South Burnett Regional Council

ECONOMIC ROAD MAP

Transforming the region

November 2022

South Burnett

Economic Road Map

Adopted by Council at the Ordinary Meeting of 23 November 2022 – Resolution: 2022/255

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Revision History

Revision	Date	Comment	Originated by	Checked by	Technical Approval	Project Approval
1	7 October 2022	Initial Draft Report	Matt Bradbury	Angus MacDonald	Chris Hewitt	Matt Bradbury
2	25 October 2022	Draft Report	Matt Bradbury	Angus MacDonald	Chris Hewitt	Matt Bradbury
3	15 November 2022	Final Report	Matt Bradbury	Angus MacDonald	Chris Hewitt	Matt Bradbury

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1 Executive Summary

1.1 ROAD MAP TOWARDS A STRONG REGIONAL ECONOMY

The South Burnett region has great agricultural potential. Developing this potential can at the same time support Queensland's transition to a cleaner-energy state. This economic road map describes how to support the economy and provides jobs while the region transitions from coal fired power generation to become a renewable energy hub.

This Economic Road Map will create 732 jobs and $111 million of additional annual agricultural production.

The Queensland Government’s Energy and Jobs Plan seeks to deliver more jobs, more industries, affordable power, lower emissions and stronger growth. This plans includes the following targets.

50% renewable energy by 2030	30% emission reduction by 2030	Net zero emissions by 2050

Tarong power stations provides 1,843 MW of firming coal generation. The State Government target to achieve no regular reliance on coal generation by 2035 will trigger further opportunities for economic diversification in the sectors of manufacturing and agriculture in the South Burnett. The Economic Road Map seeks to bolster these opportunities and minimize any significant social and economic disruption triggered by the eventual closure or transition of the site.

On 28 September 2022, the Premier of Queensland announced the Energy Workers Charter and Jobs Security Guarantee.[1] This commitment ensures that workers will have the opportunity to continue careers within the publicly owned energy businesses or elsewhere in the public sector.

The Premier has pledged not to leave regional workers or communities behind, and to work with communities to develop regional economic futures strategies for regions with existing coal plants.

This Economic Road Map has been developed under the leadership of the South Burnett Regional Council and represents the best way for the South Burnett to transition to a new, green economy. As the Energy Plan delivers energy security, this road map will deliver food security for a growing South East Queensland population and local employment for transitioning workers.

The South Burnett has substantial opportunity to become an agricultural powerhouse, feeding locals and establishing new export markets. The region has the right soil, favourable climate, growing markets and generations of farming expertise. The only limitation is water availability.

However, by using approximately one third of the water stored in Boondooma Dam currently used in the coal-fired power station, and $300 million of additional investment, four new water schemes could be developed. This commitment will result in a new agricultural powerhouse.

[1] A Palaszczuk, *Energy and Jobs Plan: Premier’s 2022 State of the State address*, media release, Queensland Government, 28 September 2022.

Local jobs retained	Thriving communities	Urban Water Security	$67M of annual agricultural production	4 new water schemes	Net Zero Agriculture

1.2 IDENTIFYING OPPORTUNITIES

In November 2018, the Australian Government announced a grant via the National Water Infrastructure Fund to conduct a feasibility study to examine a range of options to increase water supply, reliability and security, which would underpin an expansion of irrigated agriculture and deliver new jobs and economic growth in the North Burnett and South Burnett regions.

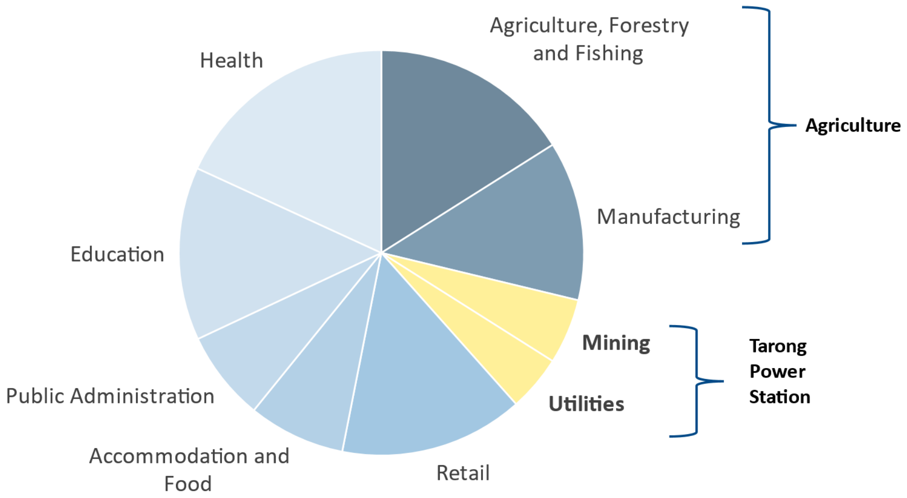
Using this funding, the South Burnett Regional Council[2] commissioned a strategic business case and an options analysis which identified many opportunities to increase agricultural production and urban resilience, which will generate substantial economic value.

A key aspect of this process is the recognition that the transition of Tarong Power Plant in 2035[3] will generate both risks and opportunities for the region.

1.3 THE FUTURE OF THE SOUTH BURNETT

Currently, approximately 30% of jobs are in agricultural production and food processing. A further 9% of employment is provided by Tarong Power Station and the associated Meandu mine.

Figure 1.1 South Burnett employment

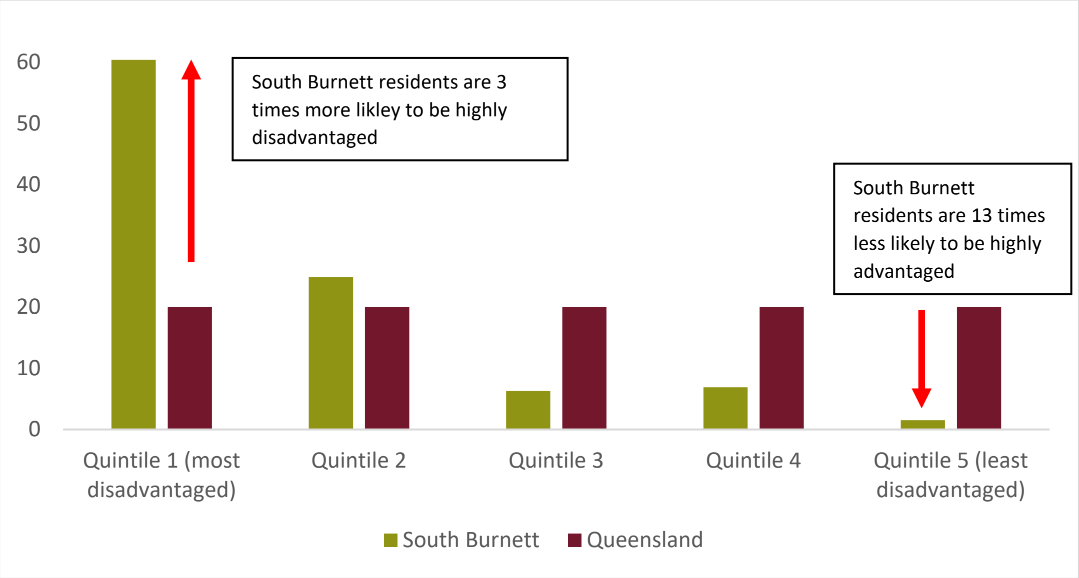


South Burnett unemployment is typically higher than the Queensland or national average – in some years over 4% higher. Although unemployment in the South Burnett follows a similar trend as in Queensland, when Queensland unemployment increases, South Burnett unemployment increases at a more pronounced rate.

The people and economy of the South Burnett are disadvantaged, relative to the rest of Queensland. Residents are three times as likely to be in the most disadvantaged quintile and 13 times less likely to be in the most advantaged quintile.

[2] The studies were undertaken jointly with the North Burnett Regional Council.
[3] A Palaszczuk, *World's biggest pumped hydro for Queensland*, media release, Queensland Government, 28 September 2022.

Figure 1.2 Comparison of socio-economic disadvantage

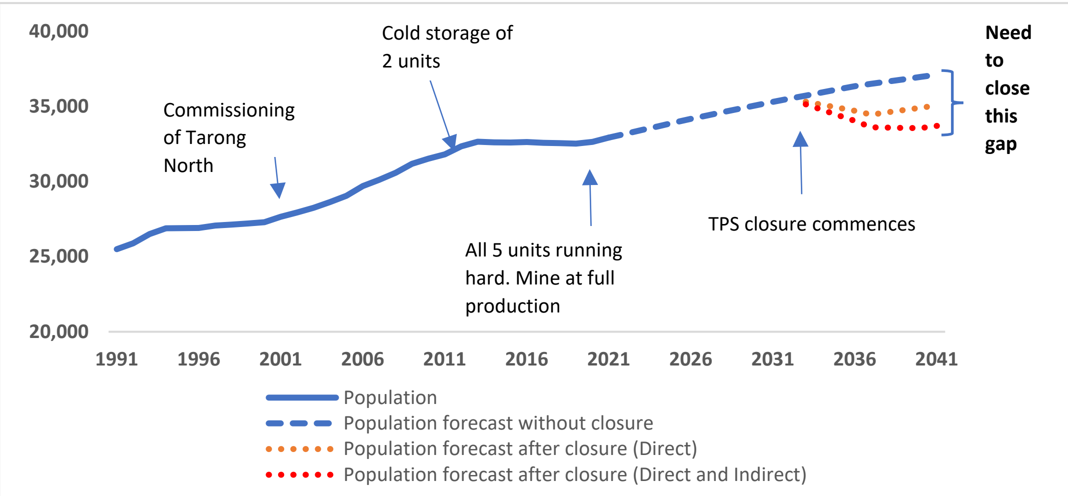


1.4 TARONG POWER STATION

In addition to the current challenges, the state-owned Tarong Power Station is scheduled to transition to a clean energy hubs to provide critical system strength, storage, and firming services rather than coal-fired generation by 2035. Governments around the world have committed to decreasing carbon dioxide emissions. In Australia, the government recently renewed its commitment to the Paris Agreement, pledging a reduction of emissions by 43% by 2030, and to net zero emissions by 2050.[4] In order to achieve this goal, across Australia almost all coal power stations are being phased out over the next 20 years.

In the South Burnett, the Tarong West Wind Farm windfarm has been announced. However, this $776 million project will provide only 15 ongoing direct jobs. Renewal energy projects tend to employ fewer people than fossil fuel power generation. While there will likely be some transition of existing workers from the power station to the energy hub, the mine workers will require alternative employment opportunities.

Figure 1.3 Forecast population if Tarong Power Station closed without replacement industry



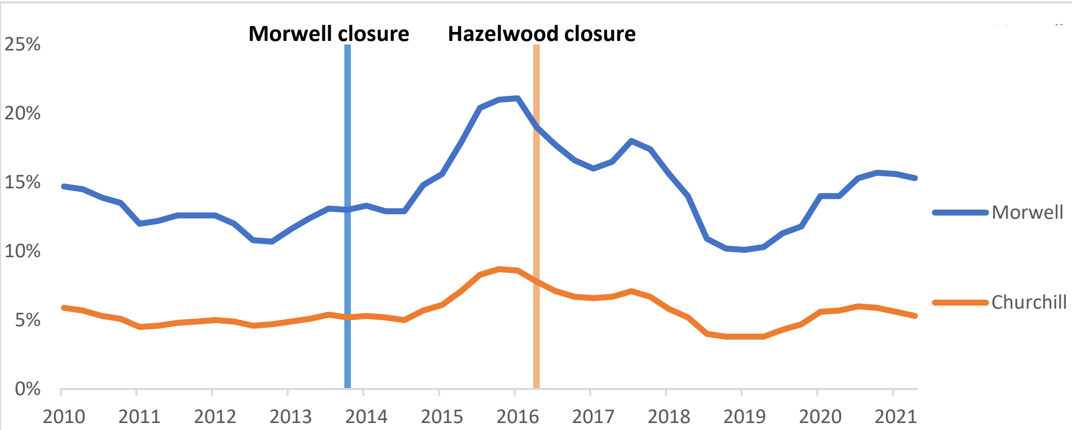
[4] (Department of Industry, 2022)

Tarong Power Station and the Meandu mine employ 732 people. The transition and closure of these assets will result is a substantial decline in employment, population and regional prosperity.

As direct jobs are lost, a further 545 local indirect jobs would be lost, leading to a total loss of population between 2,000 and 3,500.

In August 2014, the 189 MW Morwell Power Station closed, which gave insight about the regional impact of a power station closure. There was no transition assistance, and regional unemployment increased rapidly from 13% to 21%. In November 2016, the federal government announced that the neighbouring Hazelwood Power Station would close in March 2017. At this time, both the Commonwealth and Victorian government's announced assistance packages. Figure 1.4 shows the effectiveness of the transition package as the unemployment rate in the neighbouring Morwell decreased, and unemployment remain fairly constant in Hazelwood.

Figure 1.4 Latrobe Valley unemployment rate from 2010 to 2021 (%)



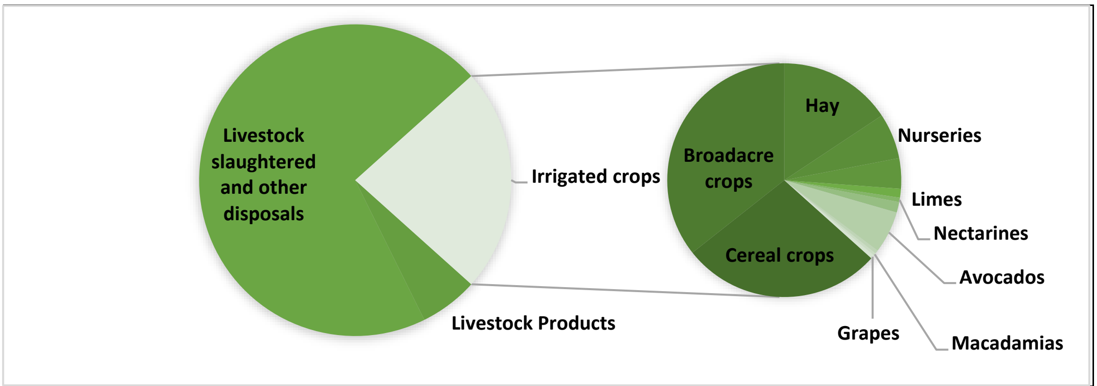
Note: Hazelwood power station was included within Churchill SA2.

This shows that the $734 million assistance package was very effective. The importance of planning appropriate regional support in advance of Tarong's transition will be advocated by the South Burnett Regional Council.

1.5 JOB-CREATING WATER INFRASTRUTURE

The Tarong Power Station has access to 30,000 ML of water from Boondooma Dam. Once the power station transitions to an energy hub, a suitable option is to use this water to create employment. The South Burnett has an abundance of excellent soil, growing conditions and generations of farming experience. The region already produces $360 million of agricultural production, with emerging export opportunities through the existing transport infrastructure.

Figure 1.5 Agricultural output in the South Burnett

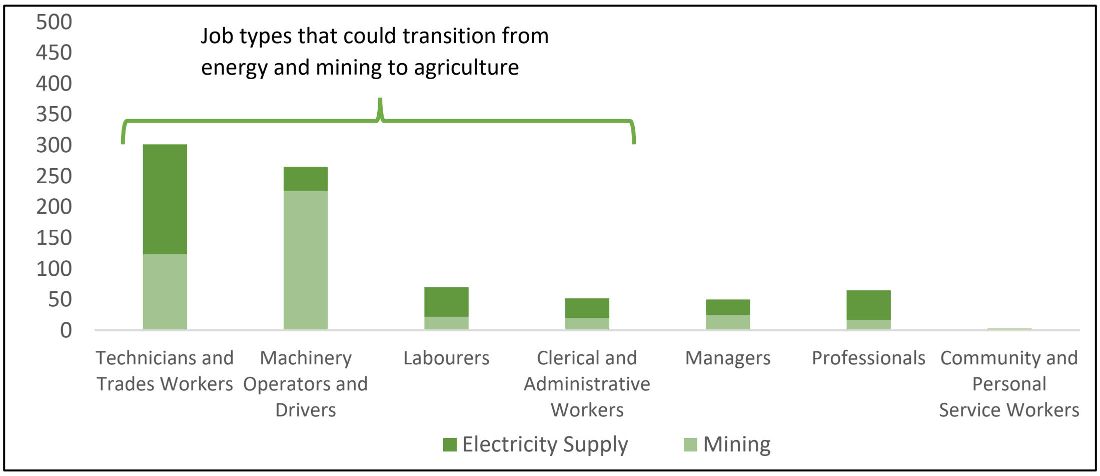


While other industries could support the transition to a clean future, agriculture is a proven job creator. By contrast, renewal energy projects create relatively few jobs. For example, the State Government has committed $776 million to the Tarong West Wind Farm to construct 150 turbines. This investment will create 15 direct ongoing jobs. By contrast, investing in water projects and agriculture, will create substantially more jobs for substantially less money.

This investigation has confirmed the viability of specific agricultural proposals that will employ locals and provide local food security and increase export opportunities. These proposals will replace the jobs lost and add $100 million to local agricultural production.

The majority of jobs to be lost at Tarong are technicians, tradespeople and machinery operators and drivers. These types of jobs are critical to modern farms where there is an increasing need for qualified machine operators and to maintain sophisticated equipment.

Figure 1.6 Jobs that could transition to agriculture



This report outlines the initial proposals to develop irrigation schemes in the South Burnett. These schemes were identified through a comprehensive Options Analysis conducted in 2020.

These three schemes include:

- Build Barlil Weir: creates 3,000 ML of 90% reliable water.
- Convert Gordonbrook into an irrigation scheme to provide 1,800 ML
- Build the Blackbutt irrigation network to supply 2,000 ML

Table 1.1 Summary of new irrigation schemes

	Barlil Weir	Gordonbrook Dam	Blackbutt irrigation
Total benefits ($M)	24.0	33.6	34.4
Total costs ($M)	12.9	28.8	24.2
Net present value ($M)	11.1	4.8	10.2
New ongoing jobs	24	154	116
Water from Boondooma	0	540	2,020
Benefit–cost ratio (BCR)	**1.86**	**1.17**	**1.42**

In addition to these projects, the remaining jobs can be created through building further irrigation infrastructure supplied by the existing Boondooma Pipeline supporting irrigation of high value agriculture utilising 8,000 ML of existing high priority allocation.

Further investigation is required to determine the exact location of the water projects. However, given the amount of highly productive soil near the existing pipeline, it is envisaged that a number of small spurs could be added to create supply nodes.

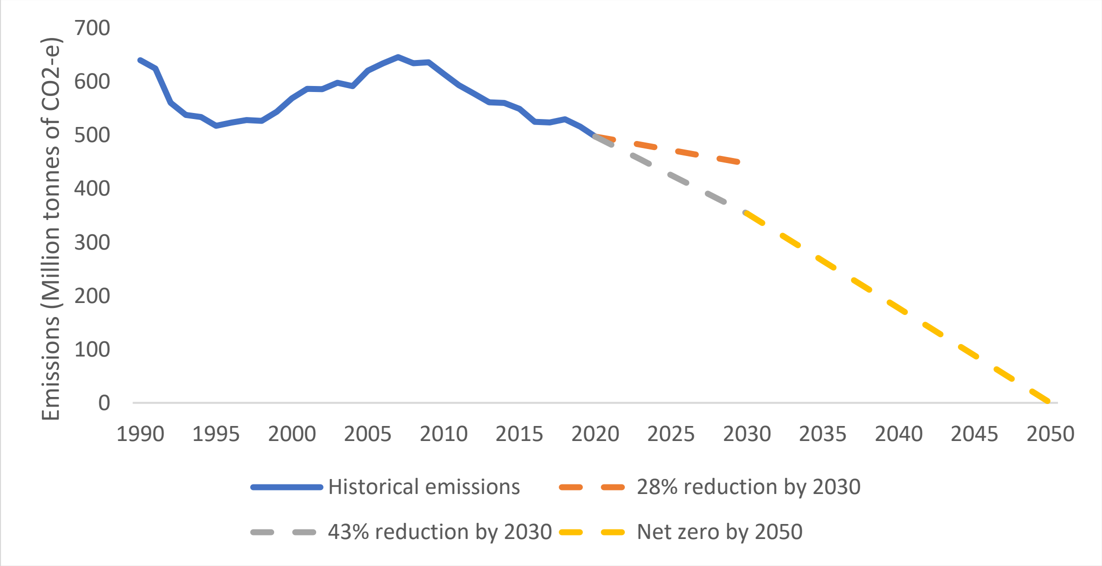
The next phase of the investigation is to identify the exact location of these projects, and confirm project viability.

1.6 NET ZERO AGRICULTURE

To meet the Government's commitments to Net Zero, these project can be built and operated on Net Zero principles, ensuring that these long life assets contribute to the Government's objectives

The Government has committed to an emission reduction. It is important that new projects that are seeking Government funding align with the commitment.

Figure 1.7 Australian emissions targets



The annual emissions for the three specific projects has been calculated to be 27,230 t of CO_2. The following outlines how these emissions can be reduced.

Table 1.2 Infrastructure emissions

Categories	Description	Example of emissions mitigation
Embodied	Production of materials used in the construction of infrastructure, as well as those from the construction process itself	• Carbon neutral or recycled plastic pipes • Green steel • Electric construction vehicles using renewable energy • Carbon offsets
Operating	Ongoing operations of infrastructure assets	• Electricity sourced from renewable energy • Carbon offsets • On-site vehicles that use fossil fuels
Enabled	Activities of infrastructure's end-users	• Soil and tree carbon projects • Emissions reduction technologies for animal protein production • Electricity from renewable energy

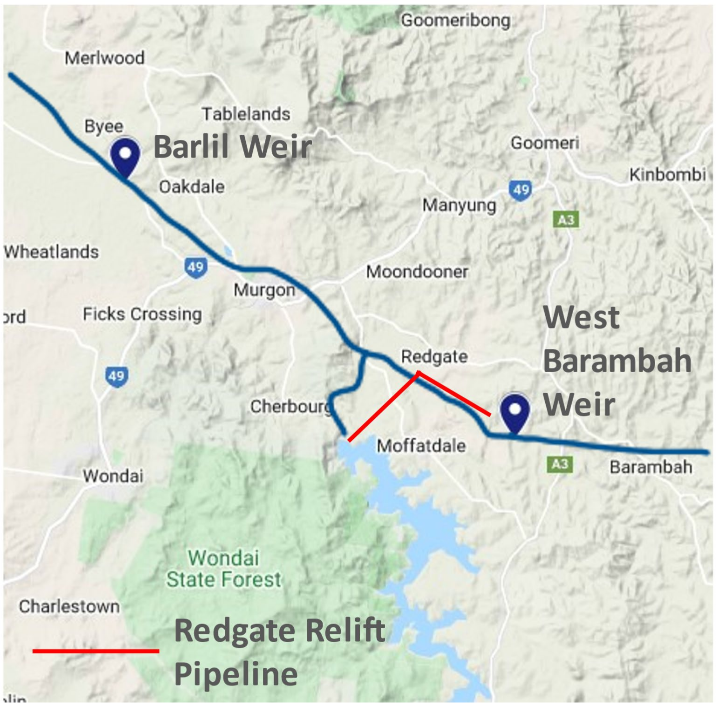
1.7 BARLIL WEIR

Customers of Sunwater's Barker Barambah Water Supply Scheme have experienced low water reliability. This constrains their ability to invest and transition towards higher-value crops that require a secure water source.

The scheme currently supports approximately 30,000 ML of medium priority water allocations with a long-term historical reliability of 78%. Building additional storage will increase reliability to 90% for some water allocations.

Irrigators support converting a relatively small amount of existing medium priority water allocations into medium priority plus (MP+) water allocations. Such a conversion would increase the reliability of this water from 78% to 90%.

Constructing Barlil Weir alone would allow for 3,000 ML of water allocations to be converted to MP+. This is approximately 10% of the scheme's volume. Constructing West Barambah Weir in addition to Barlil Weir would allow approximately 5,500 ML to be converted to MP+.



A demand assessment was conducted for MP+. This assessment identified demand for up to 8,000 ML of MP+. Some of the demand is on the Barambah Creek, which could be supplied either through the construction of West Barambah Weir, or through the construction of Barlil Weir only, with the water piped through the existing Redgate Relift.

This additional reliability would allow some irrigators to transition from broadacre crops to high value crops such as wine grapes, olives and garlic.

Barlil Weir is estimated to cost $13.1 million, while the West Barambah Weir would cost $22.5 million. As Barlil Weir provides more MP+ at a lower cost, it is the preferred site, at this stage of the investigation.

Table 1.3: Economic analysis results

	Barlil Weir	West Barambah Weir	Combined total
Total benefits ($ million)	24.0	14.6	38.6
Total costs ($ million)	12.9	21.2	34.1
Net present value (NPV) ($ million)	11.1	(6.6)	4.5
New ongoing jobs	24	24	48
Benefit–cost ratio (BCR)	**1.86**	**0.69**	**1.13**

It is recommended that a detailed business case be conducted for additional storage/s on Barambah Creek.

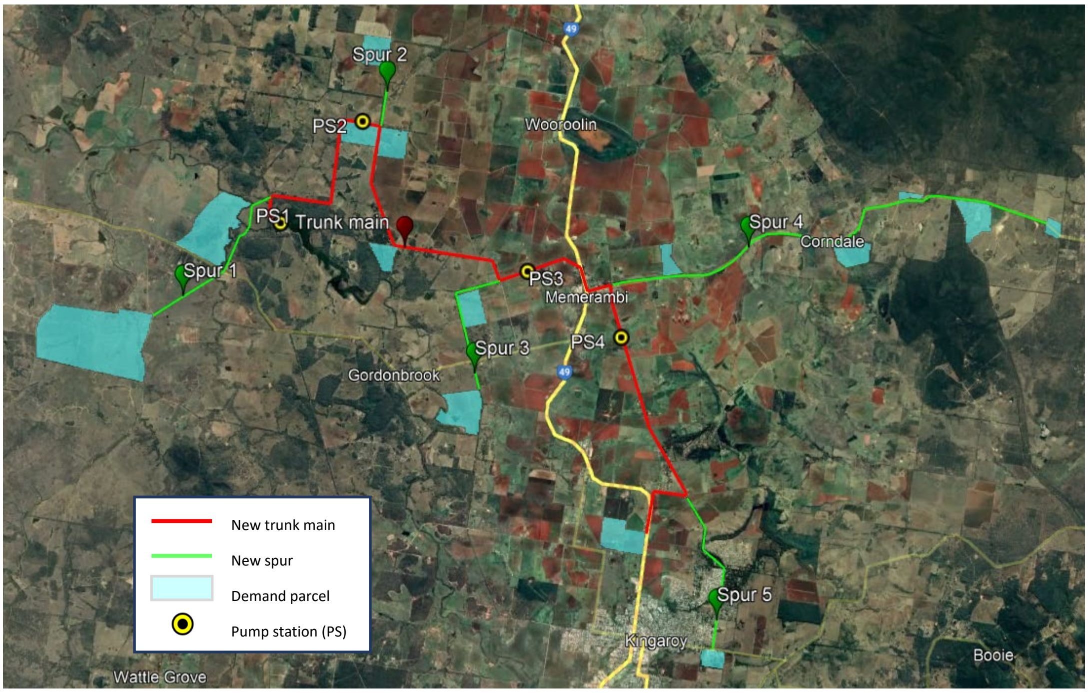
1.8 GORDONBROOK DAM

Gordonbrook Dam supplements urban water security for Kingaroy. However, there are very significant water quality issues that are costly to treat and that limit the ability to take water.

The Queensland Government's Regional Water Supply Security Assessment found that Kingaroy's urban supply could expect to experience water supply failures once every 13 years. To improve this low level of urban water security, additional water allocation needs to be acquired from Stanwell.

Once acquired, Gordonbrook Dam could be converted to irrigation use. The water quality issues that limit urban use are much more manageable for irrigation use.

A demand assessment found demand for up to 8,400 ML of water. This substantially exceeds the 1,809 ML that is available.



A pipeline network was designed to deliver water to the identified potential customers. The 54 km network will take water to 40 farms. The energy for pumping will be provided by a 480 kW solar farm, contributing to the government's net zero targets. The pipeline will cost $20.3 million.

The water will be used for high value purposes such as dairy, feedlots and pig production. This will create strong economic benefits.

Table 1.4: Economic analysis results

	Gordonbrook irrigation network)
Total benefits ($ million)	**33.6**
Total costs ($ million)	28.8
Net present value (NPV) ($ million)	4.8
New ongoing jobs	154
Benefit–cost ratio (BCR)	**1.17**

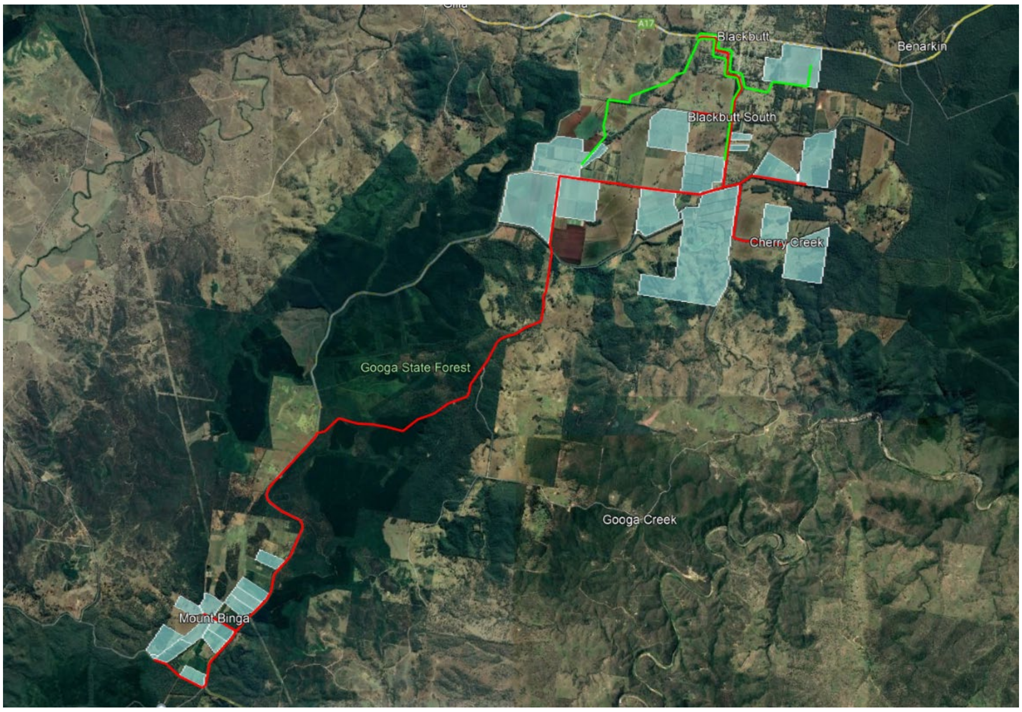
It is recommended that the South Burnett Regional Council commence acquiring water allocations from Stanwell, and undertaking binding water sales for potential Gordonbrook customers.

1.9 BLACKBUTT IRRIGATION

Blackbutt is a highly productive agricultural area 35 km south of Nanango. There is currently some access to a pipeline that brings water from Boondooma Dam. This assessment considered whether it was viable to increase the water supply to a broader group of irrigators through an irrigation network.

The demand assessment found that there is demand for up to 2,020 ML of additional water. Two supply options have been considered in delivering water to the region:

- a 24 km distribution network delivering water to customers in the Blackbutt and Mount Binga areas
- a 12 km distribution pipeline network delivering water to customers in the Blackbutt area only.



The total network, including a solar farm, pump stations and pipes would cost approximately $15 million and produce up to $13 million of additional annual agricultural production.

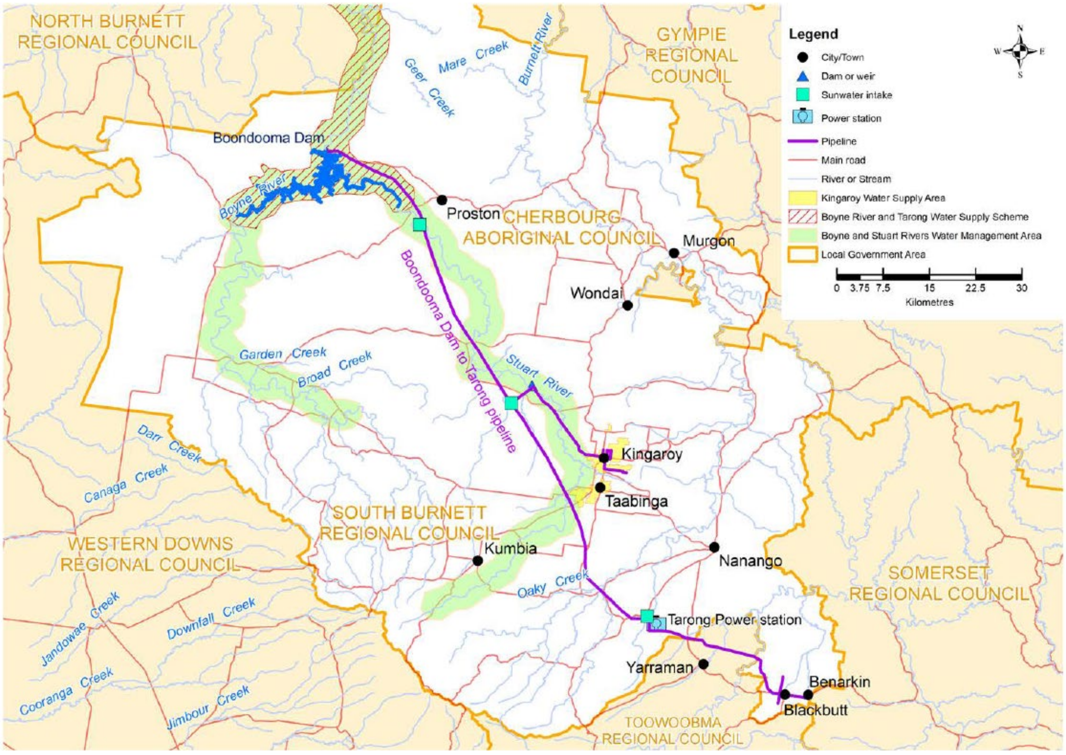
Table 1.5: Economic analysis results

	Scenario 1 – Blackbutt & Mount Binga	Scenario 2 – Blackbutt only
Total benefits ($ million)	34.4	**27.6**
Total costs ($ million)	24.2	15.9
Net present value (NPV) ($ million)	10.2	11.7
New ongoing jobs	**116**	93
Benefit–cost ratio (BCR)	**1.42**	**1.73**

It is recommended that the South Burnett Regional Council commence acquiring water allocations from Stanwell, and undertaking binding water sales for potential Blackbutt customers.

1.10 BOONDOOMA PIPELINE

Three projects have been identified and shown to be viable. Once built, and fully operational, these schemes will employ 296 people. To replace the jobs lost through Tarong's transition to an energy hub, a further 436 jobs need to be created. It is proposed to access water through the Boondooma pipeline that already runs through the area.



To create additional jobs, approximately 8,000 ML (out of 30,000 ML) is needed. There is 61,459 hectares of land suitable for horticulture, which is much more than is needed.

We have identified a range of crops and agricultural processes that could provide additional employment and sustainable agricultural production. Expansion of meat processing will provide additional employment and create substantial economic activity.

Further investigation is required to determine the exact location of the water projects.

To meet the Government's commitments to Net Zero, these project can be built and operated on Net Zero principles, ensuring that these long life assets contribute to the Government's objectives.

1.11 CONCLUSIONS AND NEXT STEPS

If no action is taken, the population of the South Burnett will decline by 10% if Tarong Power Station closes without a replacement industry. However, the Queensland Government's Energy Workers Charter and Jobs Security Guarantee will ensure that workers will continue to be employed, albeit in a different capacity.

The Premier has pledged to work with communities to develop regional economic futures strategies. The South Burnett seeks to leverage its advantages and expand its agricultural sector. This will rapidly create employment, by using some of the water currently used for energy generation.

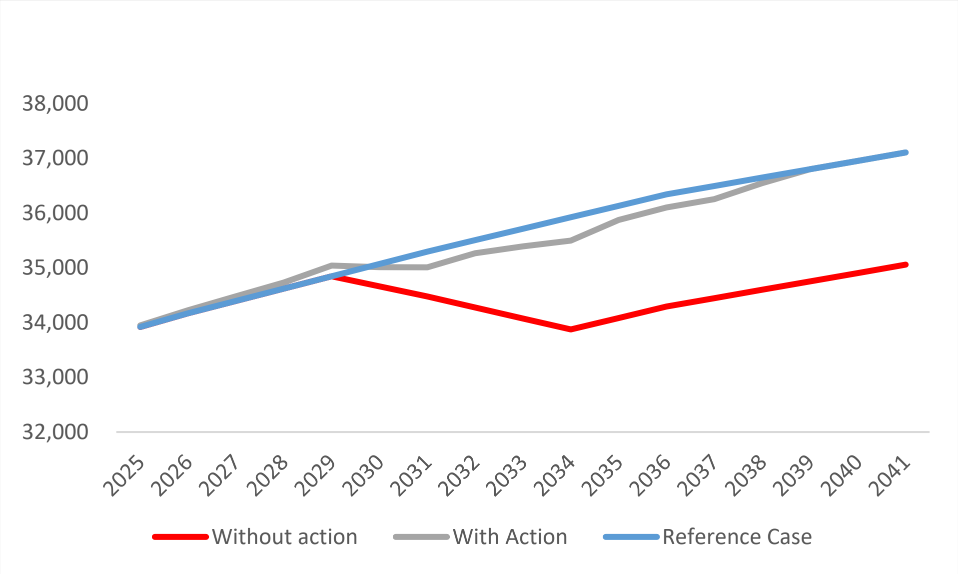
The implementation plan is summarised below.

