans, at EIS stage, should set the framework and be based on objectives.	Section 7.3

Note: there are other references to associated water throughout the ToR; however these relate to aspects of the project covered in other sections of the EIS such as decommissioning and rehabilitation, land contamination, impacts from groundwater injection, and waste generation.

1.4 Australia Pacific LNG Associated Water Management Philosophy

CSG is a developing industry in Australia and proponents are implementing strategies to deal with a number of challenges including the management of associated water. To explain the approach to associated water management, acknowledging the ongoing evolution of technology and practice, Australia Pacific LNG has developed an associated water management philosophy.

One function of the philosophy is to serve to inform the community, regulators and shareholders by providing a transparent statement outlining Australia Pacific LNGs management approach. The appropriate management of water is critical to the gas development program, as well as the long term social and environmental impact to the region. We recognise the interests of a wide range of stakeholders in the approach taken to water resources, and will be continuing with consultation as the Project progresses.

Another function of the philosophy is to articulate and embed the fundamental principles and objectives to guide decision-making. The philosophy is a synergy of both joint venture partners' water and sustainability policies and existing associated water Project commitments.

An objective of the Australia Pacific LNG is to develop the Project in a sustainable manner. This objective relates to both the outcomes we will strive to achieve, and the methods and processes applied when working towards outcomes. In particular, in developing the associated water management philosophy and approach, Australia Pacific LNG is guided by the following goals:

- Minimising adverse environmental impacts and enhancing environmental benefits associated with the activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the water resources in the operational areas
- Respecting the rights, interests and diverse cultures of the communities in which we operate
- Engaging regularly, openly and transparently with people and communities affected by the activities, considering their views in the decision-making
- Working cooperatively with communities, governments and other stakeholders to achieve positive social and environmental outcomes, seeking partnership approaches where appropriate
- Identifying, assessing, managing, monitoring and reviewing risks to the workforce, the property, the environment and the communities affected by the activities

Table 1.2 provides an outline of Australia Pacific LNG management philosophy for associated water management, delineated by the three underlying elements.

Table 1.2 Associated Water Management Philosophy

Continuously Increase Understanding

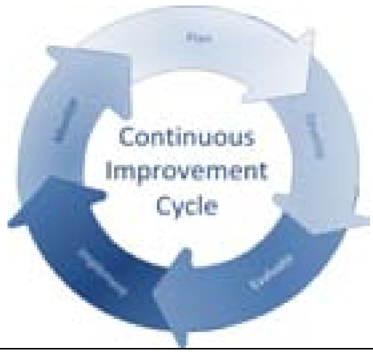
- further investigate: extraction, treatment, disposal, waste management and beneficial technologies
- engage and collaborate with stakeholders on water management impacts, strategies, monitoring and community expectations
- build a comprehensive database of the hydrogeological environment

Sustainable Management Approach

- adopt holistic water management techniques, considering environmental, social, safety and financial consequences throughout and beyond the life of the Project
- pursue economic viability of water solutions, with minimal long-term or cumulative impacts
- consult with community stakeholders, government authorities and shareholders and consider external views in decision making
- operate responsibly to manage the water resources under Australia Pacific LNG's control

Monitoring and Performance Evaluation;

- establish a strategic planning framework, promoting active response to regulatory change and stakeholder engagement
- adopt adaptive and continuous improvement management practices to plan, develop, evaluate, implement and monitor associated water management options



In developing a flexible and adaptive approach to the on-going monitoring and management of water, the Australia Pacific LNG has identified that an approach with the following elements will assist to advance the goals underpinned by the Adaptive Associated Water Management Plan. In the identification of appropriate treatment processes, an approach should be adopted that seeks to maximise the value of water. In project planning; locate and design infrastructure and planned discharges to reduce impacts to flow regimes and flooding, adapting water interaction to natural change in the environment.

1.5 Terminology

As terminology can vary within the gas industry, this plan aims to employ consistent naming and definitions to water and waste streams.

The AAWMP adopts *associated water*; referring to the untreated water stream associated with the extraction of CSG gas, often also referred to as produced water or CSG water. Once treated however, two alternate streams are defined, *permeate*; treated water and *brine*; the highly saline effluent stream.

2. Regulatory Framework

Australia Pacific LNG is seeking government approval for the Project under the State Development and Public Works Organisation (SDPWO) Act 1971. Under this Act, the Project is to be required to prepare an Environmental Impact Statement (EIS) which includes an assessment of the associated water management regime proposed by the Project and its respective impacts.

Furthermore, the Project will need to be in accordance with other relevant Queensland law, and seek additional approvals (for example development approval/s, registration certificate, water licence) to undertake the proposed disposal or beneficial reuse activities. The production of associated water is regulated by the following Queensland legislation:

- Petroleum and Gas (Production and Safety) Act 2004
- Water Act 2000 / Water Supply (Safety and Reliability) Act 2008
- Environmental Protection Act 1994 / Environmental Protection Regulation 2008
- Sustainable Planning Act 2009

2.1 Water Act 2000 / Water Supply (Safety and Reliability) Act 2008

The Water Act 2000 provides direction for the sustainable management and efficient use of water by regulating the planning, allocation and use of water in the State of Queensland. It vests in the State all rights to the use, flow and control of water in Queensland, including groundwater, overland flow and water within watercourses, lakes, springs and dams. The Act allows for the allocation and use of water for the physical, economic and social well being of the people of Queensland and Australia, whilst protecting the biological diversity and health of natural ecosystems, now and in the future.

Water produced/released during the extraction of gas is regulated by the Petroleum and Gas (Production and Safety) (P&G) Act 2004 (discussed further in Sections 2.3). Supply of 'associated water' for stock and domestic purposes within the tenure area and adjoining areas owned by the same person or use by the petroleum tenure holder, is also directed within the P&G Act.

The supply of both treated and untreated 'associated water' outside of the tenure to a third party will require either; the users to obtain a water licence; or petroleum tenure to register as a water service provider under the Water Supply (Safety and Reliability) Act 2008.

A water licence or permit is required under the *Water Act 2000* to take, interfere with or use water for an activity that is not authorised by the petroleum tenure, or for activities outside the area of the petroleum tenure. For use of associated water, other than for petroleum activities, a development approval for reuse of regulated waste is required, unless covered by a general or specific approval under the Waste Regulation. Australia Pacific LNG will have general approval for the beneficial use of a resource if it complies with the conditions of the general approval for the beneficial use of associated water set out in the Operational Policy for the Management of Water Produced in Association with Petroleum Activities (Associated Water) (Queensland Government, Environmental Protection Agency, December 2007) or can apply to DERM for specific approval for the beneficial use. Further to regulation provided in the Water Act and Water Supply Act, regional guidance for water use is to be considered. For the Walloons development area, the following plans and agreements should be recognised:

- Water Resource (Great Artesian Basin) Plan, 2006

- Great Artesian Basin Resource Operations Plan, 2007
- Murray Darling Basin Agreement, 2006

2.1.1 Water Resource Plan (Great Artesian Basin) 2006 / Great Artesian Basin Resource Operations Plan 2007

The Walloons gas fields are located within the Surat Basin, a major sedimentary basin that forms the eastern limb of the Great Artesian Basin (GAB). The Walloons aquifer, along with potential re-injection aquifers such as the Hutton Sandstones, Precipice Sandstones, Gubberamunda Sandstones, and Springbok Sandstones are subject to strict management guidelines.

The Water Resource (GAB) Plan and Resource Operations Plan were approved in 2006 and 2007 respectively. These plans regulate water licence applications within the basin's aquifers and consider the sustainable management of the resource.

The Water Resource Plan sits within the Water Act 2000, providing a strategic framework in a regional context to:

- Define the availability of water in the plan area
- Sustainably manage water and the taking of water
- Identify priorities and mechanisms for dealing with future water requirements

The Resource Operations Plan implements the Water Resource Plan specifying criteria and conditions for future and existing water availability, licensing and use.

These plans are currently restricting water licence applications for aquifers including CSG aquifers, as extraction is not considered sustainable. As outline previously, water extracted in association with CSG is recognised under the P&G Act (Section 2.3).

2.1.2 Murray Darling Basin Agreement

The Walloons development area is predominately located within the Murray Darling Basin and drains to the Condamine River.

Under the Commonwealth Water Act 2007, the Murray Darling Basin Authority is the entity responsible for the management of water within this Basin and to this end is charged with preparing the Basin Plan by 2011. The Basin Plan is to address the following issues:

- Limits on water (both surface and groundwater) that can be taken
- Identification of risks to Basin water resources (for example climate change)
- A water quality and salinity management plan
- An environmental watering plan to optimise environmental outcomes
- State water resource plans
- Trading of water rights rules

Water-sharing arrangements that are provided for in existing water resource plans will remain in place until these plans cease, as outlined in the transitional arrangements set out in the Act.

2.2 Environmental Protection Act 1994 / Environmental Protection Regulation 2008

The object of this Act is to protect Queensland's environment while allowing for development improving the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends, (that is ecologically sustainable development).

The Environmental Protection (EP) Act 1994 requires a major project such as Australia Pacific LNG's to apply for and subsequently operate under, an Environmental Authority (Petroleum Activities) (EA).

Generally, the storage, treatment or disposal of regulated waste is an Environmentally Relevant Activity (ERA), subject to exceptions. The EA approvals process will involve an assessment of ERAs that are petroleum activities. For any ERAs that are not petroleum activities, a development approval may be required.

Associated water may be considered a regulated waste under the Environmental Protection Regulation (2008) depending on quality. If associated water is treated in accordance with the conditions of a general or specific beneficial use approval, it will no longer be considered "waste" and would not trigger ERAs (see 2.2.1 below).

The EP Act provides an overarching framework for the assessment of the petroleum activity. Further guidance is provided in a series of Environmental Protection Policies (EPPs) made under the EP Act and in Operational policies issued by the Department of Environment and Resource Management. Of relevance to the management of associated water are the following:

- Environmental Protection (Waste Management) Policy 2000
- Environmental Protection (Waste Management) Regulation 2000
- Environmental Protection (Water) Policy 1997
- Operational Policy for the management of water produced in association with petroleum activities (associated water) 2007

2.2.1 Environmental Protection (Waste Management) Policy/Regulation 2000

The EP Act defines waste to include 'anything that is 'left over, or an unwanted by-product, from an industrial, commercial, domestic or other activity'. The Environmental Protection (Waste Management) Policy 2000 (the Policy) provides a strategic framework of managing waste whilst the Environmental Protection (Waste Management) Regulation 2000 (the Regulation) contains the requirements for handling specific waste streams.

Within the Regulation, saline effluents are listed as regulated wastes. Although "saline effluents" is not defined in the Regulation, the Queensland Government Discussion Paper, 'Management of water produced from coal seam gas' (Queensland Government, Department of Infrastructure and Planning, May 2009) suggests when associated water has total dissolved solid (TDS) concentration less than 10,000 mg/L it should not be regarded as saline, unless it is likely to become more concentrated by evaporation. Generally associated water released within the Walloons deposit is less than 8,000 mg/L, in which case in its produced form it should not be considered a regulated waste. However, the reverse osmosis treatment of associated water is expected to result in a concentrated saline effluent stream (brine) with a TDS concentration between 50,000 and 70,000 mg/L.

Wastes do not include a resource that is approved for beneficial use under the Regulation. When beneficial use of associated water is not achievable, associated water is considered a regulated waste for the purpose of the EP Act.

The management of wastes must be addressed within an Environmental Management Plan (EMP). An EMP subsequently should include the following:

- A description of proposed activities (in relation to petroleum extraction)
- A description of the receiving environment
- A description of the potential impacts on the environmental values of the receiving environment resulting from the ERAs
- Details of wastes generated and waste minimisation strategies
- Environmental protection commitments
- Proposed rehabilitation plans and strategies
- Financial assurance for the rehabilitation liability

These aspects have been addressed within the context of the EIS.

2.2.2 Environmental Protection (Water) Policy 2009

The purpose of this policy is to provide a framework to achieve the objectives of the EP Act in relation to Queensland waters. This policy guides the identification of environmental values, appropriate water quality objectives and the efficient use of resources and best practice environmental management.

As discussed previously, associated water may be considered a waste in terms of the EP Act, and as such would be regulated by the Environment Protection (Waste Management) Policy/Regulation 2000. Conversely it may be approved as a ‘resource,’ if a beneficial use is agreed.

The approval is provided on a case-by-case basis by the appropriate administrating authority, currently there is a general approval for associate water, pending further policy refinement.

In these cases the Environment Protection (Water) Policy will provide guidance on appropriate management of beneficial water reuse, the quality objectives and the existing environmental values that are to be considered.

2.2.3 Operational policy – management of water produced in association with petroleum activities (Associated Water) 2007

In March 2007, the Queensland EPA (now DERM) released an Operational Policy for the management and disposal of associated water. The Operational Policy promotes the beneficial use of associated water in accordance with the Environmental Protection (Waste Management) Policy 2000.

The Operational Policy puts forward a number of preferred management options (injection, direct use without treatment, treated water use) and non-preferred management options (disposal via evaporation ponds, injection after surface storage or into better quality groundwater, discharge to surface waters).

The key objectives of the operational policy are:

- To provide consistency, certainty and transparency in decision-making about appropriate management strategies for associated water during the pre-design phase of applications for non-code compliant environmental authorities (petroleum activities)
- To promote where feasible, beneficial use or injection in preference to any other disposal options, for the management of associated water
- To achieve the best net environmental, social and economic outcomes for the management of associated water whilst providing flexibility in how the outcome is achieved

If beneficial use of associated water is proposed Australia Pacific LNG may be required to apply for a development approval for reuse of a regulated waste, unless covered by a general or specific approval under the Environmental Protection (Waste Management) Regulation 2000. Australia Pacific LNG will have general approval for the beneficial use of a resource if it complies with the conditions of the general approval for the beneficial use of associated water set out in the Operational Policy or can apply to DERM for specific approval for the beneficial use.

2.3 Petroleum and Gas (Production and Safety) Act 2004

The Petroleum and Gas (Production and Safety) (P&G) Act 2004 was developed to combine the existing regulation of the petroleum and gas industries under the Petroleum Act 1923 and the Gas Act 1965 into a single piece of legislation. The development of the Act is the result of extensive consultation with the petroleum industry, landholder representatives and community groups.

In regard to associated water management, the Act provides guidance for the management of water rights. The Act indicates that a holder of petroleum tenure has the right to extract underground water in the area of the tenure, provided that is happens during the course of or results from the carrying out of an authorised activity for the tenure, including gas extraction. There is no limit to the volume of water that can be taken by the holder of petroleum tenure.

Furthermore the Act defines that the associated water can be re-used for the following activities:

- Stock and domestic purposes within the tenure area and adjoining areas owned by the same person, and
- Authorised gas production activities by the petroleum tenure holder.

Also of significant relevance, the P&G Act indicates that petroleum tenure holders who unduly affect existing Water Act 2000 bores, have a “make good” obligation. The Act defines this as either restoring supply or providing compensation for the bore being unduly affected.

A petroleum tenure holder must also comply with stringent water monitoring and reporting requirements under the P&G Act.

2.4 Queensland Coal Seam Gas Water Management Policy

The CSG Water Management Policy, CSG water is alternate term for associated water, is being developed to provide guidance on the management and disposal of associated water. Figure 2.1 below provides an overview of the policy framework, as of 20th October 2008.

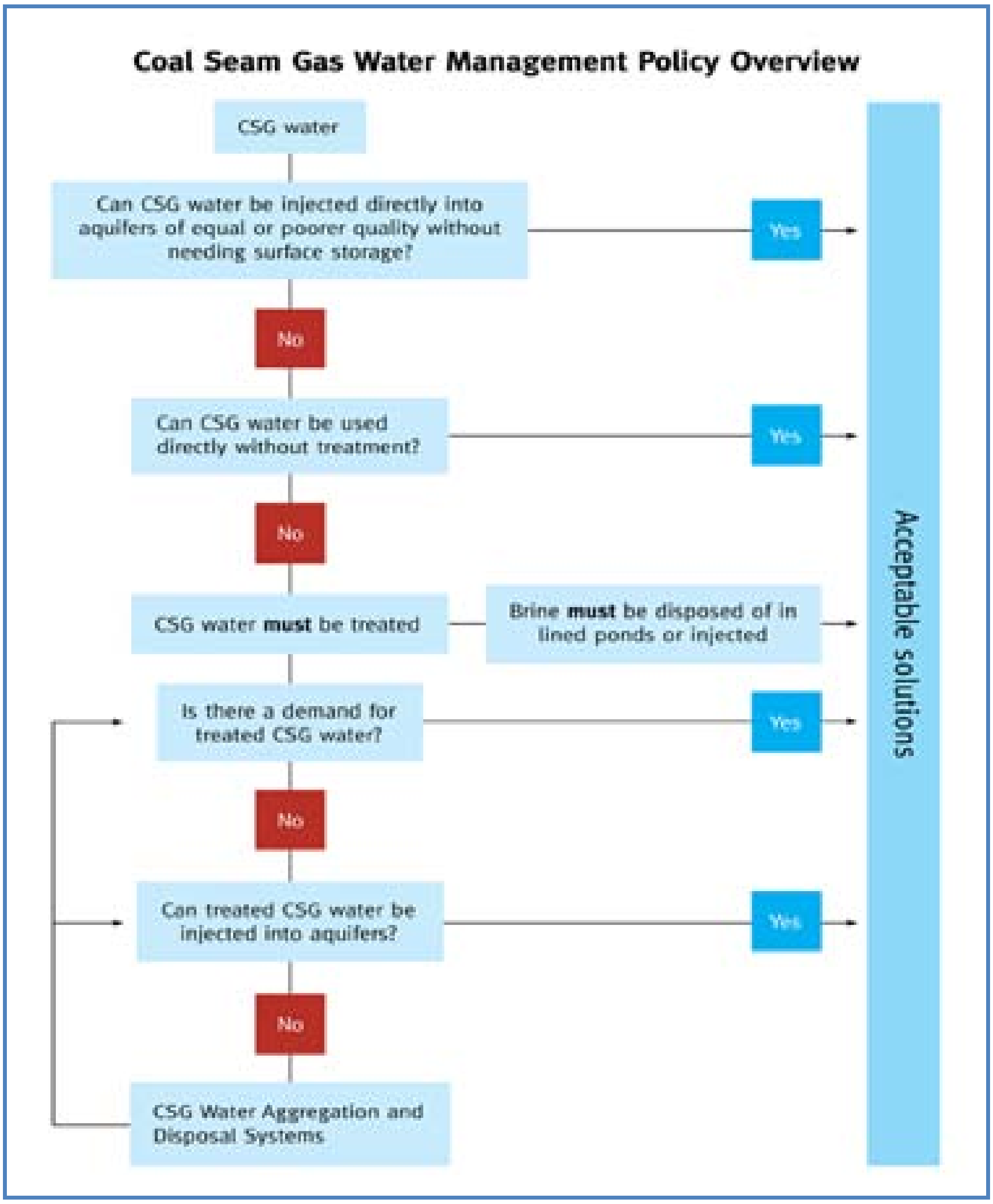


Figure 2.1 Queensland Coal Seam Gas Water Management Policy Overview

The policy identifies concerns with the current practice of evaporation ponds as a way to deal with the associated water, and in particular, with the long term legacy of the salts stored in the evaporation ponds. Furthermore the policy identifies a significant imbalance between the amount of water that will be generated over the next 30 years by CSG and the demand for this water. Thus, it aims to provide clear direction for the treatment and disposal of associated water.

Proposed features of the policy include:

- Discontinuing the use of evaporation ponds as a primary means of disposal and remediation of existing ponds is to occur within three years
- CSG producers to be responsible for treating and disposing of associated water, however if producers do not inject the water (preferred method) or have environmentally acceptable use for the untreated water they must treat the water to standards defined by the Department of Environment and Resource Management (DERM)
- Ponds for storage of brine must be fully lined to DERM standards
- A coal seam gas water management plan will be incorporated into the environmental management plan
- Water which cannot be injected or beneficially used must be aggregated for disposal

The government is yet to finalise the details surrounding the implementation and operation of its policy related to the disposal and aggregation of associated water, and is in the process of working with industry and community groups to establish clear guidelines.

In May 2009, the Queensland Government's Department of Infrastructure and Planning (DIP) issued a discussion paper titled "Management of Water Produced from Coal Seam Gas Production". The intent of the Paper is to inform stakeholders of various government criteria concerning the management of CSG and secondly, to seek stakeholder views on a number of specific issues related to these decisions prior to finalising the policy positions.

In response to the discussion paper Origin Energy and the Australian Petroleum Production and Exploration Association (APPEA) submitted comments as behalf of Australia Pacific LNG.

2.5 Sustainable Planning Act

The provisions of the Sustainable Planning Act 2009 will apply to associated water activities that are not regulated by the Water Act, EP Act, or the P&G Act. For non-exempt activities, it may be necessary to obtain a Development Permit under this Act.

2.6 Summary

The AAWMP has established a strategic, sustainable framework for associated water management, Table 1.2, which adheres to the regulatory policies detailed in Sections 2.1 to 2.5. The following points provide a summary of the regulatory and voluntary commitments Australia Pacific LNG intends to comply with:

- Sustainable management and efficient use of associated water will be undertaken (Water Act 2000)
- Re-use options within the petroleum tenures, at no cost to third parties, and disposal to a watercourse may not require a water licence under the Water Act 2000, however Australia Pacific LNG has considered the guidelines provided in the GAB ROP 2007, and Water Resource (GAB) Plan 2006
- An EIS is being undertaken to address the management of associated water (EP Act 1994)
- Transport; storage; treatment; recycling or reprocessing of associated water as a waste or brine will be regulated under the Environmental Authority (EP (Waste Management) Policy 2000)

- Protection of Queensland's environment will be maintained via the systematic identification of environmental values, establishment of appropriate water quality objectives and the efficient use of resources while allowing for gas field development activities to occur; (EP (Water) Policy 2009)
- The AAWMP will transparently detail Australia Pacific LNG approach to the management of associated water in accordance with regulatory directions (Operational Policy 2007)
- Development of associated water beneficial reuse management options (Operational Policy 2007)
- Although volumes are not specified, associated water extraction will only be undertaken in the course of authorised activities i.e. gas extraction and water removed primarily for other purposes, such as construction activities (e.g. dust suppression) or workforce sanitation is regulated under the Water Act 2000 and may require licensing (P&G Act 2004)
- Australia Pacific LNG will meet any 'make good' obligation for extraction of associated water (P&G Act 2004)
- In areas where gas extraction activities results in associated water being brought to the surface, monitoring and reporting will be regularly undertaken (P&G Act 2004)
- Use of evaporation ponds as a primary means of disposal will be discontinued (CSG Water Policy)
- Remediation of existing ponds will occur within three years (CSG Water Policy)
- Australia Pacific LNG will be responsible for treating and disposing of associated water, when no reasonable beneficial options are feasible (CSG Water Management Policy)
- Ponds for storage of brine will be fully lined to DERM standards (CSG Water Management Policy); and
- The State legislation applicable to the management of associated water will guide the treatment and disposal decisions made by Australia Pacific LNG (CSG Water Management Policy)

3. Existing Environment

3.1 Groundwater Environment

The Great Artesian Basin (GAB) at approximately 1.7 million km^2 is the largest groundwater basin in Australia and one of the largest in the world (Australian Government- Department of the Environment, Water, Heritage and the Arts, 2009). Covering approximately 22 % of Australia, of arid and semi-arid land, the artesian water supports a range of nationally important socioeconomic, natural and cultural values (Great Artesian Basin Consultative Council, September 2000).

The Australia Pacific LNG project area is situated in the Surat Basin, a sub-basin, some 280,000 km^2 in area, located in the eastern most corner of the GAB. This multi-layered, mainly confined hydrogeological system consists of up to 3,000 m of sediments ranging in hydraulic properties between productive aquifers and effective aquitards (Australian Government, 2009). A more comprehensive description of the groundwater environment is provided in Volume 5, Attachment 22 of this EIS.

3.1.1 Geological Description

The Great Artesian Basin stratigraphy comprises predominantly of basinal sediment with minor volcanic and intrusive rocks. The sequences include a range of depositional environments including shallow marine, deltaic and fluvial floodplain deposits (Parsons Brinkerhoff, August 2008).

The Surat Basin's geological ages varies from the Cretaceous Period to the Triassic Period, i.e. 50 – 250 million years old, and is predominately composed of siltstones, mudstones and sandstones. Underlying the basin are rocks of the older Bowen and Gunnedah basins, both of similar composition (Australian Government, 2009).

The Surat Basin varies in geology both vertically and horizontally, however it is broadly possible to delineate the stratigraphic succession across development area. The generalised stratigraphic sequence of the Surat Basin is summarised in Table 3.1, with younger, shallower formations at the top and older, deeper formations at the bottom. The entire sequence will generally not be encountered at any particular location within the Surat Basin due to original depositional, erosional, and structural features (such as faults). Of interest to the Australia Pacific LNG project, the Walloons unit, is the target area of gas and water extraction.

Table 3.1: - Hydrostratigraphic Sequence of the Surat Basin

Geological Unit	Formation	Lithological Description	Max Thickness	Classification
Quaternary Alluvium Units	Cainozoic Units	Various alluvium and igneous (basalt) units.	300+	Unconfined Aquifers
Shallow Unit (Mid Cretaceous)	Griman Formation	Lithic sandstone thinly interbedded with siltstone, mudstone.		
	Surat Siltstone	Thinly interbedded siltstone and mudstone.		
	Wallumbilla	Mudstone, siltstone, very fine to fine	480+	Confining Units

Geological Unit	Formation	Lithological Description	Max Thickness	Classification
	Formation: Sub-divided into Coreena and Doncaster Members in some areas	labile sandstone..		
Intermediate Unit (Upper Jurassic / Lower Cretaceous)	Bungil Formation: Sub-divided into Minmi, Nullawart Sandstone and Kingil Members in some areas	Labile to quartzose sandstone, glauconie-bearing, and calcareous in part, siltstone, mudstone, carbonaceous in part.	270+	Water Bearing Unit
	Mooga Sandstone	Well bedded to cross-bedded quartzose to lithic sandstone, in part clayey, calcareous and pebbly; siltstone and mudstone common in outcrop.	300	Confined Aquifer
	Orallo Formation	Fine to medium cross-bedded very lithic to lithic sublabile sandstone, calcareous, clayey; siltstone and mudstone, carbonaceous in part.	270	Water Bearing Unit
	Gubberamunda Sandstone	Cross-bedded quartzose to clayey lithic sandstone, some conglomerate siltstone and mudstone.	300	Confined Aquifer
Injune Creek Group (Mid-Upper Jurassic)	Westbourne Formation	Siltstone and mudstone, carbonaceous in part; very fine to fine quartzose to labile sandstone.	200	Confining Unit
	Springbok Sandstone	Fine to coarse labile sandstone, calcareous in part, rare glauconie; siltstone, mudstone, some coal.	250	Confined Aquifer
	Walloon Coal Measures	Lithic sublabile to very lithic sandstone, siltstone, carbonaceous mudstone, coal. Commonly calcareous and clayey.	650	Water Bearing Unit & Target CSG Production Zone
	Eurombah Formation	Fine to coarse clayey sublabile sandstone; some polymictic conglomerate, carbonaceous siltstone, and mudstone.	100	Confining Unit
Lower Jurassic Unit	Hutton Sandstone	Quartzose to sublabile sandstone, some siltstone and mudstone, commonly carbonaceous, minor	250	Confined Aquifer

Geological Unit	Formation	Lithological Description	Max Thickness	Classification
		conglomerate.		
	Evergreen Formation (Includes basal Boxvale Sandston Member in some areas)	Siltstone, mudstone or shale, carbonaceous in part, lithic to quartzose sandstone, minor ironstone and coal.	260	Confining Unit
	Precipice Sandstone	Quartzose sandstone and pebbly sandstone, some lithic sublabile sandstone, siltstone.	150	Confined Aquifer

3.1.2 Hydrogeological Description

The Surat Basin aquifers are large sheet like deposits that are laterally continuous. The sandstone formations of the basin provide key regional aquifers hosting water bores and producing springs.

Despite the size of these basins, groundwater moves extremely slowly, from an average of five metres per year at the recharge zones to less than one metre per year further down-gradient in the basin. This exceptionally slow flow rate results in residence times, in the centre of the basin, of up to a million years (Hennig, June 2005).

Identified as the most important aquifers within the basin, characteristics of four Surat Basin aquifers and the shallow surface level are provided below. These aquifers have significant water bearing/yielding capacities because of their physical characteristics that include thickness, porosity, hydraulic conductivity and storativity (Hennig, June 2005).

1. **Condamine River Alluvium:** This aquifer system is a shallow, unconsolidated, alluvial aquifer unit lying above Surat Basin formations at ground surface in the east and north-east of the area. The aquifer is a highly developed and exploited water resource, currently under stress from long-term over- extraction. The majority of extraction bores are located on the Condamine River floodplain, with water quality upstream of Dalby being suitable for most purposes.

2. **Gubberamunda Sandstone aquifer:** The Gubberamunda Sandstone is the most highly developed GAB aquifer in the Surat Basin, mainly due to its relatively shallow depth. Water quality is usually relatively fresh, and often potable. More than half of the available flows for the unit within the basin are estimated to be currently used, mainly for stock and domestic purposes, but also for town water supply (e.g. Roma). (Bureau of Rural Sciences Australia / Queensland Government- Department of Natural Resources and Mines, September 2003). On current estimates, more than 90 % of Great Artesian Basin bores in the Surat basin source their water from the shallow aquifers of the Gubberamunda Sandstone, the shallower Mooga Sandstone and Orallo Formation and the deeper Springbok Sandstone, which represents approximately 84 % of total use (Queensland Government, Department of Natural Resourses and Mines, 2005).

3. **Springbok Sandstone aquifer:** The Springbok formation lies directly above the Walloons Coal Measures (WCM) and occurs in eroded channels and valleys of the unit. Limited water quality information for the Springbok aquifer is available, but indicates salinity values approximately half of those observed within the WCM. The quality often limits use to stock and domestic

applications. The aquifer is not well developed across large parts of the basin, and most flows appear to originate from a basal conglomeratic layer.

4. **Hutton Sandstone aquifer:** Generally, the Hutton Sandstone has low to moderate yields. The Hutton Sandstone is generally the thickest aquifer in the Surat Basin, however the permeability of the formation is very variable and groundwater inflows are similarly inconsistent but generally concentrated in the upper part of the sequence. Water quality is better closer to the margins of the basin in the north and east of the area, where active recharge occurs. In central parts of the basin, the Hutton is generally limited to stock and non-potable domestic uses, but is still approximately half the salinity of Walloon Coal Measures groundwaters.

5. **Precipice Sandstone aquifer:** The Precipice Sandstone is the basal unit of the Surat Basin. It is generally of significantly less thickness than the Hutton Sandstone, and is absent across some north-central parts of the basin. The Precipice is generally a more consistent aquifer, but is limited by thickness and its depth within the basin. Existing groundwater quality information indicates that it is of approximately equivalent water quality to the Walloon Coal Measures across much of the area.

3.1.3 Water Chemistry Description

Salinities within the Surat Basin are brackish, and generally exceed drinking water standard (500 mg/L). Furthermore fluoride levels are often high yet pH values are often neutral to slightly alkaline (7.5 – 8.5) (Hennig, June 2005).

Table 3.2 presents the average salinities recorded in the region for each of the four Surat Basin aquifers.

Table 3.2 Groundwater Salinity of Target Aquifers

Aquifer Water Quality	Common Salinity Range (mg/L)
Condamine Alluviums	<1,000 upstream of Dalby >3,000 downstream of Dalby
Gubberamunda Sandstone	500 to 1,500
Springbok Sandstone	500 to 2,000
Walloon Coal Measures	500 (near outcrop) to 5,000
Upper Hutton Sandstone	1,000 to 2500
Precipice Sandstone	2000 to 3,500

Source: (WorleyParsons, June 2009)

3.1.4 Resource Availability

The GAB is accessed by a wide range of users including rural, urban and the various industries (irrigation, mining, petroleum, and tourism). Figure 3.1 below provides a water use break down of the basin's hydrologic resource.

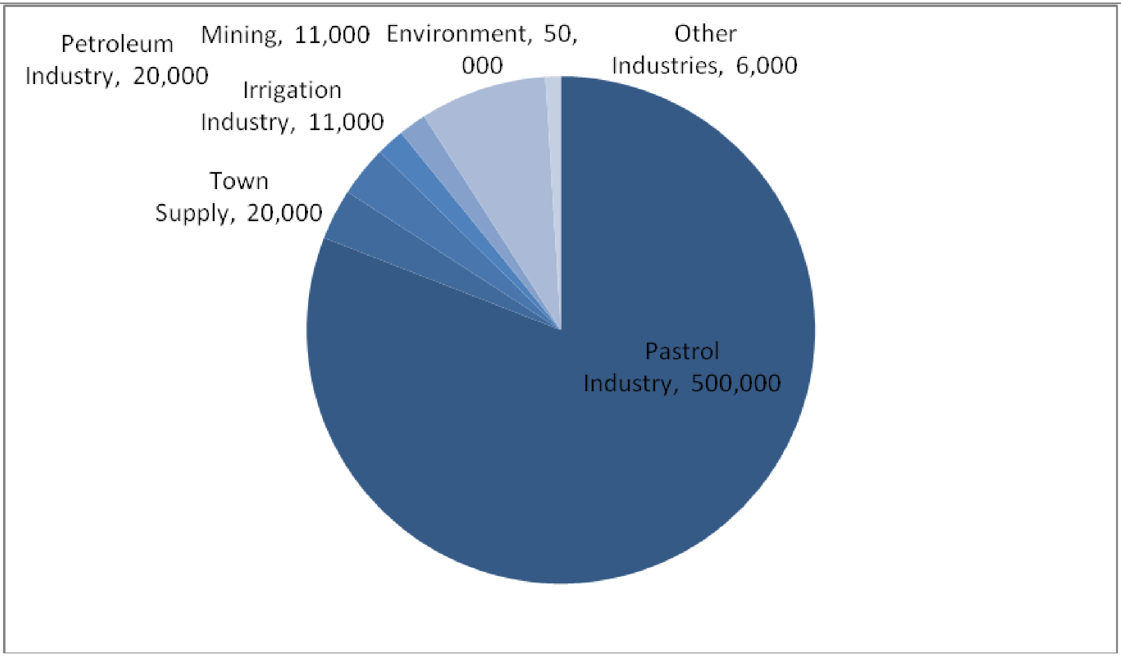


Figure 3.1 Uses of abstracted Great Artesian Basin groundwater

Source: (Great Artesian Basin Consultative Council, September 2000)

As shown in the pie chart above the total extraction from the GAB is estimated at approximately 570,000 ML/yr. This is 120,000 ML/yr above the current best estimate for sustainable yield (450,000 ML/yr) (Australian Government, 2009). Conversely it is estimated that a saving of approximately 200,000 ML/yr could be achieved through improved reticulation by pastoral users, reducing loss from seepage and evaporation from bore drains (Great Artesian Basin Consultative Council, September 2000).

3.2 Surface Water Environment

3.2.1 Catchment Descriptions

The project area reaches across three river catchments, the Condamine-Balonne, Fitzroy and Borders drainage basins. The majority of the gas wells are located within the Condamine-Balonne drainage basin. The north-western portion of the development is adjacent to the Dawson River tributaries and the isolated area of Gilbert Gully situated within the Border Rivers drainage basin.

The Dawson River catchment is a sub-catchment of the Fitzroy Basin. It has a total area of about 50,800 km^2. Limited Project infrastructure occurs within the Dawson River catchment however it is anticipated that the gas transmission pipeline to Curtis Island will traverse much of the drainage basin.

The Fitzroy Basin has extensive mineral deposit, supporting a large number of mines (particularly coal), and highly fertile soils supporting high level agricultural production. Changes to land use in the Fitzroy Basin region has been linked back to water quality deterioration with the introduction of livestock, the loss of riparian vegetation and increased pollution.

The Border Rivers catchment is located on the Queensland/New South Wales border and covers approximately 50,000 km^2. The catchment comprises several major sub-catchments including the Weir River, which drains the north-eastern section of the catchment; the south eastern part of the project area.

Flows of Condamine-Balonne drainage basin within the project area, are generally in a south westerly direction to the Condamine River. The River is part of the Murray Darling Basin and drains the northern portion of the Darling Downs. At its confluence with the Dogwood creek the Condamine River becomes the Balonne River. The river then turns south-west passing through Saint George. South of the Queensland border the Balonne River separates into a number of distributaries including the Balonne Minor, Culgoa and Narran Rivers downstream of Saint George. Some of these distributaries eventually drain to the Darling River.

The dominant land uses in the Condamine-Balonne drainage basin are dryland cropping, cattle and sheep grazing and to a lesser extent, irrigated cropping, rural residential and urban development. The natural geologic and hydrologic conditions combined with extensive land clearing and inappropriate land management practices, has lead to poor water quality, introduction of weed species, and varying habitat quality and aquatic flora and fauna diversity.

Tributaries within all three catchments generally experience long periods of low to no flow, and are referred to as ephemeral watercourses. The dominant catchment streams, i.e. Condamine River, and Dawson River, are similarly affected by climatic conditions, reduced to a series of pools and waterholes during dry periods.

3.2.2 Stream Water Quality

As previously discussed, throughout the development area watercourses are often considered ephemeral in nature, which can result in either dry beds or a series of unconnected pools during extended periods of the year. Stagnant waterbodies experience changes in physical and chemical status over time as evaporation concentrates constitutes, or rain conveys sediments and nutrients. Moreover, higher temperatures can increase microbial decomposition and oxygen demand further remobilising dissolved nutrients and metals (Aquatic Ecology, Chapter 9).

Water quality in the Condamine-Balonne catchment is characterised by elevated turbidity and nutrients and low salinity. Regularly recorded pesticide levels at sites were generally lower during drought conditions and highest during summer. It was also recognised that the elevated turbidity, hardness, pH, conductivity and total dissolved ions could be improved through better land management (Aquatic Ecology, Chapter 9).

Water quality in the Fitzroy catchment is characterised by low to moderate conductivity levels, high turbidity and suspended solids and high nutrients. Both the Fitzroy Basin Association and DERM have reported elevated metals at various sites within the Fitzroy Basin, which may be linked to mining within the catchment.

The Border Rivers catchment is characterised by low conductivity and moderate turbidity (Aquatic Ecology, Chapter 9).

3.2.3 Geomorphology

A review of published stream assessments and site visits by the Aquatic Ecology EIS team identified the following major features within and adjacent to the Project area (Aquatic Ecology, Chapter 9):

- The reach environments within the majority of the eastern streams of the Condamine drainage basin were rated as good to very good, and predominately stable
- Poor reach environments were observed in most streams within the Upper Balonne River sub-catchment, these included the upper Yuleba Creek which was rated as very poor and upper

Tchanning Creek which was considered to be poor to very poor. Furthermore the upper Yuleba Creek was considered to be eroding

- In terms of bed stability, there were a mixture of eroding and aggrading reaches, although aggrading reaches dominated within the Condamine-Balonne catchment, however, most reaches were considered to be stable, where as bed stability in Tchanning Creek were of concerns
- All Dawson River stream types assessed within the development area appeared to be either flat U-shaped or widened and infilled channels, reflecting the moderate to severe aggradation
- There were highly unstable banks at all sites assessed within the Dawson catchment, with gullying, undercuts, slips and toppling failures observed, lateral movement was slowed in sections where the channel dissected cemented tertiary deposits
- Banks were generally eroding within the Border rivers catchment with large sections of some of Weir River tributaries (for example Waar Waar Creek) being rated as unstable or very unstable
- Beds were generally infilling, with the majority of the Weir River being rated as unstable, Waar Waar Creek and parts of Paddy Creek were also rated as unstable
- Most reaches were considered to have very low or low channel diversity, a product of bed aggradation, within the Dawson River tributaries this aggradation had merged the bed with pre-existing bars and benches, reducing geomorphic variability within the channel

3.2.4 Surface Water Features

Two important wetlands were identified as potentially being impacted by the proposal – Lake Broadwater (wetland of national importance) and the Narran Lakes Nature Reserve (Ramsar listed wetland).