Table 1.6 – Implementation plan

Action	Timing	Cost
Establish a local body to oversee transition works and to identify the additional water projects	Commence in 2023 and operate until after the transition is complete	$4 million per year
Complete a detailed business case that examines the package of projects: • Barlil Weir • Gordonbrook irrigation network • Blackbutt irrigation network If the project is determined to be viable, gain environmental and planning approvals	2023–24	$5 million for the detailed business case and approvals; $1 million for geotechnical investigations
Commence preconstruction activities: • Finalise approvals • Complete a Detailed design • Prepare tendering documents • Tendering	2024–2025	$10 million
Construct schemes	2025–2030 It is proposed to stagger construction activities, to allow for a sustainable construction effort, with local contractors working on several projects across several years	$150 million
Worker transition	Assist energy workers and miners to transition into a future of clean energy and sustainable agriculture	$25 million
Community assets and urban water resilience package		$75 million
Total		**$300 million**

If this action is taken, the population decline can be averted.

Figure 1.8 Population in the South Burnett



Recommendations

It is recommended that:

1. The Queensland and Commonwealth Government's provide $300 million to allow for the South Burnett to invest in job creating water infrastructure and community projects.
2. South Burnett Regional Council continue negotiations with the State Government and Stanwell about acquiring 11,000 ML of Water Allocations. These allocations should be provided incrementally to allow for gradual increase in agricultural production during the period of transition
3. The Queensland Government apply to the Commonwealth for funding to allow for the completion of a regional Detailed Business Case to finalise investigations on additional storage on Barambah Creek, Gordonbrook Irrigation Network and Blackbutt Irrigation Network
4. The Queensland Government establish a regional body to oversee the transition. This body would have oversight of:
    a. The Detailed Business Case
    b. Identifying future water projects for job creation
    c. Pre-construction works for the projects
    d. Construction
    e. Worker transition assistance
    f. Community assets and urban water resilience.

2 The future of the South Burnett

2.1 KEY POINTS

- The future of the South Burnett region is at a crossroads. How the region prepares for the transition of Tarong Power Station will influence whether the region will prosper or whether it will decline.
- The people and economy of the South Burnett are disadvantaged, relative to the rest of Queensland. The South Burnett has perpetually higher unemployment that the rest of Queensland, and neighbouring areas. Most residents (60%) are in the most disadvantaged socio-economic quintile. Only 1.5% of residents are in the least disadvantaged quintile. Population has stagnated.
- Adding to these challenges, the 1,843 MW coal-fired Tarong Power Station will transition to an energy hub in order for Australia to meet its climate goals, including net zero emissions by 2050. The cost of climate change action should not be borne only by the regional communities with coal-fired power stations. Governments must take action to support transitioning communities.
- The South Burnett region relies on Tarong Power Station for employment, with the prosperity of the region dependent on the ramp-up and ramp-down of activities at the power station. The transition of the power station is forecast to reduce the population by approximately 10%.
- The cessation of the coal fired power generation will lead to a direct loss of 732 jobs, which if not replaced locally will reduce the region's population by up to 5,000 people. This will result in regional decline and further deterioration of socio-economic outcomes.
- However, the negative outcomes can be prevented. The region has strong comparative advantages, which could be further utilised with government support. Observations made when other power stations closed can form the basis of a blueprint for action.
- The region has a strong agricultural sector, due to the abundance of suitable soil, perfect growing conditions and generations of local agricultural expertise. However, further growth is constrained without access to additional water. The region could rapidly increase agricultural employment and production.
- Tarong Power Station has access to approximately 30,000 ML of very reliable water from Boondooma Dam. Once Tarong ceases coal fired power generation, this water can be used for alternative purposes. Stanwell owns the water allocations held in Boondooma Dam.
- Should approximately one third (11,000 ML) of the Boondooma Dam water be converted to irrigation use, then the 732 jobs lost from the power station can be replaced through modern agricultural enterprise, which requires many of the same skills of the existing Tarong workforce.
- Three distinct irrigation projects have been identified that have farming business ready to use the additional water and employ additional people.

2.2 CURRENT STATE

The South Burnett region currently experiences several challenges, with residents more likely to be unemployed, population growing slowly and residents are 3 times more likely to be highly disadvantaged than a typical Queenslander.

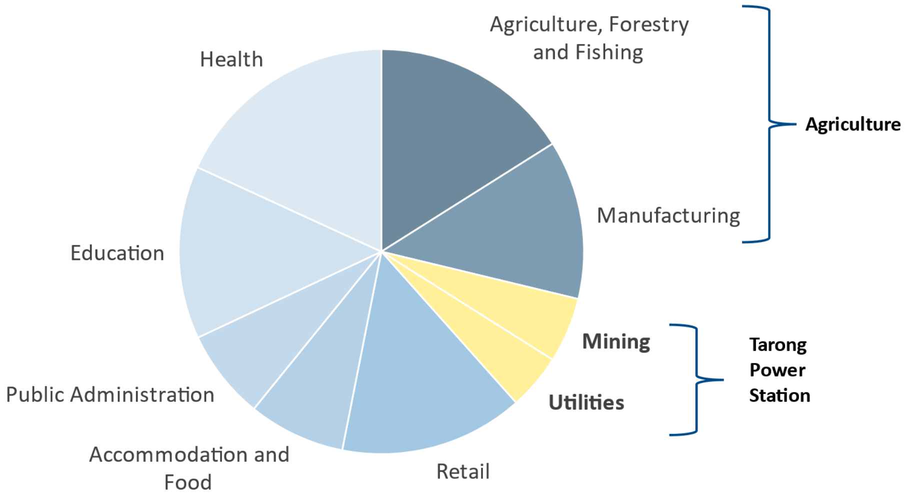
There are two dominant industries – agriculture and energy – but the energy industry is about to undertake a transition towards renewable energy. This will impact on jobs.

This section sets out the current conditions in the South Burnett, and the likely impact on the region of the transition of Tarong Power Station.

2.2.1 Employment

Currently, approximately 30% of jobs are in the agricultural production and food processing.[5] A further 9% of employment is provided by Tarong Power Station and the associated Meandu mine.

Figure 2.1 South Burnett employment

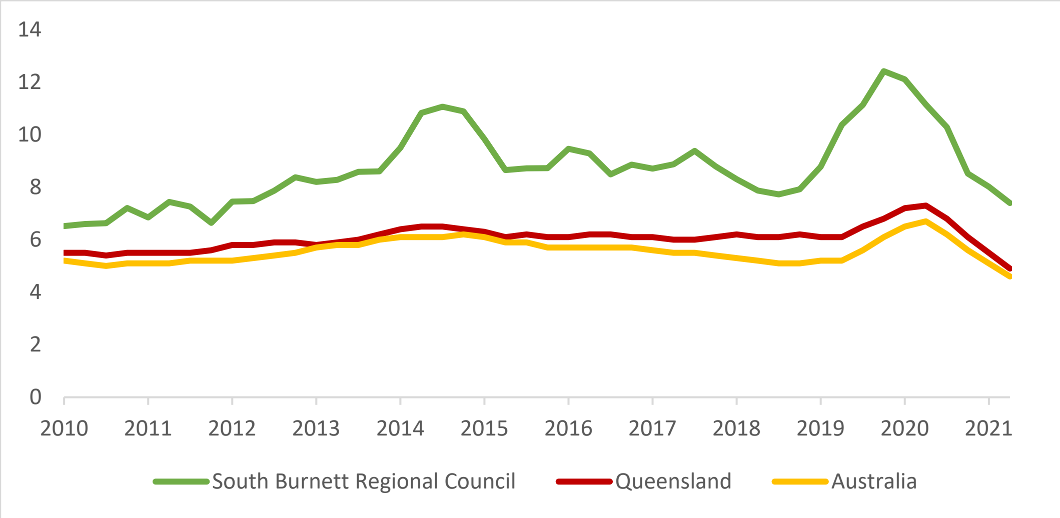


Source: ABS, Census of Population and Housing, Australia, cat no 2033.0.55.001.

South Burnett unemployment is typically higher than the Queensland or national average – in some years over 4% higher. Although unemployment in the South Burnett follows a similar trend pattern as in Queensland, when Queensland unemployment increases, South Burnett unemployment increases at a more pronounced rate.

[5]Food processing is classified as manufacturing by the ABS. See ABS, *Australian and New Zealand Standard Industrial Classification (ANZSIC) (Revision 1.0)*, 2006, cat no 1292.0.

Figure 2.2 Unemployment in the South Burnett



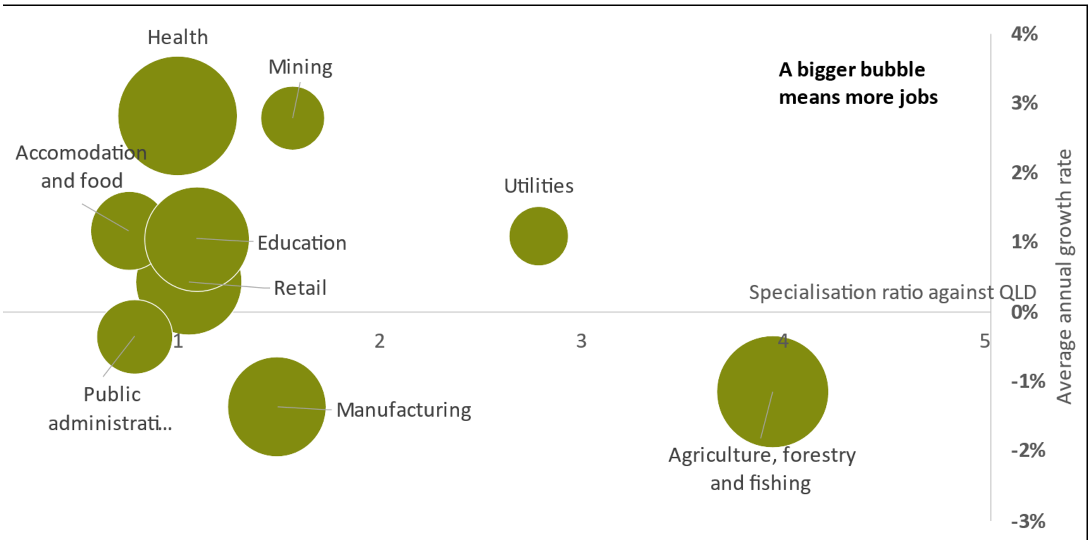
Source: ABC, Labour Force, Australia; National Skills Commission, Small Area Labour Markets, Australian Government, 30 June 2022.

Employment in the South Burnett, compared to the Queensland average, is more dominated by the agriculture and utilities.

Figure 2.3 shows that agriculture in the South Burnett employs four times as many people as the Queensland average. Likewise, utilities (including the Tarong Power Station) employ nearly three times the Queensland average.

While agriculture is a major employer, it has been experiencing a minor decline, as shown in its growth rate represented below the central axis (around a 1% decline annually).

Figure 2.3 Specialisation ratio in the South Burnett

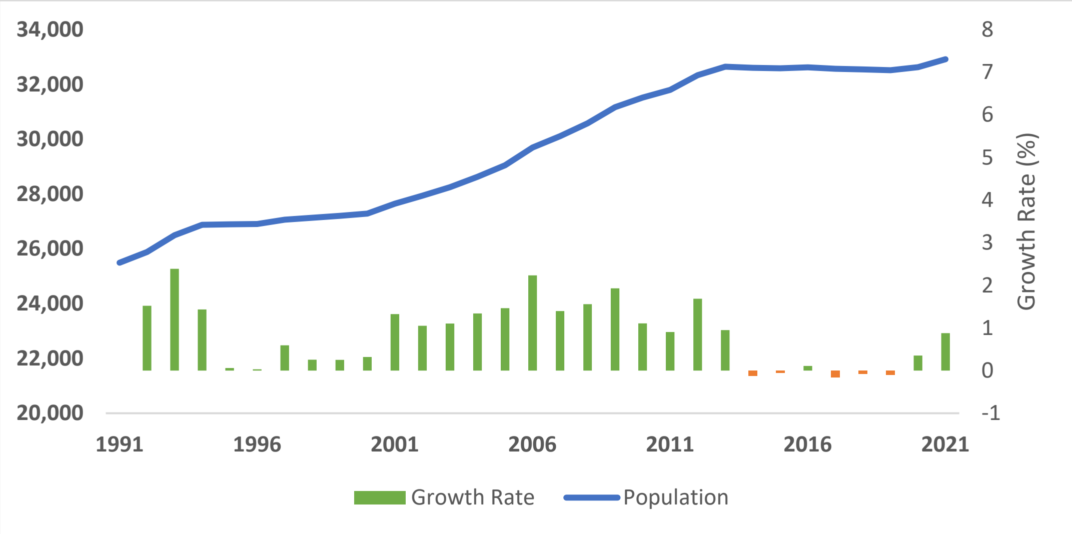


Source: ABS, Census of Population and Housing, 2011 and 2016, cat no 2033.0.55.001.

2.2.2 Population

Population in the South Burnett has grown at 0.9% annually over the past 30 years. This is much lower than the whole of Queensland average of 1.9%.

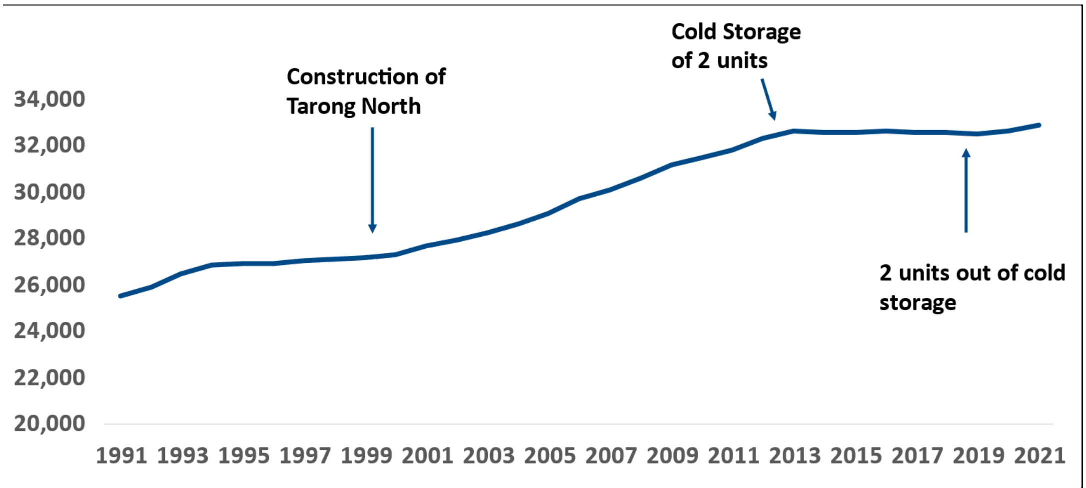
Figure 2.4 Population growth in the South Burnett



Source: ABS, Regional Population by age and sex, regions of Australia, cat no 3235.0. 2021

Within this 30-year period, there have been long periods of stagnant growth. The population of the South Burnett has been driven by the activities of Tarong Power Station. Prior to the construction and opening of Tarong North, the population was increasing at less than 0.3% per year. Annual growth increased to 1.5% after commissioning, which then tapered off when two units were put into cold storage.

Figure 2.5 South Burnett population



Source: ABS, Regional Population by age and sex, regions of Australia, cat no 3235.0. 2021

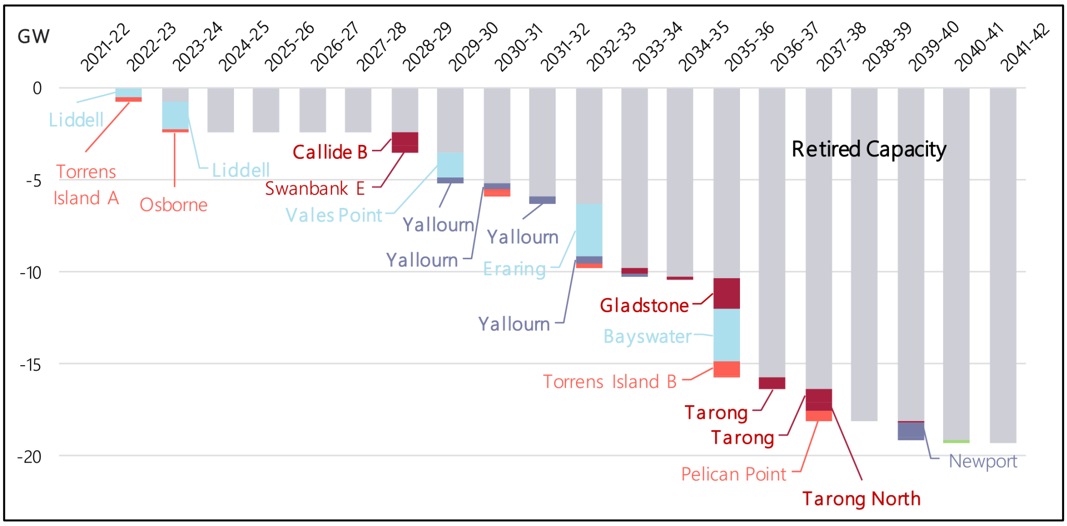
2.3 IMPACT OF THE POWER STATION TRANSITION

Governments around the world have committed to decreasing carbon dioxide emissions. In Australia, the government recently renewed its commitment to the Paris Agreement, pledging a reduction of emissions by 43 per cent by 2030, and to net zero emissions by 2050.[6] In order to achieve this goal, across Australia almost all coal power stations are being phased out over the next 20 years.

[6] (Department of Industry, 2022)

To meet nationally agreed climate change goals, Tarong Power Station was scheduled to cease generating coal fired power in 2036–37. This is one among many across Australia (Figure 2.6). However, this is now expected to be by 2035.

Figure 2.6 Forecast retirement of coal-fired power station capacity



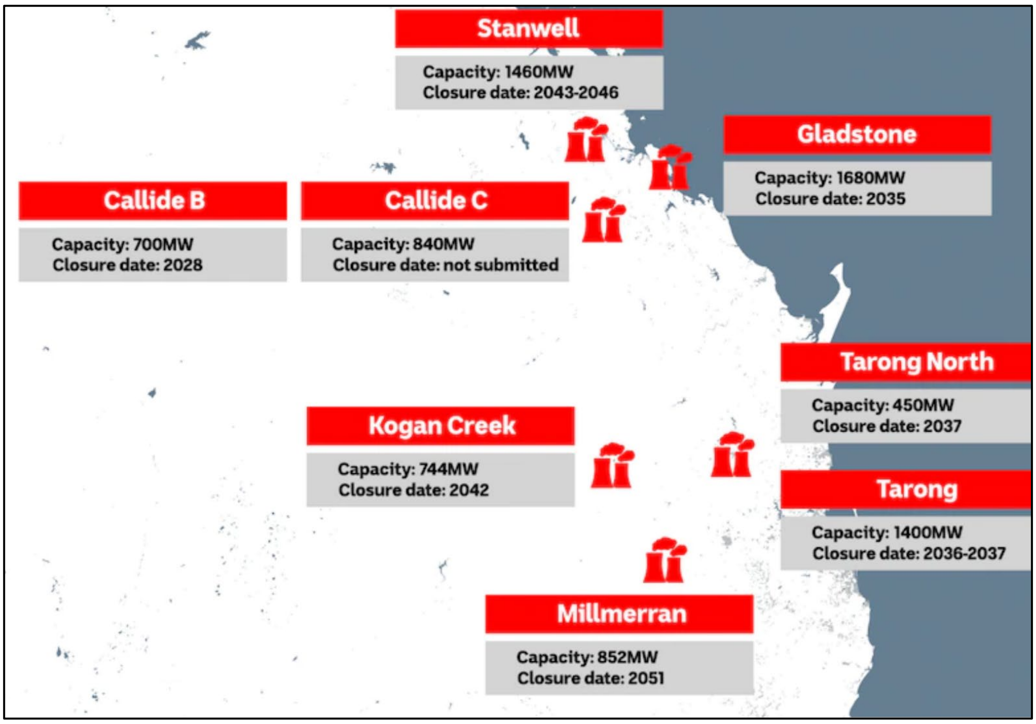
Source: AEMO, 2020 Integrated System Plan, July 2020.

Several power stations have been closed over the past decade. The impact of these closures can be observed. Where government does not provide transition support, the region severely and permanently declines, but where a transition package is provided, the region can prosper.

Tarong Power Station is one of the many coal-fired power stations that are being phased out over the next 20 years as part of the overarching plan to reduce Australia's carbon emissions. The Tarong Power Station facility is owned by the Stanwell Corporation (which itself is a state-owned corporation). The facility consists of four 350 MW units commissioned in 1984 and one 443 MW advanced cycle coal-fired unit commissioned in 2002 (referred to as Tarong North)[7], giving the power station a maximum electricity generation capacity of 1,843 MW.

[7] (Stanwell Corporation Limited, 2022)

Figure 2.7 Location of Tarong Power Station among other Queensland power stations



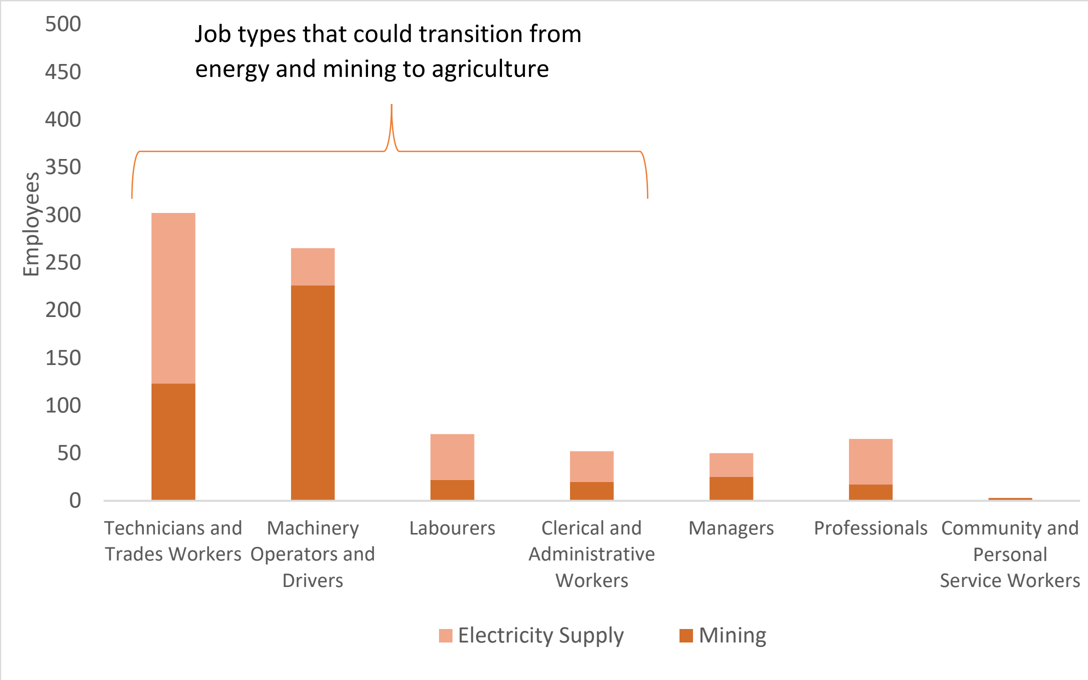
Source: ABC, 'Queensland has eight coal-fired power stations. What's their future?', ABC Radio Brisbane, online news, 12 June 2022.

2.3.1 Consequences of Tarong closing

Tarong Power Station is a significant employer in the South Burnett region, accounting for a large number of stable and reliable jobs. These jobs range from power plant operators to power distributors and power dispatchers to janitors. According to the 2016 ABS census, the electricity, gas and water services account for around 9% of the region's jobs,[8] with a large proportion directly a result of the power station. It is expected that the closing of Tarong will result in the loss of approximately 732 direct jobs.

[8] (Australian Bureau of Statistics, 2016)

Figure 2.8 Job types at Tarong Power Station and the Meandu mine



Most of the jobs are technicians, trade workers, machinery operators and drivers. Very few jobs are managers and professionals, as those are mostly based in Stanwell's head office in Brisbane.

The population is forecast to increase by approximately 0.6% annually. However, the transition of Tarong Power Station and the closure of the Meandu mine will impact on population growth.

The number of direct job losses is relatively straightforward to forecast, based on current employment levels. However, when a direct job is lost, there is also an impact on regional economic activity and downstream impacts on other industries and jobs.

Table 2.1 shows the employment multipliers for each industry. The total indirect job losses are forecast to be a further 545. Therefore, the direct and indirect job losses in total are forecast to be 1,277.

Table 2.1 Impact on indirect employment due to job losses at Tarong

Sector	Employment elasticity	Indirect employment impact
Agriculture, forestry and fishing	–0.001	1
Manufacturing	0.019	–14
Electricity, gas, water and waste services	0.053	–39
Construction	0.053	–39
Wholesale trade	0.078	–58
Retail trade	0.039	–29
Accommodation and food services	0.071	–52
Transport, postal and warehousing	0.026	–20
Inform. media and	–0.014	11
Telecommunication	0.106	–78

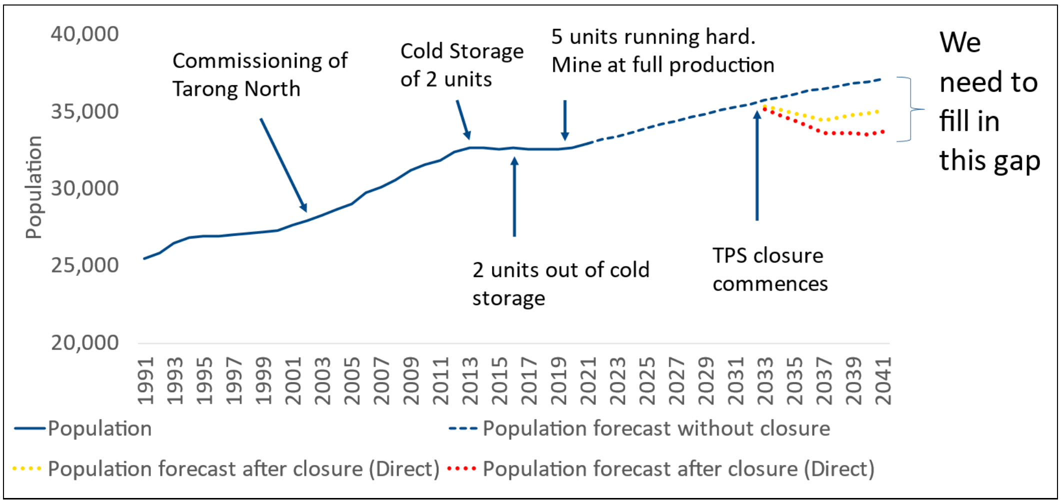
Sector	Employment elasticity	Indirect employment impact
Rental hiring and real estate services	0.094	–69
Prof. scientific and technical services	0.029	–22
Administrative and support services	0.006	–5
Public administration and safety	0.028	–21
Education and training	0.017	–13
Health care and social assistance	0.033	–25
Arts and recreation services	–0.025	19
Other services	0.125	–92
Total		**–545**

Source: Local job multipliers of mining (2014)

The loss of jobs is forecast to have a greater than 1:1 impact on the population. A worker that exits the regions due to unemployment will often leave as part of a family group. There is 2.8 people per job, so this ratio is used to forecast changes in population due to changes in jobs.

The population of the region is forecast to be between 2,000 and 3,500 lower in 2041 than without the a transition to other industries. There will likely be a decade of decline.

Figure 2.9 Forecast population if Tarong Power Station closed without replacement industry



The focus of this report is to outline strategies to take advantage of the region's advantages, namely climate, soil and water left behind from Tarong. Creating opportunities in a coordinated way will eliminate this population decline and mean that taking action on climate change will not come at the cost of regional prosperity.

2.3.2 Case study: Collinsville

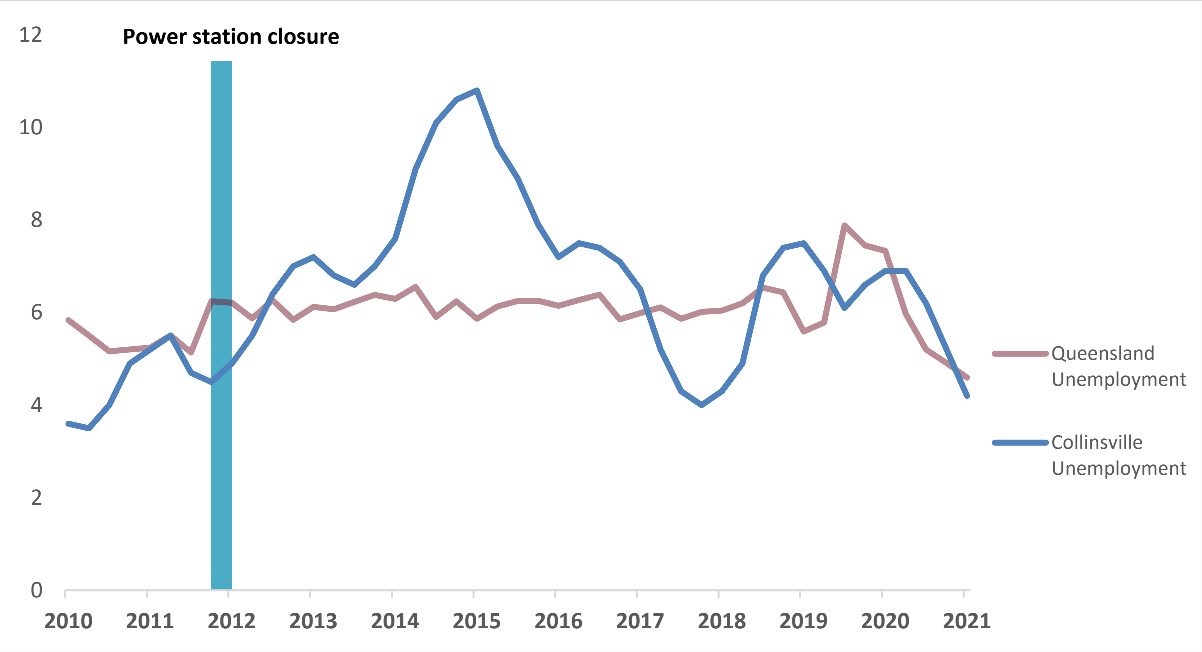
The 180 MW Collinsville coal-fired power station closed in 2012, resulting in a loss of 140 direct jobs. There was no transition plan, and the impact on the community was severe and permanent. In the wake of the closure, there was a spike in unemployment, a permanent decrease in population and a decrease in household income.

At the time of the closure, the unemployment rate in Collinsville was substantially below the rate across Queensland (4.5% vs 6.2%). Immediately after closure, the unemployment rate increased, peaking at 10.8% three years after closure.

It took until 2018, 6 years after closure, for the unemployment rate to again fall below the Queensland average. Since 2018, the Collinsville unemployment rate has been similar to the state average.

Figure 2.10 shows the Collinsville unemployment rate between 2010 and 2021.

Figure 2.10 Collinsville unemployment rate from 2010 to 2021 (%)

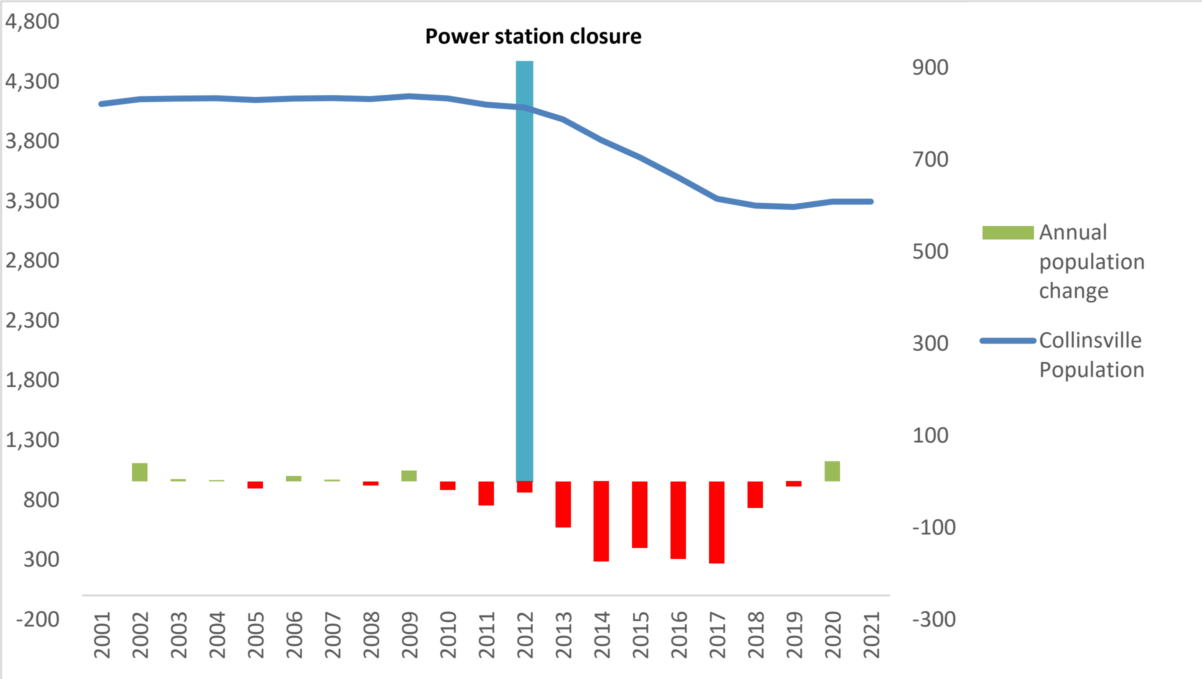


Source: National Skills Commission, Small Area Labour Markets; ABS, Labour Force (Series ID A84423284T).

While it may seem that the community has recovered since 2018, the community has a permanently lower population since the closure of the power station. Before the closure, population was fairly constant at about 4,100 people. In the year of the closure, and the 7 years later, the population declined, settling at about 3,300 people – a 20% decline. This indicates that for every job lost, the area lost 5.7 people.

By contrast, the population of Australia increased by 9.7% between 2013 and 2019.

Figure 2.11 Collinsville population from 2001 to 2021 (LHS) and annual population change (RHS)

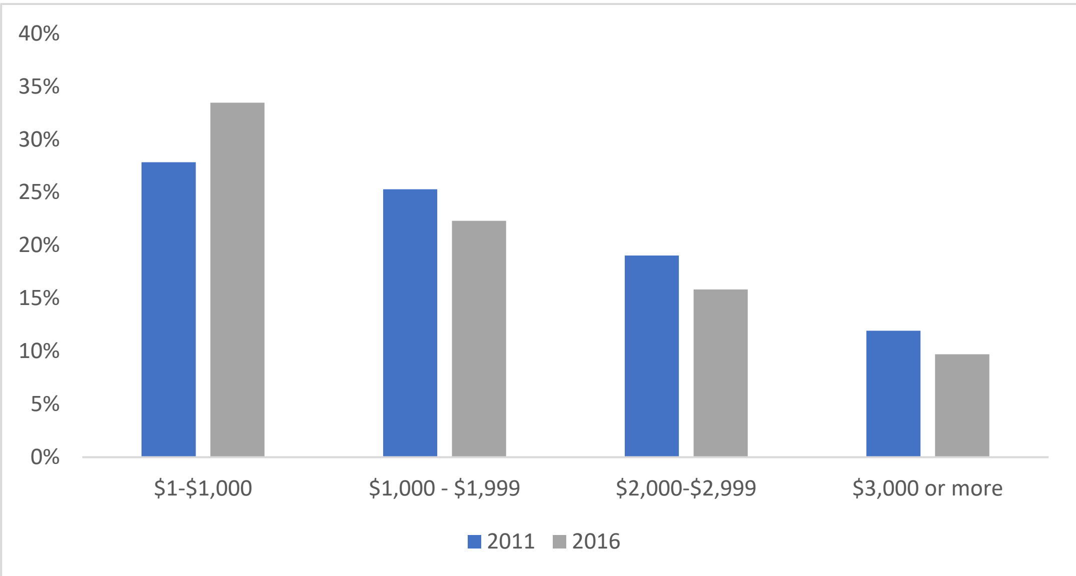


Source: ABS, Regional Population, Estimated resident population, Statistical Areas Level 2.

The improvement in unemployment levels in Collinsville is due to people leaving the area, rather than an improvement in employment outcomes.

Further, the income levels of the remaining residents declined. The portion of households with an income lower than $1,000 per week increased from 28% to 33% between 2011 and 2016. At all higher income brackets, the portion of households who were at that income level declined after the closure of the power station (Figure 2.12).

Figure 2.12 Collinsville households by weekly income, as a percentage of all Collinsville households



2.3.3 Case study: Latrobe-Gippsland

The Latrobe-Gippsland region experienced two recent coal-fired power station closures. In August 2014, the 189 MW Morwell Power Station closed. This was followed by the closure of the 1,760 MW Hazelwood Power Station.

When the Morwell Power Station closed, the local unemployment rate was 13.0%. There was no transition package for the regions, and over the next two years, unemployment increased to 21.1%. The unemployment rate in the neighbouring Churchill (where Hazelwood Power Station was located) increased from 5.2% to 8.7% (Figure 2.10).

The Hazelwood Power Station was the most intensive carbon emission producer in Australia. It was a brown-coal power station and generated around 1.52 tonnes of carbon dioxide for each megawatt hour of electricity produced. This amounted to 15 million tonnes of carbon dioxide emissions per year, which accounted for 2.8% of Australia's total emissions.

In November 2016, the federal government announced that the Hazelwood Power Station would close in March 2017. At that time, both the Commonwealth and Victorian governments announced assistance packages.

Figure 2.13 Latrobe Valley unemployment rate from 2010 to 2021 (%)

Note: Hazelwood power station was included within Churchill SA2.

Source: National Skills Commission, Small Area Labour Markets; ABS, Labour Force (Series ID A84423284T).

In both regions, the unemployment rate peaked at the time when the Hazelwood transition package was announced. Once the transition package took effect, the unemployment rate began to fall, which indicates that the substantial transition package was effective.

The transition package was for $734 million.

Table 4.2.2 Components of the Hazelwood assistance package

Level of government	Measure	Amount
Commonwealth Government	Local infrastructure	$20 million
Commonwealth Government	Labour market structural adjustment	$3 million
Commonwealth Government	Regional Jobs and Investment Package	$20 million
Victorian Government	Establishment of Community Infrastructure & Investment Fund	$174 million
Victorian Government	Establishment of Economic Growth Zone, covering Latrobe City Council, Baw Baw Shire and Wellington Shire to encourage businesses to relocate to the Latrobe Valley via financial incentives such as stamp duty concessions and fee reimbursement	$50 million
Victorian Government	Construction of new GovHub office complex in Morwell	$30 million
Victorian Government	Support services for affected workers	$22 million
Victorian Government	Establishment of the Latrobe Valley Worker Transfer Scheme via an agreement between labour unions, the Victorian government and electricity generators	$20 million
Victorian Government	Establishment of the Latrobe Valley Authority to lead work on economic transition strategies	$20 million
Victorian Government	Development of a Morwell Hi-Tech Precinct through collaboration between the Federation University, TAFE Gippsland, Gippsland Tech School and Latrobe City Council	$17 million
Victorian Government	Upgrade of 224 public housing properties	$7.8 million
Victorian Government	Energy efficiency upgrades to 1,000 homes of low-income and vulnerable households	$5 million
Victorian Government	Development of a New Energy Jobs & Investment Prospectus to develop tools to encourage investment in small-, medium- and large-scale renewable energy projects	$500,000
Victorian Government	Upgrade to the Gippsland Rail Line	$345 million
Total support		**$734.3 million**

A key component of the transition package was the establishment of the Latrobe Valley Authority.

3 Barlil Weir and West Barambah Weir

3.1 KEY POINTS

- Water reliability in the Barker Barambah Water Supply Scheme has been low. The scheme currently supports approximately 30,000 ML of medium priority water allocations with a long-term historical reliability of 78%.
- Irrigators expressed the preference to convert a relatively small amount of existing medium priority water allocations, into medium priority plus (MP+) water allocations. This would increase the reliability of this water from 78% to 90%.
- This additional reliability could be provided through the construction of Barlil Weir and/or West Barambah Weir. Constructing Barlil Weir alone would allow for 3,000 ML of water allocations to be converted to MP+, which is approximately 10% of the scheme's volume. Constructing West Barambah Weir, in addition to Barlil Weir, would allow approximately 5,500 ML to be converted to MP+.
- A demand assessment that was conducted for MP+ identified demand for up to 8,000 ML of MP+. This demand is across the scheme. Some of the demand is on the Barambah Creek, which could be supplied either through the construction of West Barambah Weir, or through the construction of Barlil Weir only, with the water piped through the existing Redgate Relift.
- This additional reliability allows some irrigators to transition from broadacre crops to high value crops such as wine grapes, olives and garlic.
- Barlil Weir is estimated to cost $13.1 million, while the West Barambah Weir would cost $22.5 million. As Barlil Weir provides more MP+ at a lower cost, it is the preferred site.

Table 3.1: Economic analysis results (base case and 7% discount rate)

	Barlil Weir	West Barambah Weir	Combined total
Total benefits ($ million)	24.0	14.6	38.6
Total costs ($ million)	12.9	21.2	34.1
NPV ($ million)	11.1	(6.6)	4.5
BCR	**1.86**	**0.69**	**1.13**

- The employment benefits that are not included in the cost–benefit analysis, which aligns with Queensland business case guidelines, include:
  - The Barlil Weir project, at full agricultural production, will employ 24 people with 7 FTEs for direct agricultural jobs and support 17 indirect agricultural jobs.
  - The West Barambah Weir project, at full agricultural production, will employ 24 people with 6 FTEs for direct agricultural jobs and support 18 indirect agricultural jobs.

3.2 BACKGROUND

The Barker Barambah WSS provides water to irrigators along Barambah Creek, with Bjieke-Peterson Dam being the primary storage. There is 4,250 ML of unallocated water with the system. KBR's investigation has sought to determine how best to use this resource.

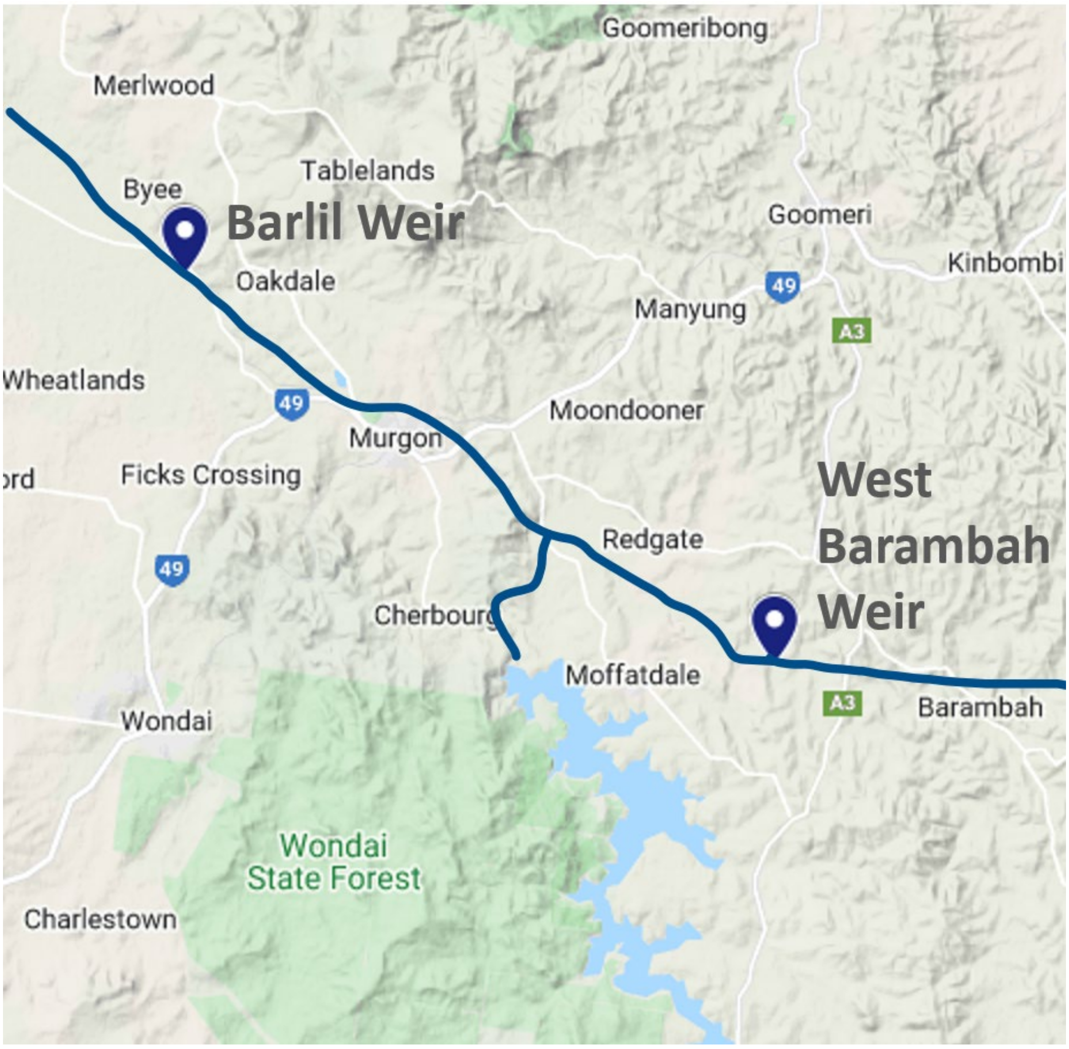
Based on consultation with irrigators and potential customers, there was a preference for access to more reliable water, rather than additional water with the existing reliability. It is expected that this will enable irrigators to transition to higher-value crops.

Consequently, we investigated whether a new product, medium priority plus (MP+), could be made available to a subset of medium priority water allocation holders. MP+ has a reliability of 90%, compared with 78% for the current medium priority product.

A number of hydrological scenarios were undertaken, based on two infrastructure options:

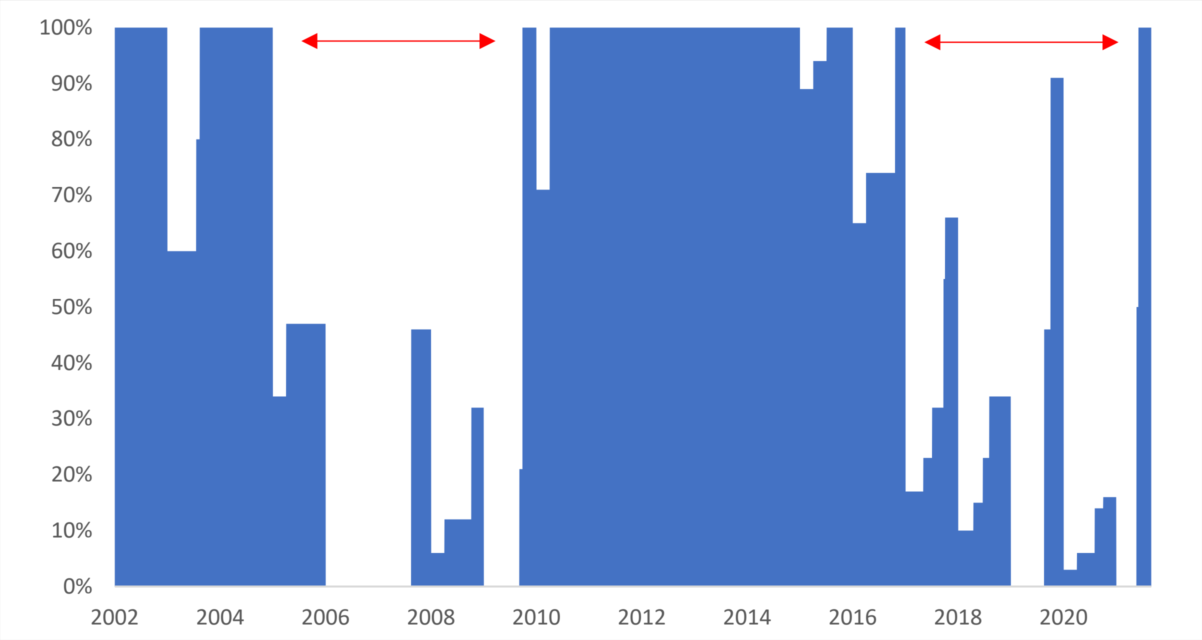
- Construction of Barlil Weir only
- Construction of Barlil Weir and West Barambah Weir.

Figure 3.1: Location of potential weir sites



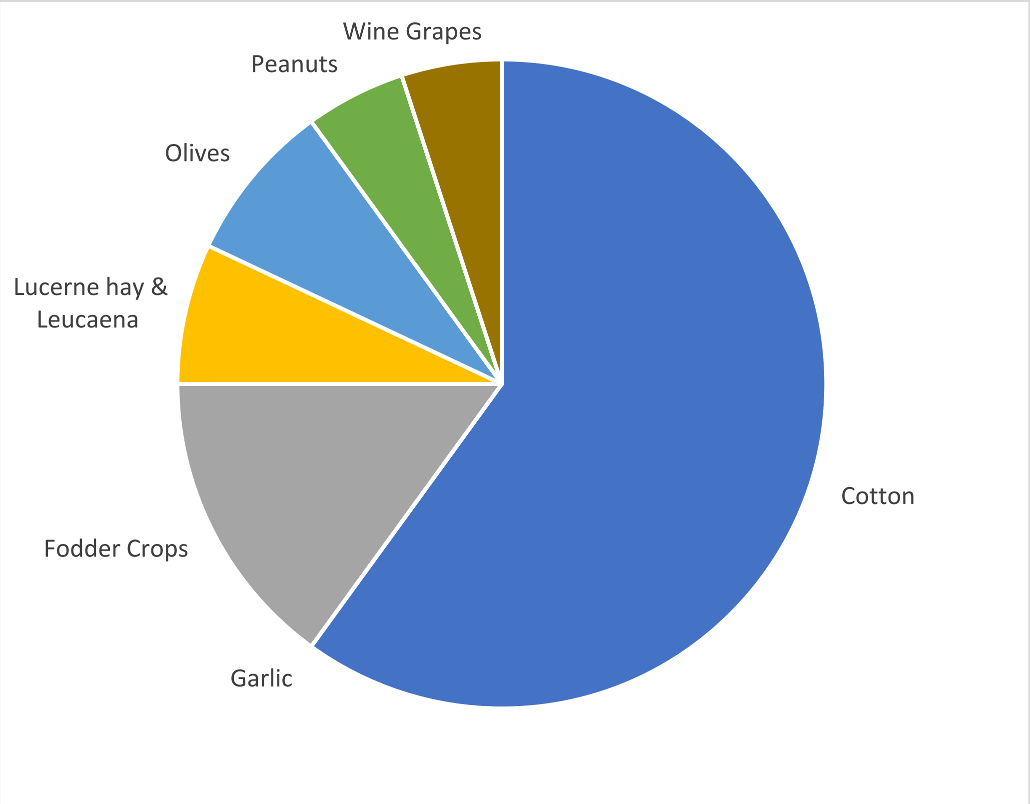
In recent years, the reliability of the scheme has been poor, with stretches with very little water availability. Between 2005 and 2010, and then again between 2017 and 2021, announced allocations have been zero, or very low for much of the time.

Figure 3.2 Barker Barambah announced allocation (MP)



Due to this reliability, the scheme primarily supports broadacre crops such as cotton, fodder and hay. There is a small amount of very high-value agriculture such as olives and wine grapes. Access to a more reliable water supply will allow for investment in higher-value crops.

Figure 3.3 Barlil Weir and West Barambah Weir crop mix (Year 1 of operation)



3.3 HYDROLOGICAL ASSESSMENT

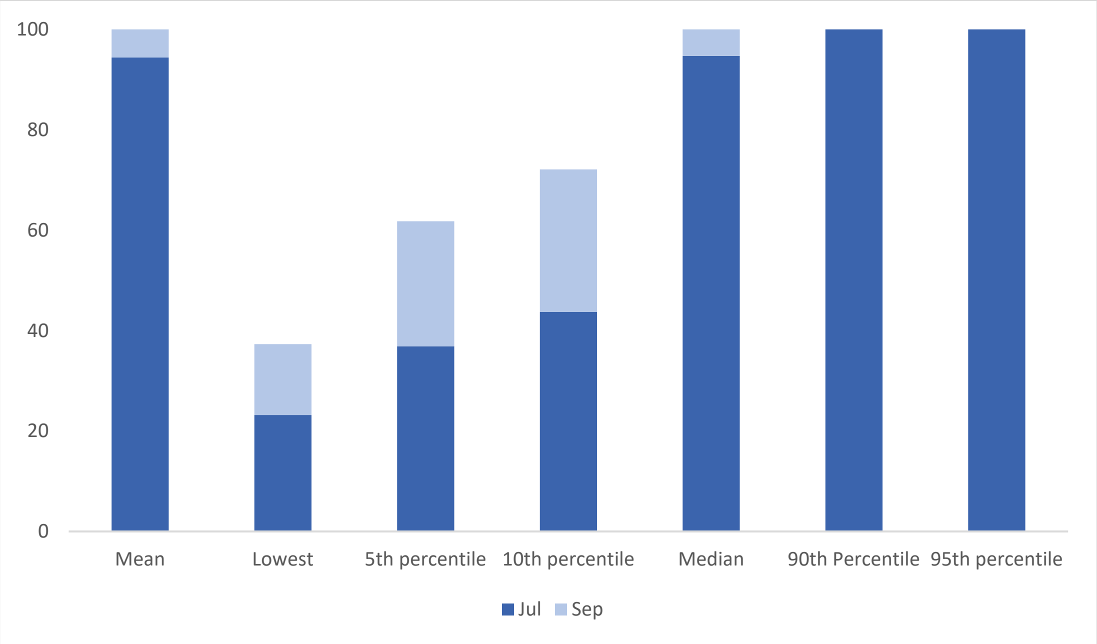
The major benefit of MP+ is during a long critically dry period. The model runs results were therefore examined to ascertain how the scheme might perform in an extended critically dry period.

An example of such a period within the available simulation period was between 2001 and 2007.

The extent to which the MP+ concept might improve access during such a period was then examined. Figure 3.4 presents the year-by-year hydrologic performance of MP and MP+ water allocations in terms of annual diversions expressed as a percentage of nominal volumes.

Comparing the MP+ performance with the base case MP performance shows that MP+ might be expected to extend a water user's access to water supplies by around 18 months to two years within an extended critically dry period.

Figure 3.4: Hydrological performance of MP and MP+

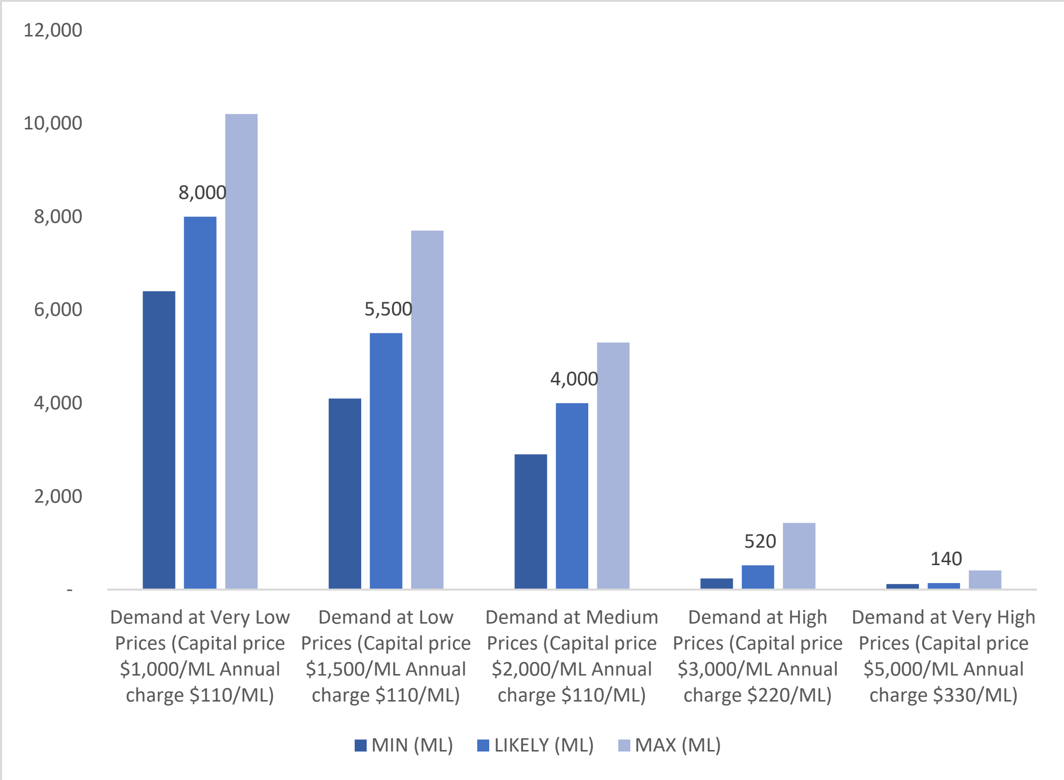


3.4 DEMAND ASSESSMENT

KBR undertook a demand assessment for agricultural and other uses of the proposed Barlil Weir and West Barambah Weir.

There are 14 businesses interested in this water who are supplying 25 farms and other entities. Minimum, likely and maximum demand volumes are as follows.

Figure 3.5: Demand for Barlil Weir and/or West Barambah Weir – medium priority plus water allocations (ML)



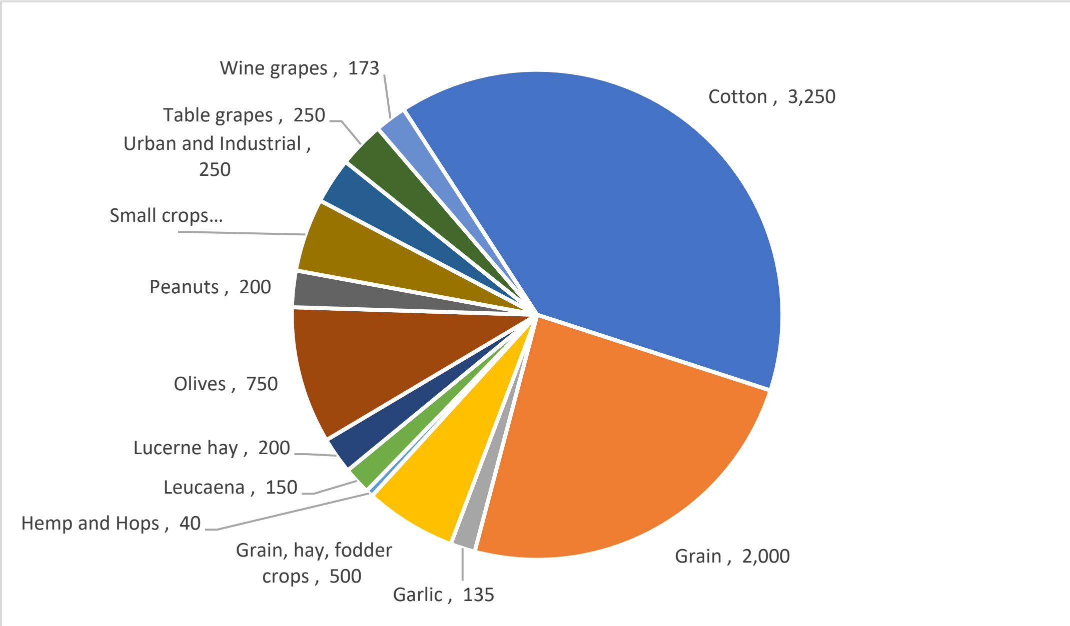
The very low price has likely demand of 8,000 ML; the low price has likely demand of 5,500ML; and the medium price has likely demand of 4,000 ML. Likely demand falls to 520 ML and 14 ML at high and very high prices.

At very low to medium price scenarios, customers have provided evidence that they support annual charges of around $110/ML and a capital price of $1,000/ML to $2,000/ML.

3.4.1 Future water uses

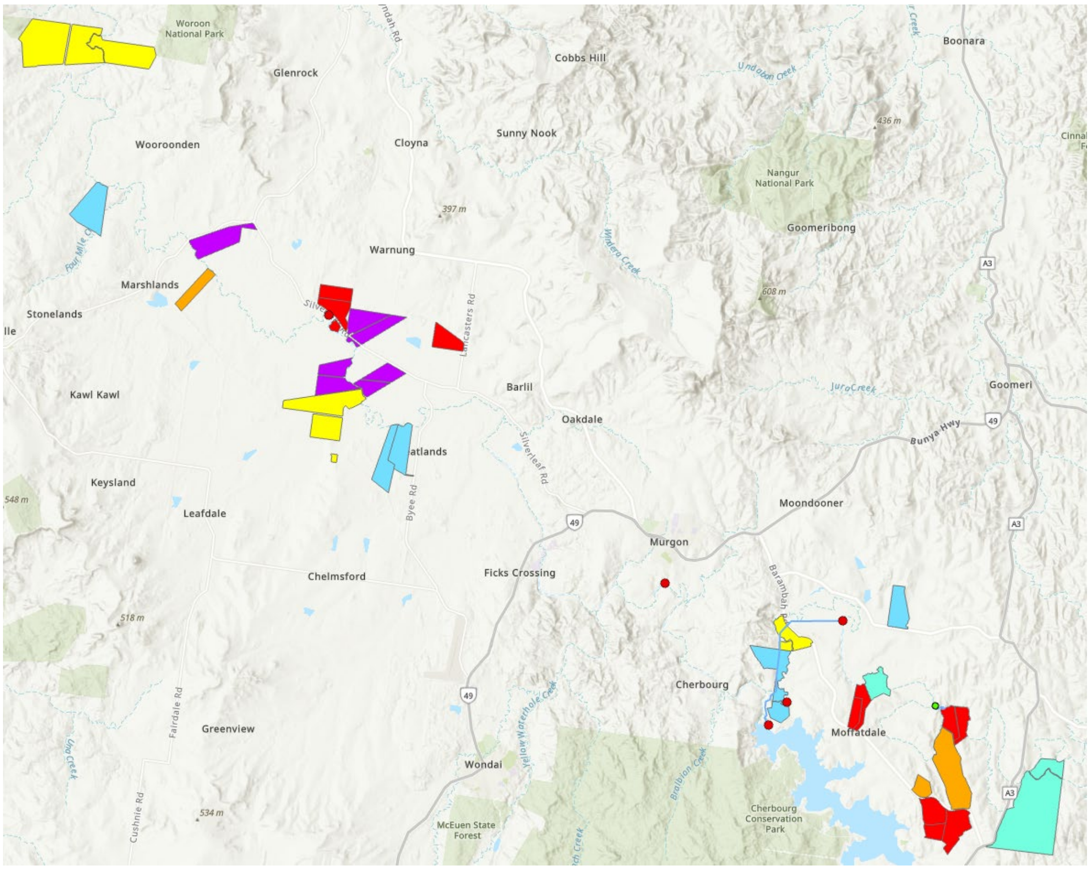
Future economic water uses include a wide and diverse array of moderate to very high value enterprises. Of note, the future enterprise mix also includes garlic, hemp, hops, olives, peanuts, vegetables, and table and wine grapes. We can therefore include the profitability of locally made wine (referred to as the wine premium) in our assessment or forecast of future economic benefits arising from this project/s.

Figure 3.6 Future water uses proposed by customers (ML)



Forecast impacts of climate change on Wide Bay-Burnett strengthen the case for this project. For example, higher average temperatures and greater rainfall variability will lead to frequent failure of dryland crops, underpinning the value of the council to progressing more reliable sources of water for agriculture.

Figure 3.7 Location of Barker Barambah demand



3.4.2 Customer capital contributions – no supply constraint

Assuming no supply constraint, customer capital revenue and capital pricing options are set out below, which indicate that optimal revenue may be achieved at a customer capital price of $1,500/ML. It is possible to identify a customer capital contribution 'sweet spot' if mid-point prices and revenues are also interpolated from the primary data. The figure below includes prices tested, mid-point prices and customer capital revenue.

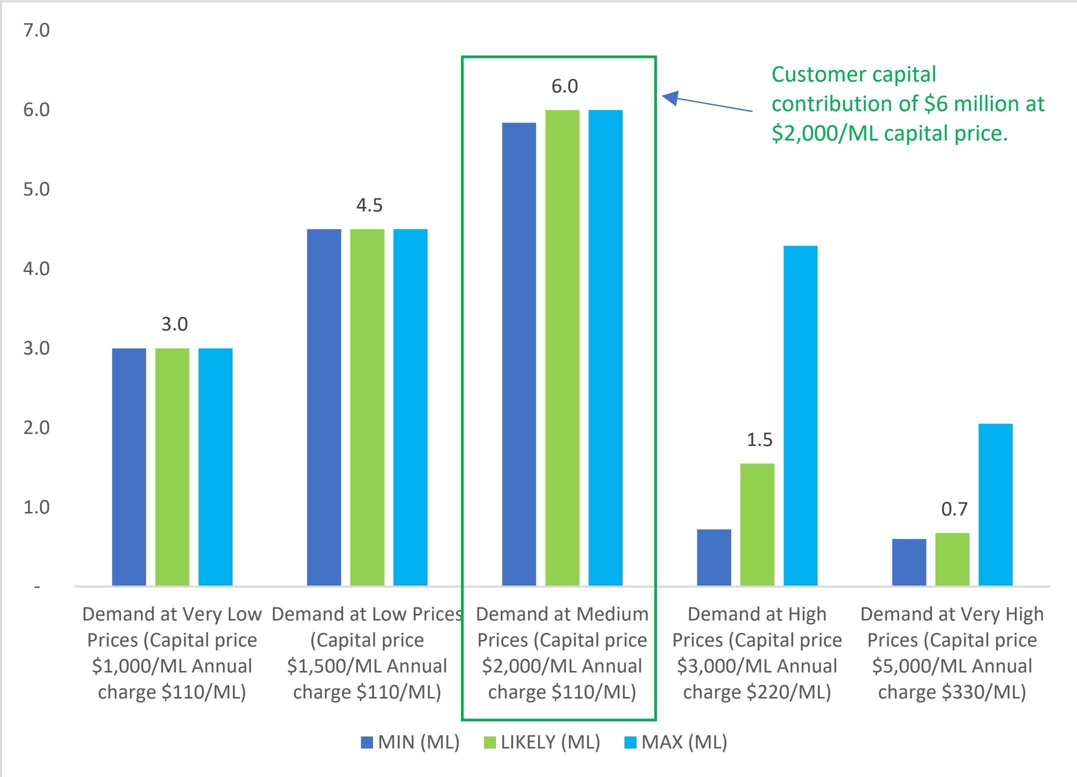
Figure 3.8 Customer capital revenue at different prices (incl. interpolation) – no supply constraint ($ million)

The figure above provides confidence that a customer capital price of $1,500/ML is likely to maximise customer capital contributions if total likely demand at this price of 5,500 ML can be met. However, the revenue of $8.3 million is based on there being no supply constraint (i.e. no limit on medium priority plus).

3.4.3 Customer capital contributions – with a 3 GL supply constraint

Given the how advanced Barlil Weir is as a project when compared to the West Barambah Weir concept, if a decision is made to progress Barlil Weir only – or Barlil Weir initially as a first stage – then the supply of new medium priority plus water allocations for sale is 3,000 ML with a monthly reliability of about 91%. Assuming a supply constraint of 3,000 ML, the forecast customer capital contributions at each price are set out below.

Figure 3.9 Barlil Weir only – customer capital contributions with a 3 GL supply constraint ($ million)



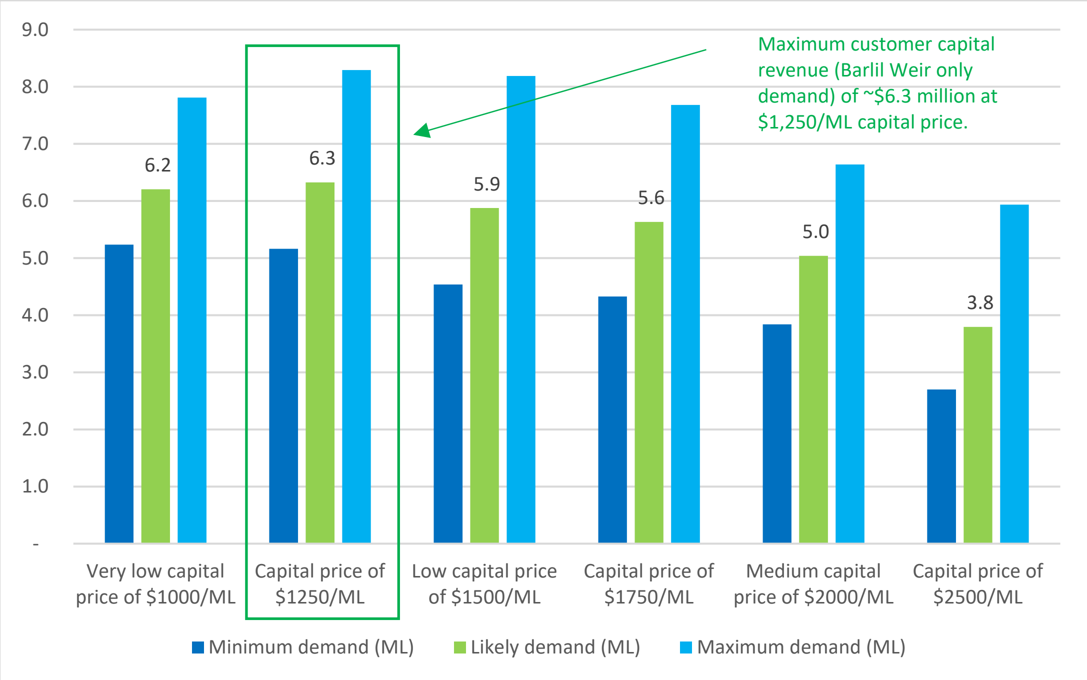
This analysis suggests that with a supply constraint – in a Barlil Weir only scenario – customer capital contributions are optimised at $6 million with a capital price of $2,000/ML.

3.4.4 Sensitivity analysis

KBR also considered what upstream demand 'drops out' if only Barlil Weir is developed – based on the self-exclusions nominated by respondents in their 'expression of interest' forms. Two questions were considered: How much 'Barlil Weir only' demand exists? What size should the larger version/s of the Barlil Weir be?

KBR seeks to maximise customer capital contributions, because 'skin in the game' is what provides a project with its best chance of securing government approvals and funding. That is, maximising customer capital contributions gets projects built. Interpolated demand volumes and capital prices were used to forecast customer capital revenue in the figure below. The figure suggests that maximum revenue of about $6.3 million can be obtained a capital price of $1,250/ML paid upfront – assuming 5,100 ML of demand.

Figure 3.10 'Barlil Weir only' customer capital revenue (incl. selected interpolated capital prices) ($ million)



There are a few price and demand scenarios at which about $6 million of customer capital contributions may be secured. Lower prices mean higher demand certainty. To achieve low prices, higher volumes of sufficiently reliable water product are needed. Further investigations will determine the upper limit of Barlil Weir's ability to supply volumes above 3 GL, noting that 5 GL of demand is associated with the optimal price above.

3.5 TOTAL PROJECT COST ESTIMATE

The costs of Barlil Weir and West Barambah Weir have been separately identified.

3.5.1 Barlil Weir costs

In 2020, Jacobs estimated the cost of the weir based on the design work undertaken in 2020. Jacobs concluded that the design was appropriate for the basis of cost estimation and that the core estimate was $8.3 million.

For the purpose of this assessment, the 2020 costs have been escalated using the applicable construction index. On average, costs have increased 16% over the past two years, reflecting a hot construction market.

Table 3.2: Barlil Weir summary cost estimate

Category	Original 2000 value ($)	Escalated value 2020 ($)	Escalated value 2022 ($)	Escalation 2020 to 2022
General	149,000	273,000	286,000	5%
Weir construction	620,000	1,211,000	1,495,000	23%
Outlet works	194,000	319,000	339,000	6%
Control building	22,000	39,000	46,000	18%
Protection	73,000	138,000	155,000	12%

Category	Original 2000 value ($)	Escalated value 2020 ($)	Escalated value 2022 ($)	Escalation 2020 to 2022
Landscaping	8,000	16,000	17,000	6%
Upstream effects	350,000	677,000	742,000	10%
Fish passage		1,800,000	2,200,000	22%
Contingency	212,000	1,069,000	1,232,000	15%
Indirect costs	309,000	858,300	930,000	8%
Land resumption	60,000	285,000	346,000	21%
Environmental approvals and offsets		1,650,000	1,900,000	15%
Total cost	**1,997,000**	**8,335,300**	**9,688,000**	**16%**

Steel and concrete make up about 80% of the direct weir construction costs. To add additional rigour, the escalated values were compared with actual costs from local supplier. For example, the concrete quote was obtained from a concrete plant in Murgon. This exercise confirmed that a 16% increase is reasonable, noting a wide range of cost changes.

Table 3.3: Barlil Weir cost estimate

Item	2020 price	2022 price	Change
Steel piles	$1,800/tonne	$2,300/tonne	30% increase
Crane hire	$500/hour	$500/hour	–
Concrete	$230–$250/m^3	$240–$260/m^3	4% increase

In the options analysis, a P90 was estimated to be 35% higher than the core estimate. Applying this to the escalated amount results in a cost of $13.1 million.

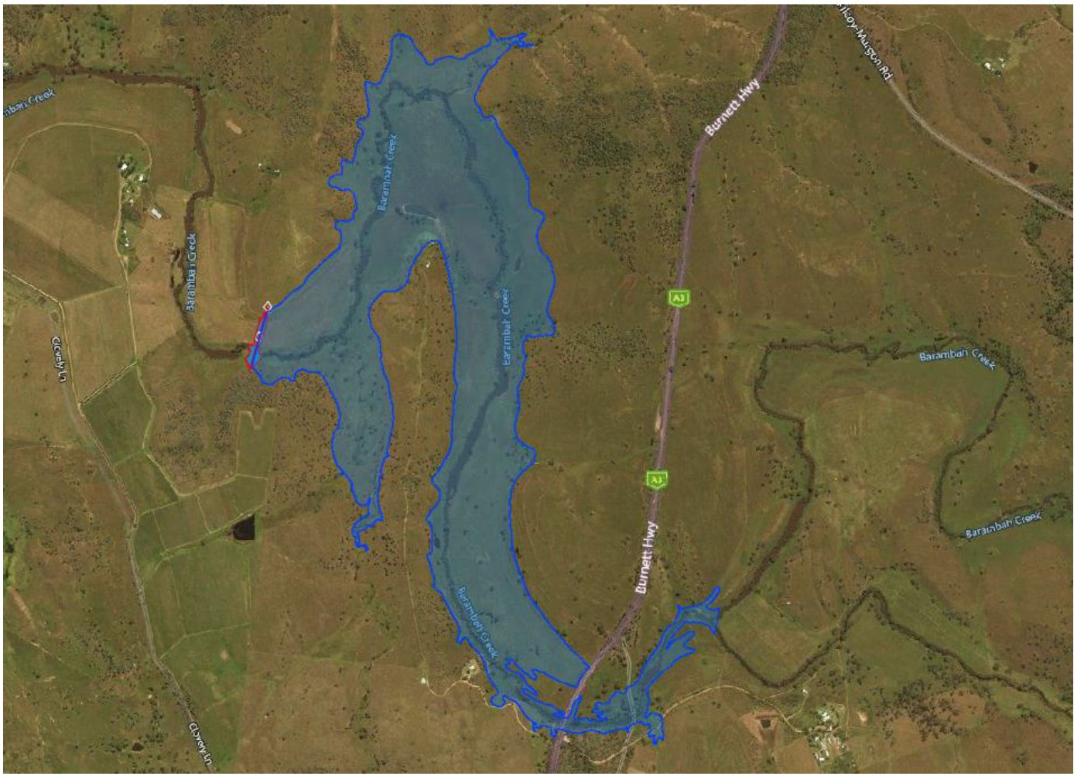
3.5.2 West Barambah Weir costs

West Barambah Weir is a proposed structure to be located on Barambah Creek, approximately 25 km upstream from the confluence with Barker Creek. Bjelke Petersen Dam is located 1.5 km upstream of this confluence.