Of particular interest to the existing surface water environment is the Condamine River. The River extends approximately 500 km and is a major tributary of the Darling River, located in the upper Murray-Darling catchment. The development traverses the major watercourse between the Chinchilla Weir (upstream) and the Condamine Township (township). The Condamine River in the vicinity of the Project area has a wide valley floor, an irregularly meandering channel, well-developed floodplain features and moderately to highly stable bed and banks. At the Condamine Township, the catchment area of the Condamine River is approximately 24,600 km^2, and the mean annual flow is approximately 370,000 ML. This reach of the river contains the regulated section of the Chinchilla Weir water supply scheme and a number of high flow extraction licences. The extraction is guided by the Condamine and Balonne Resource Operation Plan (ROP), which is consistent with the Water Resource (Condamine and Balonne) Plan 2004.

Other watercourses that have been referred to in this report include: the Yuleba, Tchanning, Woleebee and Dulacca Creek. All except the Woleebee Creek lie within the Condamine catchment and eventually drain to the main watercourse downstream of the development area. The Woleebee Creek flows north, eventually into the Dawson River. An unnamed watercourse within the Gilbert Gully development area was also identified and this is a tributary of the Weir River, one of the Border Rivers. All watercourses are described as minor and ephemeral in nature.

4. Resource Profile

CSG is a natural gas consisting primarily of methane. The subsurface gas is absorbed into coal, bonding to the surface of coal particles by hydrostatic pressure. The Australia Pacific LNG project's targeting gas resource is located in the Surat Basin, within the WCM geological strata. The WCM is approximately 300m in thickness, located between 200m to 1000m below ground level.

4.1 Gas Production, Management and Objectives

To extract the gas, production wells are drilled into the ground across the development field. Each well is designed to have an opening at depths coinciding with the WCM strata. Depending on existing well pressures, a sub-surface pump lifts the gas, and associated water, to the surface for processing.

As previously discussed, associated water bonds the gas to the coal particles and with the removal of this water the hydrostatic pressure is also reduced. This change in pressure causes localised changes in the porosity and permeability of the coal. Bonds between the gas and the coal are decreased, resulting in the pores of the coal particles shrinking together, limiting gas movement within the coal. Conversely, the shrinking of coal particles increases the space, and hence expands the gaps between the coal, known as cleats, thus increasing gas flow.

The reduction in pressure is initially localised, however expands across fields and eventually the development area as gas production is increased. Similarly, associated water flow rate varies across the development area, however they often follow the same trend; starting at a high volume discharge, which falls dramatically over time as the coal seam bed becomes depressurised. However, water production generally decreases more rapidly than gas production.

Existing gas and water parameters such as porosity and permeability vary across the development area. Gas fields are often targeted during different stages of the production to provide desired gas flow profiles. Areas of interconnected and permeable fractures permitting gas and water to flow freely are considered high quality CSG deposits. Furthermore the release of water is often managed to modify the gas pressure, therefore optimising the rate of gas production. Figure 4.1 below provides a diagram of the coal formation and well extraction process.

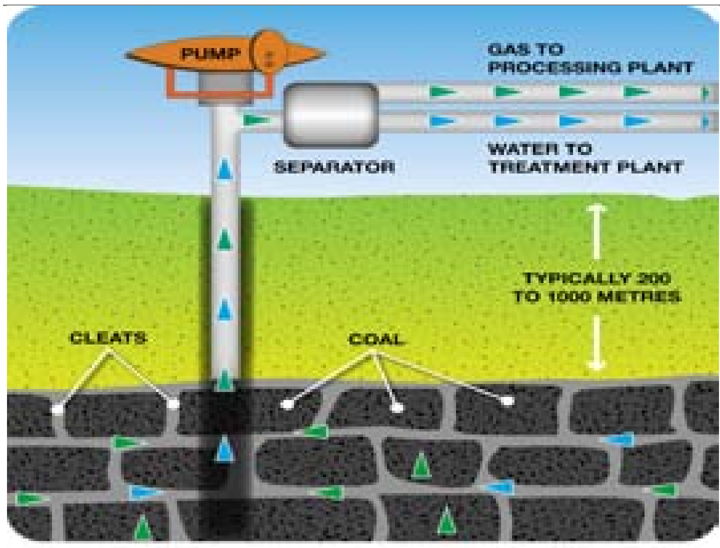


Figure 4.1 Indicative Sketch of Gas Production Well

Australia Pacific LNG's Walloons development comprises of a number of gas development areas, each with a number of fields and a corresponding series of wells. All fields are proposed to come into production over an approximate 20 year period, at a maximum rate of some 600 wells per year.

The gas profile developed for the EIS assessment provides a production rate sufficient to supply four trains at the CSG to the LNG plant located on Curtis Island. The profile presents a maximum development scenario. Piloting in the region is further assisting in the gas resource profiling, in collation with economic assessment of infrastructure requirements. Currently indications are that a gas production profile below that of the maximum development case will be adopted for the Australia Pacific LNG project.

Australia Pacific LNG gas production is to be managed to achieve two key objectives both relating to efficiency; focus gas production in early development toward better resources that is high permeability areas, and the staged development to obtain a constant gas profile, avoiding redundant infrastructure and gas supply.

4.2 Associated Water Production Profile

The associated water production profile is fundamentally a function of gas production management. The rate and staging of de-watering, the removing of hydrostatic pressure with the extraction of associated water, is adapted to achieve a gas extraction plateau across the field. Typically de-watering is initially undertaken at a rapid rate, often using pumps, however over time, the amount of water being pumped reduces, as gas ramp-up is achieved and gas extraction plateaus. Water pumping is predicted to continue until the end of the project, albeit only at reduced rates. As a result, significant quantities of water are initially produced, therefore the water management system must have sufficient capacity to handle and treat short-duration peak flows.

The periods between initial dewatering, peak water production and minimum constant flow from a well, varies across not only the different CSG fields in which the wells are drilled, but also between individual wells in the same field. Time from peak flow and "constant" minimum flow from a well may be 7 to 16 years. While sampling and test work is extensively utilised to allow a sufficient degree of performance prediction to enable decisions regarding field development, the nature of the coal seam and sub-surface structures often results in individual well performances being significantly different from that predicted.

The water profile developed in response to the EIS investigation is similar to the gas profile in that it indicates a maximum associated water production peak. In this case the peak is around 170 ML/day. This is predicted to occur within the first 20 years. However there still remains a high level of uncertainty regarding both the magnitude and timing of this estimate.

Figure 4.2 below provides a summary of the maximum anticipated water profile for the Walloons development, by area.

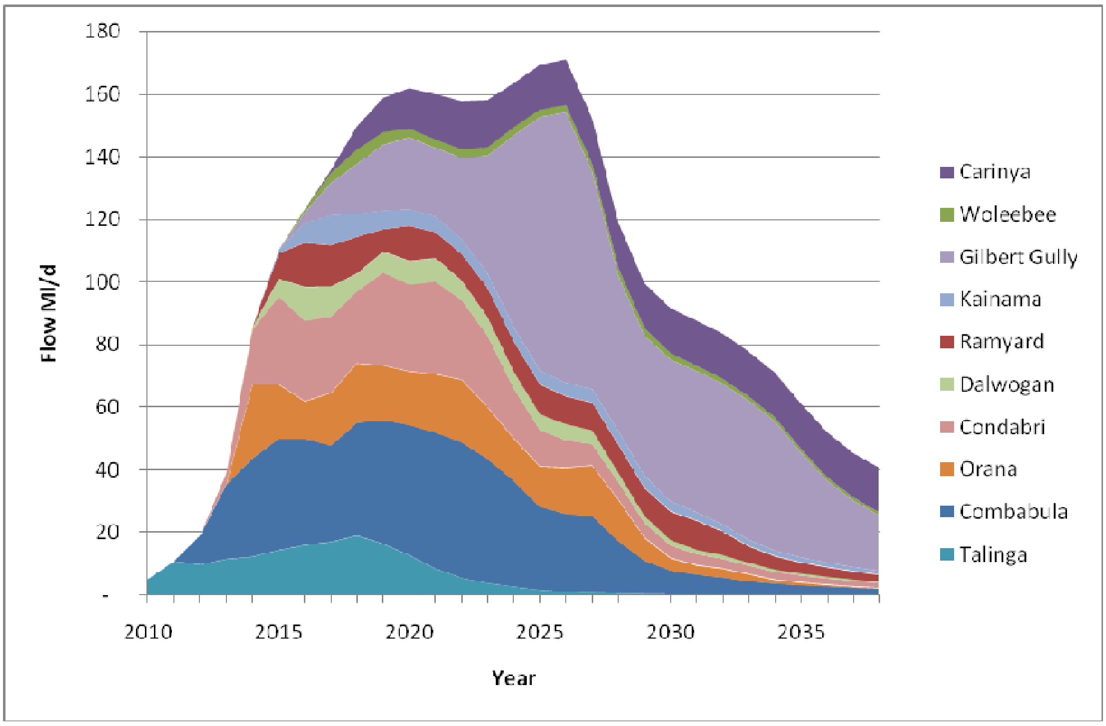


Figure 4.2 Predicted Associated Water Profile for the Walloons development

4.3 Associated Water Quality

The quality of associated water is primarily dependent upon the geology of the area in which the well, is located. Consequently water quality varies significantly in both horizontal and vertical horizons. In the Walloons deposit the associated water's key re-use inhibitors are its saline nature, high sodium absorption ratio (SAR) and high residual alkalinity. Other limiting water quality parameters of concern include fluoride, boron, pH, suspended solids, temperature and dissolved oxygen.

Associated water testing indicates that heavy metals such as mercury and arsenic are of low concentration and hydrocarbons are additionally not of concern. Table 4.1 provides a summary of key water quality parameters at four fields within the Walloons development and Spring Gully (an existing operating development) adjacent in the Bowen Basin.

Table 4.1 Walloons Development and Spring Gully Associated Water Quality

Property	Development Field[1]				
	Combabula	Talinga	Spring Gully	Orana	Condabri
Total Dissolved Solids (mg/L)[2]	6,534	2,540	7,500	2,450	3,693
pH	8.3	8.7	9	8.8	8.3
Total Suspended Solids (mg/L)3	38	39	65	9	80
Sodium Adsorption Ratio	115	160	170	135	138
Residual Alkalinity (meq/L)	13.6	37.4	43.0	30.5	29.0
Fluoride by ISE (mg/L)	0.9	3.9	5.9	3.3	1.9
Boron as B (mg/L)	0.50	0.72	3.1	0.66	0.40

Notes: 1. Values from single sample, date provided.
2. Convert from electric conductivity (Factor = 0.64).
3. Solids may be entrained sediments from wells, or of microbiological origin.

As shown above, variance in quality between fields can be substantial.

Each of the key parameters of associated water and their environmental impact, interaction with other factors and quality objectives are discussed below. Treated water quality parameters are not considered in this section and have been addressed in the Section 6.2.3 with descriptions of the proposed treatment techniques.

4.3.1 Total Dissolved Solids

Total Dissolved Solids (TDS) is a measure of all inorganic salts dissolved in water. In general the water extracted from the Walloons development is between 2,400 mg/L and 6,600 mg/L, exceeding drinking water guidelines (500 mg/L), and natural regional variance (755 mg/L) ((Queensland Government, 2009), yet far below the concentration naturally found in seawater (35,000 mg/L).

Management options of untreated water are limited by the elevated salt levels. Irrigation with saline water has been shown to result in reduced plant productivity or even lethal to crops and native vegetation; whilst it has been determined that feed water with elevated salt concentrations can cause physiological upset and sometimes death in terrestrial animals. Moreover, water of marginal quality can often cause gastrointestinal symptoms and a reduction in weight gain, milk or eggs production of livestock (Australian and New Zealand Environment and Conservation Council, 2000).

Figure 4.3 provides a summary of the tolerance of several water supply options to TDS concentration.

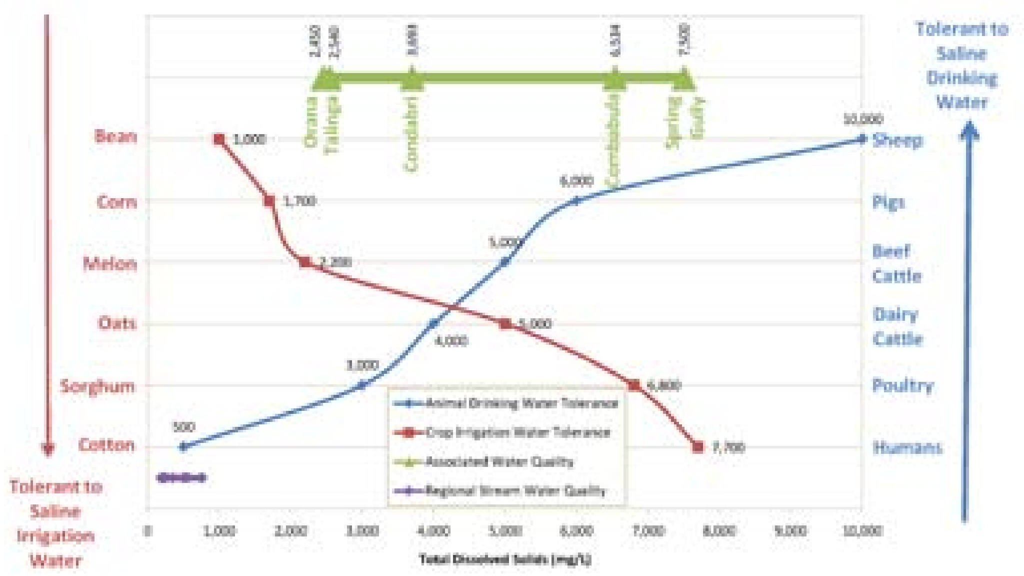


Figure 4.3 Predicted and natural salinity and environmental tolerances

Source:(Adapted from (Queensland Government, 2009) and (Australian and New Zealand Environment and Conservation Council, 2000))

4.3.2 pH

Table 4.1 indicates that Walloons development associated water is consistently alkaline, with pH values between 8.3 and 9. For agricultural uses, pH values should be maintained between 6 and 8.5, as alkaline irrigation water can affect plant growth and nutrient imbalance. Likewise, fouling is prevalent with alkaline water re-use in pumps, irrigation and stock watering systems, potentially affecting industrial and agricultural management options.

4.3.3 Total Suspended Solids

Total suspended solid (TSS) concentration impacts both CSG operational activities (e.g. clogging pipes, vessels and pumps) as well as limiting management options. The most apparent effect of use in the natural environment is the reduction in light penetration through the water column with potential impacts on the photosynthesis capability of phytoplankton and aquatic macrophytes and vegetation, feeding behaviour, respiration and reproduction (Australian and New Zealand Environment and Conservation Council, 2000). TSS also denotes the transportation of many chemical constitutes (e.g. heavy metals, nutrients, toxic organic compounds) through aquatic systems; with these constitutes strongly associated with suspended particulate and colloidal matter.

4.3.4 Sodium Adsorption Ratio

Sodicity is the presence of a high proportion of sodium (Na^{+}) ions relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water. Sodicity degrades soil structures by breaking down clay aggregates, which makes the soil more erodible and less permeable to water, consequently reducing plant growth. These factors limit leaching so that salt accumulates over long periods of time, giving rise to saline subsoils (Australian and New Zealand Environment and Conservation Council, 2000).

An estimation of sodicity levels in water can be predicted using the Sodium Adsorption Ratio (SAR). Figure 4.4 below provides permissible SAR values of irrigation water for maintaining a stable soil surface under high rainfall (Australian and New Zealand Environment and Conservation Council, 2000).

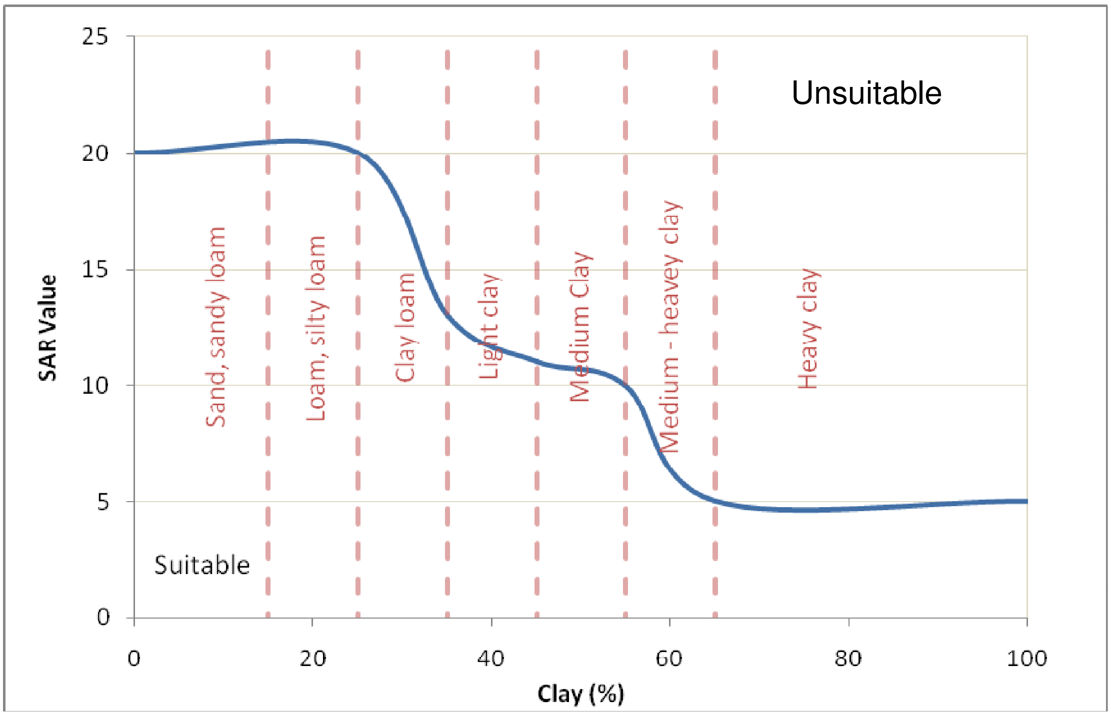


Figure 4.4 Guide to suitable SAR of irrigation water for maintaining a stable soil surface

Source: (Adapted from (Australian and New Zealand Environment and Conservation Council, 2000)).

The potentially high sodicity of associated water, >100 SAR, is likely to limit use directly to the soil surface, i.e. irrigation and discharge to watercourses.

4.3.5 Residual Alkalinity

When the ion is not neutralized with either calcium or magnesium, the remaining hydrogen ions are referred to as residual alkalinity. The bicarbonate (HCO_3^-) ion is one of the major contributors to alkalinity in water.

Elevated levels of bicarbonate in irrigation waters can adversely affect irrigation equipment, soil structure and crop foliage. Furthermore it will effectively increase the SAR, leading to soil structure problems (Australian and New Zealand Environment and Conservation Council, 2000).

4.3.6 Fluoride

Fluoride accumulates in the bones and excess uptake of fluoride can result in tooth damage to growing animals and bone lesions in older livestock. Excessive intake of fluoride can lead to fluorosis, a condition characterised by hypermineralisation. Research indicates regular consumption by stock of water containing fluoride concentrations greater than 2 mg/L progressively increases the risk of fluorosis (Australian and New Zealand Environment and Conservation Council, 2000). Furthermore fluoride in agricultural use results in crop deterioration. Australian guidelines recommend that fluoride concentrations in water used long term in agricultural, both irrigation and feed, is less than 1 mg/L (Australian and New Zealand Environment and Conservation Council, 2000). Associated water monitoring results of Walloons development indicates that untreated water will exceed irrigation, drinking water and stock watering guidelines.

4.3.7 Boron

Boron is a prominent metalloid (intermediate element with metal and non-metallic properties) within associated water. Boron in relatively small amounts is essential to the normal growth of all plants; however, this element can be toxic when present in excess. Crop species vary both in their boron requirement and in their tolerance to excess boron. In general, the maximum concentration of boron tolerated by plants in irrigation water, i.e. no reduction in yield or vegetative growth, is approximately 0.5 mg/L for sensitive vegetation such as fruit and beans, whilst crops of oat and corn are moderately tolerant to 2 mg/L (Australian and New Zealand Environment and Conservation Council, 2000). Boron dissolved in water is rapidly absorbed from the gastrointestinal tract in animals, these results in reduced hay consumption and subsequent loss of weight (Australian and New Zealand Environment and Conservation Council, 2000).

Indicative boron concentrations within the Walloon development's associated water are above the recommend 0.5 mg/L guideline. Direct use in agricultural and environmental management options may therefore be limited.

5. Associated Water Management Approach

The quantity, timing and location of associated water will depend on the:

- Rate of produced water released from wells, to provide optimum gas production; and
- Size of the gas reservoir, resulting in changes in the staging of field development.

The quantity, timing and location of water demand are similarly anticipated to fluctuate, both in terms of the life of the project and seasonal conditions. The AAWMP therefore needs to be adaptive to reflect changing supply and demand conditions, whilst remaining sustainable addressing social, economic and environmental considerations.

Australia Pacific LNG has adopted an approach to managing associated water considering:

- Environmental impacts
- Distribution complexities
- Supply contractual negotiations
- Advancement and implementation of technology
- Project development and production timeframes
- Potential legislative changes, and
- Operational requirements
- The initial management regime for associated water management, known as the "Initial Case", is focused on delivery of a sustainable management option that can be readily applied using existing technologies and customers.
- Australia Pacific LNG will optimise commercial and beneficial water use through a flexible approach including:
- Water which can be readily supplied long-term will be contracted to commercial customers
- Pursuit of opportunities for water to be managed in conjunction with other producers including water aggregation
- Investigation of beneficial uses and alternative water management technologies including aquifer reinjection

It is anticipated that the optimisation of beneficial use will occur over time as options are developed. This AAWMP will be subsequently updated and provided to the relevant regulatory agencies as the options are developed and mature. An outline of the solutions to achieve this commitment is provided in Section 7 "Optimising Beneficial Use". An indicative program for development of these preferred options is discussed in 7.3. Australia Pacific LNG considers the early and progressive implementation of the adaptive water management approach to be beneficial socially, environmentally and economically.

Section 6 details the selection process and the proposed associated infrastructure of the Initial Case.

6. Initial Case Management

6.1 Initial Case Appraisal and Selection

A decision model was developed for the selection of an Initial Case associated water management option. The model has been implemented throughout the development of the water management plan, from well extraction to the disposal. The following section primarily focuses on the management options of untreated and treated associated water streams. Section **Error! Reference source not found.** discusses the treatment technology and effluent management selection, whilst Section 6.3 provides a summary of the proposed infrastructure arrangement; both have been determined using a decision model.

A five step rational decision making model was selected to undertake the option appraisal. Figure 6.1 below, provides an outline of the process, with the five steps categorised to the right of the diagram.

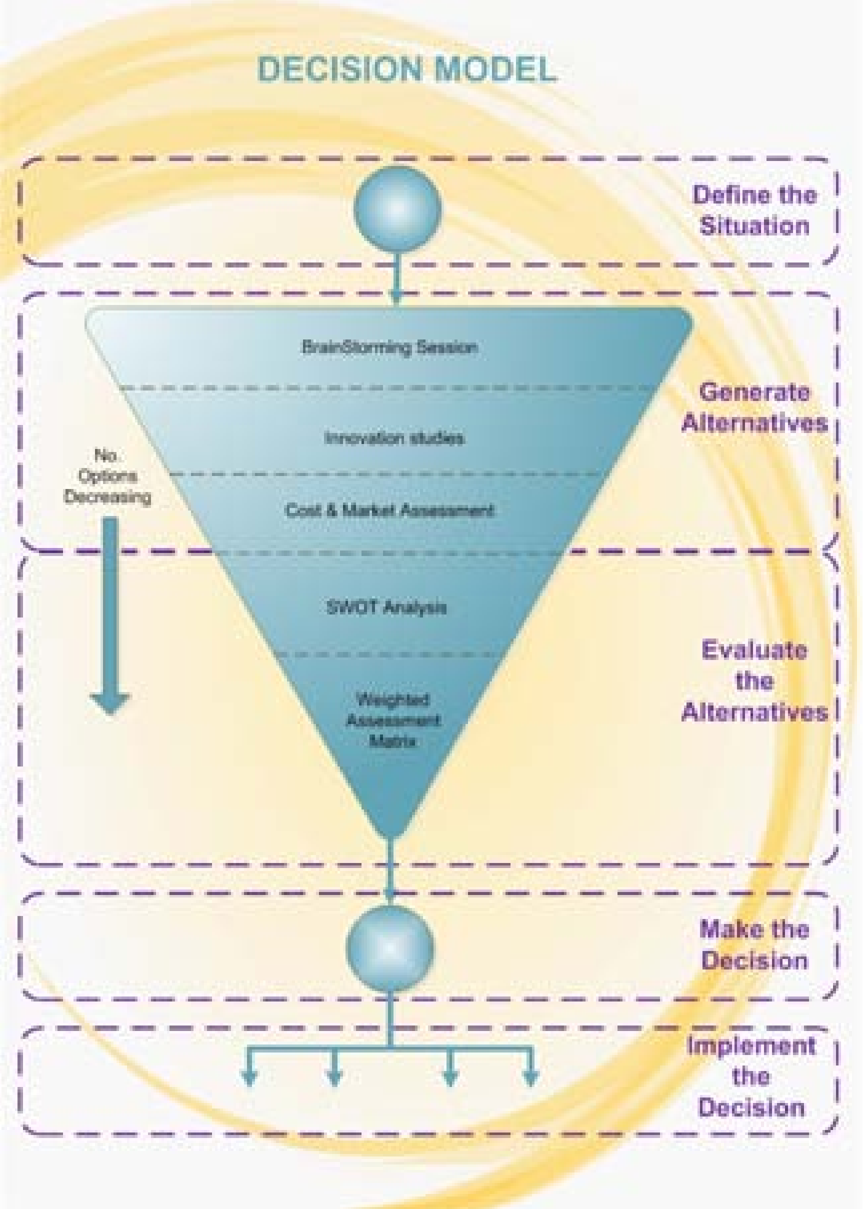


Figure 6.1 Decision Model Overview

6.1.1 Define the Situation

Both production rates and water quality will affect associated water management options. In the instance water is released into the above ground environment, some form of treatment will be required. Furthermore storage of associated (untreated) water is restricted by legislation and like conveyance is cost intensive (Queensland Government, Department of Infrastructure and Planning, May 2009).

6.1.2 Generate Alternatives

Origin Energy, joint venture partner in Australia Pacific LNG, operates and co-operates several existing coal seam gas production fields in Queensland. Initially water management practice at these fields primarily included the storage of associated water in large evaporation ponds. In 2007 Origin Energy took the pioneering step to treat the associated water at their Spring Gully field via reverse osmosis prior to discharge to a local watercourse. In 2009 after a formal process of obtaining management options for water from the community, Origin committed to a 300 ha agricultural venture of Pongamia plants at Spring Gully, in an effort to further maximise beneficial use.

Consultation, brainstorming sessions and investigation has developed an extensive list of management options for the Australia Pacific LNG project.

Brainstorming

Between May and August 2008 intensive consultation with internal and external stakeholders to establish an exhaustive list of water management options was commissioned.

A program of community engagement was undertaken from 16 June to 31 July 2008 to invite submissions and ideas for water use from the community. The program provided stakeholders with the opportunity to engage in a two-way exchange of information. The engagement program included the following:

- **Letters to stakeholders** – Letters were sent to stakeholders and surrounding property owners explaining the rationale for the call for ideas and inviting their participation.
- **Information website** – Developed a website focused on characteristics parameters and extraction of associated water, provided links to Project maps and a key questions and answers section. The website provided contact details for water use ideas.
- **Advertisements -** Public notices were placed in four local publications, requesting calls for interest in relation to associated water.
- **Community hotline** – A community hotline staffed Monday to Friday during working hours was established and publicised. The hotline received 31 calls, with the majority requesting further information about the Project.
- **Open Day** –Primary and secondary stakeholders were invited to attend an open day at the Spring Gully Gas field which included an inspection of the water treatment facility.

In total there were 21 submissions from the community that outlined ideas for the use of associated water; these were predominantly in support of agricultural uses.

Internal Stakeholders of the project were also engaged to provide a broad range of options;

- **Interviews**– A series of interviews with Spring Gully operations staff was conducted to ensure that all internal ideas were identified.

- **Workshops** - Workshops held on 18 June 2008 and 18 July 2008 invited selected design, corporate and operational staff to assist with the brainstorming effort.

All 80 water management options ideas generated were entered into a central data base where each idea was classified into broad groupings. Table 6.1 below summarises some of the suggested water management options.

Table 6.1 List of Water Management Options

No.	Category	Description
1	Existing	Five options were identified from existing activities, including evaporation ponds and stream discharge.
2	Industrial	Supply of treated/untreated water to industry, twenty-two options were suggested, of which thirteen were for proposed and existing mines and five were power stations.
3	Potable Water Supply	Supply of permeate to townships such as; Dalby, Miles, Chinchilla, Tara and Condamine, and into existing distribution networks. Options can be divided into seven urban supply locations and six bulk water supply options.
4	Agriculture	A number of landholders showed interest in accessing water supplies for existing or expansion venture, whilst a large variety of agricultural ventures, owned and operated by Australia Pacific LNG, were also identified. In total sixteen different options have been identified for Agricultural water supply.
5	Injection	As guided by government legislation and Australia Pacific LNG's own Sustainability Principles, injection and reinjection options have been explored. Eight options in this category have been specified.
6	Other	Eight options that did not fit with any of the above categories have been grouped together. These included innovative technologies such as solar ponds and algae production and large scale options like construction water and ocean disposal.
7	Salt	Eight options were proposed for salt disposal, many included the sale of salt, whilst two options were identified for injection and the existing practice of encapsulation was also specified.

Innovation Studies

Australia Pacific LNG has commissioned numerous external consultants to investigate a range of innovative options for the management of associated water and foreseen by-products. Table 6.2 provides a summary of investigations to November 2009. As discussed in Section 7.2.2, Australia Pacific LNG anticipates commissioning several more studies in the optimising of beneficial use options.

Table 6.2 **Summary of Previous Investigations**

Coal Seam Gas – Water Management Study, Agricultural Use (Wylie, September 2007)	This study evaluated the potential use and profitability of associated water for agricultural use. The study identified a number of options including: • Irrigated crops: sorghum, maize, wheat, pasture and Lucerne; • Horticultural crops: melon, grapes and cotton; • Biodiesel from algae and Kalpa/Pongamia plantations; • Agroforesty; and • Feedlots. The study also assessed the suitability of soils for irrigation and the financial benefits of supply of associated water for agricultural uses.
Coal Seam Gas Water Management Study Urban and Industrial (Parsons Brinkerhoff, December 2007)	The purpose of this study was to develop a associated water management strategy to identify potential urban and industrial water users that could benefit from associated water use. Three urban customers and five industrial users were identified that were interested in sourcing associated water.
Preliminary Discharge Assessment – Walloons Coal Seam Gas Development (S. Brizga & Associates et al., January 2008)	This study assessed the feasibility of discharging up to 35 ML/d of reverse osmosis (RO) treated water into the Condamine River from the Walloons coal seam gas field. Four potential discharge points were identified and assessed in detail. The most desirable discharge point was found to be Chinchilla Weir, based on minimal impacts and the scale of benefits from discharge at this location.
Coal Seam Gas (CSG) Water Strategic Options Analysis (Parsons Brinkerhoff, August 2008)	This study used a rapid assessment approach to compare options. The assessment approach referred to as SOAM (Strategic Options Analysis Model) is based on triple bottom line reporting. The approach examines the commercial, environmental and social dimensions of corporate decision making and ranks the water options based on the return and risk perspective of each of these dimensions. The study developed 70 ideas of water management within the 11 categories.
Surat Basin Water Grid Briefing Paper (Parsons Brinkerhoff, September 2008)	The water grid option involves the development of a small water distribution network with a major mine being the main user along with other mines, towns and selected agricultural users. This paper details the risks and returns of water grid options: • Two water grid delivery options are identified; • Origin as the sole owner, supplier and operator; and • A commercial joint venture with other major coal seam gas producers.
Aquifer Injection of CSG Production Water, Phase 1 Prefeasibility Assessment (WorleyParsons, June 2009)	The prefeasibility assessment considered the reinjection of raw and treated produced water into the aquifer system of the Surat Basin. Discussing regulatory, technical and financial constraints, the report provided a summary of the investigations and trials required to implement an aquifer reinjection water option.
Saline Water Management	The study investigated opportunities for the disposal of saline water, including

Study (WorleyParsons, August 2009b)	non-treated disposal options and brine disposal. Markets for trona, halite, calcium carbonate and combined salt were investigated and economically evaluated with consideration to a range of treatment technologies. The study also considered innovative associated water solutions such as: algae and solar heat recovery.

6.1.3 Evaluate the Alternatives

Of the 80 options identified in the "generate alternatives" exercise, ten water options and three salt options were shortlisted for the Walloons area. Section 0 below provides a summary of each option, whilst Sections 0 and 0 detail the evaluation undertaken to determine the Initial Case associated water management options.

Shortlisted Options

Option 1a: - Evaporation Ponds

Evaporation ponds primarily store associated water, and are only effective in environments, such as the Surat basin, where annual evaporation exceeds annual rainfall. Depending on geometric characteristics and inflow rates, the water is evaporated into the atmosphere, whilst the salts and other impurities remain within the storage pond. To effectively evaporate the anticipated volumes, ponds are generally shallow in depth.

The central benefit of adopting evaporation ponds as the preferred associated water management option is the limited need for water conveyance infrastructure, i.e. pipes, and lack of treatment requirements. Furthermore the option provides flexibility to gas development changes, and variance in associated water quantity and quality.

Current government policy requires evaporation ponds, as an associated water management measure, to be discontinued and all existing ponds to be remediated within the next three years (Queensland Government, Department of Infrastructure and Planning, May 2009). Furthermore existing regulatory lining requirements of ponds holding associated water are evolving, requiring further protection against seepage and consequently becoming more expensive to construct.

This option does not allow for the benefits of associated water reuse and may be interpreted as poor environmental stewardship. Evaporation ponds are useful in the exploration phase of a project due to a number of factors including limited volumes, duration and the isolated location from other major infrastructure.

Option 1b: - On-site Storage

A slight variation on evaporation ponds, on-site storage, is the storage of treated associated water, i.e. permeate. The option limits requirements for seepage protection and impacts of dam hazard. The high costs of lining may be reduced in this option, but limited economic advantage is gained due to treatment costs. Moreover with the introduction of treatment, Australia Pacific LNG may potentially duplicate storage requirements, with the need to evaporate brine, a highly saline solution, as well as eventually disposal of salts and remediating ponds.

Treatment requirement may limit gas production flexibility with the need to establish low pressure water networks and large water treatment facilities (WTF). Furthermore there will be limited beneficial uses to this approach, with large volumes of permeate being lost through evaporation. It is suggested that the Australia Pacific LNG project may reuse the water however this may only contribute to 5% of total volume stored even during peak construction periods.

Option 1c: - Discharge to major watercourses

The discharge to watercourse water management option has been delineated into the following options:

- 1c: - Discharge into major watercourse, such as the Condamine River; and
- 1d: - Discharge to minor water courses, such as the Tchanning and Yuleba.

Option 1d is discussed further in the following sub-section.

The section of the Condamine River where permeate discharges are likely to occur lies between Chinchilla Weir and the township of Condamine. The catchment area of the Condamine River at Chinchilla Weir is approximately 19,190 km^2 and the mean annual flow is approximately 280,000 ML. Whilst at the township of Condamine, the catchment area is approximately 24,600 km^2, and the mean annual flow is approximately 370,000 ML.

An advantage of discharging to a major watercourse is capacity of the ecosystem to cope with fluctuation in use and/or supply of the water. The Condamine River is a large regulated river, that is significantly constricted (Chinchilla Weir) upstream of the discharge location, and is allocated for extraction along the reach adjacent to the proposed discharge locations.

Origin Energy, as part of a separate application, have applied for a environmental authority amendment to discharge up to 35 ML/d of permeate into the Condamine River, a major upstream watercourse of the Murray Darling Basin. This option considers further expanding the WTF at Talinga and potentially constructing another at the Condabri development and consequently increasing discharge into the Condamine.

Providing additional flows in the Condamine may provide some benefits by; improving environmental flows and increasing supply for later extraction in a deplete water resource. The aquatic environments may have varying impacts from the potential change in flow regime, depending on both magnitude and extent of flow changes. These potential impacts are the subject of separate studies for the Australia Pacific LNG EIS process (Surface Water and Aquatic Ecology Appendices, Volume 5, Attachments 23 and 20).

Public consultation indicates that locally there are differing opinions between stakeholders. Some environmental groups have indicated they would prefer no addition of water flows because it is an artificial solution and does not address the environmental harm potentially caused by extraction. Whilst farmers relaying on extractions along this reach, may benefit from increased water security, within their allocation. From a social perception this option has a limited appeal, as water would not be available to the broader community for town supply irrigation, industrial and commercial use and much will be lost in seepage, evaporation and transpiration.

As a key component of the EIS investigation the discharge of treated associated water into the Condamine River has been assessed and mitigation measures required to reduce potential environmental impact to low, will be adopted as a minimum.

Option 1d: - Discharge to minor watercourses

Where water is discharged to smaller, minor watercourses, potential environmental impacts are increased.

Table 6.3 provides a summary of minor watercourses identified near proposed WTFs for discharge of treated associated water.

Table 6.3 Nominated minor watercourses

Development Area (s)	Watercourse Name
Combabula	Yuleba Creek
Ramyard	Tchanning Creek
Woleebee	Woleebee Creek
Carinya	Dulacca Creek
Gilbert Gully	Unnamed (tributary of the Weir River)

Discharging to minor watercourses presents potential increased environmental risks to landscapes, soil profiles, surrounding aquifers and nearby streams, particularly when considering the likely expansion in water volumes. As mentioned, these impacts are the subject of separate EIS studies being undertaken by Australia Pacific LNG (Surface Water and Aquatic Ecology Appendices, Volume 5, Attachments 23 and 20). Further, use of permeate in this manner is not anticipated to maximise beneficial use of coal seam gas water, with projected high losses from seepage, transpiration and evaporation in ephemeral watercourses.

As proposed in Option 1c, discharges will be limited to those proposed for mitigating risk of potential environmental impact to low, as advised in Environmental Impact Statement surface water assessments.

Option 2: - Industrial Use – Local Mines and Power Stations

The local region around Miles through to Dalby is fast evolving as an industrial hub of Queensland. New developments requiring significant amounts of water are likely to proceed as part of the Surat Basin Development. There are at least three mines (with another five new or upgraded mines planned in the Surat Basin), a power station and potential industrial customers adding to water demand in this local area

Some of this water could potentially be supplied untreated, reducing treatment costs and related power and saline waste. Water supply to industrial users will further promote the Surat Basin Development bringing development and employment opportunities to the regional communities. Supplying commercial users will further reduce demand to existing shared water resources such as the GAB and Condamine River allocations.