The height of the storage is designed to not flood the bridge on the Burnett highway. For the purpose of this assessment, this was considered a limiting factor to the storage size and the consequential storage volume.

The arrangement of the dam with the proposed full supply level inundation area is shown below.

Figure 3.11 – Inundation of proposed West Barambah Weir



A side excavated concreted spillway is proposed as the main flood routing structure. A preliminary freeboard of 1 m is proposed. The concept design assumes a 280 m earthen embankment perpendicular to Barambah Creek.

In order to prepare an initial cost estimate, a concept design of the structure was sketched with some initial volumes and dimensions measured for quantities.

Table 4.3.4 West Barambah concept design parameters

Parameter	Value
Storage volume	5,000 ML
Aboveground embankment volume	35,500 m3
Crest level	RL 316
Full supply level (spillway invert)	RL 315
Embankment height	12 m
Freeboard	1.0 m
Total embankment length	280 m
Impoundment area	200 ha
Storage ratio	140:1

Based on these parameters, the cost was estimated to be between $18 million and $32 million. A cost summary is shown below, with a more detailed estimate attached.

Table 4.3.5 West Barambah Weir indicative costs

Cost category	Low amount	Medium amount	High amount
Embankment earthworks	1,684,000	1,871,000	2,428,000
Auxiliaries and spillway	4,851,000	5,390,000	8,523,000
Contractor indirect & site overhead costs	558,000	620,000	743,400
Contractors associated project costs	404,320	504,755	664,690
Construction management & overheads	1,509,463	1,928,758	2,515,772
Design, investigations & other post-DBC activities	3,500,000	4,792,000	7,000,000
Land	700,000	1,000,000	1,875,000
Contingency	4,832,000	6,443,000	8,053,500
Total	**18,000,000**	**22,500,000**	**32,000,000**

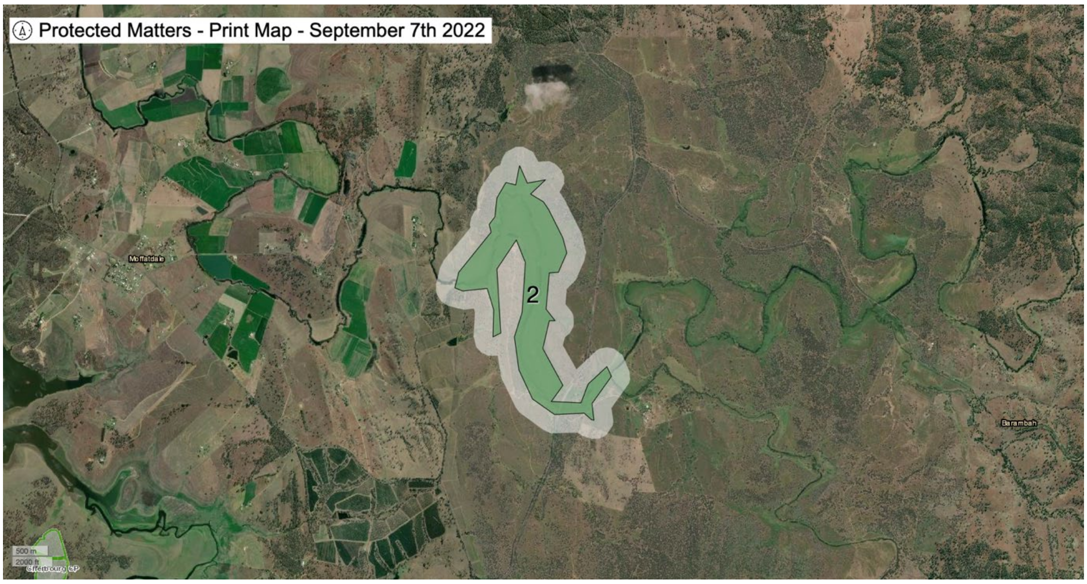
3.6 ENVIRONMENTAL COSTS AND BENETITS

A desktop assessment has identified a number of environmental values that will be impacted by the construction of West Barambah Weir. A search of federal and state databases identified that the area of interest contains:

- a number of threatened, vulnerable and critically endangered ecological communities and species, including the koala
- areas of high to very high conservation significance
- regulated vegetation, including endangered remnant vegetation.

The Protected Matters Search Tool was used to identify what, within the inundation area (+250 m buffer), is protected under the Environment Protection and Biodiversity Conservation Act 1999. This area is referred to as the area of interest (AOI). The full report is attached.

Figure 3.12 – Map showing area of inundation and 250 m buffer used in the Protected Matters Search Tool



Impacts are expected to water quality, hydrology and fish passage during construction, inundation and the life history of the impounded water.

If required, the minimum financial settlement for environmental offsets, based on a high-level desktop assessment of the project using the Department of Environment and Science Offsets Calculator, would be $2,642,285. This value is included in the cost estimate.

This desktop assessment has identified a number of environmental values that will be impacted by the construction of West Barambah Weir. On-ground investigations to confirm or deny these impacts will need to be completed. However, development impacts similar to these have been previously approved with conditions and there is the potential to offset these impacts.

3.7 NATIVE TITLE AND CULTURAL HERTIAGE

On 12 April 2022, the Federal Court of Australia determined that Native Title exists across significant land parcels within the South Burnett Council area.[9]

The determination includes areas where the Native Title Party has exclusive and non-exclusive rights in relation to the land and waters identified in the schedules:

- The nature and extent of the native title rights and interests in relation to the **exclusive areas** includes the right to possession, occupation, use and enjoyment of the area to the exclusion of all others.
- The nature and extent of the native title rights and interests in relation to the **non-exclusive areas** includes, without limitation, access, camp, hunt, and take water for person, domestic and non-commercial communal purposes.[10]

Attachment N is the Map of the Determination Area and relevant sub-maps that show the exclusive and non-exclusive areas included within the Native Title determination. As shown in the Appendix, the land areas impacted by the proposed Barlil Weir and West Barambah Weir could potentially interact with the non-exclusive areas in the Native Title determination.

[9] Bell on behalf of the Wakka Wakka People #3 v State of Queensland (No 2) [2022] FCA 370
[10] Ibid

It will be necessary, and important, that a full assessment, plan and consultation be undertaken with First Nations People to determine the impact, if any, of the proposed infrastructure on Native Title and cultural heritage in the relevant project area.

3.8 USE OF THE REDGATE RELIFT

As identified in the demand assessment, there is strong demand for reliable water clustered around both the Barlil and West Barambah sites. The capacity to deliver water to all users has been investigated.

There is already a pipeline scheme to take water to the Barambah Creek, near the proposed West Barambah Weir. Therefore, we have investigated:

- the hydrological limit of converting medium priority to MP+ water – specifically whether the conversion can take place for water drawn directly from Bjieke Peterson Dam
- subject to the above, whether MP+ water could then be delivered to areas of high MP+ demand through existing infrastructure.

Our initial review of the hydrological constraints is that construction of a 'Barlil Weir only' would increase the system efficiency and result in fewer releases made from Bjieke-Peterson Dam. his increased scheme efficiency allows for water users who are supplied upstream of the new weir to also benefit from the construction of Barlil Weir.

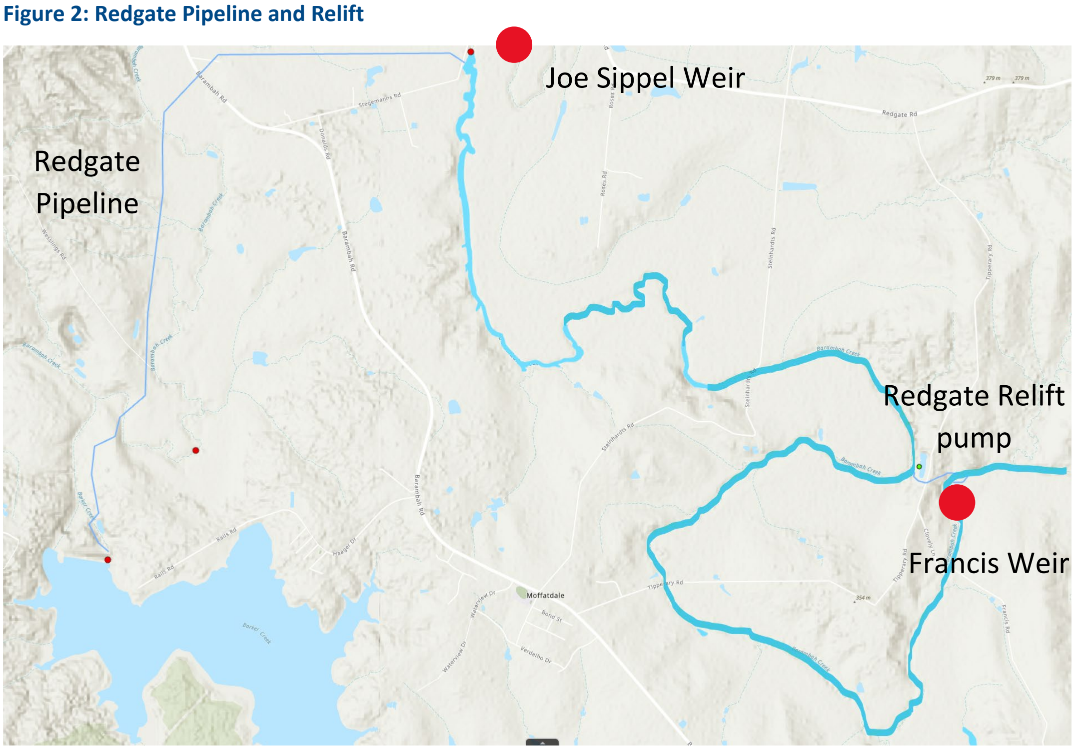
In short, customers who are supplied directly from Bjieke-Peterson Dam would be able to convert their MP water allocations into MP+ water allocations.

The Barker Barambah Water Supply Scheme currently supplies water to customers on Barambah Creek through the Redgate Pipeline and Relift.

Redgate Pipeline is a 6.2 km, 900 mm diameter reinforced concrete, rubber ring jointed pipeline that transfers water from Bjelke-Peterson Dam to Joe Sippel Weir. The pipeline has a design capacity of 34.5 ML/day. The Redgate Diversion Pipeline is a gravity pipeline. However, a pumping unit is installed on a regulated outlet at Bjelke-Petersen Dam valve house for when the dam level is too low to generate an adequate gravity flow.

Upper Redgate Relift pipeline services customers in the Upper Redgate area by pumping water from the Joe Sippel Weir to the Francis Weir where the water is released. The design capacity of the Upper Redgate Relift pipeline is 10 ML/day. The pump used to divert water through the Upper Redgate Relift pipeline must be removed when the flow in Barambah Creek exceeds 1,400 ML/day to avoid flooding the pump unit.

Figure 2: Redgate Pipeline and Relift



Our conclusion is that users along Barambah Creek would be able to access MP+ water. Accordingly, our economic assessment considers this scenario.

3.9 ECONOMIC ASSESSMENT

The economic analysis develops a coherent socio-economic narrative of the qualitative and quantitative costs and benefits that could be realised through increased water reliability in region.

This economic assessment is aligned with the Building Queensland and Infrastructure Australia frameworks. The approached for this study is as follows:

- Understand the base case.
- Where economic impacts are material and quantifiable, quantify the economic benefits and costs (i.e. net cash flows) relative to the base case.
- Test the sensitivity of key inputs.

The general parameters and assumptions include model start year, assessment period and discount rates. The starting year and assessment period are shown below.

Table 3.6 – Starting year and assessment period

Parameter	Unit	Value
Starting year	Year (period)	2023
Assessment period	Number of years	30

Discount rate scenarios, with the medium scenario (7% real) being the central scenario, are shown below.

Table 3.7 – Discount rate scenarios

Discount rate	Real discount rate, pre tax (%)
Low	4%
Medium	7%
High	10%

The alignment of these key parameters with the relevant frameworks is outlined in the table below.

Table 3.8 – Alignment of key economic assumptions

Parameter	Adopted value/s	Justification
Discount rate	7% (central) 4% and 10% (sensitivities)	These values are in accordance with Infrastructure Australia (IA) and the Queensland Treasury Cost Benefit Analysis Guide.
Starting year	2023	All benefits in the economic analysis are presented in 2022 constant prices.
Appraisal period	30 years with residual value of net benefits included	An analysis period of 30 years (operational) was adopted in line with the Queensland Treasury Cost Benefit Analysis Guide.

3.9.1 Economic benefits

The economic benefits of increased water reliability for customers are:

- **More constant production** – 13% increase water use results in an average additional annual water availability of 390 ML based on Barlil Weir allowing conversion of 3,000 ML of MP water allocations into MP+. Likewise, construction of West Barambah Weir could allow the conversion of approximately 2,500 ML, resulting in an additional 325 ML of average annual water use for agricultural production.
- **Transition to higher-value enterprises –** Customers will have access to 90% reliable water with new product. This will allow them to generate a marginal benefit through the transition to higher-value enterprises for example moving from cotton ($669/ML) to olives ($1,978/ML) generating an additional benefit of $1,309/ML.

These benefits are calculated based on key inputs:

- Demand assessment – how much water is demanded by customers and what this water will be used for
- Reliability of the water product – how much water customers will likely receive per year
- Likely water use – how water will be used for which crop
- Net margin of water use – how much economic value will be generated by each megalitre of water used by customers.

3.9.1.1 Data sources

The overall economic benefit depends on the crop mix, water use by crop in the region and the net margin of each crop. The data used in this analysis were gathered from a range of sources including:

- A demand assessment and further consultation with potential customers. This process drives the underlying crop mix and economic benefits. Customers were also asked to provide information on future plans for the water this assisted with the economic benefit calculation

- previous literature provided by the client and state government
- Agbiz farm budgeting tools from the Queensland Government, which were used to cross-check customer data and ensure margins are representable of the region.
- The AgMargins Gross Margin Calculator from the Queensland Government, which were used to cross-check customer data and ensure margins are representable of the region.

Data was collected through the demand assessment process and on-the-ground consultation, including several stakeholder meetings and engagements. This has informed the proposed crop mix and water use used to calculate the total economic benefit.

3.9.1.2 Volume of water

Medium priority water allocations in Barker Barambah scheme have a long-term monthly reliability of about 78%. Customers have indicated a preference to see an increase in the current reliability of the water products. The project aims to create approximately 3,000–6,000 ML of new medium priority plus or 'high priority agricultural' water – with 90% monthly reliability – arising from the proposed construction of the Barlil Weir and West Barambah Weir (see table below).

Table 3.9 – Water product for each project

Project	Volume of medium priority plus created (ML)	Reliability (%)
Barlil Weir	3,000	90%
West Barambah Weir	2,500	90%
Total	**5,500**	

West Barambah Weir is forecast to negatively impact the yield of up to 2,000 ML of downstream users' water entitlement. This has been excluded from the economic benefit calculation of the project. The improvement in reliability will generate more constant production. The increased volume of water delivered by each project is outlined below.

Table 3.10 – Increase in water volume delivered by project

	Demand	Annual reliability	Total
Barlil Weir	3,000	13%	**390**
West Barambah Weir	2,500	13%	**325**

3.9.2 Economic benefits of irrigated agriculture

The primary economic benefits of the project relate to more constant production and transitioning to higher-value enterprises through increased water reliability. The benefits were calculated by:

More constant production

- Determining the improvement in water reliability and subsequent increase in agricultural production.
- Amount of irrigation water likely to be used for each crop type (net of rainfall) and crop area.
- Calculating the gross margin (revenue minus variable operating costs) for each crop type per megalitre and then subtracting the fixed costs (upfront and ongoing) per hectare to obtain the net margin for each crop. This is achieved through on-the-ground consultation-driven process, industry experience and public sources. Each crop has a different net margin, depending on the yield, costs and commodity prices.

- Multiplied increase in water through improvement in reliability by the net margin to obtain the annual economic benefit and convert the annual benefits to a single net present value.

Transition to higher-value enterprises

- Determining the current enterprise mix grown by customers in the region (see table below).
- Using demand assessment results to determine the new enterprise mix associated with the increase in water reliability.
- Using the net margins calculated to determine the marginal increase in $/ML between the current and future enterprise mix.
- Multiplying this increase by the total volume of medium priority plus generated by each project.

Table 3.11 – Water product for each project

Crop	Crop mix percentage	Net margin ($/ML)	Revenue ($/ML)
Cotton	66%	552	1,046
Garlic	2%	2,094	4,977
Fodder crops	20%	440	1,082
Lucerne hay & Leucaena	2%	331	964
Olives	4%	1,978	5,853
Peanuts	3%	856	1,818
Small vegetable crops	0%	1,012	1,744
Table grapes	0%	1,737	6,410
Wine grapes	4%	1,731	2,742
Total	**100%**	**656**	**1,385**

3.9.3 Effective rainfall

The irrigation water use per hectare is the volume of water that is applied to crops. The annual amount of rainfall determines the application of irrigation water use. The total rainfall for the irrigation area is shown in the following table.

Table 3.12 Annual rainfall (mm)

	Annual total (mm pa)
Lowest	405
Median	766
Highest	1,338

Source: Australian Bureau of Meteorology, Wondai Post Office.

A 100 mm of rainfall per hectare is 1 ML per hectare, so average annual rainfall provides 7.29 ML per hectare per annum. This rainfall is then factored by the timing of rainfall compared to the crop’s demand and the ability for the crop to absorb the water (rainfall effectiveness).

The rainfall effectiveness by crop type is shown in the following table.

Table 3.13 Rainfall effectiveness by crop type

Crop type	Rainfall effectiveness (%)
Cotton and peanuts	60%

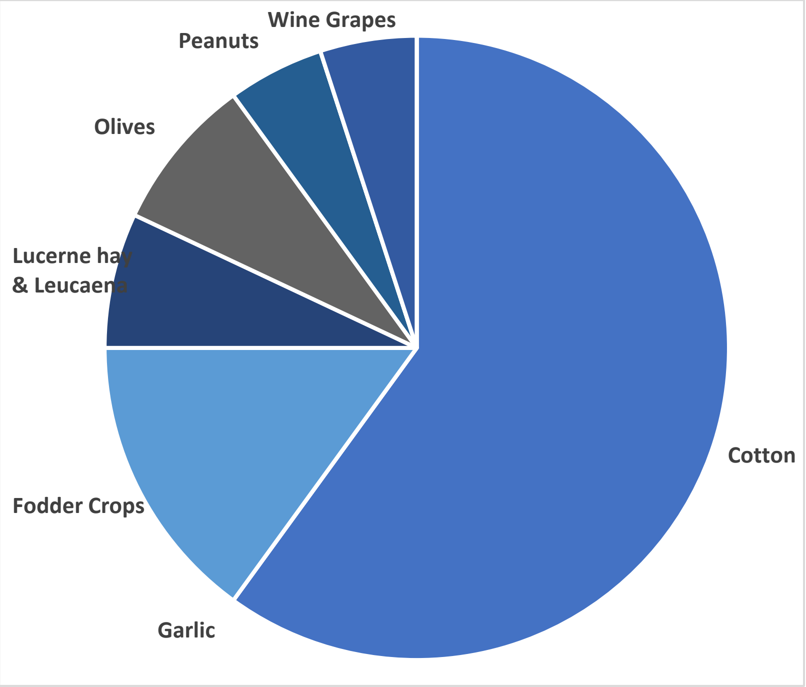
Crop type	Rainfall effectiveness (%)
Hay and fodder	80%
Vegetables	60%
Tree crops (incl table grapes and olives)	55%

Source: Consultation with growers.

3.9.4 Enterprise mix

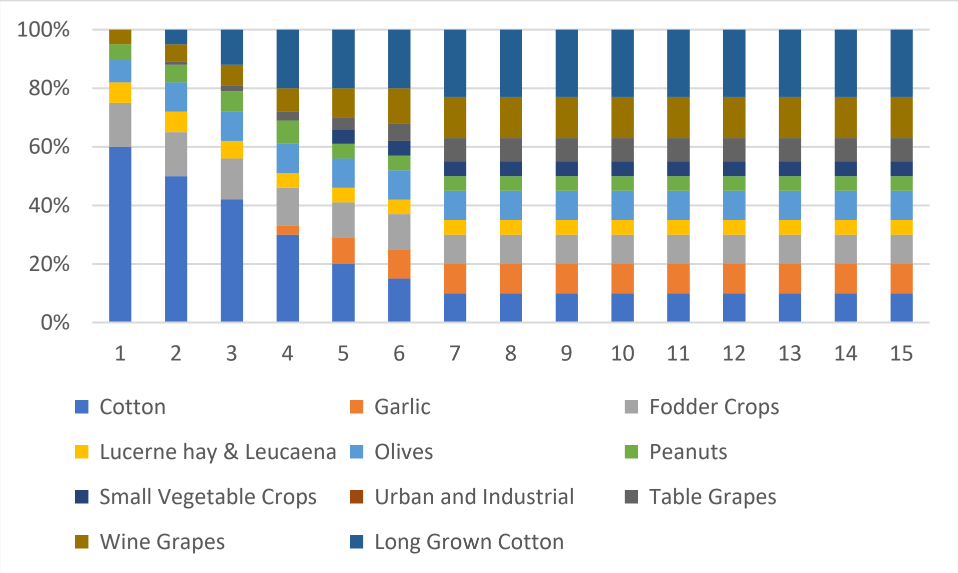
The central enterprise mix adopted for this project has been developed primarily through the results of the demand assessment process. Potential customers were asked to give detail on the crops they are proposing to develop if the project was to proceed (see the demand assessment). Data was also collected from on-ground consultation, including several stakeholder meetings and engagement, previous literature and data on the region including soil suitability, government databases and reports to further strengthen the crop mix.

Figure 3.13 Barlil Weir and West Barambah Weir crop mix (Year 1 of operation)



Over time, it is expected that the access to more reliable water will enable irrigators to invest in higher-value crops. The figure below shows this gradual transition from a cotton area towards grapes, olives and garlic.

Figure 3.14 – Barlil and West Barambah Weir – crop mix of 15+ years of operation



The net margins and irrigation volumes used to establish the economic benefits are set out below.

Table 3.14 – Barlil Weir and West Barambah Weir crop mix

Crop	Net margin ($/ML)	Irrigation water use (ML/ha)
Cotton	669	6.6
Garlic	2,094	5.6
Fodder crops	670	2.7
Lucerne hay & Leucaena	374	10.2
Olives	1,978	4.1
Peanuts	856	4.1
Small vegetable crops	1,012	3.6
Table grapes	1,737	6.0
Wine grapes	2,133	2.6
Long grown cotton	1,449	9.1
Total		

The benefits of additional tourism have also been calculated, based on the Australia-wide winery data. In total, the additional local revenue is calculated to be almost $500,000. Of this, the direct tourism benefit is $70,000 per year.

3.10 ECONOMIC COSTS

The economic costs associated with the scheme include:

- capital and operating costs
- opportunity costs associated with the base case
- downstream impacts
- environmental costs.

3.11 CAPITAL COSTS

A summary of the raw engineering costs for each project are outlined in the following table alongside the annual operating costs. These costs are set out in more detail in the engineering report.

Table 3.15 – Summary of capital and operating costs for each project ($ M)

	Barlil Weir	West Barambah Weir	Combined total
Total risk-adjusted capital cost	13.1	22.6	**35.7**
Annual operating costs	0.15	0.15	**0.30**

3.12 OPPORTUNITY COSTS ASSOCIATED WITH THE BASE CASE

An opportunity cost is associated with the transition of the targeted irrigation area from existing cropping and uses. The Round 1 demand assessment outlined a summary of the key current enterprises grown by customers. The adopted base case is that additional irrigated land will offset beef cattle.

The opportunity cost associated with the transition of the targeted irrigation area from existing cropping and uses is estimated to be $143 per hectare

Approximately 123 hectares (67 ha Barlil Weir and 56 ha West Barambah Weir) of dryland farming will be converted for irrigation use. The opportunity cost of this transition is expected to be $170,000 in NPV terms over 30 years at a 7% real, discount rate.

3.13 RESIDUAL VALUE

It is expected that the life of the project will be far longer than the approved assessment period of 30 years, so a residual value is calculated. Recent consultation with Queensland Government and Infrastructure Australia indicated that residual values can be appropriate, particularly for long-lived assets such as pipelines. The Queensland Treasury guidelines indicate that the residual value should be the lower of two values: asset value or net benefit stream for the remainder of the project life.

The residual value in year 30 of the two approaches is shown in Table 3.16

Table 3.16: Residual value – asset value and benefits stream approach ($ million)

	Barlil Weir	West Barambah Weir
Asset value	8.4	14.4
Net benefit stream	9.9	8.1

3.13.1 Benefit-cost ratios and net present values

The economic benefits of each project are presented below:

Table 3.17: Economic benefits delivered by each project ($ million)

	Barlil Weir	West Barambah Weir	Combined
Agricultural production	4.9	4.1	9.0
Incremental benefit from changes to crop mix	14.4	12.0	26.4
Wine production	3.0	2.5	5.4

Residual value	1.1	1.9	3.0
Opportunity cost	–0.09	–6.49	–6.6
Wine tourism benefit	0.7	0.7	1.4
Total	**24.0**	**14.6**	**38.6**

The results of the CBA using a 7% discount rate as per Queensland business case guidelines are shown in the table below.

Table 3.18: Economic analysis results (7% discount rate)

	Barlil Weir	West Barambah Weir	Combined
Total benefits ($ million)	24.0	14.6	38.6
Total costs ($ million)	12.9	21.2	34.1
NPV ($ million)	11.1	(6.6)	4.5
BCR	**1.86**	**0.69**	**1.13**

3.13.2 Sensitivity analysis

Sensitivity analysis have been conducted in accordance with Queensland guidelines on key inputs as shown below:

Table 3.19: Sensitivity analysis on key inputs

Case name	Economic BCR	Economic NPV ($ million)	Economic BCR	Economic NPV ($ million)
	Barlil Weir		**West Barambah Weir**	
Base case – asset value (BQ)	1.86	11.1	0.69	(6.5)
Residual value – benefits stream (IA)	1.88	11.3	0.60	(8.4)
No residual value	1.77	10.0	0.60	(8.4)
Net margins up 10%	1.89	11.5	0.71	(6.1)
Net margins down 10%	1.82	10.6	0.67	(7.0)
Net margins down 20%	1.78	10.1	0.65	(7.4)
Operating costs down 10%	1.88	11.2	0.70	(6.4)
Operating costs up 10%	1.84	10.9	0.69	(6.7)
Capex up 50%	1.29	5.3	0.47	(16.4)
Capex down 20%	2.26	13.3	0.85	(2.6)

3.14 ECONOMIC IMPACT ASSESSMENT

The preceding economic assessment has been prepared in accordance with the Queensland government's business case and CBA guidelines. These guidelines specify the types of economic benefits and costs that are suitable to include in a CBA, which have been adhered to in arriving at the NPVs and BCRs for this scheme.

The Queensland guidelines also set out those costs and benefits that should not form part of the core economic assessment but instead may be included in a broader economic impact assessment (presented below), due to their obvious and significant impacts on regions and industries and to meet state development aims.

3.15 WIDER ECONOMIC BENEFITS – JOBS CREATED BY PROJECT

The following table outlines the full-time equivalent new employment positions (jobs) supported by the medium volume case, which is common across both options.

There are two main categories:

- full-time jobs of direct agricultural employment
- full-time jobs of indirect agricultural employment in support industries, such as farm input suppliers (e.g. fertilizer, seedlings, pesticides, packaging and fuel) and services (e.g. transportation, refrigeration, mechanical, food, accommodation and accountancy).

The estimates of supported full-time jobs have been created by examining the input-output tables produced by the ABS. The following table presents the direct and indirect agricultural employment that the project supports at full production.

Table 3.20: Agricultural FTE positions

	Barlil Weir	West Barambah Weir	Combined total
Direct	7	6	13
Indirect	17	18	35
Total	24	24	**48**

Table 3.21: Construction FTE positions

	Barlil Weir	West Barambah Weir	Combined total
Direct	2	3	5
Indirect	2	4	6
Total	**4**	**7**	**11**

By the time to transition to higher-value crops is complete, the increase in agricultural production is approximately $8 million per year.

3.16 PROJECT RISKS

A preliminary risk assessment was undertaken to identify and consider the most significant risks that could impact the success and outcomes of the proposed water infrastructure projects.

The methodology for assessing the risks conforms with the Queensland Government risk management frameworks and the relevant Australian Standard AS/NZS ISO 31000:2009 Risk Management—Principles and Guidelines with is set out the preliminary risk assessment report.

The preliminary risk assessment identified ten critical risks that will potentially impact each of the proposed water infrastructure options. Each risk was assessed against the uniformed criteria and the consequences were identified and measured. Figure 3.22 shows the top risks and the assigned risk rating based on the assessment set out in the Preliminary Risk Assessment Report.

The Preliminary Risk Assessment Report provides mitigation activities for each of the identified risks, including recommending further assessment and study in any future detailed business case, or equivalent feasibility assessment, of a water infrastructure option.

Figure 3.23: Identified risks and risk levels

1. **Demand for water is lower than projected in the demand assessment for a particular project**
   MEDIUM LEVEL RISK
2. **Water is too expensive for local irrigators**
   MEDIUM LEVEL RISK
3. **Unexpected ground conditions**
   MEDIUM LEVEL RISK
4. **Construction market prices are high for due to demand**
   HIGH LEVEL RISK
5. **Failure to secure water planning approval (where required)**
   HIGH LEVEL RISK
6. **Failure to secure planning approval from State and Federal Governments**
   HIGH LEVEL RISK
7. **Significant environmental impacts identified, and projects fail to achieve approvals**
   HIGH LEVEL RISK
8. **Market prices and/or yield for crops is materially different to model**
   MEDIUM LEVEL RISK
9. **Climate change impacts on the project (right crops, adaption, yield, crop yield)**
   HIGH LEVEL RISK
10. **Project does not meet requirements and aspirations of Traditional Owners**
    HIGH LEVEL RISK

3.17 CONCLUSIONS AND RECOMMENDATIONS

There is sufficient demand to justify the construction of both Barlil Weir and West Barambah Weir. However, it is possible to supply both groups of customers with MP+, building just Barlil Weir.

Our assessment of each weir is summarised below.

Table 3.24:

	Barlil Weir	West Barambah Weir
Size	1,500 ML	4,500 ML
Cost	$13.1 M	$22.6 M
MP+	3,000 ML	2,500 ML
Impact on downstream flood harvesters	Nil	Impacts on 2,000 ML of flood harvesting
Environmental	Some approvals obtained in 2000	High-level scan identified manageable issues
Economic	BCR = 1.3 to 2.3	BCR = 0.5 to 0.85
Design	Weir design undertaken. Would need to be updated.	Concept design only

The Barlil Weir has a strong justification. The investigation of West Barambah Weir has not identified any fatal flaws, but the case for further investigation is marginal.

We recommend that a detailed business case be undertaken, with a focus on the Barlil Weir site. The size of the weir should be maximised, to meet the excess demand.

4 Gordonbrook Irrigation Project

4.1 KEY POINTS

- Gordonbrook dam supplements urban water security for Kingaroy. However, there are very significant water treatment issues that are costly to treat, and limit the ability to take water.
- The Queensland Government's Regional Water Supply Security Assessment found that Kingaroy's urban supply could expect to experience water supply failures once every 13 years. This low level of urban water security could be improved by access to additional water allocation from Boondooma Dam.
- Should Kingaroy have access to additional water from Boondooma, then Gordonbrook dam could be converted to irrigation use. The water quality issues that limit urban use are much more manageable for irrigation use.
- A demand assessment found demand for up to 8,400 ML of water. This substantially exceeds the 1,809 ML that is available.
- A pipeline network was designed to deliver water to the identified potential customers. The 54 km network will take water to 40 farms. The energy for pumping will be provided by a 480 kW solar farm, contributing to the Government's net zero targets. The pipeline will cost $20.3 million.
- The water will be used for high value purpose such as dairy, feedlots and pig production. This will create strong economic benefits.

Table 4.1: BCRs and NPVs

Discount rates	4%	7%	10%
Economic benefits	49.3	33.6	24.1
Economic costs	32.9	28.8	26.0
Net Present Value	16.4	4.8	-1.8
Benefit-cost ratio	1.50	1.17	0.93

- 154 additional jobs will be created

4.2 INTRODUCTION

Gordonbrook Dam is a 6,600 ML storage located 14 km north-west of Kingaroy on the Stuart River. It is owned and operated by the South Burnett Regional Council. South Burnett Regional Council holds an 1,809 ML high priority water allocation from Gordonbrook Dam that supplements the water supply for Kingaroy.

The primary water supply for Kingaroy is Boondooma Dam. South Burnett Regional Council currently draws approximately 30% of Kingaroy's water supply from Gordonbrook Dam and 70% from Boondooma Dam.

Gordonbrook Dam has significant water quality issues that mean that South Burnett Regional Council faces an increasingly difficult (and expensive) task to maintain drinking water standards when the dam falls below 50%.

This option proposes converting Gordonbrook Dam to exclusive irrigation use and removing the existing high priority allocation for urban usage in Kingaroy township.

4.3 HYDROLOGICAL PERFORMANCE OF GORDONBROOK DAM

Gordonbrook Dam is located within the Burnett Basin water plan area. It is located in subcatchment area 'K' as described in schedule 2 of the water plan. Within this area, the dam is in 'zone KD' within the Stuart River zone which is part of the Boyne and Stuart Rivers water management area1. Zone KD extends from AMTD 83 to 94.5km on the Stuart River and includes those sections of tributaries where there is access to flow or pondage from regulated reaches.

According to DNRME's regional water supply security assessment report (2019) :

- Council holds 1,809 ML/a of water allocation from Gordonbrook Dam
- the dam is owned and operated by Council and located about 14 km northwest of Kingaroy on the Stuart River. Built in 1942 and raised in 1987, Gordonbrook Dam has a full supply volume of 6,500 ML.
- Because of water quality issues which arise as the level in Gordonbrook Dam falls, and the capabilities of the existing treatment plant, Council currently only accesses water from Gordonbrook Dam when the dam is storing more than 3,250 ML (50% of full supply volume).
- In addition, under the current operational arrangements supply to the Kingaroy WTP comprises 30% (or less) from Gordonbrook Dam and 70% (or more) from Boondooma Dam. Once the available allocation from Gordonbrook Dam is exhausted, or Gordonbrook Dam reaches its minimum operating volume (50% of the total capacity), the required demand for Kingaroy is solely met from Boondooma Dam until Boondooma Dam reaches its minimum operating volume or Council's water allocation in the BTWSS for Kingaroy is exhausted.

The following entitlements are shown on DRDMW's water entitlement viewer at this location:

- Authorisation number 406914 – (no nominal volume) Licence to interfere by impounding/Excavation – the chief executive granted this licence under s.1037A of the Water Act to South Burnett Regional Council for infrastructure associated with an authorisation to take water previously held by Kingaroy Shire Council.
- Zone KD – tradeable unsupplemented water allocations totalling 2,411 ML made up of 2,096 ML of water allocations with the purpose of 'any' and 315 ML of water allocations with the purpose of 'agriculture'. A detailed breakdown of the supplemented water allocations are in the following table.

Table 4.2: Supplemented Water Allocations

Authorisation number	Nominal Volume	Purpose
4112AP6975	1,620 ML	Any
3988AP6975	238 ML	Any
3989AP6975	238 ML	Any
4042AP6975	27 ML	Agriculture
4044AP6975	36 ML	Agriculture
4045AP6975	45 ML	Agriculture
4046AP6975	63 ML	Agriculture
4047AP6975	108 ML	Agriculture
4048AP6975	36 ML	Agriculture

It has not been possible to cross-check the water allocations held by Council against the original licences converted under the ROP due to the early version of the ROP only being held in printed format and not being published digitally online. The volume of allocation from Gordonbrook Dam would best be confirmed by Council.

However, the above research suggests that Council hold unsupplemented water allocations – plus a licence to interfere and impound water – that collectively authorise the taking of water from the Gordonbrook Dam. It is not a supplemented scheme, there is no resource operations licence and there are no water sharing rules within any operations manual.

Unsupplemented water allocations are not described as being part of a medium or high priority group or in terms of monthly or annual reliability. Instead, the water allocation security objective performance indicator for a group of water allocations to take unsupplemented surface water is the "annual volume probability". This statistic relates to the percentage of years in the simulation period in which the volume of water that may be taken by the group is at least the total of the nominal volumes for allocations in the group.

It is not the same as annual reliability because the annual volumetric limit for an unsupplemented water allocation may exceed its nominal volume (which is not usually the case for supplemented water allocations). However, in this instance (where the water allocation's annual volumetric limit is likely to be the same as its nominal volume) it is likely to be very similar to annual reliability.

The water plan states that minimum annual volume probabilities for unsupplemented water allocations in classes 1K and 7K (one of which it is likely that the Council's water allocation will belong to) are 78% and 80% respectively. It is likely that achieving this level of performance is modelled assuming full utilisation of the entitlement i.e. not restricting supply whenever the dam is less than 50% full).

The unsupplemented water allocation performance for Council's water entitlement (if fully utilised) appears to be more akin to that of a medium priority rather than high priority supplemented water allocation.