Discussions with a range of mining and power companies to supply both treated and untreated water are in progress. Large mining developments are anticipated to require approximately 10,000 MLpa whilst power stations only comprise a relatively small percentage, using less than 1,000 MLpa. The estimated water demand for local mine and power station industrial users (within a 120 km radius), at best, is approximately 30 % of the peak water profile.

The presence of a large reliable water source is likely to make future large scale industrial development very attractive but this demand is unlikely to occur within the timeframe of the initial Walloons development. Furthermore, potential customers are widespread and fragmented giving rise to challenges for sales and transport infrastructure.

Option 3: - Potable Water Supply – Town Supply

The Australia Pacific LNG project area is situated in the Surat Basin located in the eastern most corner of the GAB. Covering much of the arid and semi-arid land in Australia, the artesian water supports a range of nationally important socioeconomic, natural and cultural values.

Many townships in the Surat Basin are examining alternative water sources. The Dalby Township relies on shallow groundwater and in recent times has experienced a depleted water supply. Chinchilla's primary source of water is from the Chinchilla Weir and the town is investigating alternative sources such as a bore into the Great Artesian Basin to meet increasing local demand.

It is recognised that water supply in the Surat Basin and the protection of existing water resources is of great concern to community and Government stakeholders. Municipal water supply, while providing social benefits, faces high economic, commercial and regulatory constraints associated with supplying small volumes of very high quality water across long distances.

Data provided for predicted water demands indicates that an increase in demand of 130 % over the next 20 years was likely (Parsons Brinkerhoff, December 2007). Total demand however is still comparatively small, with a probable maximum of 20 ML/d. Predicted and current (2006) demands are shown below in Table 6.4.

Table 6.4 Current (2006) and Predicted water demands in the region

Urban Centre	2006		2026		Increase
	Population	Water Demand (ML/d)	Population	Water Demand (ML/d)	
Dalby	9,778	6.0	20,534	12.60	210 %
Chinchilla	5,942	2.4	9,270		~156 %
Miles	1,298	1.5	1,713		~132 %
Condamine	373	0.12	492	0.16	132 %
Wandoan	767	0.6	368	0.29	48 %

The option of town supply should be distinguished from aggregated regional supply options (i.e. to Nathan Dam and the SEQ water grid). These larger scale options have not been shortlisted for the Initial Case, as the regulator and commercial negotiations are considered unachievable within the appropriate timeframe.

Option 4a: - Agricultural Use – Existing

This option considers supply of water to existing agricultural uses in the area where CSG infrastructure traverses properties and neighbouring properties to facilities.

Current agricultural water supply within the study area is primarily provided by the Chinchilla weir water supply scheme and private water harvesting development from the river system and overland flow (as guided by the Condamine and Balonne Resource Operations Plan (ROP) (Queensland Government, Department of Natural Resources and Water, December 2008)) and extracted from licensed water bores (as guided by the Great Artesian Basin ROP (Queensland Government, Department of Natural Resources and Water, February 2007)). Average abstractions within the entire

Condamine Balonne system are about 700,000 ML/yr (abstractions as high as 1,300,000 ML have occurred in a single year) (CSIRO, 2008).

Within the Surat Basin agricultural use constitutes approximately 88 % of total abstractions from the GAB in Eastern Downs (QLD) zone. The allocation of water from the Chinchilla weir to downstream users, of around 600 ML/year, requires the release of significant amounts due to losses through seepage.

Land use within the study area was determined using Queensland Land Use Mapping Program (QLUMP) data. The analysis identified grazing as the dominant land use covering approximately 74 % of the area (Conics, October 2009). Cropping occurs throughout the development area, the central portion of the Project area, i.e. surrounding the Condamine River.

Investigations undertaken in 2007 (Wylie, September 2007) identified that irrigated agriculture in the Chinchilla area mainly comprises of cotton, whilst small amounts of horticultural crops such as melons are farmed to the north of Chinchilla. Other crops such as wheat, maize, oats, sorghum, and millet are also harvested in this area. The southern region is identified by QLUMP as conservation/production forestry however, much of this area is also currently grazed (Conics, October 2009). Table 6.5 below provides a summary of the land uses in the Project Area.

Four feedlots and a piggery operate in the Chinchilla-Condamine area. The industry predominately uses bore water (from the Hutton Sandstones) for water supply, supplemented with allocations from regulated watercourses (Wylie, September 2007).

Table 6.5 Land Use categorisation of the Project Area

Land Use Category	Area (Ha)	Project Area (%)
Grazing	1,080,672	74
Forestry	207,386	14
Cropping	130,133	9
Other	42,651	3
Irrigation	6,707	<1

Source: (Conics, October 2009)

Previous experience of supplying water to existing agriculture has been unsuccessful, primarily due to the conditions of the supply. In these instances, Australia Pacific LNG has stipulated that seasonal variance will be required, however annual consumption needs to be reasonably constant. If supply to existing agriculture is to become a viable option, an agreement must be reached where conditions of supply are agreeable to both parties.

Option 4b: - Agricultural Use – Australia Pacific LNG own and operate

Unlike Option 4a, Option 4b should have a greater flexibility of supply, both annually and seasonally. As the owner operator, Australia Pacific LNG can manage the land practices and more directly the irrigation, to meet water production and treatment rates.

The irrigation area required to utilise the volume of water produced is dependent on a number of factors including the volume of water produced in time, the volume of storage available for permeate, the type of crops grown and the intensity of production applied to the development. The cause of these symptoms is referred to as ‘seasonality’.

An analysis of land suitability identified that approximately 30 % of the development area was classified as Class A crop land, i.e. good quality agricultural land (Conics, December 2009). The majority of the Class A land occurs throughout the middle of the development area, surrounding the plains of the Condamine River, and it is then scattered throughout the development area (Conics, October 2009). The selection of irrigated crop may vary between location depending on local conditions and projected water supply. Nevertheless irrigation crops will be preferably located close to WTF, reducing conveyance infrastructure requirements.

A number of irrigated crops have already been investigated in relation to suitability, primarily water demand and potential profit. Initial investigations have considered a mixture of grain crops (Sorghum, Maize and Wheat) and irrigated pasture (Lucerne). Although Chinchilla is renowned for melon production, horticultural crops are not preferred as they are often in oversupply, whilst another locally abundant crop; cotton has a seasonal water demand that is unlikely to meet water production. The emerging biodiesel industry provides alternatives such as Pongamia trees. This option provides very high environmental returns, both as a renewable energy resource but also in providing a carbon sequestion option. Australia Pacific LNG has successfully undertaken trials with Pongamia at their Spring Gully WTF, and most recently a plantation has been developed for use of all treated water produced from this facility.

Option 5: - Aquifer Injection – Treated Water

The injection into underground formations represents a common approach internationally to onshore management of produced water. Injection is the process of emplacement of water into an aquifer, reservoir or coal bed by pumping the water into an injection well in an area that is capable of receiving and storing the water.

Injection of water into the ground is dependent upon a number of variables such as the:

- Quality and quantity of water being injected
- Storage capability of the receiving formation
- Chemical compatibility of the water and underground environment.

There are technical and regulatory considerations that need to be addressed in regard to this option, with significant operational consequences if not met. Direct injection of water into aquifers of equal or poorer quality is an option considered favourable by the Queensland Government (Queensland Government, Department of Infrastructure and Planning, May 2009).

The option further provides great operational flexibility and has limited capacity and sustainability disadvantages that inhibit many other beneficial use options that require the development of short-term markets. Appropriately designed and operated injection systems can buffer the impacts of associated water extraction, and address the requirement to “make good”.

Although pre-feasibility investigations (WorleyParsons, June 2009) suggest reinjection into the Surat Basin can be undertaken with significant potential social and environmental benefits, there are uncertainties remaining, which Australia Pacific LNG are addressing through further detailed desk top and field feasibility studies.

Australia Pacific LNG is planning to apply for approval to trial aquifer injection either by directly injecting associated water, or by injecting blended associated and permeate water. Due to the time required to complete the studies to reduce uncertainties and provide a basis for regulatory approval, the Initial Case assessment of this option focuses primarily on the injection of permeate water.

Option 6: - Ocean Disposal

By transporting associated water to the ocean, the need for intensive treatment is negated. Of a lower salt content than seawater, 10,000 mg/L to 35,000 mg/L, the need for salinity treatment is avoided and imbalances can be minimised.

This disposal option would provide little regional social benefit; however in contrast the local footprint of the Project would be reduced and would require a large pipeline traversing either directly east, or north east in the easement of the gas transmission pipeline, to convey associated water to the coast for disposal.

With its large capital cost, once the infrastructure is built, there is little opportunity to alter the capacity such as in the case of higher than estimated water production. Furthermore the pipeline would require significant design and construction would require timely environmental approvals.

Coastal discharge may have potential environmental impacts, and be costly.

Option A: - Brine Encapsulation

The water treatment often results in a concentrated saline effluent; referred to as brine. Brine encapsulation is one of three options focused on the disposal of brine. Encapsulation incorporates the process of evaporation whereby, overtime, the water will evaporate from the brine solution with the remaining salt products being encapsulated in lined ponds. Once production is complete, or evaporation ponds are at capacity of salt products, they are then sealed to the environment, in accordance to environmental regulations.

This option would require the clearance of several hundred hectares of land located intermittently across the project site for large ponds. Land area nominated for pond construction should, as far as practicable, minimise adverse impacts on sensitive terrestrial ecosystems, agricultural lands and useful surface or groundwater resources. Regardless, brine encapsulation is subject to monitoring and requires significant rehabilitation and management requirements (Queensland Government, Environmental Protection Agency, December 2007).

Option B: - Salt Recovery

Saline water can be managed through the recovery of salt from brine storage ponds. This reuse opportunity works in the same fashion as brine encapsulation. Brine mixtures are stored in lined ponds and over time the water evaporates from the pond, leaving a salt substance. At the end of life, the salt is removed from the ponds, treated or processed as required and sold on the market.

The primary saleable salt product contained in associated water is Trona and requires the concentration of the brine to reach beyond approximately 200,000 mg/L TDS in order to crystallise. A more effective method to achieving this concentration is the use of mechanic evaporation, often known as brine concentration.

Trona is often used in soda ash and also has some domestic markets. Other salt products removed from the Trona prior to its sale can be trucked away for disposal. An alternative option for the disposal of contaminated salts is for the highly concentrated streams to be inputted to a chloralkali process for production of other substances including sodium hydroxide, sodium hypochlorite and hydrochloric acid.

In addition Australia Pacific LNG has commissioned investigative studies and physical trials to improve the efficiency and recovery of selected treatment systems. Primarily the studies suggest the adoption of a brine concentration process such as secondary reverse osmosis to achieve the highest practical salinity for conventional reverse osmosis technology. Brine concentration has the potential to significantly reduce the footprint of brine ponds and therefore potentially represents an additional environmental benefit.

The option reduces residual waste streams, and potentially the need for leaving the waste long term onsite. This opportunity is restricted primarily on the efficiency on pond evaporation, cost of mechanical evaporation (concentration) and the market demand for salts.

Option C: - Brine Injection

Brine injection considers the disposal of liquid saline streams into aquifers. Injection of brine can be delineated into two disposal choices of:

1. Injection of RO Brine in its pure form; or
2. Injection of RO Brine and treated RO water blends.

This may be accomplished by injecting into deeper suitable aquifers in the immediate vicinity of the CSG production area, injection into the coal seams from where the associated water originated and/or piping of brine to distant suitable aquifers or depleted oil or gas fields. Both the technical and economical feasibility of injection to deeper aquifers is still under investigation. Australia Pacific LNG is currently undertaking field studies to ascertain the options in the project and surrounding areas for injection of highly saline substances to aquifers.

Strengths Weaknesses Opportunities & Threats Analysis

A Strengths Weaknesses Opportunities and Threats (SWOT) Analysis, a common strategic planning tool, has been undertaken by Australia Pacific LNG to ensure that there is a clear objective defined for the selection of a initial water management option, and that all factors related, both positive and negative, are identified and addressed. The process of SWOT involves four areas of consideration:

- **Strengths:** attributes that are considered to be important to the ultimate success of the project;
- **Weaknesses:** attributes that prevent the achievement of a successful result to the project;
- **Opportunities:** potential elements that will prove helpful in achieving the goals set for the project; and
- **Threats:** potential factors that could threaten the success of the project.

The outcomes of the SWOT analysis provided a matrix of advantages and disadvantages for each option. Often attributes were duplicated in alternate options, suggesting beneficial and detrimental themes.

A predominant strength of options 1a to 1d, 4b, 5 and 6 was the limited reliance on outside parties, which conversely was a weakness for the external supply options (option 2, 3 and 4a). Flexibility of discharge to storages and, to a limited extent watercourses, also dominated as a potential strength in options 1a to 1d, whilst lack of seasonal variance in demand featured as a strength in storage (1b), industrial (2), potable (3), and reinjection (5) and ocean disposal (6). Furthermore the beneficial use, option 2, 3, 4a, 4b and 5 were identified as preferred in current government policy.

Weaknesses highlighted were often the converse of strengths previously identified. Storage in evaporation ponds, option 1a, was listed as a non-preferred option and is proposed to be discontinued, as required by government policy. Economic feasibility of small supply options, requiring distribution, such as option 3 and 4a were also identified. High capital expenditure of pipelines, contractual negotiations, inflexible and seasonal supply requirements were outlined as weaknesses for numerous options.

Opportunities often identified potential social and environmental benefits of the management option, suggesting that it may improve community relations and provide environmental compensation. Option 2, 4a and 5 acknowledged that poor quality water supply may be appropriate, this would result in both lower treatment requirements and reduced brine pond footprint. A re-occurring threat was potential liabilities associated with the supply of high quality water. Timely approval and construction requirements for options requiring significant infrastructure were also prominent. Options with no treatment requirements, option 1a and 6, or potential for reduced treatment, option 2, 4a and 5, listed the threat of seepage of saline water into the natural environment.

The three salt options focussed on the benefits of reduced footprints, remediation and preference in government policy. Estimated high capital costs reflected negatively on salt recovery and brine injection whilst the long term exposure and monitoring requirement of encapsulation featured as a threat.

In general the SWOT Analysis assisted in the definition of alternative options to achieve the objective of managing associated water in the most socially, financially and environmentally advantageous means. The analysis provided direction and clarification of the options under consideration. It also provided an oversight distinguishing likely opportunities given the project parameters, requirements and ultimate project objective.

Weighted Assessment Matrix

The SWOT analysis may provide an outline of advantages and disadvantages for each option, but it does not however define the preferred options. The Weighted Assessment Matrix (WAM) is a tool designed to aid decisions. This tool is used for a multi-criteria decision, where criteria are 'weighted' based on their importance to the decision. The goal is to provide an objective assessment of a decision. To determine the most appropriate associated water management option a WAM was undertaken as a workshop with key Australia Pacific LNG staff members.

There are essentially three steps to completing the Assessment Matrix:

1) Identify Criteria: Table 6.6 lists the five criteria established for selection of the associated water Initial Case management option:

Table 6.6 WAM Criteria

Regulatory Approval	Compliance to existing and anticipated future regulation is essential for the award to gas production licensing.
Minimal environmental and community impacts	In the short and long terms, reducing liability and operational risks to the Project.
Flexible capacity	To match the scheduled and unscheduled variance in the water profile. Furthermore, management options with limited supply both seasonally and annually are preferred.
Readily implemented	Limited investigation or negotiation, during a condensed project program.
Sustainable practice	i.e. minimal redundant infrastructure resulting in adaptation to beneficial use options

2) Determine Weightings: Each criterion must be assigned a 'weighting' - Table 6.7.

Table 6.7 Criteria Weightings

Criterion	Weighting
Regulatory Approval	40%
Minimal environmental and community impacts	15%
Flexible capacity	20%
Readily implemented	20%
Sustainable practice	5%

3) Define Scoring: Provide a scoring magnitude and order with respective description to determine how well each option fits the criteria -Table 6.8.

Table 6.8 Scoring Definitions

Scoring	Definition
1	Significantly deficient of criterion
2	Deficient of criterion
3	Meets criterion
4	Exceeds criterion
5	Significantly exceeds criterion

Beneficial use options, option 2, 3,4a, 4b and 5 scored well in regard to regulatory approval, either listed as a preferred management use or incorporating aquifer injection. Both evaporation ponds and on-site storage score poorly in regulatory approval and minimal impacts, as the long-term storage was consider to provide little community benefit and an extensive footprint. As previously discussed, both storage and watercourse discharge provided a flexible capacity, whilst Australia Pacific owned and operated agricultural also scored well in this category.

Although identified as the preferred option, aquifer reinjection lacked the readiness of implementation to score highly overall. A similar result in this category also impacted salt options, salt recovery and brine injection. Existing options all scored high in this category with storage, discharge to watercourses and Australia Pacific LNG owned and operated agriculture in current practice. Sustainable practice considered the construction of major infrastructure and the long term beneficial optimisation of options. Whilst storage options scored poorly, agricultural options score high.

The workshop provided the following ranking, Table 6.9 for treated and brine water management options, as well as the salt management options in Table 6.10.

Table 6.9 Initial Case water management option ranking, WAM analysis

Rank	Options	No.
1	Agricultural Use; Australia Pacific LNG own and operate	4b
2	Discharge to Major Watercourses	1c
3	Potable Water Supply - Town Water Supply	3
4	Aquifer Injection – Treated Water	5
5	Industrial Use – Local Coal Mines &Power Stations	2
6	Agricultural Use – Existing	4a
7	Discharge to Minor Watercourses	1d
8	On-site Storage	1b
9	Evaporation Ponds	1a
10	Ocean Outfall	6

Table 6.10 Initial Case salt management option ranking, WAM analysis

Rank	Options	No.
A	Brine Pond – Encapsulation	A
B	Brine Pond – Salt Recovery	C
C	Brine Injection	B

6.1.4 Implement Decision

The preferred Initial Case is anticipated to consist of:

- Australia Pacific LNG owned and operated agricultural use, crops and plantation site selection is to be location based and will be undertaken to maximise sustainable water re-use, whilst equating to actual water production profiles
- The option will be complemented with existing agricultural water supply, where successful negotiations can be reached prior to water production commencement
- Opportunistic discharge of high quality treated water to major watercourses, as to cause minimum environmental impact

As an interim measure and occasional water surplus management method, Australia Pacific LNG proposes that treated water be discharged into local defined watercourses when impacts to stream ecology and flow regime will be minimal.

Although the Initial Case has selected brine to be stored in large evaporation ponds to be encapsulated at the end of the project, innovative technologies such as crystallisation and brine injection are being trialled. Furthermore Australia Pacific LNG has committed to progress efforts to find appropriate markets for recovered salt sale and re-use.

6.2 Associated Water Treatment

6.2.1 Treatment Approach

All management options listed above will require some form of treatment. Australia Pacific LNG proposes that from the water's separation at the well head, the water is conveyed in a low pressure gathering network, and where topographical constraints dictate, will be pumped to a WTF for treatment.

The physical nature of the coal seams limits the quantity of the CSG resource for extraction to a localised area around the well. Furthermore, gas flows from CSG wells significantly vary between, and sometimes even through, what are known as development areas. The Australia Pacific LNG Walloons deposit consists of ten development areas, each having several potential development fields. While wells may be located across the entire Walloons development, it is currently anticipated that the initial gas demand could be satisfied by developing all or some of the following four areas and associated fields (not in order):

- Talinga
- Condabri
  - Condabri South
  - Condabri Central
- Orana
  - Orana
  - Orana North
- Combabula
  - Pine Hills
  - Combabula
  - Reedy Creek

The number and location of wells to meet the gas demand is dependent on the amount of gas that can be produced from a well associated with the CSG field/reservoir into which the well is drilled. Although several pilots have operated throughout the Walloons development, a clear understanding of water production, at a field level, is progressively being developed. Therefore the capacity and location of water treatment facilities needs to reflect an ability to adapt to changing conditions, ensuring sustainable development.

Investigations into mobile treatment facilities indicated they are inherently unreliable and have high operational costs due to servicing and maintenance. They are also unlikely to meet the high recoveries which can be achieved with an optimised permanent plant. Furthermore the distance across the entire development field is substantial hence piping capital costs are significant. It is hence recommended that water treatment facilities are located central to several gas development areas, and are modular, to adopt to development sequence and associated water production rates.

For the scale of development being considered, a modular 20 ML/d facility has demonstrated to be the lowest cost option. These facilities can be further optimised by adopting incremental increases of 5ML/d as required. These facilities also provide cost benefits when centralised within a development field, however this may require legislative change to occur as piping across tenure boundaries is not permitted.

Australia Pacific LNG proposed a treatment approach that is appropriate for the beneficial use and, moreover, is to be selected on a site by site basis therefore reducing unnecessary waste energy and products and improving efficiency. All treatment processes are to be continuously reviewed and optimised.

6.2.2 Selection of Treatment Technology

Water suitable for river discharge would generally be suitable for irrigation of most crops on most soils. Therefore, the water treatment system required would be consistent with that required for river discharge. For the development of the Spring Gully water treatment facility (WTF), and more recently for the Talinga WTF, Australia Pacific LNG has investigated and trialled a range of treatment techniques to achieve watercourse discharge water quality objectives. The treatment process presented below is based on the existing WTFs, i.e. Spring Gully and Talinga, and although treatment requirements are anticipated to vary with end use, these will principally consist of the same key components in the Initial Case. The process can be summarised in three stages:

- Preparation and buffering feed ponds providing a buffer storage, removal of coarse sediment and allowing temperatures to be reduced prior to entering the facility
- pre-treatment technologies comprising disc filtration, membrane filtration and ion exchange to remove larger particles and alter parameters to improve desalination processes
- Desalination comprising using reverse osmosis

Reverse Osmosis (RO) involves diffusive mechanism, where pressure in excess of osmotic pressure is used to force feed water through a semi-permeable membrane.

6.2.3 Summary of Treatment Process

From the gas extraction wells the water is pumped to the surface and separated into gas and water streams. Each stream is linked to gas and water low pressure pipe networks which will deliver the two streams to the respective processing facilities; the gas to gas processing facilities and associated water to the water treatment facilities. The preliminary water treatment phases are referred to as 'pre-treatment' and consist of a number of chemical dosing and filtration systems. Plate 6.1 provides a conceptual 3D model of the Talinga WTF.

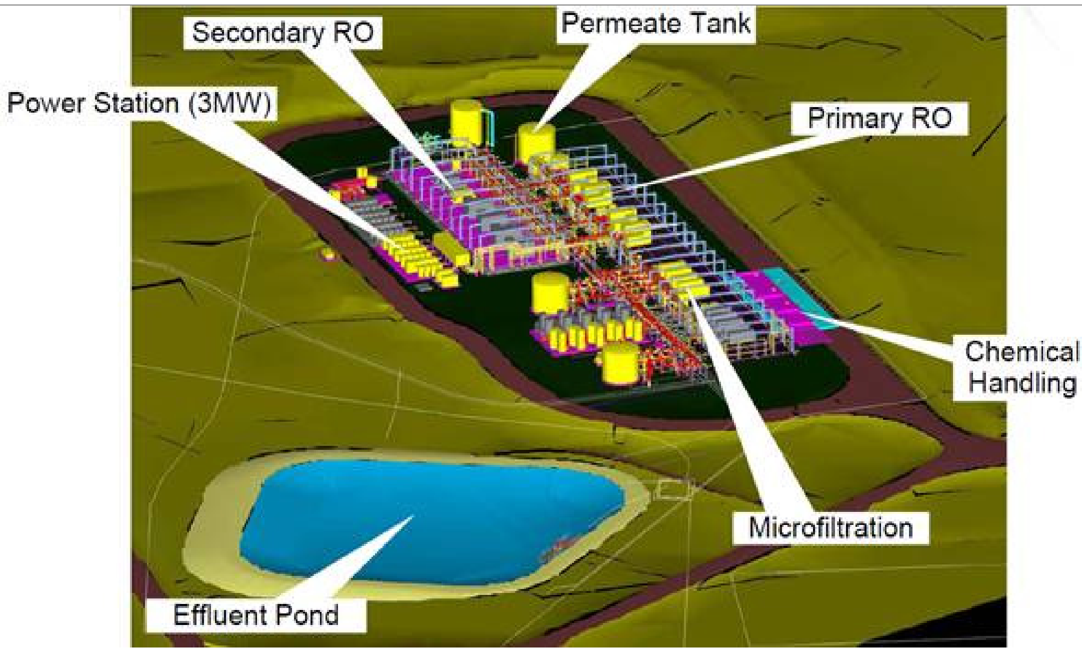


Plate 6.1 Conceptual model of a water treatment facility

The feed pond is a storage area into which associated water from the low pressure gathering system will flow from the extraction wells to where the WTF inflow will be drawn. The ponds provide a buffer storage capacity for periods when the WTF is operating at reduced capacity or shut-down. Operationally, the feed pond also allows coarse sediment to settle whilst the temperature is reduced to the ambient temperature approximately 35°C. The pond is designed to hold approximately ten days of the facilities capacity, i.e. pond capacity is 400 ML for a 40 ML/d WTF, and will be lined to the appropriate regulatory standard.

At the inlet of the facility a pumping system will take suction from the feed ponds sending associated water through the treatment processes. The inlet works include coarse screening, stop-gate installation points and plant feed pumps. Prior to feed a disinfection system will be implemented via the inlet channel. The system, and its operation, shall comply with Orica and Australian health and safety standards.

Once disinfected, the feed water will pass through the disc filtration system to remove coarse solids (nominally up to 400 µm). The next phase of filtration is undertaken using a membrane filter for the removal of fine solids (nominally up to 0.1 µm). Plate 6.2 below shows a photo of a membrane filtration system at Origin's Spring Gully WTF.

Plate 6.2 Membrane filtration system at Spring Gully WTF

After passing through the filtrate tank, a process buffer, the ion exchange system will remove cations, and improve water hardness to protect the RO system from scaling.

Each primary RO unit will draw water from a common pressure-controlled feed header and produce permeate that meets the discharge quality criteria. These are 3 stage units designed to achieve high recoveries while maintaining good cross-flow in tail end elements. The recoveries of these units are limited to reliably achievable cleaning intervals (target cleaning in place (CIP) intervals more than 1 month).

An indication of permeate water quality is provided in Table 6.11, a recent compile of monitoring results from Spring Gully WTF discharge.

Table 6.11 Spring Gully Permeate Water Quality Results

Parameter	Units	Mean
Electrical conductivity	µS/cm at 25°C	126
pH	std	7.7
Residual alkali (as Na_2CO_3)	meq/L	0.365
Total Alkalinity	mg/L	19
Sodium Adsorption Ratio		4.6
Sodium	mg/L	26
Potassium	mg/L	1.15
Chloride	mg/L	30
Fluoride	mg/L	0.05

Parameter	Units	Mean
Boron	mg/L	0.420
Barium	mg/L	0.011
Strontium	mg/L	0.019
Total Nitrogen	mg/L	0.094
Total Phosphorus	mg/L	0.043
Ortho phosphorus	mg/L	0.007

Very high recovery RO is achieved via the secondary RO units to ensure base-line site recovery is not compromised by possible low reliability of units operating at very high salinities.

Currently Origin is trialling the use of secondary osmosis at their Talinga WTF. Optimally the system will reduce brine effluent by half. It is proposed, if the trial is successful, to adopt secondary reverse osmosis as a standard component. Additionally, other facilities for further concentration of brine may also be implemented to minimize brine pond area.

The transfer ponds or tanks serve as a smaller holding capacity from which pipeline transfer pumps can take suction as well as providing a small holding capacity should there be a pipeline shutdown. Both ponds and tanks will be designed appropriately to safety contain the contaminated waste stream. Table 6.12 provides the Talinga design basis for a brine stream that may be directed to the brine pond.

Table 6.12 Predicted Brine Pond Inflow Water Quality Parameters

Property	Units	Range
TDS	mg/L	15,000 to 100,000
pH		8 – 9.5
TSS	mg/L	< 20
Temperature	°C	< 35

The design for high salt concentration considers an efficient brine concentration mechanism whilst the large sediment sizes allows for inefficiency in the upstream feed ponds. Furthermore the waste stream is anticipated to contain dilute solutions of acid and alkaline cleaning solutions or flushed chemical spills.

The brine pond is a storage area into which the brine reject will be discharged and stored. This pond may be located locally or remotely to the WTF. If located remotely, a smaller brine transfer pond or tank (to be determined in FEED) will be constructed locally to the WTF from which the brine transfer pumps will take suction before transportation via pipeline.

The brine storage pond will be used to encapsulate all produced brine. This may be subjected to further treatment in the future. Further processing of brine (resulting in a similar brine storage pond) is to be studied and considered as part of FEED.

The facility to deliver the process outlined above is already under construction at Australia Pacific LNG's Talinga operations. It is estimated that approximately 95 % of the associated water can be recovered as treated water which has a salt content of less than 0.15 grams per litre. A simple system flow diagram is provided in Appendix B.

6.3 Infrastructure Plan and Layout

6.3.1 Site Selection

Australia Pacific LNG commissioned Worley Parsons to undertake a Site Constraints Analysis for the development of the Walloons development.

Initially a number of sites were identified as potential locations for water treatment facilities. A high level assessment was undertaken, considering each site in regard to three broad categories of functionality: technical, environmental, and social. These categories were expanded to criteria for the undertaking of a multi-criteria analysis.

Table 6.13 below, provides a summary of the 12 criteria.

Table 6.13 Site Constraint Analysis Criteria

Category	Sub-category	Criteria
Technical	Utilisation of plant	Selection relevant to regional wells
		Proximity to brine ponds
	Constructability	Available Area (less than 2 % slope and cleared)
	Re-use Opportunities	Proximity to major water courses
		Proximity to potential downstream users (industrial/commercial industry)
		Proximity to good agricultural land
Environmental	Noise	Proximity to Sensitive Receptors
		Mitigation Terrain
	Natural Conservation	Ecological Significance
		Proximity to Environmentally Sensitive Areas
Social	Local	Social and Public Amenity
	Cultural Heritage	Proximity to Indigenous Site

The analysis established nine sites, including an alternate site at two locations, and the existing Talinga WTF.

The initial development plans to meet the start-up of the LNG facilities do not require all identified WTF's operating. Based on current development assessments, only two WTF's will initially be constructed; one each in the north western development area (Combabula) and the eastern development area (Condabri). In addition, the existing WTF at Talinga will be expanded to treat water from the eastern development area (Orana).

6.3.2 Infrastructure Schedule

The water production rate peaks and levels out over time, and varies depending on the field development profile. Initial indications are that the associated water production could peak at around 170 ML/d, but is not predicted to occur for approximately 20 years from start-up of the LNG facilities. By contrast this could reduce to half this figure approximately 5 years after full operation of the LNG facilities.

Table 6.14 below provides the EIS schedule of works for water treatment facility construction and expansion.

Table 6.14 Predicted Water Treatment Infrastructure Schedule

Year[1]	Water Treatment Facility Locations							TOTAL Walloons Operated
	Reedy Creek / Meeleebee	Horse Creek	Condabri	Talinga	Woleebee	Gilbert Gully	Byme Creek	
2010	-	-	-	20 ML/d	-	-	-	20 ML/d
2011	20 ML/d	-	-	40 ML/d	-	-	-	60 ML/d
2012	20 ML/d	-	20 ML/d	40 ML/d	-	-	-	80 ML/d
2013	40 ML/d	-	20 ML/d	60 ML/d	-	-	-	100 ML/d
2014	60 ML/d	20 ML/d	40 ML/d	80 ML/d	20 ML/d	-	-	140 ML/d
2015	60 ML/d	20 ML/d	40 ML/d	80 ML/d	20 ML/d	20 ML/d	-	160 ML/d
2016	60 ML/d	20 ML/d	40 ML/d	80 ML/d	20 ML/d	20 ML/d	20 ML/d-	160 ML/d
2017	60 ML/d	20 ML/d	60 ML/d	80 ML/d	20 ML/d	20 ML/d	20 ML/d	180 ML/d
Peak	80 ML/d[2]	20 ML/d	80 ML/d[3]	80 ML/d	20 ML/d	80 ML/d[3]	20 ML/d	220 ML/d[3]

1 - Years refer to calendar years, and construction and commissioning is to be completed by the end of the stated year.

2 – Peak capacity occurs at 2019

3 – Peak capacity occurs at 2023

7. Optimising Beneficial uses

'Beneficial use' refers to the utilisation of associated water to add value.

Australia Pacific LNG has committed:

'To find the highest and best use for the water produced on a case by case basis.'

This means that each operating site will be individually examined to scope its unique water profile, available management options, the specific environmental and geological conditions, and potential commercial, community and landowner outcomes. Subsequently the selected water management option (or options) will be chosen in light of these parameters and requirements of Australia Pacific LNG. Moreover this means that Australia Pacific LNG is committed to find the highest value beneficial use option for associated water.

The Initial Case water management options, as selected in Section 6.1, provide a readily applied, initial management approach. As uncertainties regarding water quantity and quality diminish, contractual arrangements can be successfully negotiated to provide a reliable and sustainable supply of water and technological difficulties can be overcome. Implementation of beneficial use management options, will be in the order of three to five year from the Project start, and extend through the peak production period.

7.1 Option Overview

Beneficial use options are being further investigated for the management of both water and brine products. Options identified during internal and external brainstorming exercises (Section 0) were reassessed against the following criteria for optimisation selection:

- Opportunity for sustainable beneficial use; socially, environmentally and economically
- Reduction of environmental impact
- Regulatory approval
- Sustainable practice
- Achievable implementation in a 3 to 5 year time period

Options from one salt and six water categories are shortlisted below in Table 7.1.

Table 7.1 Beneficial Use Associated Water Management Options

No.	Category	Option
1	Existing Practices	No options were considered to provide significant beneficial use opportunities in this category, therefore no further development is proposed.
2	Industrial Use	Key opportunities in the industrial sector include both existing and proposed mines and power stations. Initial investigations of other industrial opportunities, primarily Australia Pacific LNG owned and operated, require substantial capital expenditure.
3	Potable Water Supply	Water supply is often restricted by the high cost of piping and the low volume demand. Australia Pacific LNG plan to investigate a range of high quality water supply networks, construction, operation and ownership of these networks is

No.	Category	Option
		yet to be determined. Urban supply may be to the following townships: Dalby, Miles, Chinchilla, Condamine, Wandoan, Tara, Toowoomba and Roma. Bulk water supply to the Chinchilla weir, the proposed Nathan Dam and the SEQ Water grid also provides opportunities to use existing distribution networks and organisations. Agreements and liabilities in relation to supply remain considerable constraints.
4	Agriculture	Negotiation with landholders of existing agricultural ventures neighbouring key water infrastructure or where associated infrastructure traverses properties will continue to find a mutually beneficial agreement. Conveyance of water to agricultural customers beyond the development area is likely to be economically unfeasible. Australia Pacific LNG will further explore agricultural opportunities, potentially trialling new crops and expanding current plantations. Both of the above sub-options form part of the Initial Case however further optimisation will be beneficial.
5	Injection	Injection and reinjection options are being further investigated with improved hydrogeological understanding of the area from current and ongoing detailed feasibility studies and trials.
6	Other	The feasibility of the emerging technologies of algae management and solar ponds has been investigated as alternatives to other salt and associated water management options.
7	Salt	Although reinjection of brine is actively being pursued, other key opportunities for reuse lie in the concentration or crystallisation of brine and the sale of salt products.

7.2 Option Development

7.2.1 Commercial Agreements

Key obstacles in the implementation of opportunities in the industrial, potable water supply and agricultural sectors are the agreement of commercial terms and costings of water supply. Negotiations with a range of end users, including regional councils, mining and power companies are in progress. Nevertheless, to accelerate contracting water supply Australia Pacific LNG has already implemented a function group aimed at achieving commercial agreements with stakeholders.

Industrial Use

Water supplied to industry is anticipated to be primarily utilised for coal washing, dust suppression and for steam make up and cooling tower water in power plants. Provision of water to industry for operational needs is anticipated to reduce demand on other water resources such as surface and groundwater extractions and where alternative sources of water are not available actually allow those developments to proceed.

Large industrial customers such as mines and power stations offer a constant reliable demand for water. However the Project's water profile is certain to change, in both magnitudes and development staging, to optimise gas production. This needs to be taken into account in entering into potential supply contracts.

Numerous opportunities to supply mines and power stations within a 120 km radius of the development area have been identified, however only a small number of these exist and often already have an established water supply.

As a potentially substantial water demand, two proposed mines may provide long term contracts, limiting extraction from other surface and groundwater resources. One of the two northern mines is currently under environmental approval and planned to commence operations in 2012. Water supply to smaller proposed mines in the local area will also be explored, as will mines further afield; particularly to the east however these are often economic unfeasibility due to pipeline costs.

Although many of the existing mines may have sufficient water supply, if in opportune locations, potential network connections will be investigated. Potential water demand agreements with established power stations will provide opportunities with planned growth.

A critical consideration in the beneficial use of associated water by industry is the quality of water to be supplied. Often uses by mines and power station will permit water of poorer quality, therefore potentially allowing for a lower level of treatment. Supply of low quality water however may establish risks regarding transmission and liability. Other supply contract considerations are the proximity of the water industry to the project sites and points of water extraction/treatment; costs to Australia Pacific LNG for supply of water to industry; and costs of water treatment facilities required for adherence to DERM stipulations prior to on selling. Both the quality and quantity of water which will be extracted from the CSG is currently being developed and will be of a variable nature. A more comprehensive and accurate estimate of the availability of water supply will assist contract negotiations with potential industry users.

Potable Water Supply

Agreements and liabilities in relation to supply remain considerable constraints of potable water management options. The responsibility of water quality and consequently the liability of damage to human health, although highly unlikely, is a perception issue Australia Pacific LNG wishes to avoid. These issues will need to be addressed with any contractual arrangement for the supply of potable water.

Water supply is often restricted by the high cost of piping and the low volume of demand. Australia Pacific LNG plans to investigate a range of high quality water supply networks, however the construction, operation and ownership of these networks is yet to be determined. Australia Pacific LNG will continue to work with the Western Downs Regional Council to study options to make water available to Miles and other towns near the gas field development.

Bulk water supply to the Chinchilla weir, Glebe weir, the proposed Nathan Dam and the SEQ Water grid also provide opportunities to use existing distribution networks and organisations. Opportunities to connect with the SEQ water grid are substantial however initial investigation indicates economic feasibility relies on all CSG producers (Australia Pacific LNG, Santos, QGC, Arrow) adopting the approach.

Agricultural Use

Providing improved water supply access to established irrigation schemes may permit expansion of existing industry stock and/or opportunity for development of new agricultural production areas.

Additional water supply will also limit the drawdown on current ground and surface water supplies, improving ecological flows.

A combination of low value and low volume demand often results in agricultural water distribution networks being economically unfeasible. Furthermore, the climatic constraints affecting agriculture, consequently resulting in fluctuating and inflexible storage requirements, does not equate to the water supply profile. Where infrastructure traverses properties and neighbouring properties, negotiation with landholders will continue to find a mutually beneficial arrangement. Agricultural demand beyond the development area will need to be substantial to provide economic feasibility.

Australia Pacific LNG owned and operated agricultural ventures avoid commercial agreement regarding water supply. Conversely, commercial viability of agricultural pursuits relies on production crop markets and pricing. Variability and contract supply conditions are to be considered during crop selection.

Both of the above sub-options form part of the Initial Case and hence will be likely to be implemented within the Project to some magnitude. Their success in implementation combined with progression of other beneficial use options will determine the expansion of agriculture.

Salt recovery

Similarly to Australia Pacific LNG owned and an operated agricultural option, salt recovery financial viability is heavily dependent on external markets.