There is little scope within the current water planning framework for making changes to the Council's unsupplemented water allocation to achieve a higher hydrologic performance (i.e. to that akin to a high priority supplemented water allocation). It is possible that the unsupplemented water allocation could be subdivided and traded to other water users although expediting these steps may require a specific change to the water management protocol.

4.4 DEMAND ASSESSMENT

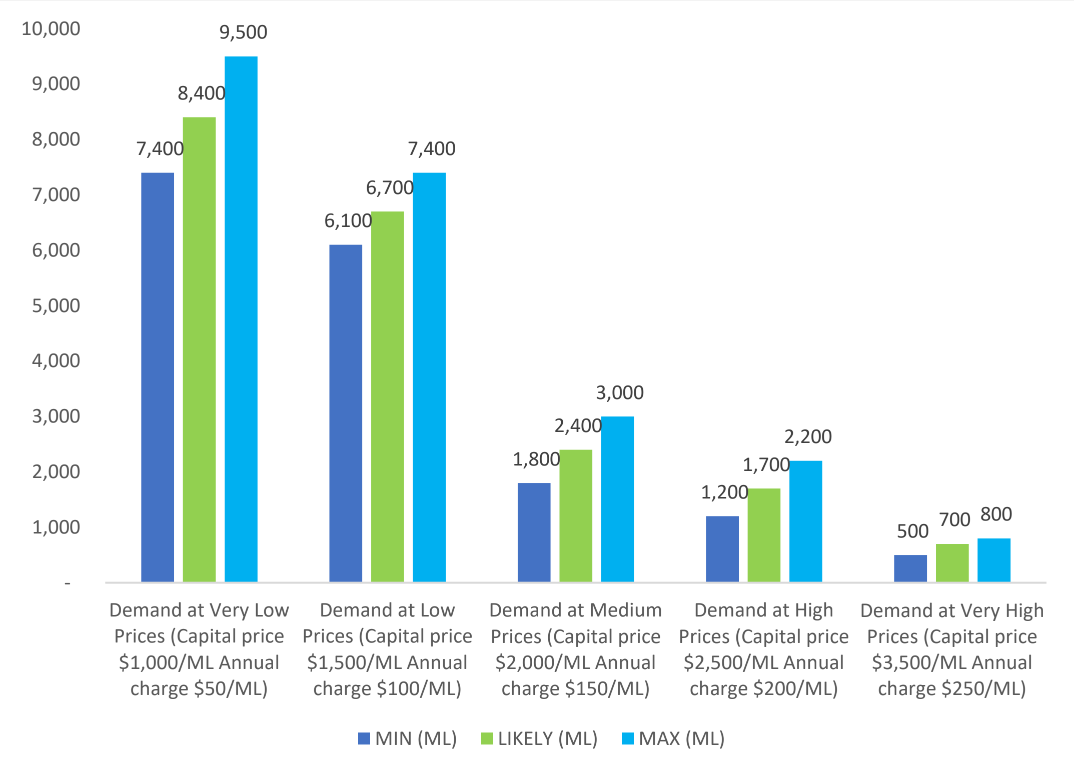
KBR was engaged to conduct a demand assessment for agricultural and other uses of the Gordonbrook Dam.

There are 25 businesses interested in this water supplying 48 farms and other entities. Minimum, likely and maximum demand volumes are as follows. Likely demand at the optimal price will drive the engineering.

4.4.1 Demand and water uses

The very low price has likely demand of 8,400 ML. The low price has likely demand of 6,700ML. The medium price has likely demand of 2,400 ML. Likely demand falls below the available Gordonbrook Dam 1,800 ML of supply at the high and very high prices.

Figure 4.1 Demand for Gordonbrook Dam (ML)



Future economic water uses change as prices change. For example, peanut demand falls as prices rise. At higher prices intensive livestock, citrus and avocados reflect a higher proportion of the albeit significantly lower demand. A high priority product may be needed by intensive livestock, avocado and citrus growers. A medium priority product may be better suited to peanuts and other annual crops.

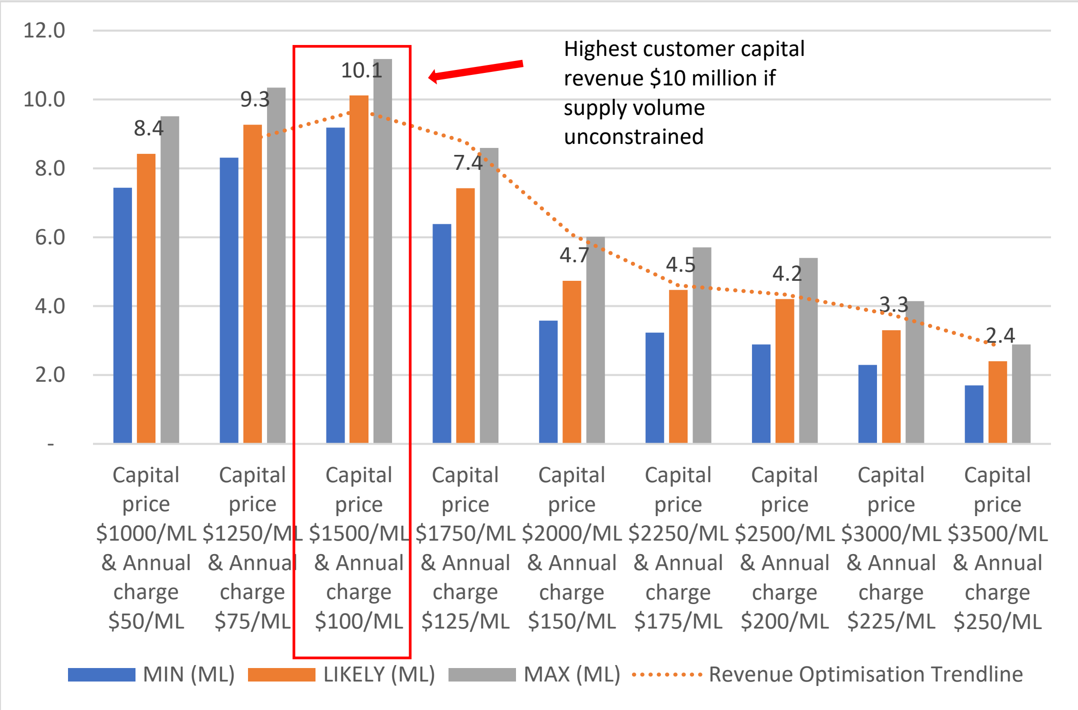
Forecast impacts of climate change on the Wide Bay-Burnett region strengthen the case for this project. For example, higher average temperatures and greater rainfall variability will led to frequent failure of dryland crops. This underpins the need for Council to progress a reliable source of irrigation and livestock water.

4.4.2 Customer capital contributions – No supply constraint

Assuming no supply constraint, customer capital revenue and capital pricing options are set out in Figure 1.2, which indicates that optimal revenue may be achieved at a customer capital price of $1,500/ML.

Experience has shown that it is possible to identify a more precise customer capital sweet spot if mid-point prices and revenues are also derived / interpolated from the primary demand data. The figure below includes prices tested and implied mid-point prices and customer capital revenue.

Figure 4.2 Customer capital revenue at different prices (incl. interpolation) ($ million)



The figure above provides confidence that a customer capital price of $1,500/ML is likely to maximise absolute customer capital contributions if all demand (i.e. 6,700 ML) can be met, giving the project its best chance of success. However, the revenue of $10 million is based on the likely demand with no supply constraint.

If a Round 2 demand assessment were to be undertaken at say $1,500/ML the forecast 6,700 ML demand volume may justify using all available water from Gordonbrook Dam (1,800 to 2,400 ML), with the balance of supply emanating from Boondooma Dam, combined into one potentially staged project.

Larger volumes of demand would justify developing a delivery network with greater capacity. Such a project would be more costly in absolute capital cost terms, but more affordable from a customer perspective. This is because supplying a higher volume lowers fixed annual charges ($/ML), due to the economies of scale.

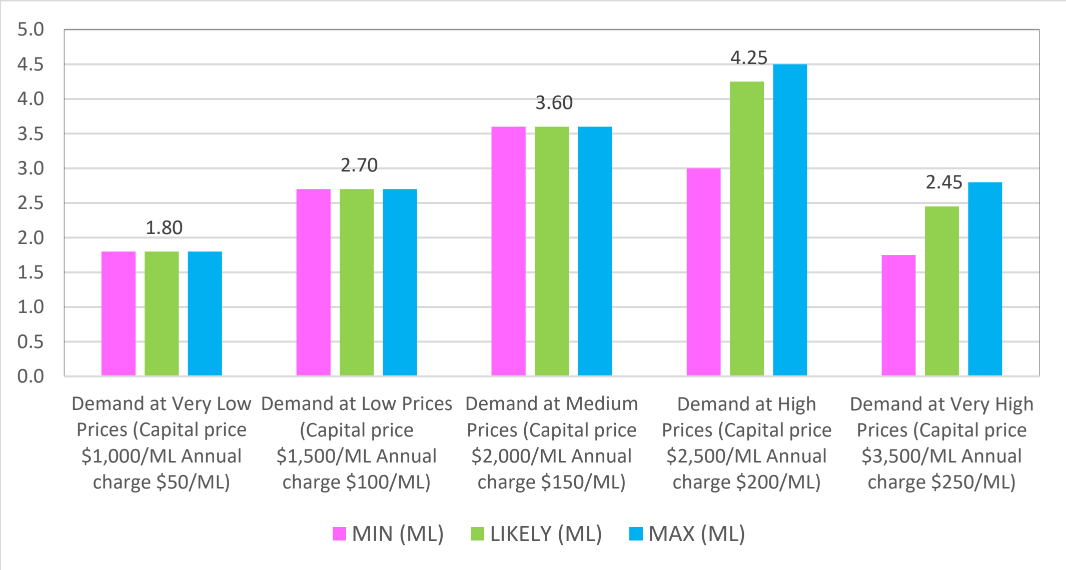
4.4.3 Customer capital contributions – With supply constraint

If Council confirms that it only holds 1,800 ML of water entitlements from Gordonbrook Dam, and ultimately no additional supply of water is found, assuming a supply constraint of 1,800 ML the forecast customer capital contributions and capital pricing options are in Figure 1.3. This analysis suggests customer contributions are optimised at a capital price of $2,500/ML.

The likely demand at this point is 1,700 ML, which may allow a higher reliability water product to be developed from Council's 1,800 ML. Alternatively, in a future demand assessment all 1,800 ML may be sold. As a result of adopting $2,500/ML as a capital price the revenue may be $4.25 million (1,700 ML) or $4.5 million (1,800 ML).

One consequence of adopting too high a capital price may be lower than expected demand in future demand assessments and therefore lower economic benefits. Moreover, the cost effectiveness of a low volume pipeline distribution network is not favourable due to poor economies of scale, as noted above. Volume is the key to reducing fixed annual charges per ML – and fixed annual charges can often drive demand at water sales.

Figure 4.3 Customer capital revenue at different prices with a supply constraint of 1,800 ML ($ million)



4.4.4 Demand Conclusions

As part of the broader economic road map being undertaken for Council, demand volumes exceeding Gordonbrook Dam's available supply, will support the business case for Council to access other sources.

At very low, low and medium prices demand exceeds supply. This demand could be met by Gordonbrook and Boondooma dams combined. Depending on the available supply volume, our revenue analysis suggests an optimal customer capital price for a future demand assessment of:

- $1,500/ML if the project is not supply constrained, which would raise $10 million from customers, or
- $2,500/ML if the project is constrained to 1,800 ML supply, raising up to $4.5 million from customers.

The optimal capital price depends on the supply available, but also the reliability of the water product/s.

Further hydrological assessments will be required to determine water product options and their reliability. It is recommended that further hydrological analysis establish the maximum volume of water that Gordonbrook Dam can supply, and the reliability of its water product/s. Consideration could be given to the development of a high and medium priority product given the high value future economic water uses proposed by customers.

Detailed consideration should be given to meeting additional demand from this process (e.g. by purchasing water from Boondooma Dam and connecting it to the proposed Gordonbrook Dam water delivery network). Engineering options for improving water quality (e.g. via blending or treatment) should be considered.

4.5 PIPELINE DESIGN AND COST ESTIMATE

4.5.1 Basis of design

The project will deliver water year-round to customers through a new distribution network. A solar farm has been included to reduce the annual charge to customers, as well as achieve a net-zero energy target.

It is anticipated that the scheme will operate year-round, with interruptions for scheduled and unscheduled maintenance. The basis of design for the network is detailed in Table 4.3. and underpins the development of a cost-efficient low pressure, low volume pipeline network.

Table 4.3 Basis of design

Design parameter	Assumption	Comment
Scheme reliability	Instantaneously delivery	
Round 1 demand	6,765 ML	Demand at lower prices
Scheme infrastructure design demand	1,800 ML	The supply capacity of Gordonbrook Dam is 1,800 ML/year and is the limiting factor on the design demand for the scheme.
Delivery period	270 days, 24hrs/day	
Peak flowrate	31 L/s	Individual customer flowrates will vary.
Flow velocity	Maximum 2.4 m/s Minimum 0.9 m/s	
Source pressure	0 m	The water will be sourced from downstream of the dam wall and therefore will be at atmospheric pressure.
Delivery pressure	5 m residual pressure at customer outlet valve	Depending on outlet location and scheme demand, residual pressure will vary.
Pump efficiency	70%	
Pipeline losses	Friction coefficient, 150 No losses for valving or bends	HDPE pipe
Solar sizing	8 hrs/day solar generation 2.5 ha/MW land area	A location for the solar farm has not yet been selected, though vacant land is available throughout the scheme.
Civil asset design life	100 years	
Mechanical asset design life	40 years	
Solar asset design life	30 years	

4.5.2 Pipeline and pumping design

The distribution network has been designed to deliver water to customers using an efficient route through road reserves to viable parcels of demand based on the upper supply limit of 1,800 ML per year and the results of the Round 1 Demand Assessment. With the total expressed demand far outstripping the 1,800 ML/year available from Gordonbrook Dam, only a limited portion of the expressed demand can be supplied.

The pipeline route and the parcels it services have therefore been chosen selectively based on the scale of clusters of demand combined with the customer willingness to pay.

The indicative pipeline route is shown in Figure 4.4, along with the location of demand parcels that will be supplied by the scheme (from the Round 1 Demand Assessment) and the proposed location of pump stations. Elevation profiles of the trunk main (Figure 4.5) and pipeline spurs (Figure 4.6 through Figure 4.8) following.

The 59 km pipeline network starts with a raw water pump station downstream of the Gordonbrook Dam and runs in a general east / south-east direction to key parcels of demand and sufficient scale. There is a significant climb of approximately 165 m from the raw water pump station to the peak elevation point in the network, requiring three pump stations to overcome the lift required. Five spurs of the trunk main take water out to parcels off the main route.

Figure 4.4 Proposed pipeline alignment (red) through design parcels (blue) and existing pipelines in Gordonbrook (green)

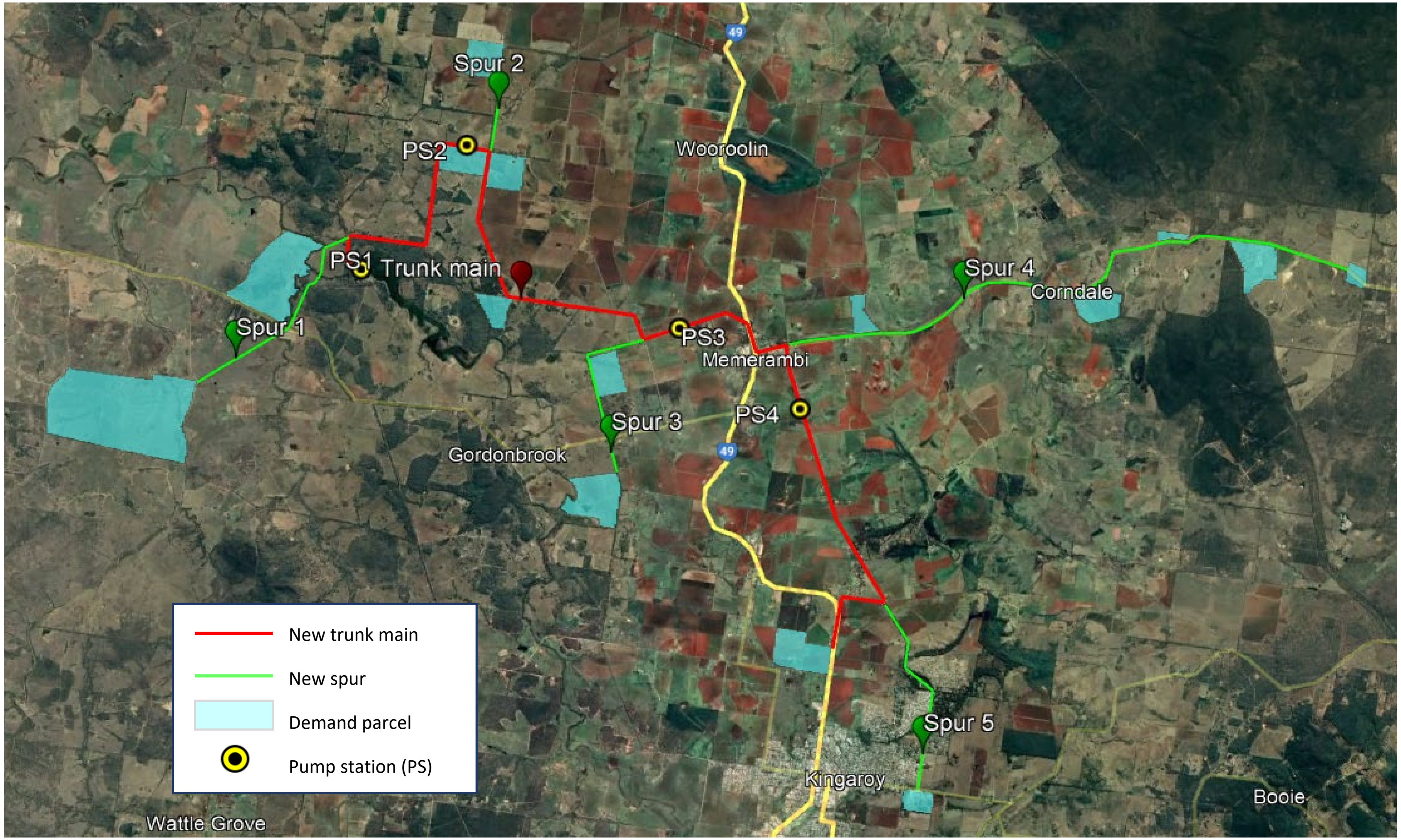


Figure 4.5 Propose trunk main elevation profile

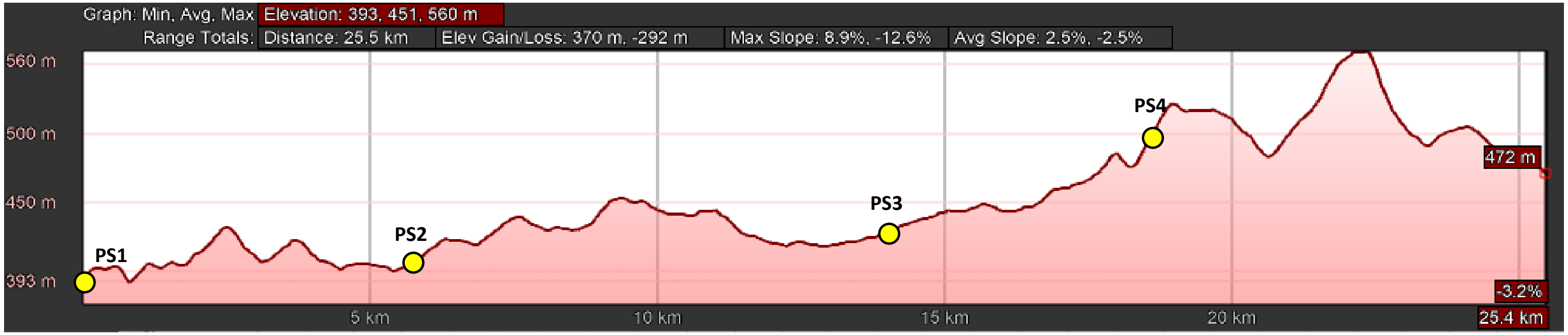


Figure 4.6 Spur 1 (left) and Spur 2 (right) elevation profiles

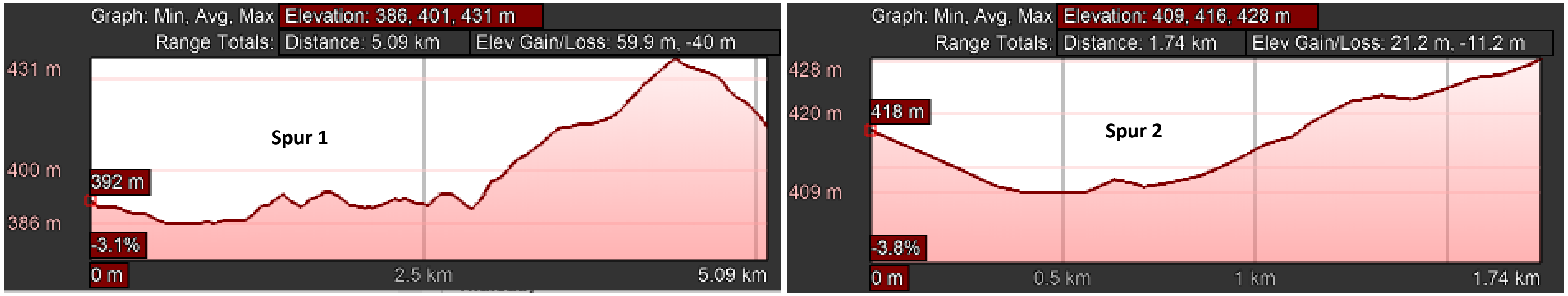
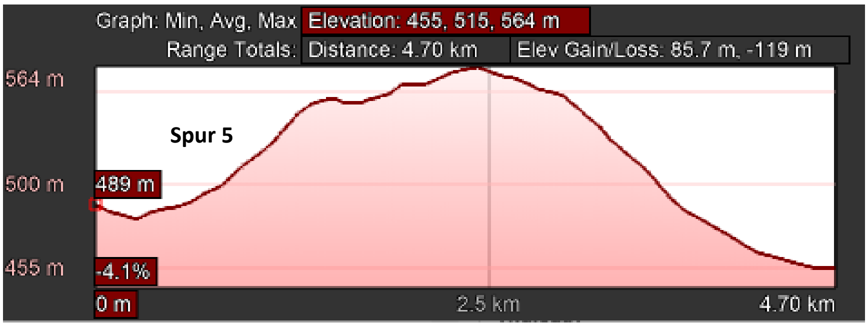


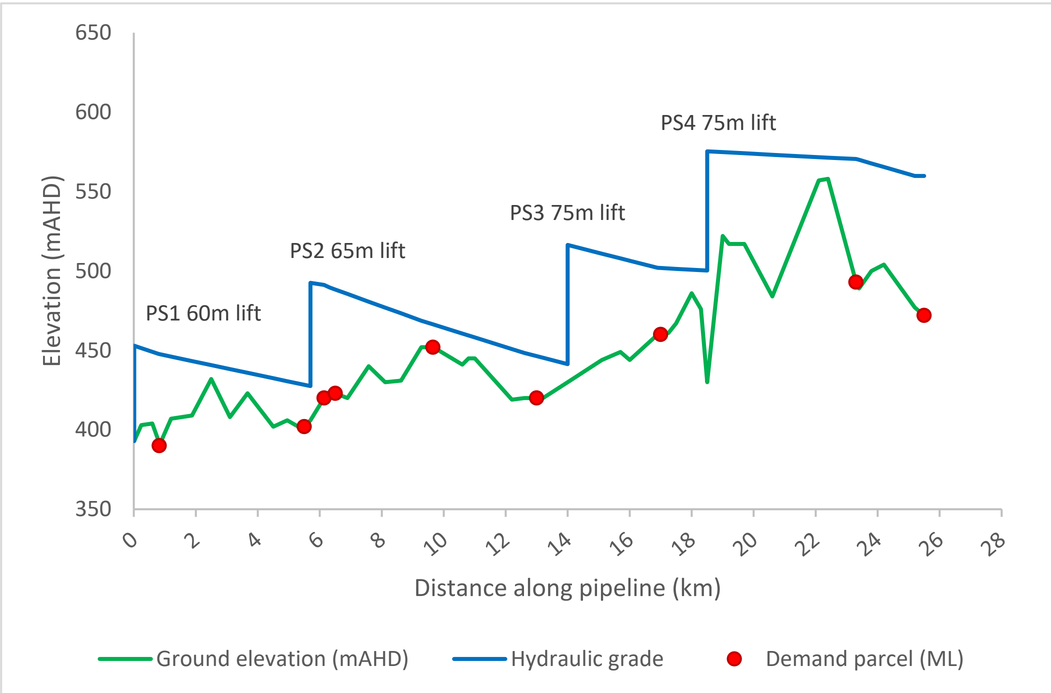
Figure 4.7 Spur 3 (left) and Spur 4 (right) elevation profiles

Figure 4.8 Spur 5 elevation profile



The hydraulic grade of the pipeline is displayed in Figure 4.9 below, which presents the hydraulic performance of the pipeline during peak demand with all customers drawing water from the network simultaneously. The proposed pipeline route and sizing with the selected pump station duty points overcomes all elevation rises and supplies the minimum 5 m pressure to customer property outlets, including those on the network spurs.

Figure 4.9 Pipeline elevation, hydraulic grade and location of demand parcels



Also displayed are the positions and volumes of parcels of demand along the proposed trunk main route. Where multiple parcels of demand are on a spur, the total demand of the spur is displayed.

Five spurs from the trunk main deliver water to parcels that are off the main route. These spurs also cross areas of highly variable elevation, and have been sized to deliver at least 5 m of pressure at the outlet of the customer connection where possible.

Where the customers are at the end of the spurs and downhill of the main (e.g., Spur 4), their pressure will be at or above minimum pressure. Where there is a peak along the pipeline route or a rise to the end, the hydraulics may need further refinement and should be a focus of subsequent, more detailed engineering.

The lengths of pipe by size are presented in Table 4.4.

Table 4.4 Pipeline length by diameter

Diameter (mm)	Length (m)
Distribution main	
110	2,200
160	6,400
250	10,760
315	6,140
Distribution subtotal	**25,500**
Spurs	
250	5,090
110	1,700
180	4,120
280	13,700
63	4,700
Spurs subtotal	**29,310**
TOTAL	**54,810**

The pump station sizing is presented in Table 4.5.

Table 4.5 Pump station lift (m) and size (kW)

Pump station	Lift (m)	Size (kW)	Energy (kWh/year)
PS 1	60	65	420,000
PS 2	65	54	350,000
PS 3	75	38	246,000
PS 4	75	1	9,000
TOTAL		**158**	**1,026,000**

4.5.3 Solar farm design

The scheme includes a solar farm to offset and generate power beyond the net-zero energy target, and to achieve a cost saving for customers by reducing their annual charge by 20%. The solar farm specifications are presented below in Table 4.6.

Table 4.6 Proposed solar farm specifications

Item	Value
Solar farm size (kW)	480
Solar farm area (ha)	1.4

The solar farm is sized so that the solar energy generated during daylight hours will fully offset the day of pumping. This means one third of the solar farm capacity will fully power the scheme during daylight hours, and the remaining two thirds of its capacity will generate additional power to offset the pumping occurring overnight.

This arrangement achieves net-zero energy over the 270 operational days of the scheme, plus additional energy exports during the other 95 days of the year for an overall net-positive scheme. This is demonstrated in Table 4.7. Over a full year, the scheme will export 376,000 kWh.

Table 4.7 Solar energy – pumping offsets and additional exports

Item	Energy (kWh/year)
Pumping energy required	**1,026,000**
Solar directly powering day-time pumping	342,000
Solar offsetting night-time pumping	684,000
Solar subtotal	**1,026,000**
Solar power additional exports	376,000
Total solar energy generated	**1,402,000**
Net solar exported	376,000

4.5.4 Cost estimate

The capital estimate breakdown is presented in Table 4.8 with a total capex estimate of $9.85 million including 30 per cent contingency. A more detailed breakdown is provided in Appendix A.

Table 4.8 Capital estimate for proposed network

Item description	Cost ($)
Pipelines	9,440,000
Customer connections	260,000
Pump stations	1,380,000
Solar farm	740,000
Testing and commissioning	120,000
Subtotal	**11,940,000**
Contractor indirect costs	1,790,000
Subtotal	**13,730,000**
Client indirect costs	795,000
Contingency (40%)	5,810,000
TOTAL	**20,335,000**

The operational estimate breakdown is presented in Table 4.9. A more detailed breakdown is provided in Appendix A.

Table 4.9 Estimated cost of operating the proposed network

Item description	Cost ($/annum)	Customer charge ($/ML)
Infrastructure maintenance	38,100	21
Staffing allowance	120,000	67
Power cost	136,800	76

Item description	Cost ($/annum)	Customer charge ($/ML)
Solar farm power exports	-53,000	-29
Annualised replacement	112,600	63
TOTAL	**384,500**	**197**

The 20% saving to customers' annual charges, resulting from the inclusion of a solar farm to offset power consumption, is demonstrated in Table 4.10.

Table 4.10 Savings to customers through solar farm

Item	Opex impact ($)	Customer charge impact ($/ML)
Opex without solar	**479,000**	**266**
Power replaced by solar at 20c/kWh	-68,400	-38
Solar power exported during the pumping day at 5c/kWh	-34,700	-19
Solar power exported during scheme downtime at 5c/kWh	-18,200	-10
Increase to annualised replacement of assets	26,800	+15
Final opex with Solar	**384,500**	**214**
Savings delivered to customers through solar	**-94,500**	**-53** **20% saving**

4.5.5 Potential for design Optimisation

The pipeline route and the parcels it services have been selected chosen based on Round 1 Demand Results. This has directly guided the selected route and reach of the scheme. There may be alternative routes based on future demand assessment that are more optimal in terms of the cost to deliver the water and the potential for greater benefit from its use.

A review of the proposed pipeline route should therefore be triggered by new data on customer demand and willingness to pay, to optimise the economic benefit of the limited water resource from Gordonbrook Dam.

4.6 ECONOMIC ASSESSMENT

The economic analysis develops a coherent socio-economic narrative of the qualitative and quantitative costs and benefits that could be realised through a new pipeline to provide agricultural customers with water from Gordonbrook Dam.

This economic assessment is aligned with the Building Queensland and IA frameworks. The approached for this study is as follows:

- Understand the base case
- Where economic impacts are material and quantifiable, quantify the economic benefits and costs (i.e. net cash flows) relative to the base case.
- Test the sensitivity of key inputs.

The general parameters and assumptions include model start year, assessment period and discount rates. The starting year and assessment period are shown below.

Table 4.11: Starting year and assessment period

Parameter	Unit	Value
Starting Year	Year (period)	2022
Assessment Period	Number of years	30

Discount rate scenarios, with the medium scenario (7% real) being the central scenario, are shown below.

Table 4.12: Discount rate scenarios

Discount rate	Real discount rate, pre-tax (%)
Low	4%
Medium	7%
High	10%

The alignment of these key parameters with the relevant frameworks is outlined in the table below.

Table 4.13: Alignment of key economic assumptions

Parameter	Adopted value/s	Justification
Discount rate	7% (central) 4% and 10% (sensitivities)	These values are in accordance with Infrastructure Australia (IA) and the Queensland Treasury Cost Benefit Analysis Guide.
Starting year	2022	All benefits in the economic analysis are presented in 2021 constant prices.
Appraisal period	30 years with residual value of net benefits included	An analysis period of 30 years (operational) was adopted in line with the Queensland Treasury Cost Benefit Analysis Guide.

4.6.1 Agricultural benefits

The economic benefits of additional water are largely improved agricultural production in the region. They are calculated based on key inputs:

- Demand assessment – how much water is demanded by customers and what will this water be used for.
- Reliability of the water product – how much water will customers likely receive per year
- Likely water use – how water will be used for which crop
- Net margin of water use – how much economic value will be generated by each megalitre of water used by customers.

4.6.2 Data sources

The overall economic benefit depends on the crop mix, water use by crop in the region and the net margin of each crop. The data used in this analysis were gathered from a range of sources including:

- demand assessment and further consultation with potential customers. This process drives the underlying crop mix and economic benefits. Customers were also asked to provide information on future plans for the water this assisted with the economic benefit calculation.

- previous literature provided by the client and state government.
- Agbiz farm budgeting tools – Queensland Government. Used to cross checked customer data and ensure margins are representable of the region.
- AgMargins Gross Margin Calculator - Queensland Government. Used to cross checked customer data and ensure margins are representable of the region.

data was collected through the demand assessment process and on-the-ground consultation, including several stakeholder meetings and engagements. This has informed the proposed crop mix and water use used to calculate the total economic benefit.

4.6.3 Direct Economic benefits

The economic benefits of the potential project are calculated based on key inputs

- Demand assessment – how much water is demanded by customers
- Reliability of the water product – how much water will customers likely receive per year
- Likely water use – Agriculture, Industrial and High Care
- Net margin of water use – how much economic value will be generated by each ML of water used by customers.

The three inputs are detailed in the following sections.

4.6.4 Demand assessment summary

The demand for new water from this project, resulting from the Round 1 EOI demand assessment process is as follows. Round 1 demand assessment was undertaken to determine likely customer demand for additional water. The following scenarios have been included as part of the economic assessment.

Table 4.14 Water products

Medium priority	High Priority Ag
Reliability	90%
Capital charge – once-off upfront ($/ML)	$2,500

The results of the demand assessment are shown in Table 4.15.

Table 4.15 Likely water demand (ML/annum)

Water product	Demand Volume (ML)
Medium priority (80% reliability)	1,809

Detailed information on the demand assessment is provided in the Demand Assessment report.

4.6.5 Economic benefits of agriculture

The primary economic benefits of the project relate to increased agricultural output as net margins (profit per megalitre of water applied). The benefits were calculated by:

- determining the amount of water likely to be used for each enterprise (net of rainfall) and crop area.
- calculating the gross margin (revenue minus variable operating costs) for enterprise type per megalitre and then subtracting the fixed costs (upfront and ongoing) to obtain the net margin for each crop. This is achieved through on-the-ground consultation-driven process, industry experience and public sources. Each crop has a different net margin, depending on the yield, costs and commodity prices.
- multiplied amount of water by reliability by the net margin to obtain the annual economic benefit and convert the annual benefits to a single net present value.
- Sensitivities conducted on key inputs as a result of higher costs or changing variables to understand the reflexivity of each net margin.

4.6.6 Effective rainfall for crops

The irrigation water use per hectare is the volume of water that is applied to crops. The annual amount of rainfall determines the application of irrigation water use. The total rainfall for the irrigation area is shown in the following table.

Table 4.16: Annual rainfall (mm)

	Annual Total (mm pa)
Low (10th percentile)	533
Medium (median)	743
High (90th percentile)	1,033

Source: Australian Bureau of Meteorology, 30-year average to 2020 at Wooroolin

A 100mm of rainfall per hectare is 1ML per hectare so average annual rainfall provides 7.4 ML per hectare per annum. This rainfall is then factored by the timing of rainfall compared to the crop's demand and the ability for crop to absorb the water (rainfall effectiveness).

The rainfall effectiveness by crop type is shown in the following table.

Table 4.17: Rainfall effectiveness by crop type

Crop type	Rainfall effectiveness (%)
Avocados, irrigated peanuts and horticulture	60%
Fodder	80%
Citrus	55%

Source: Consultation with growers

4.6.7 Enterprise mix

The central enterprise mix adopted for this project has been developed primarily through the results of the demand assessment process. Potential customers were asked to give detail on the enterprises they are proposing to develop if the project was to proceed (see Demand Assessment report).

Data was also collected from on ground consultation, including several stakeholder meetings and engagement, previous literature and data on the region including soil suitability, government databases and reports to further strengthen the enterprise mix.

Table 4.18: Proposed enterprise mix

Economic Benefit	Percentage of Demand
Avocados	12%
Citrus	4%
Dairy	18%
Feedlot	21%
Hay / Lucerne	3%
Horticulture	3%
Peanuts	12%
Pig production	21%
Sorghum	6%
Total	**100%**

4.6.8 Net margins

Net margins (irrigation profit after fixed and variable costs) is a key component of the economic benefits for the scheme. The scheme generates economic benefits for:

- irrigated crops
- livestock and dairy production.

4.6.8.1 Irrigated crop net margin

The primary economic benefit resulting from the demand assessment is increased irrigated agricultural output.

The key inputs to the net margin analysis include but not limited to:

- Gross income – yield and revenue from each crop type.
- variable costs – fertiliser, seeds, weed and pest control and harvesting costs
- upfront fixed costs – Discing and Raking, Land Levelling, cost of trees, planting and Irrigation systems
- ongoing fixed costs – fixed labour, insurance and professional services and maintenance
- irrigation water use.

The effective rainfall differs based on the timing of the crop water demand and therefore the irrigation water use required.

The following table outlines the key parameters to calculate the net margin per megalitre of water for each irrigated crop.

Table 4.19: Net margins adopted for economic assessment

	Water applied (ML/ha)	Revenue ($/ha)	Gross margin ($/ha)	Net margin ($/ha)	Net margin ($/ML)
Avocados	7.5	42,000	33,000	20,774	2,755
Citrus	7.9	77,500	50,000	31,539	3,986

	Water applied (ML/ha)	Revenue ($/ha)	Gross margin ($/ha)	Net margin ($/ha)	Net margin ($/ML)
Hay / Lucerne	10.1	9,800	3,800	3,365	335
Horticulture	3.5	6,930	4,430	3,656	1,033
Peanuts	4.0	7,500	4,250	3,533	874
Sorghum	2.6	1,600	700	426	167

4.6.8.2 Livestock and dairy production

Potential water customers included an integrated fodder/dairy, a feedlot and a pig producer. All of these customers suffered substantial economic damage during the last drought so it is clear that water is a constraint for these customers.