Salt recovery relates to the storage and/or further treatment of the brine discharge from reverse osmosis treatment. Evaporation either naturally via large storage ponds, or mechanically via brine concentration, conditions separated salts such as Halite and Trona from WFT effluent. Halite and Trona product/s can be sold for use in either feedstock for the production of soda ash and/or for low grade acid neutralisation dependent upon the potential of contaminants in the product.

The critical concern for this reuse option is that the market for Halite is very competitive. Halite can be extracted from the ocean at a cost much less than the treatment costs required for its production via WTFs. The cost of selling the salt by-products may be too high to compete with the current market prices. Other points to consider are the remediation costs associated with storage ponds. Trona is a more readily marketable resource and is expected to clear the market more quickly. The regulations governing this management option, irrespective of by-product, are rigorous and the financial impact of decommissioning and rehabilitation at project end cannot be overlooked.

7.2.2 Emerging technologies

Australia Pacific LNG continues to work towards additional beneficial use options with a number of technically and industrially emerging reuse options currently undergoing research and development. These options are being considered for implementation in the next three to five years. Options being considered include aquifer reinjection, solar pond power generation, algae production and brine concentration.

Aquifer reinjection

Aquifer reinjection is the injection of associated water, whilst the term 'injection' is used for the injection of permeate (a blend of permeate and associated and brine) into groundwater storages or aquifers. Both can be accomplished via injection into the original source strata from where the water was initially extracted or an alternate stratum with appropriate hydrogeological characteristics. The success of either option is highly dependent upon injectate water quality, receiving aquifer water quality, aquifer mineralogical and biological properties and the transmission and storage capacity of the selected reservoirs, and injection well design. Appropriately designed and operated injection system can potentially buffer the impacts of associated water extraction, and address the requirement to "make good".

These methods have been used commonly in offshore oil applications and in international CSG production fields, as well as for mining, extractive industries and urban water management applications. Reinjection of produced water from CSG operations into aquifers is also an option considered favourable by the Queensland Government in the discussion paper (Queensland Government, Department of Infrastructure and Planning, May 2009). Key constraints of this option are achieving the appropriate hydrochemical characteristics to maintain reinjection efficiency and the availability of aquifers with suitable hydraulic characteristics.

The measurement of aquifer hydraulic and mineralogical properties from overlying and underlying sandstone aquifers will allow an assessment of the physical properties of potential target aquifers. It will also allow the assessment of the chemical compatibility of discharge and background receiving waters and will significantly improve the reliability of aquifer reinjection feasibility studies.

While aquifer reinjection would not provide an income stream to Australia Pacific LNG, if proven feasible, this option appears to provide a solution which allows CSG production while maintaining a water balance within the Great Artesian Basin and minimising the project ecological and social footprint on the land surface.

Technical feasibility studies completed by Australia Pacific LNG to date have shown that aquifer reinjection is theoretically possible with potentially significant environmental and social benefits. Studies to date have focused on reinjection of associated water, permeate water and brine concentrate from the reverse osmosis process. A number of potential target aquifers have been identified. Australia Pacific LNG would like to move forward from "theoretical" to "practical" studies as quickly as possible. Further studies and trials are considered essential to reducing any uncertainties in hydraulic properties and chemical compatibility of the potential reinjection aquifers.

The project area within the Great Artesian Basin (GAB) geological environment and the water resource demands placed on groundwater are unique. Therefore it is necessary to proceed carefully with studies in a phased approach to ensure that chosen water management strategies are appropriate within the geological, social and water resource policy setting.

Australia Pacific LNG is scoping several reinjection trials and has approached Government to obtain advice on the approval process. It is proposed that Government are involved and engaged throughout feasibility studies and trials to ensure that any benefits and outcomes from the studies would be made available immediately to inform Government during future approval and policy development.

The uncertainties will be further reduced through these feasibility studies and potentially field scale trials. Moreover additional data to support aquifer injection feasibility studies is currently being obtained through exploration and production drilling programs.

Solar Pond Power Generation

Solar pond power generation involves the use of intense saline water to collect and store solar thermal energy. The heat trapped in the pond as a result of the pond's 'halocline' structure can be extracted and used to operate an Organic Rankine Cycle turbine or Stirling engine for generating electricity (WorleyParsons, August 2009b). Energy stored in the solar ponds is available 24 hours a day.

The technique is largely untested and the economics of large scale production is yet to be undertaken. Further investigation, trialling, and feasibility studies are required to progress this as a viable water management option.

Algae Management

Multiple opportunities exist for the opportunistic management of naturally occurring and farmed algae. The potential for algae production and beneficial reuses ranges between providing stock feed from minimalistic development and harvesting of seasonal algae, to large scale commercial farming using photobioreactors. In order to commercially cultivate algae, additional harvesting inputs are required (as so with cropping in terms of fertilisation). Algae cultivation requires additional carbon dioxide which can be sourced from carbons emissions thus resulting in carbon capture, and nitrogen which can be sourced from the water treatment process (reverse osmosis/micro filtration reject) (WorleyParsons, August 2009b).

Key constraints to this associated water management option include:

- Regulatory approval required
- Ongoing monitoring and reporting as a result of restricted approvals may be too rigorous
- Commercial returns for the product are not fully known
- Algae management via photobioreactors is largely untested on a reasonable, commercial scale
- Significant additional research and development investment is required prior to implementation

Salt recovery

As previously discussed in Section 0, salt recovery involves the brine discharge from RO treatment to be concentrated into a salt substance. This process is to some degree naturally undertaken within brine storage ponds currently established in the Initial Case.

For improved efficiency, and therefore a reduction in brine pond footprint, the evaporation process can be mechanically undertaken when evaporators are driven by energy transferred from the condensation of steam across a heat transfer surface. There are a variety of mechanical concentration systems available on the market and selection is often driven by fouling capacity.

The selection of brine concentrator and energy and waste efficiency must also be considered with other salt reduction and market opportunities.

7.3 Plan Execution

Australia Pacific LNG has established adaptive approach for the implementation of AAWMP. The progression from Initial Case to beneficial use will occur within three to five years of project initiation and involve the evolution of associated water management options.

A number of key milestones/dates have been established to ensure the beneficial use options are implemented during the transitional period. Appendix C provides a summary of milestones to be achieved within a high level timeline. Although not all beneficial use options may be implemented, the timeline indicates the path of implementation of each category if considered feasible and suitable during the option appraisal process.

7.4 Future Commitments

In October 2009 the Australia Pacific LNG Steering Committee/Board agreed to a number of key commitments in relation to the management of water, as outlined in Table 7.2 below.

Table 7.2 Associated Water Management- Key Commitments

Groundwater	A regional scale groundwater study has been completed as part of this EIS. Australia Pacific LNG will continue to assess cumulative impacts from associated water extractions over time.
	Australia Pacific LNG is committed to collaborating with the Queensland Government in support of their *Blueprint for Queensland's LNG Industry* (2009), and other CSG operators in the region, to develop an agreed approach to regional groundwater monitoring and cumulative effects groundwater modelling.
	Australia Pacific LNG will work with Government to develop a publically accessible database which will contain easily interpreted groundwater level and quality monitoring data.
	Australia Pacific LNG is committed to managing and implementing appropriate (early intervention) strategies to minimise adverse impacts as a consequence of its proposed CSG activities, both during and after the completion of operations.
	Australia Pacific LNG will comply with the P&G Act "make good" provisions.
	Australia Pacific LNG will involve community groups in the implementation of the ongoing groundwater monitoring programme and will consult with stakeholders on strategies to "make good" any impacts as required under relevant legislation.
	As part of the ongoing monitoring programme, Australia Pacific LNG will conduct further evaluations of the potential for fugitive gas migration during CSG production and, where necessary, develop appropriate monitoring and control measures to mitigate any residual risks.
	Australia Pacific LNG will employ CSG well and infrastructure designs and construction methods, in accordance with relevant legislation and standards agreed in consultation with Government, which minimise the potential for impacts to the local and regional groundwater regime.
	Australia Pacific LNG will actively investigate alternative water management technologies including aquifer reinjection.
	Australia Pacific LNG will participate in studies into the long term sustainable water supply options for the region and will support programmes for water conservation within the region.
Water self-sufficiency / use own water	Field development and operational planning will consider the use of associated water (either treated or untreated) to meet the forecast water requirements of the Project.
	Water efficiency measures will be implemented for gas development and production activities.
	Australia Pacific LNG will be as self-sufficient as practical for all construction and operational water requirements.

Provision of water to Western Downs Regional Council	Australia Pacific LNG will continue to work with the Western Downs Regional Council to study options to make water available to Miles and the impacted towns near the gas field development.
	Australia Pacific LNG will participate in studies into the long-term sustainable water supply options for the region and Australia Pacific LNG will support programs for water conservation within the region.
Provision of water to impacted landowners	Australia Pacific LNG will offer impacted landholders, near to the water pipeline network, the opportunity to access water on commercial terms or as a compensation offset, subject to availability and relevant approvals.
Provision of water for commercial and beneficial use	Australia Pacific LNG will optimise commercial and beneficial water use through a flexible approach including: • water which can be reliably supplied long term will be contracted to commercial customers • investigation of opportunities for water to be managed in conjunction with other producers including water aggregation
Procurement	Australia Pacific LNG will require all major contractors to submit water conservation plans.
Brine Management	Australia Pacific LNG will minimise the number and size of ponds and line all associated water and brine ponds.
	Australia Pacific LNG will actively investigate improved water management technologies to address brine beneficial use.

8. Risk Assessment

8.1 Assessment Overview

A risk-based evaluation tool has been developed for the EIS which categorises and ranks risks, in terms of potential impact and probability of occurrence. Using the findings from the impact assessments undertaken for the EIS investigation, impacts relating to the management of associated water have been collated and addressed. When applied to associated water this evaluation becomes the basis for assessing and comparing, in a reasonable framework, the impact of dealing with associated water. The nature of the tool developed for these risk assessments is such that it provides for the ongoing reassessment of risks according to availability of information.

The outcomes of the risk assessment are provided in Section 8.3 at the end of this document. This risk assessment draws from the impact analysis provided in Section 8.2 and includes proposed mitigation measures Section 8.3 for the identified impacts.

8.2 Impact Identification

Environmental impacts were identified for the three associated management options selected in Initial Case, i.e. agriculture, discharge to watercourses and salt encapsulation. The assessment only considered operational aspects of selected options as construction and commissioning impacts have been addressed elsewhere in the EIS.

Table 8.1 provides an overview of impacts identified for the selected Initial Case operation of associated water management options.

Table 8.1 Potential impact identified for Initial Case management options

No.	Potential Impact Mechanism	Potential Impacts
Agriculture		
1	Erosion from exposed areas	Clearing for agriculture may initiate, or exacerbate, overland and/or gully erosion. This impact mechanism is of particular concern where land is steep, consists of highly erodible soils or is adjacent to watercourses. Sediment-laden runoff can increase turbidity, harm aquatic flora and fauna and disrupt natural geomorphic mechanisms.
2	Contamination of water and soil environments from poor quality irrigation water	Irrigation with untreated water may result in the contamination of both water and soil environments. Constitutes often present in associated water, such as boron and fluoride, combined with high salinity, high SAR and high suspended solids levels, will impede crop growth and yield. Common impacts include: surface sealing and crusting, reduced infiltration, drainage, aeration, macroporosity and permeability. High salinity levels of specific ions are often toxic to crops, and at a minimum, can result in poor germination and establishment. Figure 4.3 provides a brief summary of crops tolerant to high salinity levels. Whilst crop selection may avert some potential issues relating to high salt levels, the accumulation and saline absorption of soils introduces other potential impacts. Long term damage to soil environments from the increased osmotic pressure reduces hydraulic conductivity, resulting in difficulties of crops to extract water from the soil. Soil structure is also damaged by high SAR value water irrigation. As discussed previously, sodic soil can lead to the destruction of natural aggregation resulting in soils becoming dense, cloddy and structureless. Sodic soils limit the ability of plants to uptake water and nutrients from the soil due to dispersed small clay particles that clog pore spaces.
3	Offsite surface drainage caused by irrigation	Irrigation water travelling over the soil surface can also lead to local and off-site surface drainage issues. These primarily include: • erosion and runoff, harming aquatic habitats and fouling waters used for recreational activities • salt washoff • the spread of pathogens and weeds Erosion and runoff is discussed in Impact 1, however, unmitigated the impacts can be distributed within the catchment, from overland runoff, or conveyance in streams. Cumulative impacts can exacerbate these effects, for example, reduced infiltration and hydraulic conductivity resulting from poor irrigation water, can lead to increased runoff.

No.	Potential Impact Mechanism	Potential Impacts
		Salt washoff exists primarily when irrigation of saline soils, both artificially and naturally, results in the transport of salt to neighbouring areas. Impacts from runoff over saline soils will be similar to those detailed in Impact 2, and are generally a result of the degradation of soil from salination. In addition to mobilising and moving salt, irrigation can also result in the leaching of chemicals (for example nitrogen) and pesticides. This can contribute to poorer off-site water quality, potentially leading to contamination of soils and waterways.
4	Deep drainage caused by irrigation	Excessive irrigation of crops, i.e. irrigation greater than crop requirements, or inefficient irrigation methods: such as flood irrigation, can lead to the leakage of irrigated water past the plant root zone. Known as deep drainage, the abundance of subsurface water can contribute to movement and rise of watertables. Salt is often stored deeper in the soil profile and deep drainage can cause the mobilisation of these salts, increasing the salinity of groundwater. Impacts of salinity are detailed further In Impact 2 of this table. Furthermore deep drainage may move laterally and become baseflow to streams or drain to lower unsaturated zones or aquifers, potentially to water logging soils or to create shallow water tables. Poor quality water and soil types can exacerbate impacts of deep drainage. It should be noted however that this seepage is unlikely to provide the appropriate depth of groundwater contribution potentially needed to “make good”. It may however supplement or negate groundwater extract for existing agricultural use, therefore potentially providing a positive ecological adjustment.
Stream Discharge		
5	Change in geomorphology due to increased flow	Stream power is frequently quoted as an indicator of potential for geomorphic change. Preliminary hydraulic modelling predicted varied impacts on stream power within the streams identified for discharge due to increased flow. However, streams within the study area are classified as unpredictable and intermittent, both with regard to base and high flows. Constant and/or high flow discharges need to be assessed as continuous and magnitudinal changes rather than discrete events. The modelling indicated that little impact would be a result in wet periods such as January – May, however impacts in the dry season may occur in the short-term, especially on steep and minor watercourses. General geomorphic impacts relating to these changes in flow are expected to result in (Volume 5, Attachment 20): • exacerbation of existing gullying at the gully confluence with the main channel, particularly those more recently formed examples • notch erosion resulting from reduced variability of flows downstream of the release points

No.	Potential Impact Mechanism	Potential Impacts
		• increased bank failures resulting from notch erosion • increased bank instabilities resulting from increased wetting of banks consisting of dispersive clays • exacerbated meander migration resulting from permeate discharge close to meander bends • increased entrainment of bed sediments, resulting in redistribution downstream Modelling further determined that between low flow conditions and up to bank full conditions, the additional discharges to the Condamine River are not likely to result in significant geomorphologic impacts. Within the minor watercourses predicted velocities and stream powers were considered relatively low with the exception of Yuleba Creek (Volume 5, Attachment 23).
6	Localised erosion at discharge points	Depending on location, and proposed rate of discharge, localised scour or erosion of river banks may result from both event and constant discharge. Consequently this could lead to sediment laden flows, increased turbidity and subsequent smothering of flora or sedimentation of channel beds.
7	Impacts to Aquatic Ecology from change in flow regime	Native aquatic flora and fauna have adapted to intermitted flow environments that have prevailed over recent times. There are conflicting opinions within the scientific community as to whether changes to community structure resulting from increased discharges during the low (or no) flow period would impact the waterways positively or negatively. However, there is consistent agreement that the impacts associated with sustained base flows are unlikely to directly impact the fishes within the study area. Smaller macroinvertebrate species may have issues regarding the maintenance of aquatic refugia and tolerance to constant flows, however the introduction of flows may compensate for upstream constrictions (Chinchilla Weir) and agricultural and industrial extractions. Furthermore transmission losses and presently unused downstream extraction licences may limit the reach of any potential negative or positive impact to the Aquatic Ecology.
8	Impacts to Aquatic Ecology from inappropriate water quality discharge	Water Quality sampling undertaken and collated as part of the Queensland Water Quality Guidelines (Queensland Government, 2009) identified the mean salinity for the Condamine – MacIntyre Zone was 355 µS/cm (227.2 mg/L), with 90 and 10 percentile values of 755 µS/cm (483.2mg/L)and 189 µS/cm (121 mg/L) respectively. Discharge of untreated associated water will impact both local aquatic flora and fauna, with impacts exacerbated during periods of no or little flow. Other parameters, such as Boron, TSS and pH are also identified as potential contaminates to the aquatic environment at specific levels (refer to Section 4.3). Conversely some treatment methods can result in the removal of elements essential to species development. For example Calcium

No.	Potential Impact Mechanism	Potential Impacts
		concentrations in RO permeate is such that crustaceans in local environments may have insufficient calcium for the regeneration of exo skeletons. Although impacts may only be significant to local smaller species, food chain impacts can result in wide spread impacts to stream health including stream flora and fauna (Aquatic Ecology, Volume 5, Attachment 20).
Salt Encapsulation		
9	Contamination resulting from brine pond overflows	There is potential for highly contaminated brine water to enter the environment following periods of heavy rainfall and subsequent containment failure. Furthermore structural failure of the storage, referred to as “sunny day failure”, may also result in the discharge of contaminated material in to the environment. Material stored within brine ponds contains high salinities, concentrations of some heavy elements (e.g. boron, barium, magnesium and strontium) and nitrates. Detrimental impacts to local biota could occur if this contaminated water was released to local watercourse (Volume 5, Attachment 20).
10	Contamination resulting from brine pond seepage	Release of contaminants to groundwater via leaching of the brine ponds is probable in the absences of internal lining or capping protection. Substantial seepage can alter groundwater flow patterns by way of mounding, whilst even moderate seepage can adversely affect water quality in shallow groundwater systems. Contamination of groundwater may be detrimental to vegetation, soil, adjacent watercourses, aquatic ecology and nearby landholder bores.

8.3 Mitigation Measures

Mitigation measures are proposed to reduce or even eliminate risks. The Australia Pacific LNG EIS risk framework assesses the effectiveness of each measure. These are determined by considering the implementation and reliability of each measure in combination with the hierarchy of control.

The hierarchy of control definitions is as follows:

Eliminate:

Remove the hazard for example eliminating a requirement to carry out the task, use a piece of equipment or utilise a chemical.

Substitute / Transfer:

Replace the material, plant or work practice with a less hazardous one for example replacing a hazardous chemical with a less hazardous one.

Transfer or out-source the risk to another party i.e. insurance.

Engineer:

Make a structural change to the work environment or work process to interrupt the path between the employee and the risk.

Engineering the solution to minimise risk is highly desirable as the process reduces the reliance on human behaviours to effect long lasting positive change. There are a number of aspects to engineering controls

- Redesign the way in which work is performed, modify equipment to change the way a task is performed or engineer change to the process steps to eliminate hazardous activity. One may also completely automate a process where there is minimal or no human interaction.
- Isolate a hazard by physically guarding the hazard, enclosing the hazard thus preventing human contact, locking a process/equipment thus preventing access by any unauthorized personnel, remove the hazard by engineering means such as ventilation.

Administration:

Administration controls are the procedural aspects of managing hazards, such as planned and preventative maintenance programs, standard operating procedures, lock out/tag out procedures. Education and training and the rotation of staff thus minimising exposure.

Personal Protective Equipment (PPE)

Personal Protective Equipment is the last and least effective control method used. It involves staff wearing appropriate PPE such as steel mesh gloves, safety shoes, aprons, goggles etc, to isolate the person from the hazard. This control method is not highly effective because it relies totally on human behaviour. PPE often forms part of the ‘short term’ controls methodology.

Proposed mitigation measures for each of the potential impact mechanisms are summarised below in **Error! Reference source not found.**.

Table 8.2 Proposed Mitigation Measure for Initial Case Management Option Impacts

No.	Potential Impact Mechanism	Mitigation Measure
Agriculture		
		Where crop irrigation is proposed Australia Pacific LNG will prepare a Resource Utilisation Plan (RUP). The RUP essentially addresses impacts relating to land and water management planning. It also contains additional details regarding the quality of the treated associated water, measures to ensure that the use of the water does not cause environmental harm and waste management. The RUP will be submitted DA and will provide further detail of the below mitigation measures.
1	Erosion from exposed areas	This impact is to be addressed by a combination of four mitigation measures: • Implementation of stormwater and erosion control measures, such as: swales, rip rap, sediment traps and potentially sediment basins in vulnerable locations • Selection of appropriate land preparation techniques, irrigation systems and crops • Appropriate selection of land for irrigation is essential in avoiding erosion and sites that are flat and consist of non-dispersive soils will be preferred over steep, gullying sites • Monitor and maintain, via site audits to identify, predict and remediate areas susceptible to erosion
2	Contamination of water and soil environments from poor quality irrigation water	There are a number of issues associated with irrigation, regardless of the quality of the water that is being used. However, the situation is exacerbated if poor quality water is used. In response to the risk posed to the land and water environments with the use of associated water for irrigation, water will be treated to a high quality. Details of proposed Initial Case treatment technology are provided in Section 6.2. As suggested, objective water quality will alter depending on local environmental constraints and crop tolerances. A risk assessment framework will be applied for the selected water quality parameters, comparing local and crop requirements to regulatory guidelines. Assessment should demonstrate that agricultural practices will not have an adverse impact on the surrounding environment, primarily stream salinity. Associated water will be treated in accordance with current DERM guidance.

No.	Potential Impact Mechanism	Mitigation Measure
		Permeate water quality monitoring should be undertaken as part of the treatment process. Continuous review of crop response should lead to adaption of quality specifications.
3	Offsite surface drainage caused by irrigation	Much of the area where CSG production is proposed is comprised of low fertile soils, significantly limiting irrigated agriculture (Table 6.5). Land management needs to focus on minimising salinity risk compared with existing land uses of grazing and dryland cropping. Corresponding to appropriate site selection (Impact 1), when developing an irrigation scheme Australia Pacific LNG will undertake a soil mapping investigation on a "farm-scale" to assist with the sustainable development of the crop. Australia Pacific LNG will also commission experts in irrigation layout and management practices to avoid runoff to adjacent properties or watercourses and restrict potential salt wash-off and the spread of pathogens and weeds. Permeate used for irrigation will be monitored to demonstrate that it does not have an adverse impact on the surrounding environment, especially stream salinity. A water quality monitoring program will be established on and surrounding the irrigation scheme in vulnerable locations.
4	Deep drainage caused by irrigation	By adopting the following sustainable irrigation techniques and management, many of the impacts relating to deep drainage can be avoided: • Minimise excess drainage of water and prevent excessive salt accumulation within and below the root zone; • Maintain crop or plant productivity and match water applied, both by irrigation and naturally, with the crop requirement, and; • Establish a monitoring program, considering existing environment, plant production, water quality, local ground and surface water The adoption of an appropriate and, most efficient irrigation system is also relative to crop and site constraints. Slower and controlled irrigation systems such as spray, furrow and trickle irrigation are preferred methods with regulators. Cumulative impacts of irrigating large areas within the CSG development are to be investigated using a risk assessment framework for proposed additional irrigation schemes as part of the RUP.
Stream Discharge		
5	Change in geomorphology	Initial hydraulic modelling indicates that discharge regimes mimicking nature flows maybe beneficial to aquatic ecology environment. They may also provide a geomorphic response closer to the existing condition, with limited sediment transport in dryer months and significant in wetter

No.	Potential Impact Mechanism	Mitigation Measure
	due to increased flow	periods. Furthermore limiting discharges during dry periods will reduce magnitude and occurrence of short-term impacts. Once a discharge regime has been determined further refinement of the existing hydraulic model may provide guidance on potential impacts of unseasonal flow. Discharge regimes can be altered accordingly to result in low impact to the geomorphic condition. Once a discharge regime is implemented, a suitable monitoring program may establish an improved understanding of existing geomorphic variance and impacts, if any, additional stream discharge may cause.
6	Localised erosion at discharge points	Where proposed discharge rates may cause scour and erosion damage to local bed and banks, engineering controls to diffuse stream power will provide localised control of velocity reducing scour and erosion at the discharge location. All discharge locations should be regularly inspected for scour and erosion damage, this includes adjacent banks and downstream reaches where grades have slackened.
7	Impacts to Aquatic Ecology from change in flow regime	As detailed in the Surface Water and Aquatic Ecology chapters (Volume 5, Attachment 20 and 23 respectively) a government calibrated, integrated quantity and quality model (IQQM) was undertaken for the Condamine River. Primarily the model considers potential discharges and extractions to the River against allocations, anticipated flows and synthetically estimated natural flows. The modelling was compared against environmental flow objectives (EFOs) as defined in the ROP (Queensland Government, Department of Natural Resources and Water, December 2008) as indicative impacts to aquatic ecology. It suggested that a number of discharge regimes will meet EFOs. Predominately regimes mimicking seasonal variance, i.e. lower discharges in dryer periods, were more successful in meeting the adopted guidelines. Australia Pacific LNG will undertake monitoring of aquatic ecology response to additional flow, especially as some research suggests improved ecological conditions.
8	Impacts to Aquatic Ecology from inappropriate water quality discharge	Queensland Government policy requires CSG producers to treat their water unless it can be injected directly into aquifers of equal or poorer quality, or an environmentally safe direct use for the untreated water has been found. Hence water will be treated prior to discharge to watercourses. Furthermore, permeate discharged to watercourses for flow augmentation will be treated to a high water quality level. As a precautionary measure, proposed permeate concentrations should be compared with the relevant species protection levels by using the ANZECC/ARMCANZ

No.	Potential Impact Mechanism	Mitigation Measure
		(2000) species sensitivity distribution. This may include increasing concentration of certain parameters, such as calcium, in the permeate discharge to appropriate levels to prevent aquatic flora and fauna harm. Details of proposed Initial Case treatment technology are provided in Section 6.2.
Salt Encapsulation		
9	Contamination resulting from brine pond overflows	A dam failure impact assessment undertaken by WorleyParsons indicated that these ponds fell into the "significant hazard category" according to DERM guidance. This classification was due to high contaminant concentrations within the brine ponds and large storage volumes. The brine ponds will require appropriate engineering design, management and controls to meet regulatory requirements for the hazard category. The design will include: effective geotechnical design of sealing structures, maintenance of suitable amounts of freeboard to account for wetter than average periods, substantial spillway and containment designs such that releases are avoided. Brine ponds will be constructed in a cellular manner, reducing total volumes of discharge in the case of a dam failure. Regular scheduled infrastructure audits should be conducted by competent and qualified technicians and designers to ensure quality design of infrastructure. Continuous maintenance and monitoring of embankment structures are recommended essentially this is to be undertaken following severe storms. Encapsulation of brine ponds should be undertaken in such way as to ensure long term integrity of the cap. At design stage the landscape location, geological and hydrological stability, and ongoing management and monitoring requirements are to be considered.
10	Contamination resulting from brine pond seepage	Seepage to groundwater will be managed through the appropriate engineering design and construction of the ponds as required by regulators. Current practice includes the lining of ponds, this will be continued at a minimum. Ponds are to be monitored as part of the groundwater monitoring program. Monitoring is to include both quality and level, providing an opportunity for early detection and response in the event of seepage.

8.4 Risk Assessment Summary

The overall risk of potential impact to surrounding environments was assessed for each impact identified. The risk was calculated using the risk matrix prepared for the EIS, and is comprised of two key components:

- **Likelihood:**
  Establish using Table 8.3, as a function of exposure and probability; and
- **Consequence:**
  A qualitative assessment using Table 8.4 descriptions.

The subsequent risk is determined using Table 8.4 and can be classified as:

- Negligible
- Low
- Medium
- High
- Very High

Risks were then re-assessed with mitigation measures considered adopted. Table 8.5 presents the residual risks for each potential impact mechanism.

Table 8.3 Likelihood Rating Matrix

			Exposure					
			Not in 100 years	AT least once in 100 years	At least once in 10 years	At least once a year	At least 4 times a year	At least once per week
			E1	**E2**	**E3**	**E4**	**E5**	**E6**
Probability	Not known to occur in a comparable activity internationally but plausible	**P1**	0	0	0	0	1	1
	Know to occur in a comparable activity internally but unlikely	**P2**	0	0	0	1	1	2
	Has occurred or could occur for this or a comparable activity in Australia	**P3**	0	0	1	1	2	3
	Expected to occur infrequently during this activity	**P4**	0	1	1	2	3	4
	Expected to occur occasionally during this activity	**P5**	1	1	2	3	4	5
	Expected to occur frequently during this activity	**P6**	1	2	3	4	5	6

Table 8.4 Australia Pacific LNG Risk Matrix

			Likelihood					
			1 Remote	2 Highly Unlikely	3 Unlikely	4 Possible	5 Likely	6 Almost Certain
Consequence	Long Term destruction of highly significant ecosystem or very significant effects on endangered species or habitats	Catastrop	M	M	H	H	VH	VH
	Major offsite release or spill, significant impact on highly valued species or habitats to the point of eradication or impairment of the ecosystem. Widespread long-term impact.	Critical	L	L	M	H	H	VH
	Offsite release contained or immediately reportable event with very serious environmental effects, such as displacement of species and partial impairment of ecosystem. Widespread medium and some long-term impact.	Major	L	L	L	M	H	H
	Moderate effects on biological or physical environment and serious short term effect to ecosystem functions. (e.g. oil spill impacts on shoreline)	Serious	N	L	L	L	M	H
	Event contained within site. Minor short term damage to area of limited significance. Short term effects but not effecting ecosystem functions.	Moderate	N	N	L	L	L	M
	Minor consequence, local response. No lasting effects. Low level impacts on biological and physical environment to an area of low significance	Minor	N	N	N	L	L	L

Table 8.5 Risk Assessment Summary

No.	Potential impact mechanism	Consequence	Likelihood	Residual Risk
Agriculture				
1	Erosion from exposed areas	Minor (1)	Highly Unlikely (2)	Negligible
2	Contamination of water and soil environments from poor quality irrigation water	Minor (1)	Unlikely (3)	Negligible
3	Offsite surface drainage caused by irrigation	Moderate (2)	Highly Unlikely (2)	Negligible
4	Deep drainage caused by irrigation	Moderate (2)	Highly Unlikely (2)	Negligible
Watercourse Discharge				
5	Change in geomorphology due to increased flow	Minor (1)	Unlikely (3)	Negligible
6	Localised erosion at discharge points	Minor (1)	Unlikely (3)	Negligible
7	Impacts to Aquatic Ecology from change in flow regime	Minor (1)	Unlikely (3)	Negligible
8	Impacts to Aquatic Ecology from inappropriate water quality discharge	Minor (1)	Unlikely (3)	Negligible
Salt Encapsulation				
9	Contamination resulting from brine pond overflows	Critical (5)	Beyond Remote (0)	Negligible
10	Contamination resulting from brine pond seepage	Moderate (2)	Unlikely (3)	Low

Of the 10 identified key environmental risks assessed, all but one was subsequently reduced to negligible rankings with the effective implementation of proposed mitigation measures. The negligible rankings were predominantly due to water treatment commitments and the assimilation of discharges to reflect existing flow regimes and limited volumes of continuous flows.

9. Conclusion

Australia Pacific LNG has adopted an adaptive approach to managing associate water considering distribution complexities, supply contractual negotiations, project development and production timeframes, as well as legislation, policy and environmental impacts.

An Initial Case has been established to focus on delivery of a sustainable management option that can be readily applied using existing technologies and customers. Australia Pacific LNG will optimise commercial and beneficial water use over time. This AAWMP will be subsequently updated and provided to the relevant regulatory agencies as the options are developed.

A five step rational decision model was adopted for the appraisal and selection of an Initial Case for associated water management. The model commenced with defining the situation and was continued by developing ideas through internal and external investigation processes (evaluating issues using two recognised management process). The process concluded with the final selection.

Two management options were selected for the management of permeate, whilst a single salt management option has been proposed for Initial Case of the Project. The concept design of the Initial Case for management of associated water is as follows:

- A low pressure water collection system delivering water to a series of central locations
- Short-term storage ponds to facilitate initial water treatment and operational flexibility
- A water treatment facility to treat the water to a standard suitable for use in the respective management option
- Australia Pacific LNG owned and operated agricultural use, complemented with negotiated water supply to existing agricultural ventures
- Opportunistic discharge of high quality treated water to major watercourses, as to cause minimum environmental impact, considering seasonal and annual variations
- Brine evaporation ponds to be encapsulated following end of use

An indicative program for development of these preferred options is in the order of three to five years; however Australia Pacific LNG considers the early implementation of these options to be beneficial socially, environmentally and economically. Current efforts are continuing to pursue alternative beneficial uses for associated water management. The rapid development of this Project will also result in increasing pressure to define management options, for their early implementation. A number of key milestones/dates have been established to ensure the beneficial use options are implemented during the transitional period. Six options are currently targeted for further development:

Water supply to industrial use: - Negotiations are proceeding with industries such as the existing and proposed mines and power stations in the Surat basin.

Potable water supply: - Working with the Western Downs Regional Council to study options to make water available to Miles and towns near the gas field development.

Agricultural Use: - Further to the proposed irrigation ventures proposed in Initial Case, agricultural options will provide greater benefit and will incorporate local existing agricultural ventures.

Aquifer Injection: - A series of alternatives have been proposed for investigation, including both permeate and blended associated water. Studies are currently underway and trials are planned for 2010, subject to regulatory approval.

Innovative Technologies: - Despite the required technological advances, the beneficial use options Solar Pond Power Generation and Algae Management require further investigation.

Salt Recovery: - The possible future use of salt recovery processes to reduce waste products is to be developed with trials proposed for 2010-2011 using brine concentration.

Key environmental risks associated with the Initial case management approach were evaluated using the agreed risk assessment framework. The assessment identified 10 environmental key risks, all but one were subsequently reduced to negligible rankings with the implementation of mitigation measures. The substantial reduction in risk was predominantly due to water treatment commitments, and the assimilation of discharges to reflect existing flow regimes and continuous flows limited to short-term time periods.

Although risks are mostly negligible, further efforts to reduce or eliminate environmental risk in relation to associated water are to be undertaken. Australia Pacific LNG intends to adopt a continuous improvement approach in all aspects of associated water management. This AAWMP will be used to establish a strategic planning framework promoting active response to monitoring results, regulatory change and outcomes of stakeholder engagement.

Bibliography

AECOM (July 2009). Feasibility Study for Aggregation of CSG Water.

Australian and New Zealand Environment and Conservation Council (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Artarmon: Australian Water Association.

Australian Government (2009, 5 13). Australian Natural Resource Atlas. Retrieved from Groundwater Management Unit: Great Artesian Basin - Surat - Queeensland: http://www.anra.gov.au/topics/water/availability/qld/gmu-great-artesian-basin-surat-queensland.html

Australian Government- Department of the Environment, Water, Heritage and the Arts (2009, August 29). Water for the Future. Retrieved from Great Artesian Basin: http://www.environment.gov.au/water/locations/gab/index.html

Bureau of Rural Sciences Australia / Queensland Government- Department of Natural Resources and Mines (September 2003). Groundwater Recharge in the Great Artesian Basin Intake Beds, Queensland.

Conics (December 2009). Good Quality Agricultural Land, A Discussion.

Conics (October 2009). Good Quality Agricultural Land, Impact Assessment, Australia Pacific LNG Project.

CSIRO (2008). Water Availability in the COndamine-Balonne, A report to the Australian Government from the CSIRO Murray - Darling Basin Sustainable Yields Project.

Golder Associates (September 2008). Groundwater Impact for the Coal Seam Gas Operations, Chinchilla, Surat Basin.

Great Artesian Basin Consultative Council (September 2000). Great Artesian Basin, Strategic Management Plan. Canberra.

Hennig, A (June 2005). A Summary of the Hydrogeology of the Southern Eromanga and Surat Basins of the Great Artesian Basin. Bentley, Western Australia: Innovative Carbon Technologies Pty Ltd.

Origin Energy (April 2008). Walloons Water Management Strategy.

Parsons Brinkerhoff (August 2008). Coal Seam Gas (CSG) Water Strategic Options Analysis.

Parsons Brinkerhoff (August 2004). Coal Seam Gas Water Management Study.

Parsons Brinkerhoff (December 2007). Coal Seam Gas Water Management Study Urban and Industrial.

Parsons Brinkerhoff (September 2008). Surat Basin Water Grid Briefing Paper.

Queensland Government (2000). Environmental Protection (Waste Management) Policy. Environmental Protection Act 1994 .

Queensland Government (2000). Environmental Protection (Waste Management) Regulation. Environmental Protection Act 1994 .

Queensland Government (2009). Queensland Water Quality Guidelines. Department of Environment and Resource Management.

Queensland Government (2000). Water Act.

Queensland Government, Department of Employment, Economic Development and Innovation, LNG Industry Unit (August 2009). Blueprint for Queensland's LNG Industry.

Queensland Government, Department of Infrastructure and Planning (May 2009). Management of water produced from coal seam gas production - Discussion Paper.

Queensland Government, Department of Infrastructure and Planning (May 2009). Management of water produced from coal seam gas production. Discussion Paper .

Queensland Government, Department of Natural Resources and Water (December 2008). Condamine and Balonne Resource Operations Plan.

Queensland Government, Department of Natural Resources and Water (February 2007). Great Artesian Basin - Resource Operations Plan.

Queensland Government, Department of Natural Resourses and Mines (2005). Hydrogeological Framework Report for the Great Artesian Basin Water Resource Plan.

Queensland Government, Environmental Protection Agency (December 2007). Management of Water Produced in Association with Petroleum Activities (Associated Water) - Operational Policy.

S. Brizga & Associates et al. (January 2008). Preliminary Discharge Assessment – Walloons Coal Seam Gas Development.

The Coordinator - General (December 2009). Terms of reference for an environmental impact statement; Australia Pacific LNG Project. Queensland Government, Department of Infrastructure and Planning.

WorleyParsons (June 2009). Aquifer Injection of CSG Production Water - Phase 1 Prefeasibility Assessment.

WorleyParsons (July 2009). Australia Pacific LNG Project - Associated Water Management Option Assessment.

WorleyParsons (August 2009). Australia Pacific LNG Project - EcoNomics Assessment of Sustainable Water Management Strategies.

WorleyParsons (August 2009b). Saline Water Management Study.

Wylie, P. (September 2007). Coal Seam Gas - Water Management Study Agricultural Use.

Appendix A Abbreviations

AAWMP	Adaptive Associated Water Management Plan (AAWMP)
APPEA	Australian Petroleum Production and Exploration Association
CSG	Coal Seam Gas
DA	Development Approval
DERM	Department of Environment and Resource Management, Queensland Government (previously EPA)
DIP	Department of Infrastructure and Planning, Queensland Government
EA	Environmental Authority
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EP	Environmental Protection
EPA	Environmental Protection Authority, Queensland Government (now DERM)
ERA	Environmentally Relevant Activities
GAB	Great Artesian Basin
LNG	Liquefied Natural Gas
ML	Mega Litre
ML/d	Mega Litre per Day
P&G	Petroleum and Gas (Act)
QLUMP	Queensland Land Use Mapping Program
RO	Reverse Osmosis
ROP	Resource Operations Plan
RUP	Resource Utilisation Plan
SAR	Sodium Adsorption Ratio
TDS	Total Dissolved Solids
ToR	Terms of Reference
TSS	Total Suspended Solids
WCM	Walloons Coal Measures
WTF	Water Treatment Facility