Detailed consultation with the customers provided indicative net margins for water use. The revenues and costs associated with operations are not provided due to commercially sensitive nature.

Table 4.20: Livestock and dairy net margins ($/ML)

	Net margin ($/ML)
Fodder/dairy	1,000
Feedlot	3,165
Pig producer	3,728

4.6.9 Summary of direct economic benefits

A summary of the direct economic benefits assessed including the percentage of demand and weighted net margin is provided in the table below.

Table 4.21: Summary of economic benefits

Enterprise	Percentage of demand	Economic benefit ($million, 7% discount rate
Avocados	12%	5
Citrus	4%	3
Dairy	18%	3
Feedlot	21%	10
Hay / Lucerne	3%	0
Horticulture	3%	0
Peanuts	12%	2
Pig production	21%	24
Sorghum	6%	0
Total	**100%**	**46**

4.6.10 Economic costs

The economic costs associated with the project include:

- Boondooma dam water purchases
- Opportunity cost of Boondooma Dam water entitlements

- Additional upfront and operating costs for Gordonbrook Dam and new irrigation scheme
- Pipeline capital and operating costs

There are other operating costs (including renewals) associated with Gordonbrook Dam that SBRC is already paying and would continue even if the dam was not converted. These costs are not included this analysis

4.6.10.1 Boondooma dam water purchases

The conversion of Gordonbrook dam to irrigation results in additional water to be purchased from Boondooma dam to maintain urban water security for Kingaroy. Preliminary modelling indicates that an additional 540ML will be required from the time that Gordonbrook dam is converted.

SBRC has provided indicative costs for purchasing additional water from Boondooma dam. The costs are for temporary allocations rather than permanent trades. Further negotiation with Sunwater may provide a permanent trade price.

The temporary trade costs are:

- Fixed access charge - $132/ML
- Consumption charge - $501.79/ML

The consumption charge ($501.79) has been used for the cost of Boondooma dam water purchases as it is assumed that SBRC will receive Boondooma Dam entitlements as part of the Just Transition process.

The annual consumption cost is $270,000

4.6.10.2 Opportunity cost of Boondooma Dam water entitlements

The assumption of SBRC receiving 540ML of water entitlements means that the water is provided at a market price. The market price represents the opportunity cost of using this water for Kingaroy urban water supply rather than another use. Therefore, an upfront opportunity cost of $5,000/ML for the 540ML has been included in the analysis. SBRC and Stanwell have had previous discussion about purchasing water entitlements from Boondooma Dam at $5,000/ML.

The result is an upfront opportunity cost of $2.7 million.

4.6.10.3 Additional upfront and operating costs for Gordonbrook dam

The additional upfront cost for the Gordonbrook Dam is the water sales process. A preliminary assessment of the cost of water sales is $350,000 to secure binding water sales.

The additional ongoing costs for the Gordonbrook Dam are shown in Table 4.22

Table 4.22: Additional operating costs

Item	Annual
Administration officer (1 FTE)	85,000
Vehicles (fuel, depreciation, interest)	12,000
Environmental compliance / customer farm plans	12,000
Legal	6,000
Materials	6,000
Occupancy costs (rent)	3,000

Item	Annual
Small plant & equipment (Generator/pumps)	2,520
Communications (Operator mobiles & tablets)	2,400
Communications (Web hosting, email & Wi-Fi)	1,440
Total	**130,360**

4.6.10.4 Pipeline infrastructure

The water released from Gordonbrook Dam will be delivered via a pipeline to customers. The pipeline capital costs are shown in Table 4.23.

Table 4.23: Pipeline capital costs

Pipelines	9,440,000
Customer connections	260,000
Pump stations	1,380,000
Solar farm	740,000
Testing and commissioning	120,000
Subtotal	**11,940,000**
Contractor indirect costs	1,790,000
Subtotal	**13,730,000**
Client indirect costs	795,000
Contingency (30%)	5,810,000
Water sales	350,000
TOTAL	**20,685,000**

The operating costs associated with the pipeline are shown in Table 4.24.

Table 4.24: Pipeline annual operating costs

Item description	Cost ($/annum)
Infrastructure maintenance	38,100
Power cost	136,800
Annualised replacement	112,000
Total	**286,900**

The economic benefit of solar generation that is exported to the grid has not been included as there is no identified service need for new generation in the area and the solar generation will likely offset generation that would have occurred anyway. The revenue from export of solar has, however, been included in the financial analysis and customer pricing to offset financial costs.

4.6.11 Economic results

The economic assessment has been prepared in accordance with Building Queensland's business case and CBA guidelines. These guidelines specify the types of economic benefits and costs that are suitable to include in a CBA, which have been adhered to in arriving at the NPVs and BCRs for this scheme.

Table 4.25: BCRs and NPVs

Discount rates	4%	7%	10%
Economic benefits	$49.3 million	$33.6 million	$24.1 million
Economic costs	$32.9 million	$28.8 million	$26.0 million
Net Present Value	16.4	4.8	-1.8
Benefit-cost ratio	1.50	1.17	0.93

The project has a net economic benefit based on the assumed economic benefits and costs at a 7% discount rate.

4.6.12 Wider economic benefits

The Building Queensland guidelines also set out those costs and benefits that should not form part of the core economic assessment but instead may be included in a broader economic impact assessment (presented below), due to their obvious and significant impacts on regions and industries and to meet state development aims.

The table below outlines the full-time equivalent positions that could be realised with additional water delivered to the region.

There are two main categories:

- full-time jobs of direct agricultural employment
- full-time jobs of indirect agricultural employment in support industries, such as farm input suppliers (e.g. fertilizer, seedlings, pesticides, packaging and fuel) and services (e.g. transportation, refrigeration, mechanical, food, accommodation and accountancy).

The estimates of supported full-time jobs have been created by examining the input-output tables produced by the ABS. The following table presents the direct and indirect employment that additional water could support based on the demand assessment scenarios.

Table 4.26: Employment at full production (FTEs)

Agricultural employment	Full production
Direct	54
Indirect	100
Total	**154**

The direct jobs are largely the result of increased water for the feedlot, dairy and pig production while the indirect jobs relate to the range of suppliers to that industry. The average annual jobs during construction are shown in Table 4.27.

Table 4.27: Construction jobs (FTEs)

Agricultural employment	Annual average
Direct	22
Indirect	54
Total	**77**

4.7 FINANCIAL ASSESSMENT

4.7.1 Key points

- The financial assessment of the project focuses on the financial impacts to customers, SBRC and, potentially, State and Federal Government.
- The capital and operating costs of the entire scheme are used to develop likely customer prices.
- The likely customer charges are shown below.

Table 4.28: Likely customer charges ($/ML)

Pricing	$/ML
Fixed charge	150
Variable charge	90
Total	**240**

- The customer contribution to the pipeline capital costs represents 22% of the capital costs.
- Customers will pay for all ongoing maintenance, operating and renewal costs associated with the dam, pumps and pipes. Over 30 years, customers will contribute 51% of total scheme costs.
- The financial implication for SBRC is an increase of $270,000 per year from additional water purchases from Boondooma Dam to maintain urban water security. This amount, based on average Kingaroy water usage, is an approximate increase of $0.22/kL for all urban users.

4.7.2 Financial analysis

The financial analysis focuses on the total capital and operating costs for operating the water project including existing costs. These costs include:

- Existing Gordonbrook Dam costs
- pipeline capital and operating costs.

The costs form the basis for determining the cost-reflective ongoing charges/prices for the prospective customers.

The costs of purchasing additional water from Boondooma Dam are not included in the customer charges for the scheme but provided separately as a potential increase in prices for Kingaroy urban water customers.

4.7.3 Existing Gordonbrook dam costs

The existing costs of operating Gordonbrook dam will have to be recovered from the irrigation customers. The existing operating costs for Gordonbrook dam are shown in Table 4.29.

Table 4.29: Existing Gordonbrook dam operating costs ($)

Item	Annual ($)
Inhouse Regular Inspections and reporting	5,200
Comprehensive Inspections 5 Yr	4,400
20 Yr Safety Review	4,250
EAP	12,600
EAP Reports	1,000
Piezometers	1,300
Camera	2,000
Instrumentation	300
Monitoring	1,040
Special Inspections	25,000
Destratifer	2,740
Minor Concrete Repairs/Grouting	5,000
Vegetation Management	10,000
Pest/Termites	1,000
Fences	1,000
Total	**76,830**

Source: Email from South Burnett Regional Council - 13 July 2022

4.7.4 Gordonbrook Dam renewals and upgrades

Gordonbrook Dam renewals will be recovered by irrigation water customers following the commencement of the pipeline.

SBRC provided detailed renewals and forward expenditure data for Gordonbrook Dam. The total identified renewals costs are shown below.

Table 4.30: Gordonbrook Dam renewal and upgrade costs ($)

Project description	Cost ($)
Dam safety	
Year two Gordonbrook Dam Spillway AFC Works D&C - Construct	5,000,000
Year three Gordonbrook Dam Spillway AFC Works D&C - Post Con	6,000,000
Gordonbrook Dam Safety Hazard Action Project - Drainage Holes in Abutments	70,000
Gordonbrook Dam Safety Hazard Action Project - Fencing	42,000
Gordonbrook Dam Diversion Tunnel Assessment	75,000
Gordonbrook Dam - Filter Blanket Construction Downstream Slope	2,800,000
Gordonbrook Dam - Riprap Installation Upstream Dam Wall	700,000
Gordonbrook Dam - Seepage Monitoring Design	1,540,000
Sub total	*16,227,000*
Urban water	
Gordonbrook WTP Potassium Permanganate Dosing	420,000
Gordonbrook WTP Raw Water Off Stream Storage year one of the project	4,000,000

Project description	Cost ($)
Gordonbrook WTP Raw Water Off Stream Storage year two of project	1,500,000
Gordonbrook Dam Filter Media Replacement	350,000
Sub total	*6,270,000*
Dam water reliability	
Gordonbrook Dam Dredging	1,400,000
Sub total	*1,400,000*
Total	**23,897,000**

However, the conversion of Gordonbrook Dam to irrigation will mean that the renewal and forward expenditure costs relating to urban water will not be incurred by irrigation customers.

In addition, the dam safety requirements are a function of previous us and should be funded by either existing renewals/expenditure funds or through a separate process. The conversion of the dam should be predicated on the dam meeting required safety performance criteria.

Therefore, the renewals that will be collected through irrigation charges are proposed to be the dam water reliability costs which converts to $50,000 per year over the 30-year life.

4.7.5 Additional upfront and operating costs for Gordonbrook dam

The additional operating costs for the Gordonbrook Dam are shown below:

Table 4.31: Additional operating costs ($)

Item	Annual ($)
Administration officer (1 FTE)	85,000
Vehicles (fuel, depreciation, interest)	12,000
Environmental compliance / customer farm plans	12,000
Legal	6,000
Materials	6,000
Occupancy costs (rent)	3,000
Small plant & equipment (Generator/pumps)	2,520
Communications (Operator mobiles & tablets)	2,400
Communications (Web hosting, email & Wi-Fi)	1,440
Total	**130,360**

4.7.6 Pipeline costs

The pipeline capital costs are shown below.

Table 4.32: Pipeline capital costs

Item description	Cost ($)
Pipelines	9,440,000
Customer connections	260,000
Pump stations	1,380,000
Solar farm	740,000
Testing and commissioning	120,000

Item description	Cost ($)
Subtotal	**11,940,000**
Contractor indirect costs	1,790,000
Subtotal	**13,730,000**
Client indirect costs	795,000
Contingency (30%)	5,810,000
Water sales	350,000
TOTAL	**20,685,000**

The operating costs associated with the pipeline are shown below.

Table 4.33: Pipeline operating costs

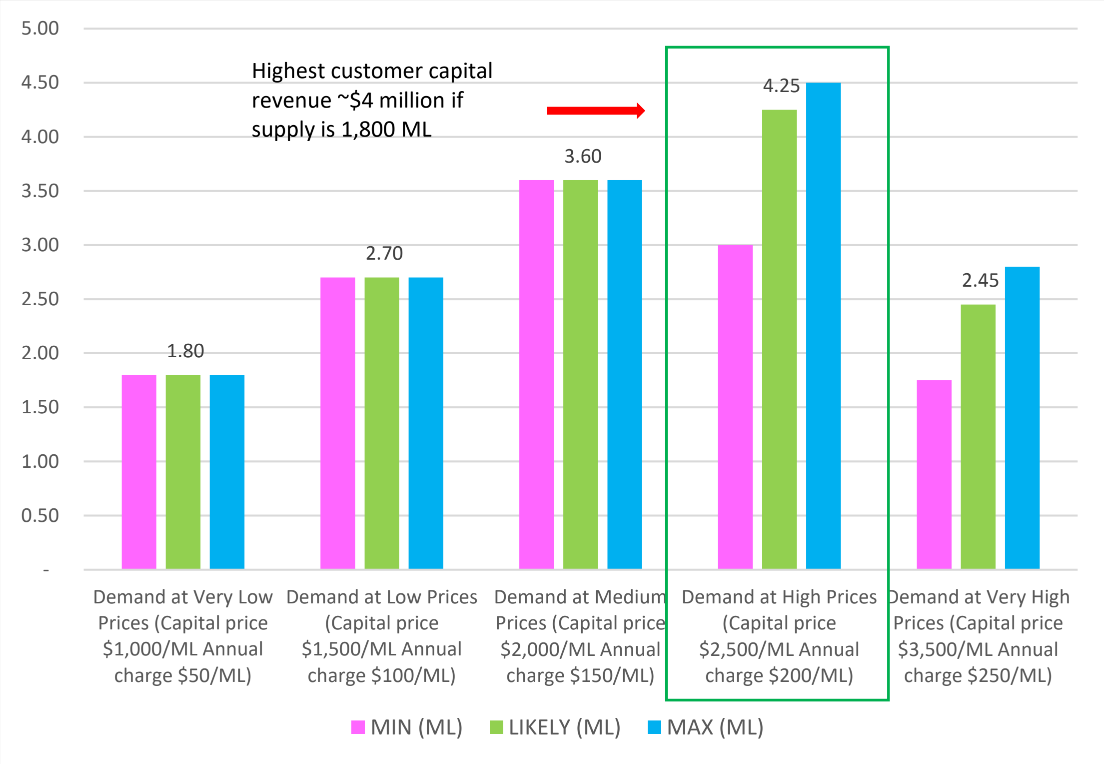
Item description	Cost ($/annum)
Infrastructure maintenance	38,100
Power cost	136,800
Solar farm generation	-53,000
Annualised replacement	112,000
TOTAL	**233,900**

4.7.7 Customer contribution

The Round 1 demand assessment provided indicative customer demand. The details of the Round 1 demand assessment are provided in a separate report.

Figure 4.10 presents estimated customer capital revenue based on a supply of 1,800 ML.

Figure 4.10 Customer capital revenue at different prices with a supply constraint of 1,800 ML ($ million)



The figure above shows in a supply of 1,800ML that customer capital revenue is optimised at a capital price of $2,500/ML.

The sale of all 1,809 ML in a future water sales process would result in customer capital contributions of $4.5 million.

4.7.8 Customer pricing

The recovery of costs incurred by SBRC for the operation and administration of the scheme results in the likely prices to be charged to growers. The fixed and variable pricing, based on the split of fixed and variable operating costs, is shown in Table 4.34: Customer charges – fixed and variable ($/ML)

Table 4.34: Customer charges – fixed and variable ($/ML)

Pricing	$/ML
Fixed charge	150
Variable charge	90
Total	240

4.7.9 Funding

The customer contribution amount ($2,500/ML) will be provided as part of payment for the capital costs of the pipeline. The amount provided by customers will be insufficient to cover the entire costs. State or Federal Government funding should then be accessed to contribute to the remainder of the capital costs as shown in Table 4.35

Table 4.35: Funding for capital costs ($ million)

Funding	
Customer contribution ($ million)	4.5
Government funding ($million)	16.2
Total ($ million)	20.7
Customer contribution	22%
Government funding	78%
Total	100%

The customer contributions would provide 22% of the pipeline capital costs with the remainder to be sourced from State or Federal Government funding. Customers will pay for all ongoing maintenance, operating and renewal costs associated with the dam, pumps and pipes. Over 30 years, customers will contribute 51% of total scheme costs.

4.7.10 Council financial impacts

The increased purchases of Boondooma Dam water will result in higher costs for SBRC. The consumption charge ($501.79) has been used for the cost of Boondooma dam water purchases as it is assumed that SBRC will receive Boondooma Dam entitlements as part of the Just Transition process.

The analysis indicates that the purchase of 540ML of Boondooma Dam water results in an additional annual cost of $270,000. The present value of this additional cost to SBRC, using a 7% real discount rate, is $4.2 million over 30 years.

The average total volume of water sourced from the Kingaroy network from 2008-09 to 2018-19 was 1,250ML/annum[11]. The additional costs, averaged over the average water use, is approximately $216/ML or $0.22/kL.

[11] Department of Regional Development, Manufacturing and Water, 2022 Kingaroy regional water supply security assessment, https://www.rdmw.qld.gov.au/__data/assets/pdf_file/0006/1508649/kingaroy-rwssa.pdf

5 Blackbutt Irrigation Project

5.1 KEY POINTS

- Blackbutt is a highly productive agricultural area 35 km south of Nanango. There is currently some access to a pipeline, that brings water from Boondooma dam.
- This assessment considered whether it was viable to increase the supply to a broader group of irrigators through an irrigation network.
- The demand assessment found that there is demand for up to 2,020 ML of additional water.
- Two supply options have been considered in delivering water to the region:
  - 24km distribution network delivering water to customers in the Blackbutt and Mount Binga areas.
  - 12km distribution pipeline network delivering water to customers in the Blackbutt area only.
- The total network, including a solar farm, pump stations and pipes would cost approximately $15 million.
- Access to new water can produce a direct economic benefit up to $59 million (excluding infrastructure costs) and deliver an additional 198 (60 direct and 138 indirect) new permanent jobs in agriculture and supporting industries.
- The results of the economic analysis for the two options are shown in the table below.

Table 5.1 - Economic analysis results for supply options (7% discount rate, likely demand $1,000 per ML)

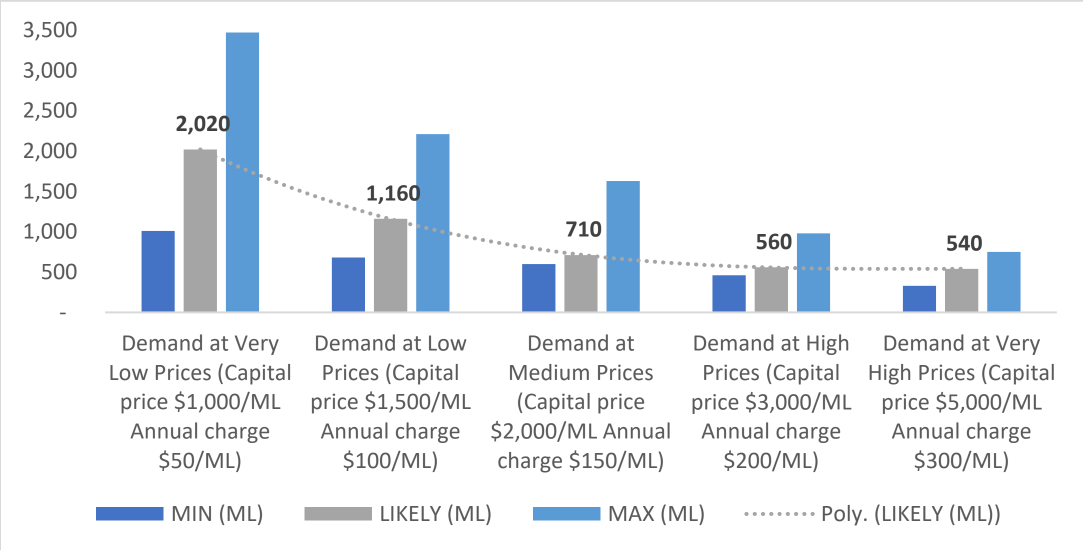
Supply Options	Scenario 1 – Combined infrastructure (Blackbutt & Mount Binga)	Scenario 2 – Blackbutt only
Volume of water delivered (ML)	2,020	1,623
Total benefits ($ million)	34.4	27.6
Total costs ($ million)	24.2	15.9
NPV ($ million)	**10.2**	**11.7**
BCR	**1.42**	**1.73**

- The BCR of both supply options is above 1 with positive NPV's. This indicates the project delivers greater benefits that the total project costs.

5.2 DEMAND ASSESSMENT

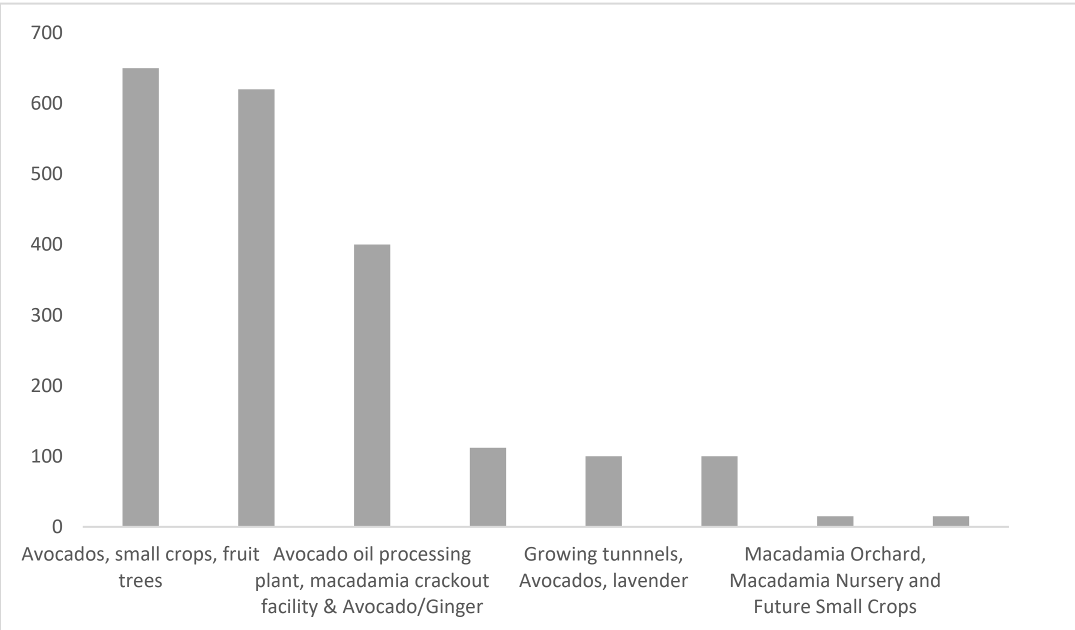
KBR undertook a demand assessment for the Blackbutt Irrigation Project. This assessment identified strong demand for new water across 24 properties. Likely demand was identified up to 2,020 ML.

Figure 5.1: Blackbutt Demand (ML)



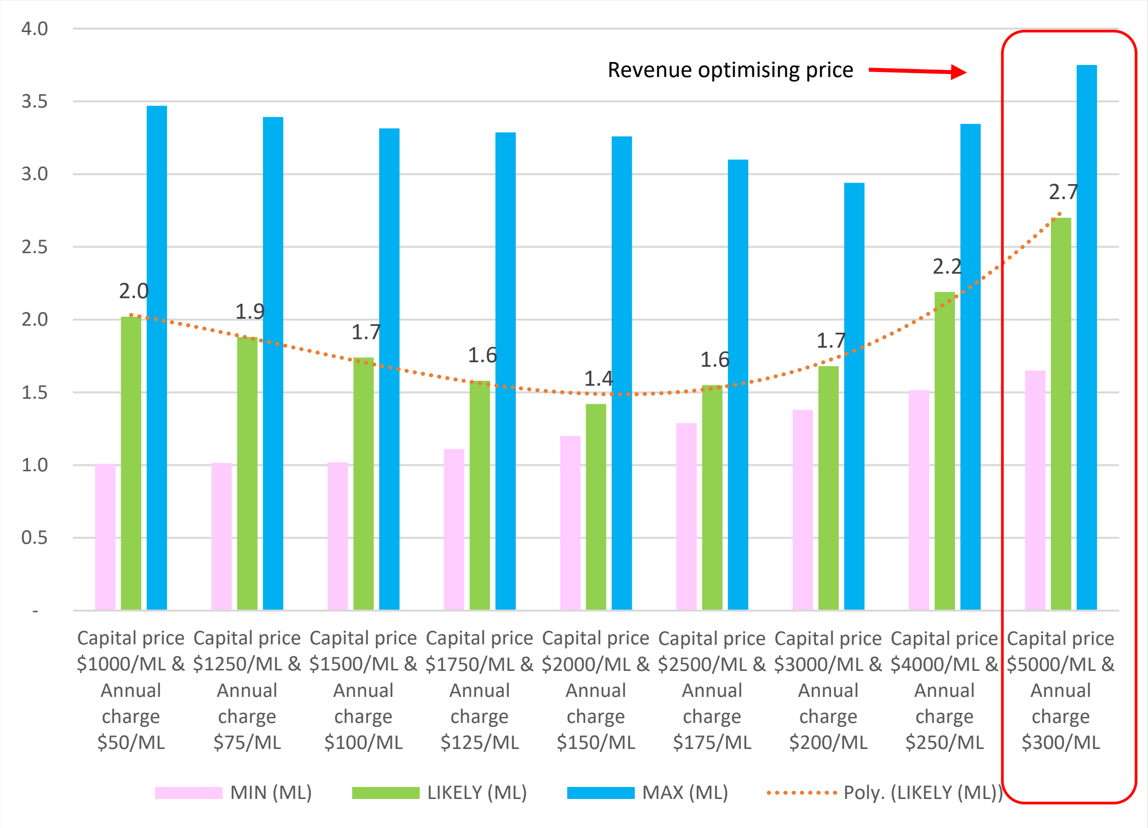
As a result of responses received, demand ranges from 330 ML to 3,470 ML. However, likely demand ranges from 540 ML to 2,020 ML. As expected, demand drops as the price increases. However, the demand plateaus beyond $3,000 per ML, indicating a strong base of demand. Based on likely demand, across these price points, the project could raise between $2.0 and 2.7 million from customers.

Figure 5.2: Round 1 Water Demand per enterprise (likely water use)



Note: This chart is based on customer supplied data which did not always break down water use into single commodities. For example, avocadoes are combined with other commodities.

Figure 5.3 Customer capital revenue at different prices (incl. interpolation) ($ million)



The figure indicates that a customer capital price of $5,000 per ML is forecast to maximise absolute customer capital contributions at $2.7 million. However, this price is very high, which may see a failure in Round 3 binding water sales, when growers consider alternative capital investments.

It is relevant therefore to consider two other revenue optimising scenarios:

- $2.2 million may be raised at $4,000/ML
- $2.0 million may be raised at $1,000/ML – which will have the highest certainty of Round 3 success.

Accordingly, the engineering design and costing has considered 2 scenarios. One scenario is to calculate the costs to supply all demand expressed (2,100 ML) and the second Scenario is to deliver 1,700 ML to just Blackbutt, excluding demand from Mt Binga.

5.3 PIPELINE DESIGN AND COST ESTIMATE

5.3.1 Basis of design

The project will deliver water year-round to customers through a new pipeline and pumping distribution network. A solar farm has been included to reduce the annual charge to customers, as well as achieve a net-zero energy target.

It is anticipated that the scheme will operate year-round, with allowance for interruptions for scheduled and unscheduled maintenance. The basis of design for the network is detailed in Table 4.3. and underpins the development of a cost-efficient low pressure, low volume pipeline network.

Table 5.2 Basis of design

Design parameter	Assumption	Comment
Scheme reliability	Instantaneously delivery	
Round 1 demand	2,100 ML	
Scheme infrastructure design demand	1,600 ML	Assumed 500 ML will be supplied through existing connections.
Delivery period	270 days, 24hrs/day	
Peak flowrate	27 L/s	Individual customer flowrates will vary.
Flow velocity	Maximum 2.4 m/s Minimum 0.9 m/s	
Source pressure	60 m	The pressure available from the source trunk main has not been confirmed. Additional pumping may be required.
Delivery pressure	5 m residual pressure at customer outlet valve	Depending on outlet location and scheme demand, residual pressure will vary.
Pump efficiency	70%	
Pipeline losses	Friction coefficient, 150 0.1% friction loss for Boondooma to Blackbutt bulk transfer main No allowances made for valving or bends	HDPE pipe
Solar sizing	8 hrs/day solar generation 2.5 ha/MW land area	A location for the solar farm has not yet been selected, though vacant land is available throughout the scheme.
Civil asset design life	100 years	
Mechanical asset design life	40 years	
Solar asset design life	30 years	

5.3.2 Bulk water transfer

The proposed network will be supplied 2,100 ML/year from the Boondooma to Blackbutt pipeline. This pipeline traverses 111 km across an elevation range from 282 mAHD to a peak of 546 mAHD located at roughly 92 km along the route.

The energy required to pump 2,100 ML over this significant climb has been calculated at approximately 2.6 GWh/year, as presented below in Table 5.3.

Table 5.3 Bulk water supply and energy requirements from Boondooma to Blackbutt

Item	Value
Annual demand (ML/year)	2,100
Days of operation (days/year)	270
Lift to peak elevation (m)	228
Distance of peak along trunk main (km)	92,000
Friction loss to peak (m)	92
Total pumping head (m)	320
Pump station size (kW)	404
Bulk water pumping energy (kWh/year)	2,616,000

To achieve net-zero, the construction of a new solar farm to fully meet the energy requirement of the scheme is proposed. The solar farm specifications are presented below in Table 5.4.

Table 5.4 Proposed solar farm specifications

Item	Value
Solar farm size (kW)	1,220
Solar farm area (ha)	3.4

This will achieve net-zero energy over the 270 operational days of the scheme. Over the course of the full year, additional solar energy generation will provide further benefits in reducing the overall pumping cost for the bulk water pipeline.

5.3.3 Network pipeline and pumping design

The network has been designed to follow the most efficient route through road reserves to customers. The indicative pipeline route is shown in Figure 4.4, with elevation profiles following.

The 23.6 km pipeline starts at the northern end of Blackbutt at a connection to the Boondooma to Blackbutt pipeline at the D'Aguilar Highway. It runs through Blackbutt South, west along Blackbutt Crows Nest Road, then south along Googa Creek Road and Douglas Road. It then follows Googa Road to Mount Binga.

Figure 5.4 Proposed pipeline alignment (red) through design parcels (blue) and existing pipelines in Blackbutt (green)

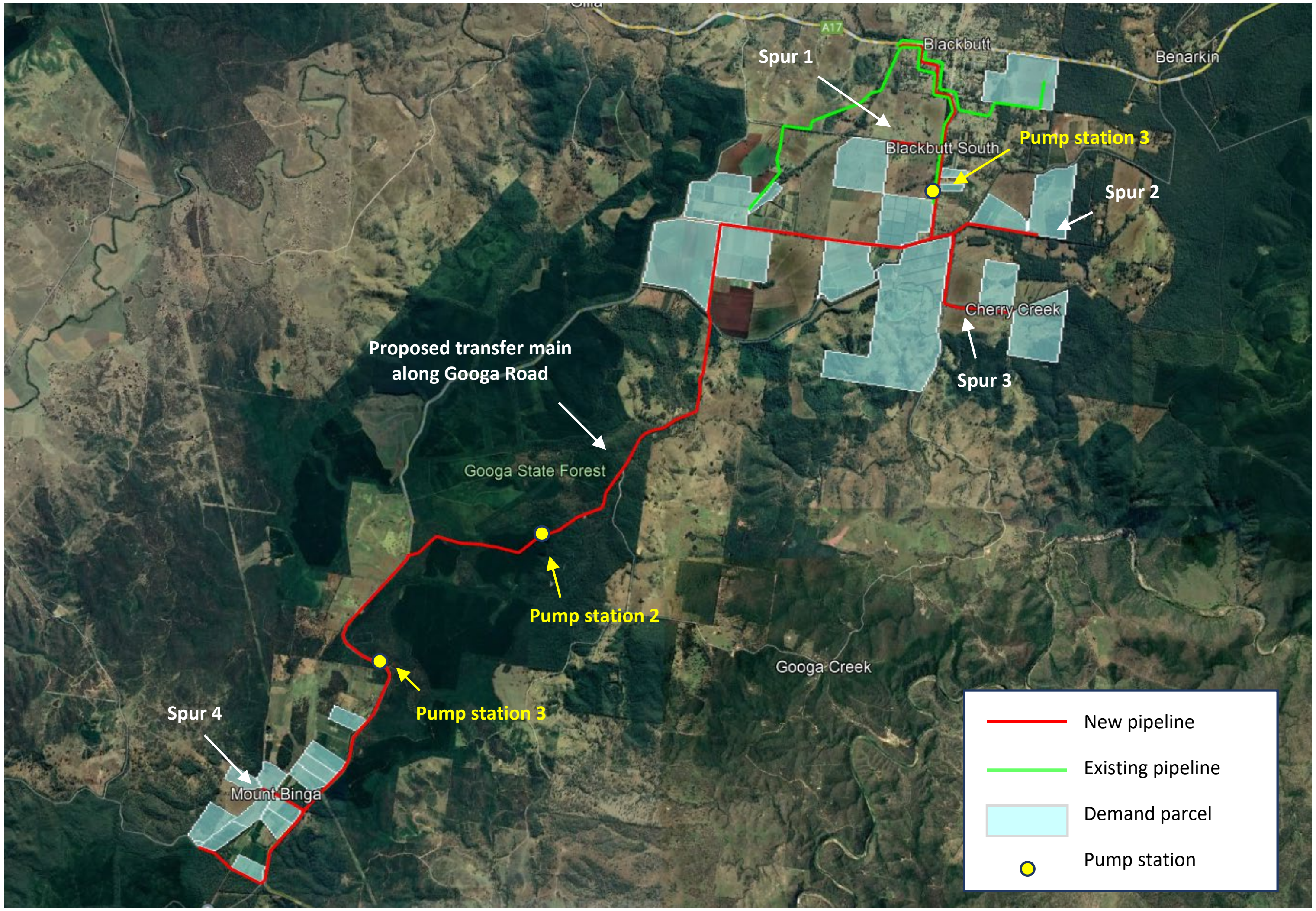


Figure 5.5 Proposed network trunk main elevation profile

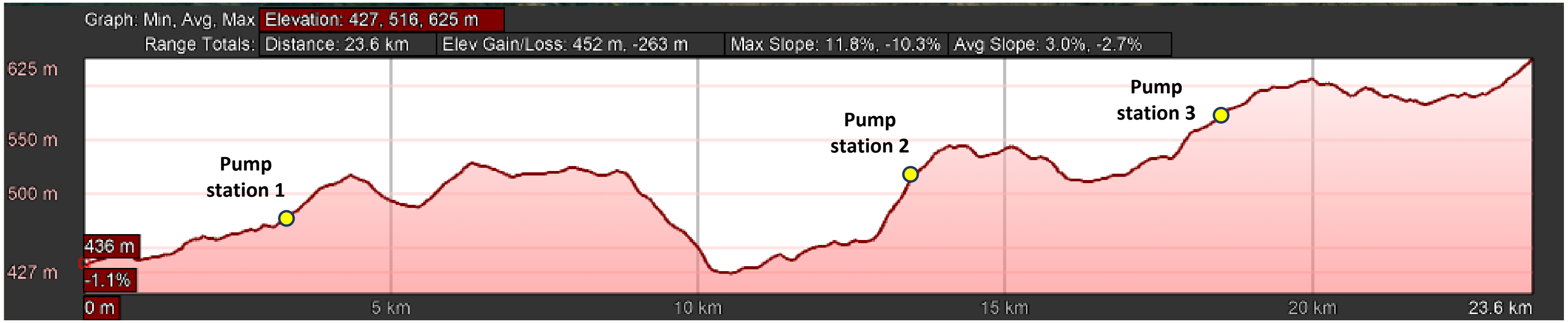
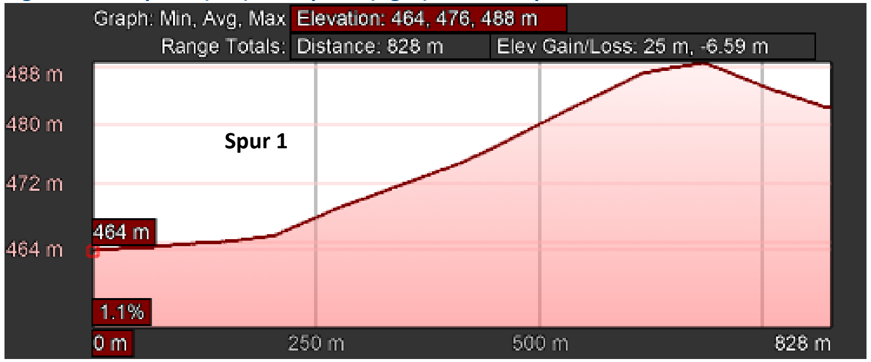


Figure 5.6 Spur 1 (left) and Spur 2 (right) elevation profiles



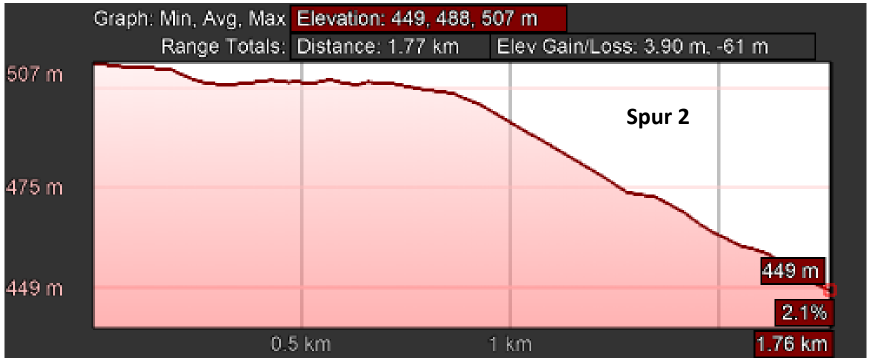
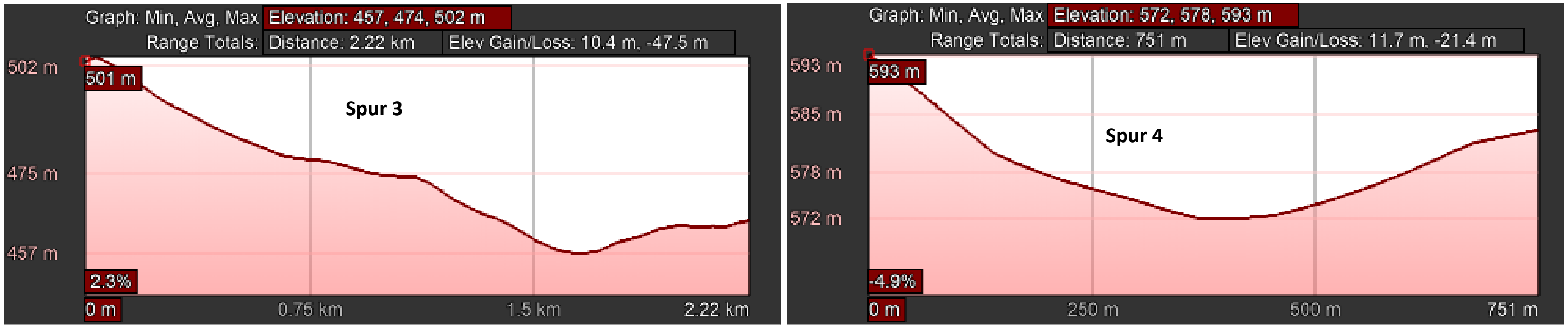


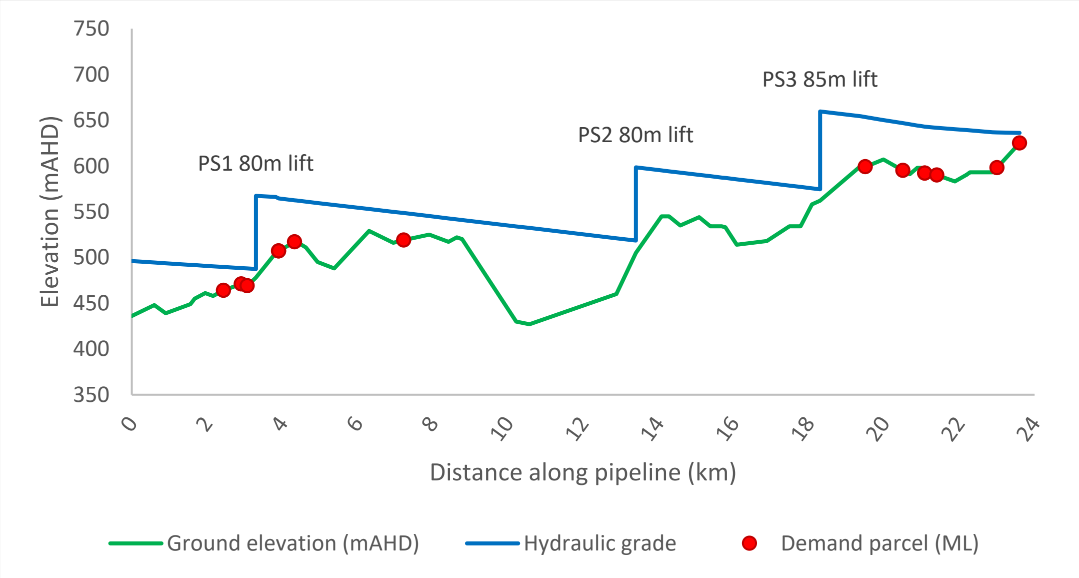
Figure 5.7 Spur 3 (left) and Spur 4 (right) elevation profiles



The elevation profile in Figure 4.5 shows the significant rise from Blackbutt to Mount Binga that must be overcome by a staged pumping effort. Three pump stations have been positioned to provide both adequate pressure to customers and the lift required to overcome the hills along the proposed route.

The hydraulic grade of the pipeline is displayed in Figure 4.9 below, which presents the hydraulic performance of the pipeline during peak demand with all customers drawing water from the network simultaneously.

Figure 5.8 Pipeline elevation, hydraulic grade and location of demand parcels



The location of demand parcels along the route have also been displayed to demonstrate the clustering of demand at the start and end of the pipeline. There is approximately 12 km of trunk main and two pump stations between the two clusters.

Four spurs from the trunk main deliver water to parcels that are off the main route. These spurs also cross areas of highly variable elevation, and have been sized to ensure at least 5 m of pressure at the customer connection. Generally, the customers are at the end of the spurs and downhill of the main, indicating that pressure will be higher than 5m. The exception is Spur 1, which must overcome a 22 m rise and may require pumping assistance depending on the source pressure available at the trunk main.

The lengths of pipe by size are presented in Table 4.4.

Table 5.5 Pipeline length by diameter

Diameter (mm)	Length (m)
Distribution main	
140	2,620
160	999
180	601
200	12,430
225	3,120

Diameter (mm)	Length (m)
355	3,830
Subtotal	**23,600**
Spurs	
90	5,570
TOTAL	**29,170**

The pump station sizing is presented in Table 4.5.

Table 5.6 Pump station lift (m) and size (kW)

Pump station	Lift (m)	Size (kW)	Energy (kWh/year)
PS 1	80	72	464,000
PS 2	80	22	144,000
PS 3	85	24	153,000
TOTAL		**117**	**761,000**

5.3.4 Network solar farm design

The scheme includes a solar farm to offset and generate power beyond the net-zero energy target, and to achieve a cost saving for customers by reducing their annual charges by 20%. The solar farm specifications are presented below in Table 4.6.

Table 5.7 Proposed solar farm specifications

Item	Value
Solar farm size (kW)	360
Solar farm area (ha)	1.0

The solar farm is sized so that the solar energy generated during daylight hours will fully offset the day of pumping. This means one third of the solar farm capacity will fully power the scheme during daylight hours, and the remaining two thirds of its capacity will generate additional power to offset the pumping occurring overnight.

This arrangement achieves net-zero energy over the 270 operational days of the scheme, plus additional energy exports during the other 95 days of the year for an overall net-positive scheme. This is demonstrated in Table 5.8. Over a full year, the scheme will export 290,000 kWh.

Table 5.8 Solar energy – pumping offsets and additional exports

Item	Energy (kWh/year)
Pumping energy required	**761,000**
Solar directly powering day-time pumping	254,000
Solar offsetting night-time pumping	507,000
Solar subtotal	**761,000**
Solar power exports during scheme downtime	290,000
Total solar energy generated	**1,051,000**
Net solar exported	**290,000**

5.3.5 Network capital cost estimate

The capital estimate breakdown is presented in Table 5.9with a total capex estimate of $10.8 million including 40 per cent contingency. A more detailed breakdown is provided in Appendix A.

Table 5.9 Capital estimate for proposed network

Item description	Cost ($)
Pipelines	4,905,000
Customer connections	230,000
Pump stations	1,070,000
Solar farm - bulk water transfer	1,880,000
Solar farm - distribution network	555,000
Testing and commissioning	70,000
Subtotal	**8,725,000**
Contractor indirect costs	1,310,000
Subtotal	**10,035,000**
Client indirect costs	730,000
Contingency (40%)	4,305,000
TOTAL	**15,070,000**

5.3.6 Network operational cost estimate

The operational estimate breakdown is presented in below. A more detailed breakdown is provided as an appendix.

Table 5.10 Estimated cost of operating the proposed network

Item description	Cost ($/annum)	Cost ($/ML/annum)
Infrastructure maintenance	23,500	11
Staffing allowance	100,000	48
Power cost	101,500	48
Solar farm generation	-39,900	-19
Annualised replacement	142,400	68
TOTAL	**327,600**	**156**

There is an almost 20% saving to customers' annual charges resulting from the inclusion of a solar farm to offset power consumption, as demonstrated in Table 5.11.

Table 5.11 Savings to customers through solar farm

Item	Opex impact ($)	Customer charge impact ($/ML)
Opex without solar	**398,000**	**190**
Power replaced by solar at 20c/kWh	-50,700	-24
Solar power exported during the pumping day at 5c/kWh	-26,200	-12

Item	Opex impact ($)	Customer charge impact ($/ML)
Solar power exported during scheme downtime at 5c/kWh	-13,700	-7
Increase to annualised replacement of assets	20,100	10
Final opex with Solar	**327,600**	**156**
Savings delivered to customers through solar	**-70,500**	**-34** **18% saving**

5.3.7 Potential for staging

Approximately 80 per cent of the demand is located in Blackbutt, at the start (northern end) of the distribution network. The remaining 20 per cent is in Mount Binga, and requires the larger proportion of the infrastructure.

The relative contribution of the Blackbutt demand cluster compared to the Mount Binga demand cluster to the scope and cost of the project is presented in Table 5.12

Table 5.12 Blackbutt and Mount Binga contributions to scope and costs

Item	Blackbutt	Mount Binga	Total
Demand (ML)	1,700	400	**2,100**
Demand (%)	81%	19%	**100%**
Length of pipelines (m)	12,050	17,120	**29,170**
Count of pump stations (no.)	1	2	**3**
Size of pump stations (kW)	72	46	**117**
Size of solar farm (kW)	220	140	**360**
Capital cost ($)	9,550,000	5,520,000	**15,070,000**
Capital cost ($/ML)	5,600	13,800	**7,200**
Operational cost ($/year)	262,600	65,000	**327,600**
Operational cost ($/ML/year)	154	162	**156**

There is an option to stage the project to deliver the majority of water to the larger Blackbutt demand cluster for just under two-thirds of the total estimated budget at $9.6 million (Stage 1), and defer the Mount Binga scope to a later date for $5.5 million (Stage 2).

This may have an advantage of creating further interest in the new water product beyond what has been captured in the Round 1 demand assessment, which can then be included in the scope of Stage 2 (if it is cost effective to do so).

5.4 ECONOMIC ASSESSMENT

5.4.1 Approach

The economic analysis develops a coherent socio-economic narrative of the qualitative and quantitative costs and benefits that could be realised through the Blackbutt Irrigation Project.

This economic assessment is aligned with the Queensland Government and Infrastructure Australia (IA) frameworks. The approached for this study is as follows:

- Understand the base case

- Where economic impacts are material and quantifiable, quantify the economic benefits and costs (i.e. net cash flows) relative to the base case.
- Test the sensitivity of key inputs.

The general parameters and assumptions include model start year, assessment period and discount rates. The starting year and assessment period are shown below.

Table 5.13 – starting year and assessment period

Parameter	Unit	Value
Starting Year	Year (period)	2022
Assessment Period	Number of years	30

Discount rate scenarios, with the medium scenario (7% real) being the central scenario, are shown below.

Table 5.14 – Discount rate scenarios

Discount rate	Real discount rate, pre tax (%)
Low	4%
Medium	7%
High	10%

The alignment of these key parameters with the relevant frameworks is outlined in the table below.

Table 5.15 Alignment of key economic assumptions

Parameter	Adopted value/s	Justification
Discount rate	7% (central). 4% and 10% (sensitivities)	These values are in accordance with Infrastructure Australia (IA) and the Queensland Treasury Cost Benefit Analysis Guide.
Starting year	2022	All benefits in the economic analysis are presented in 2021 constant prices.
Appraisal period	30 years with residual value of net benefits included	An analysis period of 30 years (operational) was adopted in line with the Queensland Treasury Cost Benefit Analysis Guide.

5.4.1.1 Irrigated agriculture

The economic benefits of additional water are largely improved irrigated agricultural production in the region. They are calculated based on key inputs:

- Demand assessment – how much water is demanded by customers and what this water will be used for.
- Reliability of the water product – how much water will customers likely receive each year

- Likely water use – how water will be used for which crop
- Net margin of water use – how much economic value will be generated by each megalitre of water used by customers.

5.4.2 Data sources

Overall economic benefit depends on crop mix, water use by crop and the net margin of each crop. The data used in this analysis were gathered from a range of sources including:

- Round 1 demand assessment and further consultation with potential customers. This process drives the underlying crop mix and economic benefits. Customers were also asked to provide information on plans for the water which assisted with the economic benefit calculation.
- Previous literature provided by the client and Queensland Government.
- Agbiz farm budgeting tools – Queensland Government. Used to cross check customer data and ensure margins are representable of the region.
- AgMargins Gross Margin Calculator – Queensland Government. Used to cross check customer data and ensure margins are representable of the region.

Data was collected through the demand assessment process and on-the-ground consultation, including several stakeholder meetings and engagements. This has informed the proposed crop mix and water use used to calculate the total economic benefit.

5.5 DIRECT ECONOMIC BENEFITS

The economic benefits of the potential project are calculated based on key inputs

- Demand assessment – how much water is demanded by customers
- Reliability of the water product – how much water will customers likely receive per year
- Likely water use – Agriculture, Industrial and High Care
- Net margin of water use – how much economic value will be generated by each ML of water used by customers.

The three inputs are detailed in the following sections.

5.6 ECONOMIC BENEFITS OF IRRIGATED AGRICULTURE

The primary economic benefits of the project relate to increased irrigated agricultural output as net margins (profit per megalitre of irrigation water applied). The benefits were calculated by:

- Determining the amount of irrigation water likely to be used for each crop type (net of rainfall) and crop area.
- Calculating the gross margin (revenue minus variable operating costs) for each crop type per megalitre and then subtracting the fixed costs (upfront and ongoing) per hectare to obtain the net margin for each crop. This is achieved through on-the-ground consultation-driven process, industry experience and public sources. Each crop has a different net margin, depending on the yield, costs and commodity prices.
- Multiplied amount of water by reliability by the net margin to obtain the annual economic benefit and convert the annual benefits to a single net present value.
- Sensitivities conducted on key inputs because of higher costs or changing variables to understand the reflexivity of each net margin.

5.7 EFFECTIVE RAINFALL

The irrigation water use per hectare is the volume of water that is applied to crops. The annual amount of rainfall determines the application of irrigation water use. The total rainfall for the irrigation area is shown in the following table.

Table 5.16 Annual rainfall (mm)

	Annual Total (mm pa)
Low (last 15 years)	846
Medium (last 30 years)	829
High (last 100 years)	862

Source: Australian Bureau of Meteorology, 30-year average to 2020 at Blackbutt Post Office

A 100mm of rainfall per hectare is 1ML per hectare so average annual rainfall provides 8.3 ML per hectare per annum. This rainfall is then factored by the timing of rainfall compared to the crop's demand and the ability for crop to absorb the water (rainfall effectiveness).

The rainfall effectiveness by crop type is shown in the following table.

Table 5.17 Rainfall effectiveness by crop type

Crop type	Rainfall effectiveness (%)
Avocados	60%
Fodder and Small Crops	80%
Tree crops and Macadamias	55%

Source: Consultation with growers

5.8 CROP MIX

The central crop mix adopted for this project has been developed primarily through the results of the Round 1 demand assessment process. Potential customers were asked to give detail on the crops they are proposing to develop if the project was to proceed (see Section 2 of this Demand Assessment report). Data was also collected from on ground consultation, including several stakeholder meetings and engagements, previous literature and data on the region including soil suitability, government databases and reports to further strengthen the crop mix understanding.

Table 5.18 – Round 1 Demand Assessment – Crop Mix

Economic Benefit	Percentage of Demand
Avocados	68%
Avocado Oil Processing Plant	18%
Lucerne Hay	5%
Macadamias	6%
Mandarins	3%
Total	**100%**

5.9 NET MARGINS

Net margins (irrigation profit after fixed and variable costs) is a key component of the economic benefits for the scheme. The scheme generates economic benefits for:

- Irrigated crops

- Avocado oil processing facility

5.9.1 Irrigated crop net margins

The primary economic benefit resulting from the demand assessment is increased irrigated agricultural output.

The key inputs to the net margin analysis include but not limited to:

- Gross income – yield and revenue from each crop type.
- variable costs – fertiliser, seeds, weed and pest control and harvesting costs
- upfront fixed costs – Discing and Raking, Land Levelling, cost of trees, planting and Irrigation systems
- ongoing fixed costs – fixed labour, insurance and professional services and maintenance
- irrigation water use.

The effective rainfall differs based on the timing of the crop water demand and therefore the irrigation water use required.

The following table outlines the key parameters to calculate the net margin per megalitre of water for each irrigated crop using HPA water.

Table 5.19 – Net margins adopted for economic assessment

Enterprise	Irrigation Water use required (ML/ha)	Revenue ($/ML)	Gross Margin ($/ML)	Net Margin ($/ML)	Yield per ha (t/ha)
Avocados	7.0	4,555	3,274	1,875	10.6
Lucerne Hay	9.4	1,046	406	359	14.0
Macadamias	6.0	4,107	3,277	1,730	4.5
Mandarins	7.4	10,416	6,720	4,239	50.0

5.9.2 Avocado Oil Processing

The establishment of an avocado oil processing facility in the region was documented by a respondent through the demand assessment process. The new water provided will allow this facility to operate which currently isn't possible with the water constraints faced in the Blackbutt area. The facility will use locally grown and sourced avocados as the critical input to oil production.

Avocado oil is produced by recovering oil from ripe avocados through mechanical extraction. The key input cost to this process is purchasing the avocados. Producer usually seek to use lower cost avocados that have not met local-market quality standards. This results in a lower input cost but also make use of avocados that traditionally would have little value. By removing the "lower" class fruit from the local market also provides significant indirect benefits to growers by increasing the local-market price due to reduced fruit volumes.

The economic value of this new water is the net margin received by the processes for the avocado oil produced annually. To determine the net margins and relevant inputs we have engaged closely with the respondent to get a strong understanding of the potential economic benefit this could bring to the region.

The water use scenario adopted for the avocado oil processing facility are as follows:

Table 5.20 – water demand for avocado oil processing

Water use	Volume (ML's/year) to operate facility
Low	50.0
Medium	75.0
High	100.0

The following table outlines the key parameters to calculate the net margin per megalitre of water avocado oil production using HPA water.

Table 5.21 – Avocado oil processing key parameters

Economic Benefits	Value
Annual revenue of facility ($ Million)	7.06
Net margin of operation ($ Million)	1.86
Water use (ML)	75
Revenue per ML ($/ML)	94,080
Net margin per ML ($/ML)	24,863

A Net margin of $24,863/ML has been applied to the 75ML of water demand for Avocado oil processing.

5.10 SUMMARY OF DIRECT ECONOMIC BENEFITS

A summary of the direct economic benefits assessed is provided in the table below.

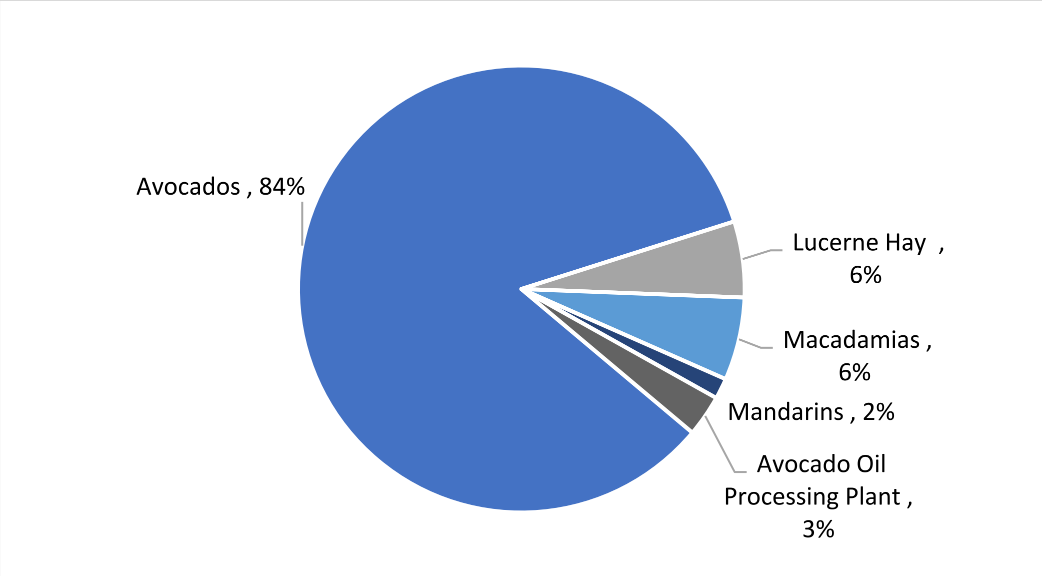
Table 5.22 – Summary of economic benefits

Enterprise	Percentage of demand	Net Margin ($/ML)	Revenue ($/ML)
Avocados	84%	1,875	4,555
Lucerne Hay	6%	359	1,046
Macadamias	6%	1,730	4,107
Mandarins	2%	4,239	10,416
Avocado Oil Processing Plant	3%	24,863	94,080
Weighted average	-	**2,508**	-

The weighted net margin of $2,508 per ML will be used for consideration of the direct economic benefits obtained from new water being supplied to Blackbutt. The difference between the percentages outlined in the demand assessment are due to the water directly used in the proposed avocado oil processing facility. Further consultation with the respondent indicated that a smaller percentage of specified demand (75 ML) will be used in the facility, with the rest of the demand used to grow avocados.

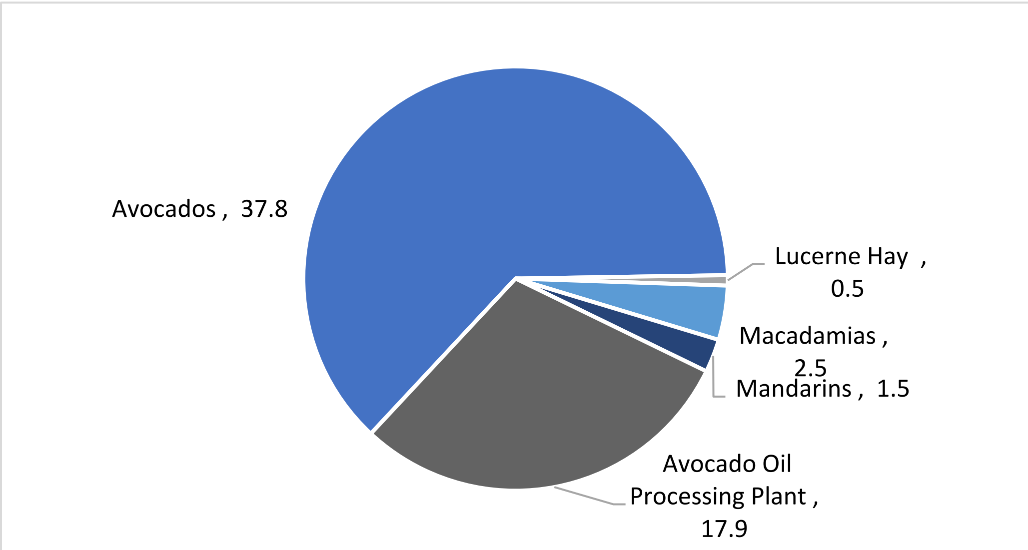
The following chart outlines the percentage of demand (ML's) that is allocated to each enterprise.

Figure 5.9 – Breakdown of the water use for each enterprise (percentage of demand)



The following chart outlines the total value (NPV over 30 years) of each enterprise. It is clear that the avocado oil processing facility delivers a significant economic benefit for a very small portion of the water supply.

Figure 5.10 – Breakdown of the direct economic benefit for each enterprise ($ Million, NPV over 30 years, 7% discount rate, demand at $1,000 per ML)



5.11 ECONOMIC COSTS

The economic costs associated with the project include

- Risk Adjusted capital and operating costs
- Opportunity costs associated with the base case

Two supply options have been considered in delivering water to the region:

1. 24km distribution delivering water to customers in the Blackbutt and Mount Binga areas.
2. 12km distribution pipeline delivering water to customers in the Blackbutt area only.

5.11.1 INFRASTRUCTURE OPTIONS

The primary water supply infrastructure solution will deliver water to the customers in Blackbutt and Mount Binga who have responded to the demand assessment process through a 24km distribution pipeline.

Approximately 70 per cent of the demand requiring new infrastructure is located in Blackbutt, at the start (northern end) of the distribution network. The remaining 30 per cent is in Mount Binga and requires the larger proportion of the infrastructure. Therefore, the economic assessment has considered a second supply option through a smaller distribution network to deliver water just to the Blackbutt area.

Further detail of these options is documented in the concept design report.

Table 5.23 – Infrastructure supply options

Item description	Scenario 1 – Combined infrastructure (Blackbutt & Mt Binga)	Scenario 2 – Blackbutt only
Distance of pipeline (km)	24	12
Location of customers	Blackbutt and Mount Binga	Blackbutt only
Assumed volume of water delivered (ML's, nominal allocations)	2,020	1,623

5.11.2 CAPITAL AND OPERATING COSTS

A summary of the capital costs for the two supply options are shown in the following table. A full breakdown is provided in the engineering report.

Table 5.24 – Summary of capital costs for water supply options ($ millions)

Item description	Scenario 1 – Combined infrastructure (Blackbutt & Mt Binga)	Scenario 2 – Blackbutt only
Pipelines	4.91	2.27
Customer connections	0.23	0.23
Pump stations	1.07	0.49
Testing and commissioning	0.06	0.03
Subtotal	**6.27**	**3.02**
Contractor indirect costs	0.94	0.45
Subtotal	**7.21**	**3.47**
Client indirect costs	0.37	0.18
Contingency (30%)	2.28	1.11
TOTAL	**9.85**	**4.76**

The following table outlines the operating costs for both supply options.

Table 5.25 – Summary of operating costs for water supply options ($ millions per annum)

Item description	Scenario 1 – Combined infrastructure (Blackbutt & Mt Binga)	Scenario 2 – Blackbutt only
Water supply price	1.39	1.12
Infrastructure maintenance	0.02	0.01
Staffing allowance	0.10	0.05
Power cost	0.15	0.09
Annualised replacement	0.09	0.04
TOTAL	**1.75**	**1.32**

5.11.3 Benefit-cost ratios and Net Present Values

The results of the CBA using the capital and operating costs outlined above and a 7% discount rate as per Queensland business case guidelines are shown in the table below.

Table 5.26 – BCR and NPV of water supply options

Supply Options	Scenario 1 – Combined infrastructure (Blackbutt & Mt Binga)	Scenario 2 – Blackbutt only
Volume of water delivered (ML)	2,020	1,623
Total benefits ($ million)	34.4	27.6
Total costs ($ million)	24.2	15.9
NPV ($ million)	**10.2**	**11.7**
BCR	**1.42**	**1.73**

The BCR of both supply options is above 1 with positive NPV's. This indicates the project delivers greater benefits that the total project costs.

5.11.4 Sensitivity analysis

Sensitivity analysis have been conducted on the demand volumes and prices per ML received through the demand assessment process. This analysis has been conducted using the combined infrastructure (Blackbutt & Mt Binga infrastructure solution and displays the key economic metrics.

Table 5.27 – Sensitivity analysis on demand volume and price ($/ML) combined infrastructure solution

Supply Options	Likely Demand at $1,000 per ML	Likely Demand at $1,000 per ML (without Avocado Oil Processing Benefit)	Likely Demand at $2,000 per ML	Likely Demand at $5,000 per ML	Maximum Demand at $1,000 per ML
Water Allocations (ML)	2,020	2,020	710	535	3,470
NPV ($ million)	**10.2**	**0.2**	**-12.1**	**-15.1**	**34.9**

Supply Options	Likely Demand at $1,000 per ML	Likely Demand at $1,000 per ML (without Avocado Oil Processing Benefit)	Likely Demand at $2,000 per ML	Likely Demand at $5,000 per ML	Maximum Demand at $1,000 per ML
BCR	**1.42**	**1.01**	**0.50**	**0.38**	**2.44**
Total Ag Employment	116	70	41	31	199
New agricultural revenue ($ million per annum)	12.9	7.8	4.5	3.4	22.2

The BCR of the is positive at the demand price of $1,000 per ML even with the removal of the avocado oil processing benefit. Once the price moves above $2,000 per ML the BCR drops well below zero. This is primarily due to significantly lower demand volumes at these prices. Further the water supply option has been calculated delivering allocation volume of 2,020 ML. There has been no update on the capital and operating costs at the lower demand volumes.

5.11.5 Economic impact assessment

The preceding economic assessment has been prepared in accordance with Building Queensland's business case and CBA guidelines. These guidelines specify the types of economic benefits that are suitable to include in a CBA, which have been adhered to order to use these to be able to derive NPVs and BCRs for this scheme at the next stage of investigation.

The Building Queensland guidelines also set out those costs and benefits that should not form part of the core economic assessment but instead may be included in a broader economic impact assessment (presented below), due to their obvious and significant impacts on regions and industries and to meet state development aims.

5.11.6 Wider economic benefits

The table below outlines the full-time equivalent positions that could be realised with additional water delivered to the region.

There are two main categories:

- full-time jobs of direct agricultural employment
- full-time jobs of indirect agricultural employment in support industries, such as farm input suppliers (e.g. fertilizer, seedlings, pesticides, packaging and fuel) and services (e.g. transportation, refrigeration, mechanical, food, accommodation and accountancy).

The following table presents the direct and indirect employment that additional water could support based on the demand assessment scenarios.

Table 5.28 – Agricultural employment under each demand scenario

Demand scenario	Direct	Indirect	Total
Scenario 1 - Likely Demand at $1,000 per ML	36	80	**116**
Scenario 2 -Likely Demand at $2,000 per ML	12	28	**41**
Scenario 3 - Likely Demand at $5,000 per ML	9	21	**31**
Scenario 4 - Maximum Demand at $1,000 per ML	60	138	**198**
Scenario 5 – Blackbutt only Likely Demand at $1,000 per ML	28	65	**93**

Table 5.29 – Wider economic benefits under each demand scenario

Demand scenario	Total Agricultural Jobs	Industry value-add ($M)	Additional agricultural revenue ($M)
Scenario 1 - Likely Demand at $1,000 per ML	116	11.8	12.9
Scenario 2 -Likely Demand at $2,000 per ML	41	4.2	4.5
Scenario 3 - Likely Demand at $5,000 per ML	31	3.1	3.4
Scenario 4 - Maximum Demand at $1,000 per ML	198	20.3	22.2
Scenario 5 – Blackbutt only Likely Demand at $1,000 per ML	93	9.5	10.4

The estimates of supported full-time jobs have been created by examining the input-output tables produced by the ABS.

6 Economic and sustainability opportunities for the region

6.1 OPPORTUNITIES

The transition of the Tarong Power Stations will provide a significant opportunity for the South Burnett Region to pivot away from fossil fuel dependent economic activity towards sustainable industries and sources of economic growth. The region has significant advantages that position it to invest in sustainable growth opportunities, including (without limitation):

- Robust existing agricultural sector and highly experienced and capable workforce.
- Proximity to major transport and population centres in Brisbane, Bundaberg, and Toowoomba.
- Fertile soils that are high suitable for the cultivation of high value, high margin agricultural crops.
- Significant water catchments and sources.

While the above sections relate to specific projects, this section outlines the economic and sustainability opportunities for the region and identifies areas for further analysis and assessment to develop and progress growth in the region.

Boondooma Dam and the associated pipeline will remain once coal-fired power generation ceases. The region will proposer if a portion of this water can be used for sustainable and profitable agriculture. This will enable that the number of jobs will grow, rather than shrink during the transition period.

6.2 WATER BEING LEFT BEHIND

The Tarong power stations have access to two sources of water[12]:

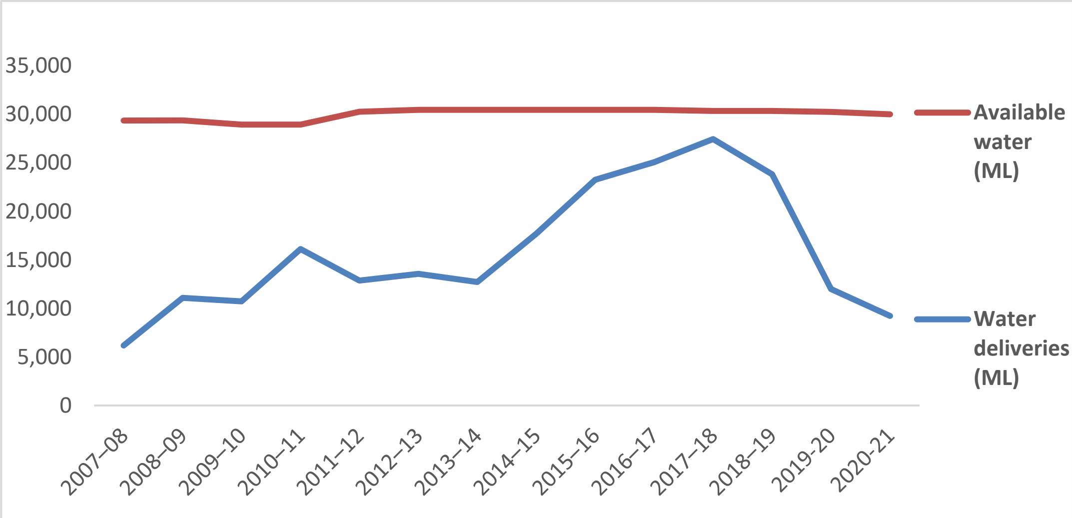
- a 29,990 high priority allocation from Lake Boondooma
- an allocation from Lake Wivenhoe, or the Western Corridor Recycled Water Scheme.

Boondooma Dam, along with a 95 km pipeline from the dam to the power plant were both constructed specifically for Tarong Power Station in 1982, along with three pumping stations – Boondooma, Melrose and Ellwoods Road – and three balancing storages at Melorse, Ellwoods Road and Goodger.

Stanwell is mindful that Lake Boondooma is also a source of drinking water to the town of Kingaroy. In order to ease the pressure on this shared resource, Stanwell has initiated a strategy to reduce usage from Lake Boondooma in 2019–20. This strategy has been effective, with actual water use dropping from 27,000 ML to 9,000 ML (Figure 6.1).

[12] Stanwell, *Sustainable water practices, a top priority for Tarong power stations*, Stanwell news, 14 January 2020.

Figure 6.1 Tarong Power Station water use from Boondooma Dam



Source: Sunwater Annual Reports, scheme statistics.

When Tarong Power Station ceases coal fired power generation, the water allocations will remain the property of Stanwell and could be transferred to other owners. The economic and social disruption caused by Tarong's transition to an energy hub could be managed if this water is put towards job creating and productive purposes.

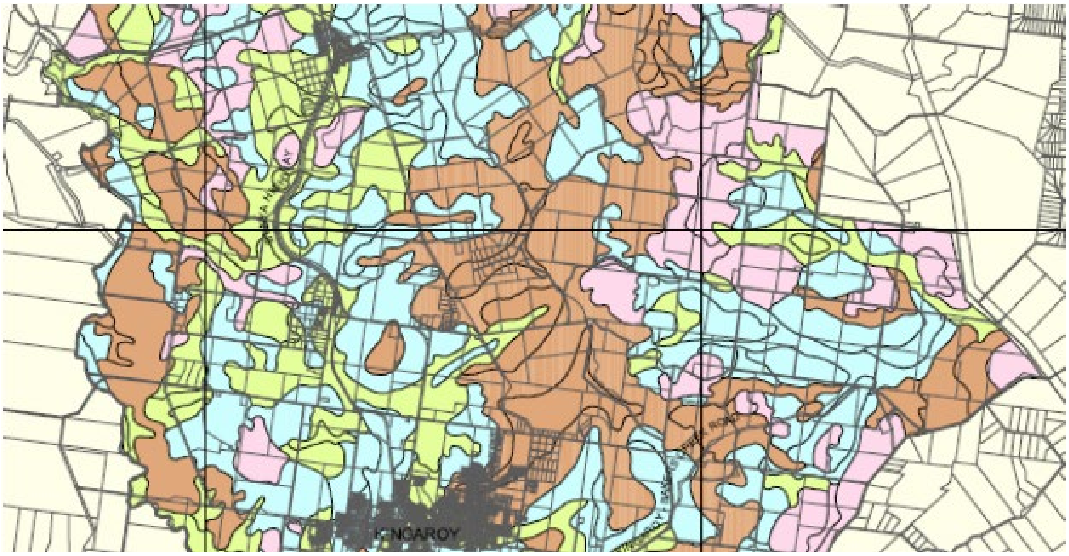
6.3 AGRICULTURAL OPPORTUNITIES

The area already has a substantial agricultural industry with the capacity for growth. There is an abundance of suitable soil, local agricultural experience, and growing commodity and export markets.

6.3.1 Soil suitability

The South Burnett has large areas of land currently unutilised for cropping. To determine if this land is suitable for irrigated crop production, we conducted a soil feasibility study in the area, focusing on the region adjacent to the Boondooma to Tarong Pipeline. The study found there is 61,459 hectares of land suitable for horticulture. The green and blue areas in Figure 2-17 are areas suitable for irrigated crop production, while the brown and pink areas are unsuitable. There is high variability in the soil across the region, and therefore further detailed soil studies are recommended.

Figure 6.2: Soil suitability



Source: PeritusAg Crop Feasibility Review – July 2022

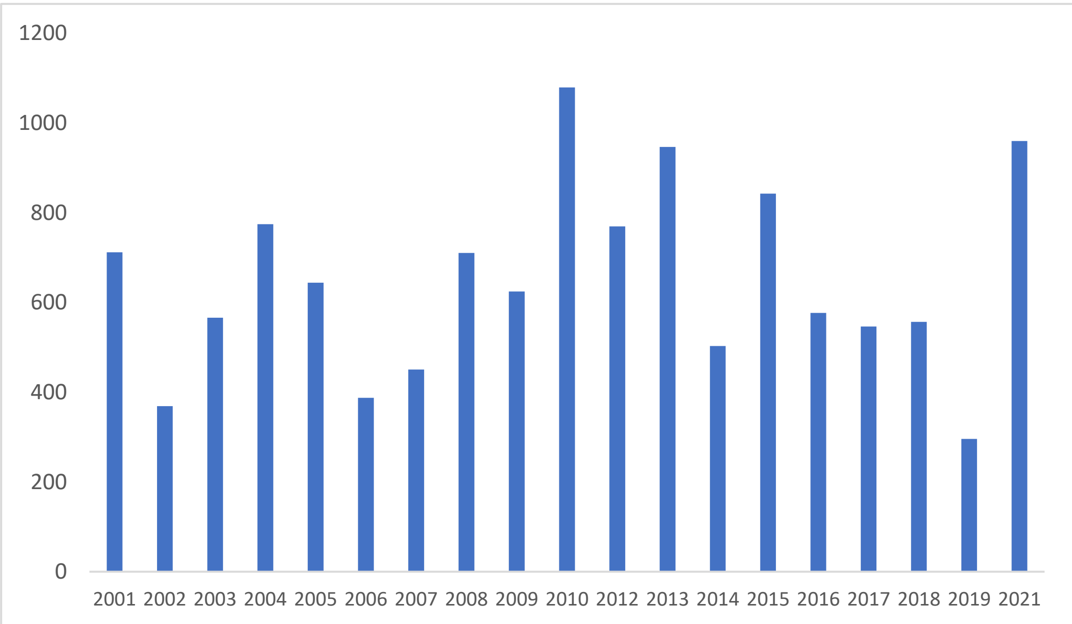
6.3.2 Climatic conditions

Climatic conditions impact the suitability of an area for agricultural production. These conditions include rainfall and temperature and are predicted to change over time.

6.3.3 Rainfall

The South Burnett area has highly variable annual rainfall. For example, 2021 saw more than three times the rainfall received in 2019. This makes rainfall unreliable as a single source of water for agricultural production.

Figure 6.3: Annual rainfall for Kingaroy (mm)

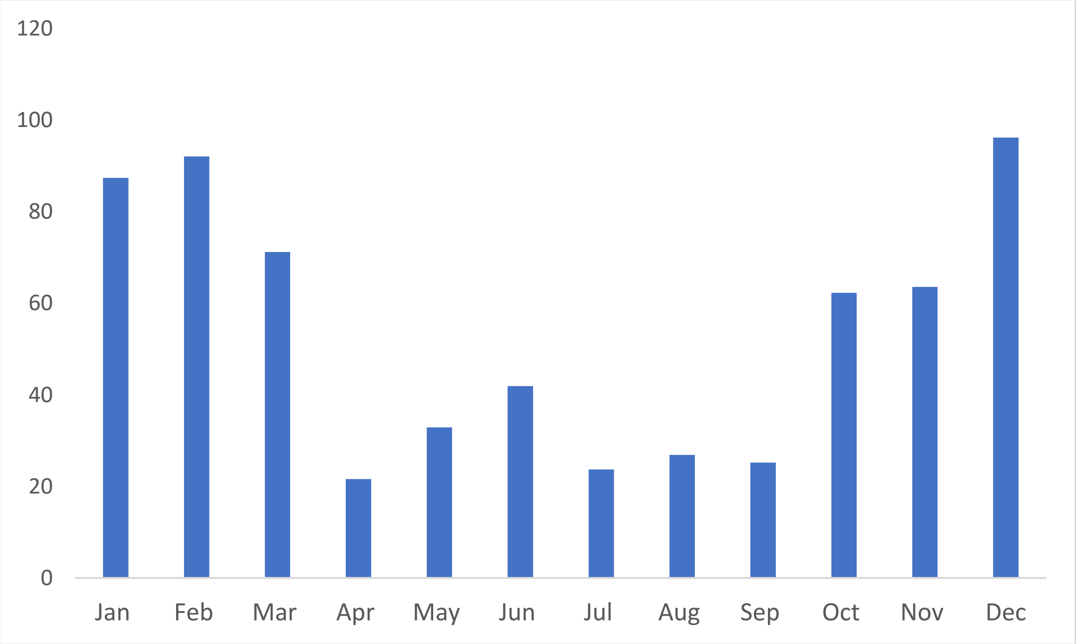


Note: Years with missing data have been excluded.

Source: BoM, Kingaroy, station 40922.

Figure 6.4 shows the average rainfall for each month of the year. South Burnett (Kingaroy) has a rainfall pattern with a dominance of summer rainfall, and less rainfall over the winter months. This rainfall pattern is suited to irrigated perennial crops or summer-grown annual crops, as rainfall will occur during peak water demand for these crop types.

Figure 6.4: Monthly rainfall for Kingaroy (mm)



Source: PeritusAg, Crop Feasibility Review, July 2022.

6.3.4 Temperature

Temperature can affect agricultural production at both its highs and lows. Higher temperatures increase evaporation and therefore increase the amount of water required for irrigation, and can also cause some crops to wilt and spoil. Lower temperatures (below freezing) can lead to frost damage of plants. PeritusAg completed a crop feasibility study for the subject area of the South Burnett, and as part of this study it assessed the average and highest and lowest temperatures on record in the area (see Figure 8).

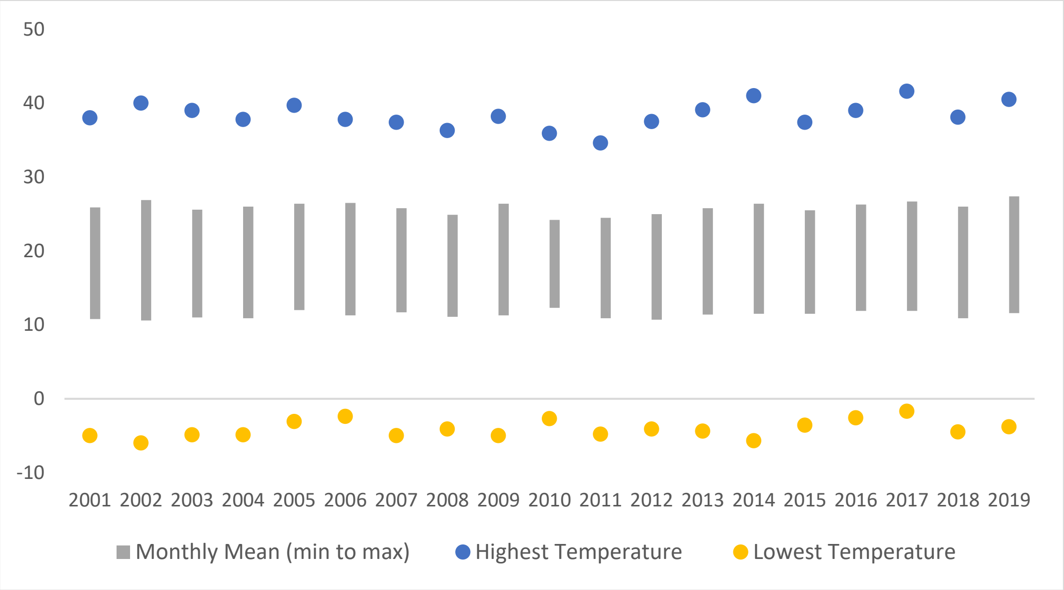
The South Burnett has quite variable temperatures throughout the year, with both the maximum and minimum temperatures creating risks for cropping.

- The maximum temperatures could pose risks to some perennial crops. High temperatures (35–40°C) can be managed through mitigations such as cooling misters or shade structures. These measures can be less effective in temperatures above 40°C; however, in the South Burnett this only occurs on average less than one day a year and is therefore a lower risk.
- On approximately 20 days per year there is a risk of minor or major frost events, which can damage sensitive crops. The report also notes that frost risk is currently being managed through site selection, favouring elevated areas that have been found to avoid frost damage.

The full PeritusAg report is available as an appendix to this report.

Whilst there are some peak temperatures (high and low) that create risks for cropping, these can be managed through site selection, mitigation measures (e.g. shade structures) and crop selection. The average temperatures in the South Burnett are suitable for irrigated agriculture.

Table 6.1 Average temperature

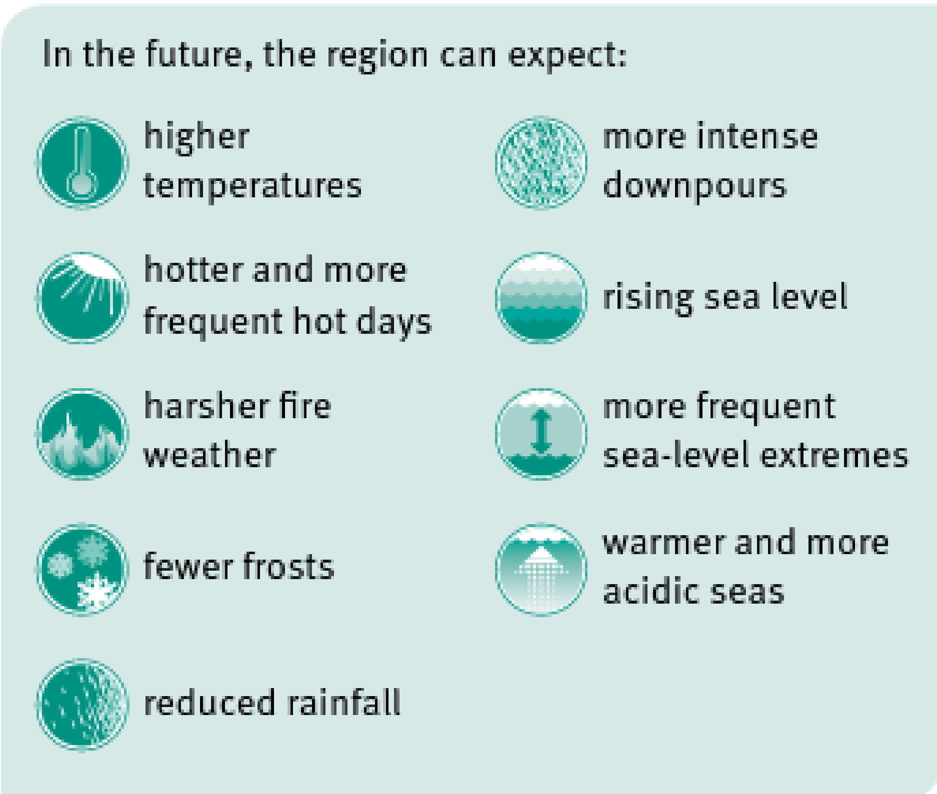


6.3.5 Predicted changes over time

Climate change will impact agricultural production in the South Burnett as follows:

- Increased temperatures may lead to difficulties in supplying sufficient water to meet agricultural demand and heat damage to crops.
- Conditions may increase plant diseases, weeds and pests, and allow some pest species to move southwards into areas where they are currently excluded.
- Lower rainfall and increasing evaporation will cause more frequent depletion of soil moisture, reduced ground cover and lower livestock-carrying capacity.
- Harsher fire weather poses a threat to the timber industry and broad-acre farming.

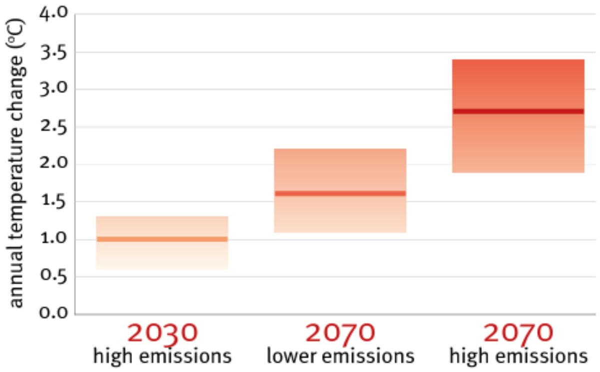
Figure 6.5 Impacts of climate change on for Wide Bay–Burnett region



Source: Wide Bay Burnett Climate Change Impact Summary.

Maximum, minimum and average temperatures are projected to continue to rise. For the near future (2030), the annually average temperature increase is forecast to be 0.6 to 1.3°C above the climate of 1986–2005.

Figure 6.6 Temperature change for Wide Bay-Burnett region under different emissions scenarios



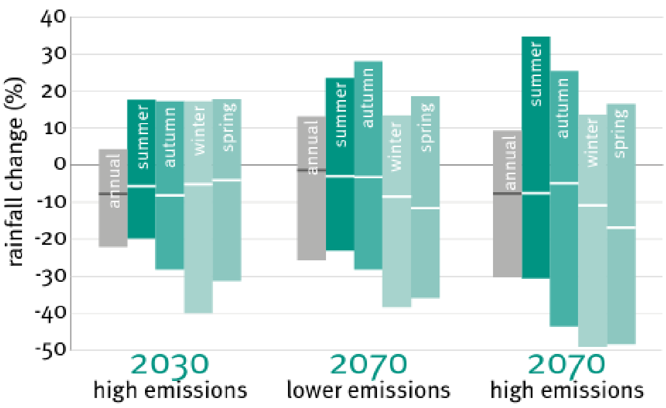
Projected annual average temperature changes for the Wide Bay–Burnett region. The horizontal line on each bar is the middle (median) projected temperature change. The extent of each bar indicates the range of projected changes.

Source: Wide Bay Burnett Climate Change Impact Summary.

By 2070, forecast warming is 1.1 to 3.4°C, depending on future emissions. The region's summer average temperature is 25°C. This could rise to over 26°C by 2030 and to over 28°C by 2070.

High climate variability is likely to be the major factor influencing rainfall changes in the next few decades. Rainfall projections for 2070 show little change or a decrease in average rainfall, particularly in winter and spring.

Figure 6.7 Climate forecasts



Projected annual and seasonal rainfall changes for the Wide Bay–Burnett region. The horizontal line on each bar is the middle (median) projected rainfall change. The extent of the bar indicates the range of projected changes.

Source: Wide Bay Burnett Climate Change Impact Summary

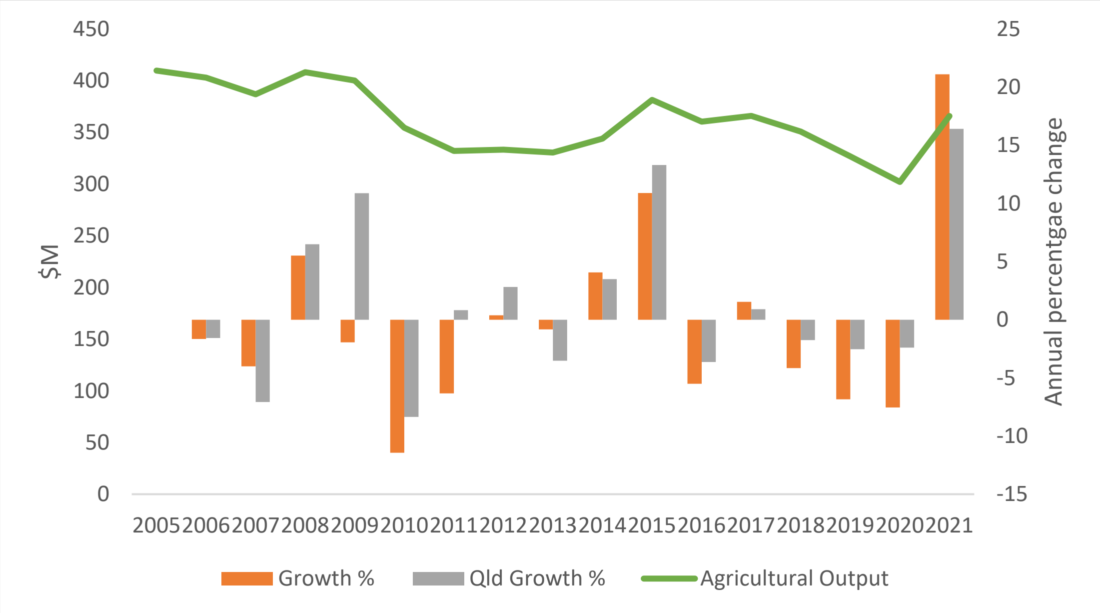
However, forecasts show that rainfall will be highly variable and that rainfall intensity is expected to increase.

In summary, climate change will deliver to the Wide Bay-Burnett region higher average temperatures and greater rainfall variability (and intensity), which will drive deteriorating soil moisture and the need for a more reliable supply of water for irrigation as dry land crops will more frequently fail.

6.4 CURRENT AGRICULTURAL PRODUCTION

Agricultural output in the South Burnett has averaged around $360 million annually, although it has been gradually declining over time (Figure 12). The pattern of growth is similar to that of Queensland as a whole, especially in more recent years, although when Queensland agricultural output is declining South Burnett declines by more, and when Queensland is growing, South Burnett has a higher growth. There were three years of decline from 2018 to 2020; however, agricultural output has recently bounced back.

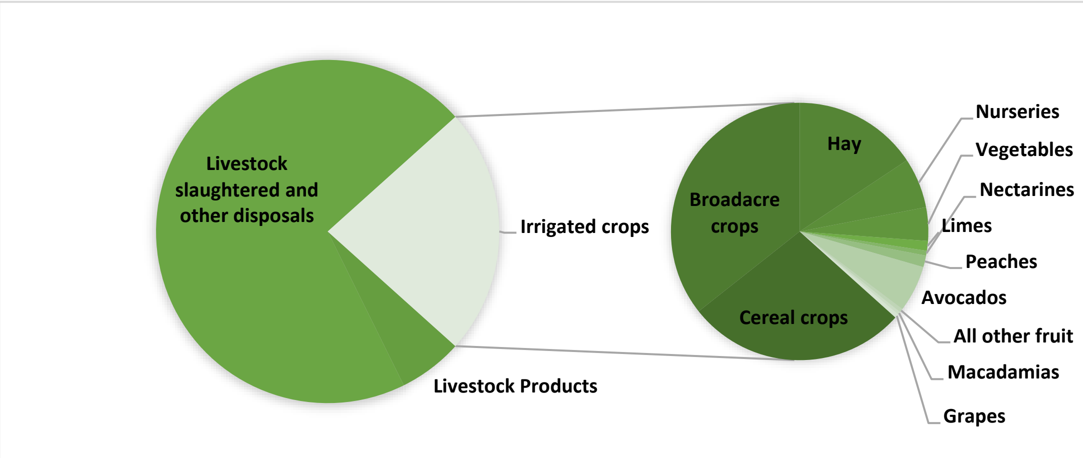
Figure 12 Agricultural output in the South Burnett



Source: economy.id, South Burnett Regional Council, Time series industry sector analysis.

The South Burnett area is traditionally a dryland cropping region with minimal irrigated crop production. As shown below, the predominant agricultural production relates to livestock, with irrigated crops making up 23% of output. These crops are largely broadacre, cereals and hay, with other higher-value crops making up a very small proportion of agricultural output in the region. The crop selection and dominance of livestock reflects the dryland cropping nature of the region.

Figure 13 South Burnett agricultural output by crop



6.5 EXISTING WATER SUPPLY ALLOCATION AND MANAGEMENT

The South Burnett area has a few different sources of water supply; however, they are all near capacity and are providing a constraint to growth in the area. This creates risks for the future of South Burnett both in terms of agricultural and other industrial production and also urban water supplies.

6.5.1 Existing water supply sources

There are two water supply schemes within the South Burnett Regional Council area: the Barker Barambah and the Boyne River and Tarong water supply schemes. Both are owned and operated by Sunwater.

The Barker Barambah Scheme sources its water from the Bjelke-Petersen Dam, and two weirs operate in the scheme downstream of the dam — Joe Sipple Weir and Silverleaf Weir. In addition, a 6.2 km gravity pipeline diverts water from the dam to Joe Sipple Weir on Barambah Creek to meet the needs of farmers in the Redgate area. Along with irrigation users, South Burnett Regional Council uses its allocation for urban water supplies to supplement the town water supply for Murgon, Wondai and Byee.

The Boyne River and Tarong Scheme draws water from Boondooma Dam and supports Tarong Power Station and irrigators along the Boyne River. Irrigation water from the Boondooma Dam is released to supplement natural flow in the lower Boyne River. Tarong Power Station is supplied via the Boondooma to Tarong Pipeline, which includes three pumping stations along its 95 km route. South Burnett Regional Council uses its allocation from Boondooma for urban water supplies for Kingaroy, which includes industrial users such as Swickers pork processing.

Figure 6.8 is an extract from the Burnett Water Plan showing the locations of the two key storages, Boondooma Dam and Bjelke-Petersen Dam.

Figure 6.8: Extract from Burnett Water Plan map

Source: Burnett Water Plan.

Table 1.1 outlines the total volume in each of the water supply schemes, the water allocations held and the remaining uncommitted water allocations. This shows that there is very limited capacity within the existing water supply sources in the South Burnett.

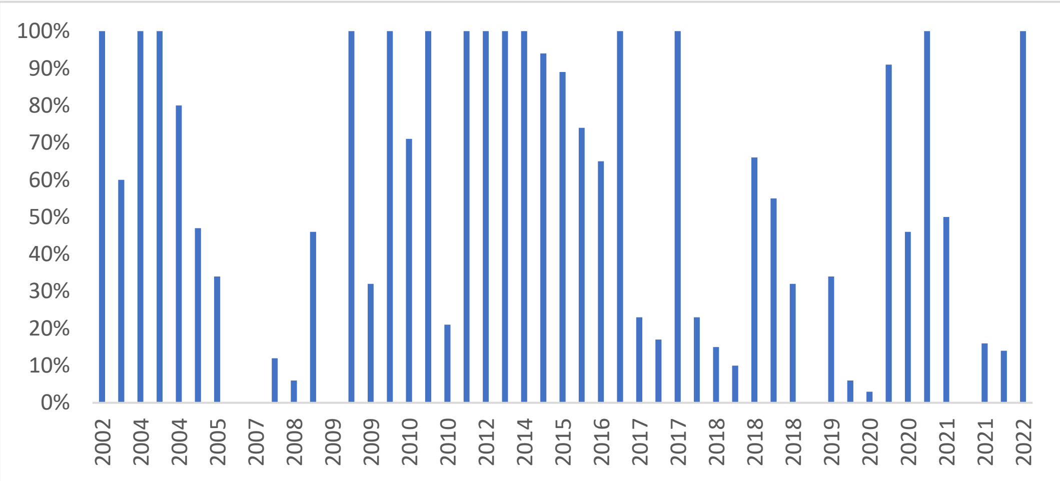
Table 6.2 Uncommitted water allocations in the South Burnett

	Total full supply volume (ML)	Water allocations held by customers (ML)	Uncommitted water allocations (ML)
Barker Barambah	136,190	33,512	793
Boyne River and Tarong	204,200	41,785	0

Barker Barambah

The Barker Barambah water supply scheme is a reliable a source for high priority customers such as South Burnett Regional Council (monthly reliability of 99.8%). However, the reliability for medium priority users for irrigation is not strong, with a monthly reliability of 78%. Figure 6.9 outlines the historical announced allocation for medium priority water allocations in the scheme. The percentage reflects the proportion of their water allocation that a customer is allowed to take within that year. This scheme has seen several years of reduced allocation or no allocation for medium priority irrigation customers.

Figure 6.9: Historical Barker Barambah announced allocations

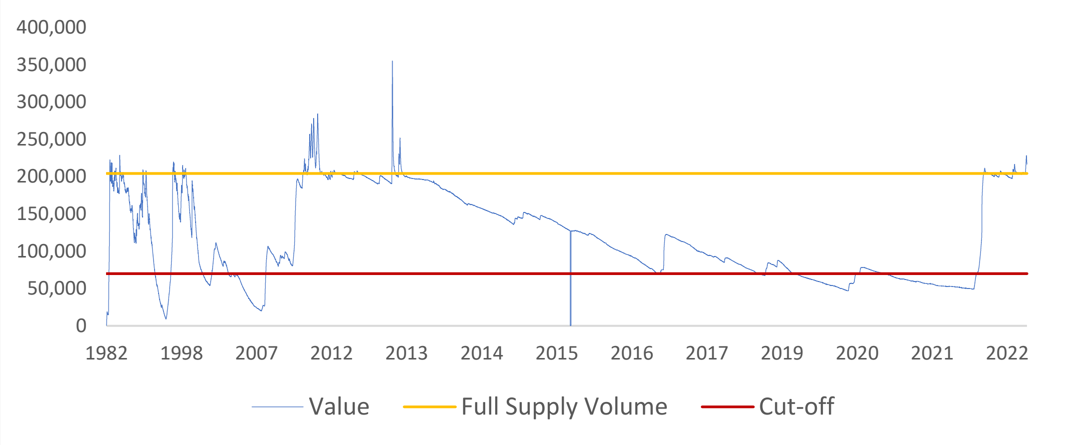


Source: Sunwater.

Boondooma Dam

Boondooma Dam as a supply source for high priority customers (such as South Burnett Regional Council and Tarong Power Station) is quite good. However, the rules of the Boyne River and Tarong water supply scheme include a cut-off rule, which has downsides for medium priority water allocation holders. When the volume of Boondooma Dam falls to 70,000 ML, the medium priority irrigation customers are cut off and can no longer take any water. As shown in Figure 6.10, this has occurred several times in the history of the dam.

Figure 6.10: Historical Boondooma Dam levels



Source: Sunwater.

6.5.2 Urban water security

Urban water security has been recognised by the Queensland Government as being a concern for the town of Kingaroy in the South Burnett. This led the Department of Regional Development, Manufacturing and Water to undertake a Regional Water Supply Security Assessment (RWSSA) in partnership with South Burnett Regional Council. While focused on Kingaroy, with the planned connection for the town of Nanango, both towns were included in the assessment.

The population of Kingaroy and Nanango is around 20,000, which represents the majority of the population of South Burnett (around 62% of the population). As at the time of the assessment in 2019, Kingaroy and Nanango had urban water demand of 1800 ML/a. This includes the water requirements for Swickers pork processing plant, which is approximately 400 ML/a in total; however, some is met from Swickers' own groundwater sources.

Until Nanango is connected to Kingaroy, Nanango is supplied through bores only (alternative Cooyar Creek supply was decommissioned due to water quality and reliability issues). These have their own security and other supply issues.

The South Burnett supplies water for Kingaroy from both Boondooma Dam and Gordonbrook Dam (Table 6.3).

Table 6.3 Storage use for South Burnett urban water supply

	Boondooma Dam	Gordonbrook Dam
Council water allocation	1,825 ML/a of high priority 1,260 ML assigned to Kingaroy (remainder for other SBRC communities)	1,809 ML/A All supplied for Kingaroy
Share of Kingaroy Water Treatment Plant supply (operational decision)	70% 1,260 ML	30% 540 ML
Access constraints	Nil for high priority supply to MP users (irrigators) ceases when dam falls below 70,000 ML	Only accessing when dam is above 50% full supply volume (due to water quality concerns and existing capability of the WTP)

The RWSSA found that demand on the Kingaroy supply system (when including Nanango) has a likelihood of failing every 1 in 4 years. Even without Nanango connected, supply to Kingaroy alone supply may fail 1 in 13 years. These likelihoods worsen each year as population grows.

The key driver of these expected supply failures is the low reliability of Gordonbrook Dam staying above 50%. In those times the Boondooma allocation alone is insufficient to meet the urban water demand. The reliability of Boondooma dam is not the concern, only that the allocation from this source is not sufficient. A larger allocation would relieve urban water security risk.

6.6 EXISTING INFRASTRUCTURE

South Burnett has strong existing infrastructure, which provides easy and convenient access for production, including good roads to major markets and logistical hubs. Distance to key locations is outlined in Table 1.1 below. Road transportation is the key form of access to the area.

Wellcamp Airport (only 1.5 to 2 hours from South Burnett) opened a new Regional Trade Distribution Centre in July 2021 which has improved moving agricultural production to export. The centre includes state-of-the-art refrigerated storage, freezer rooms and temperature-controlled transit areas.

Two flights each week depart from Wellcamp to transport local goods to Hong Kong, Singapore, China, and as far away as Dubai, Canada, the United States and Europe.

Table 6.4 Distance of major markets and logistical hubs from the South Burnett

	Brisbane (Rocklea)	Bundaberg Port	Wellcamp Airport
Nanango	192 km (2 hours 15 mins)	288 km (3 hours 15 mins)	132 km (1 hour 30 mins)
Kingaroy	217 km (2 hours 30 mins)	266 km (3 hours)	147 km (2 hours)

6.7 EXPORT OPPORTUNITIES

The South Burnett Regional Council area consumes a lot of its own agricultural production, and there is opportunity that if production were to expand it could be exported outside the region. Most of South Burnett's agricultural output is consumed within the local South Burnett area (58%), while 38% is sent elsewhere within Australia, and only 4% is exported internationally. This contrasts with Queensland, which exports more to other states, although international exports remain a similarly small proportion.

Figure 17 Proportion of agricultural output exported

Source: economy.id, South Burnett Regional Council, Industry sector analysis – Agriculture.

An assessment was undertaken in relation to the domestic and international market demand for key agricultural crops to assess and understand the viability and growth potential for agricultural production in relation to the water infrastructure options. The Export Market Analysis for the Economic and Sustainability Roadmap is set out as an appendix.

The Export Market Analysis assesses each agricultural crop in relation to the following:

- Australian production volume and trends
- Domestic consumption
- Existing international exports
- Future export opportunities for Australian produce

The overall finding of the Export Market Analysis is that significant export market opportunities exist for each of the agricultural crops, particularly in Asian markets. Australia's collection of free trade agreements, and other trade cooperation agreements, have provided a low tariff export environment for each of the crops assessed. Notwithstanding this, there is an ongoing need for Australia and Queensland Government support with the establishment and maintenance of strong trade relationships and pathways into each of the export markets to facilitate access for Australian producers.

Table 6.5 summarises the findings in relation to each of the agricultural crops in relation to the domestic capacity and demand, and export opportunity.

Table 6.5: Domestic capacity and demand, and export opportunity

Crop	Domestic capacity and demand	Export opportunity
Peanuts	High	High
Fodder	Medium	High
Cotton	Low	High

Crop	Domestic capacity and demand	Export opportunity
Avocados	Medium	High
Macadamias	Medium	High
Mandarins (Citrus)	High	High
Lemon (Citrus)	Medium	High
Peaches and Nectarines	Medium	High

6.8 SUSTAINABILITY STRATEGY AND OPPORTUNITY STATEMENT

The sustainability strategy (attached) sets out the Sustainability Strategy and Opportunity Statement for South Burnett (Sustainability Strategy). The Sustainability Strategy identifies initiatives, programs, policy changes and capital projects that can enhance both the sustainability and economic opportunity for the region.

The Sustainability Strategy includes:

- Overview of the risks and opportunities that exists for the South Burnett region generated by the transition of the Tarong Power Plant in 2037
- Analysis of the transition for the region after the Tarong Power Plant transition. The alignment to "Just Transition" is explored as well as the region's position to achieve United Nations Sustainable Development Goals
- Recommendations of business initiatives that achieves the strategy objective of maintaining and improving employment levels in South Burnett beyond 2037.

The Sustainability Strategy identifies and assesses the economic development options for the region based on the Just Transition sustainability framework and the United Nations Sustainability Development Goals.

Just Transition is a framework one that eliminates and replaces environmentally degrading activities with innovative and sustainable industries. It enables community-led initiatives to address environmental injustice and develop a sustainable local economy that promotes social equity by including and empowering all community groups.

United Nations Sustainability Development Goals framework includes 17 Goals and 169 targets to tackle the world's most pressing social, economic, and environmental challenges in the lead-up to 2030. While originally developed for national governments to implement, it is recognised that social and environmental issues require action by local and regional governments.

6.9 SUSTAINABILITY GOALS

The Sustainability Options Analysis outlined identified Intensive Livestock, Meat Processing and Avocadoes as three potentially viable economic and sustainable development options. The Sustainability Strategy conducted a further detailed assessment of these three options against the Just Transition and SDG sustainability frameworks. The results of the assessment demonstrated that the three options align with, and promotes the SDG framework, in the following ways:

- **Goal 1 No Poverty** by reducing the region's exposure to climate-related events and other economic, social and environmental shocks

- **Goal 2 Zero Hunger** by enabling increased investment, including through enhanced international cooperation, in rural infrastructure
- **Goal 3 Good Health and Well-Being** by reducing the number of illnesses from hazardous chemicals and air, water and soil pollution and contamination
- **Goal 6 Clean Water and Sanitation** by reducing pollution and minimizing the release of hazardous chemicals and materials, and implementing integrated water resource management
- **Goal 8 Decent Work and Economic Growth** by creating the conditions to achieve higher levels of economic productivity through diversification, technological upgrading, and innovation, including through a focus on high value sectors; fostering full and productive employment and decent work for all women and men; and enabling a shift to safer working environments for all workers
- **Goal 9 Industry Innovation and Infrastructure** by developing quality, reliable, sustainable, and resilient infrastructure to support economic development and human well-being
- **Goal 11 Sustainable Cities and Communities** by providing universal access to safe and liveable public spaces, and supporting positive economic, social, and environmental links between urban, peri-urban, and rural areas
- **Goal 12 Responsible Consumption and Production** by moving towards a more sustainable use of natural resources and reducing toxic waste generation
- **Goal 13 Climate Action** by enhancing education, awareness-raising and human and institutional capacity on climate change mitigation measures
- **Goal 17 Partnerships for the Goals** by promoting effective public-private partnerships to generate and disseminate new knowledge about sustainable development

The options align with the Just Transition framework by enabling the people of South Burnett – and especially those most vulnerable to the transition such as those currently employed by the Tarong power station – by facilitating employment opportunities in new sectors, offering re-skilling opportunities, and creating new and cleaner jobs. The options also supports companies and sectors, by creating attractive conditions for public and private investment, as well as the wider region by supporting the transition to low-carbon and climate-resilient activities, investing in economically viable initiatives to support the economy of the region.

6.10 OPPORTUNITIES IN THE SOUTH BURNETT

For the development of this Sustainability Strategy, fourteen economic opportunities were investigated and assessed against a set of eight criteria to determine their viability in supporting South Burnett through its post-coal transition.

The identified options underwent a high-level multi-criteria assessment, and include cotton, peanuts, beans, chickpeas, corn, pumpkin, watermelon, macadamias, citrus, stone fruit (peaches and nectarines), wine grapes, intensive pig and dairy farming, and pig processing.

The assessment was conducted against a set of eight criteria including suitability to soil and climate conditions, export potential, net margin, sustainability, availability of existing infrastructure and local knowledge, and job creation.

Figure 6.11 shows the outcomes of the multi-criteria assessment. The assessment revealed that intensive pig and dairy farming and meat processing have the highest economic potential and were therefore selected as viable new business opportunities for South Burnett to pursue. The option of avocado farming underwent a full-scope economic feasibility assessment which is provided in the Export Appendix.

Figure 6.11 multi-criteria assessment

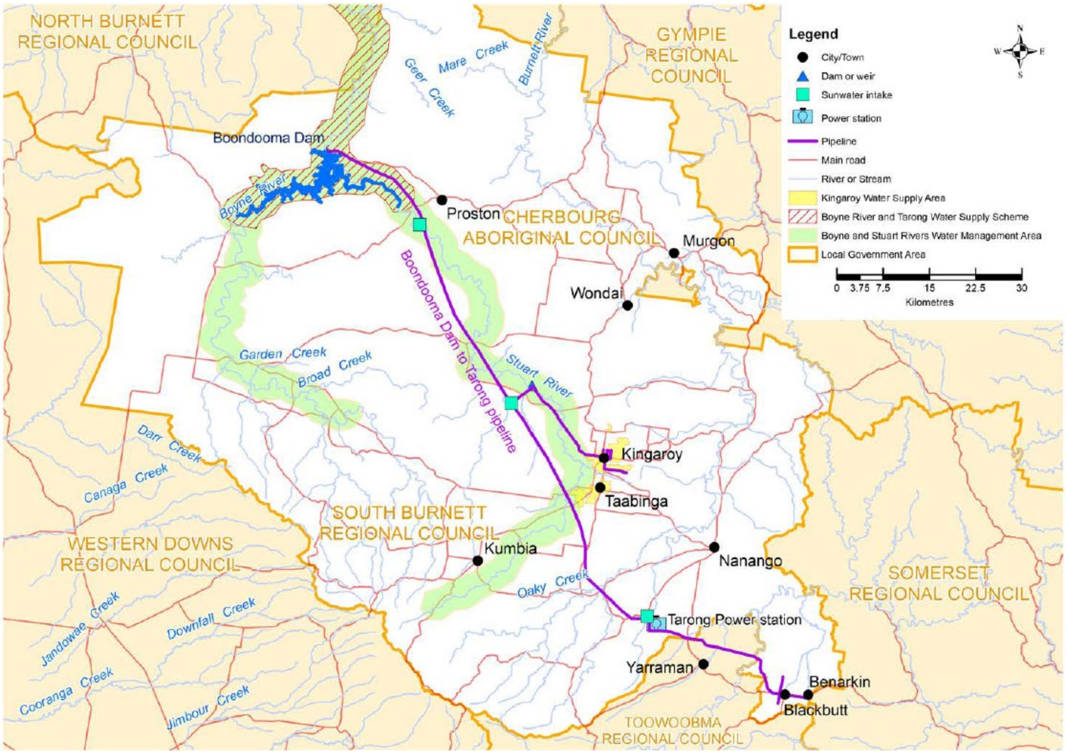
	Crop Suitability (Soil and Climate)	Domestic Market	Export Potential	Net Margins	Job creation	Sustainability	Existing Infrastructure and local knowledge	Benefits from scale / coordination	Average
Cotton	5	1	3.5	2	2	2.5	4	2	2.8
Peanuts	5	5	4	2.5	3	4.5	5	5	4.3
Beans (pulses)	5	2	4	2	2	4	5	5	3.6
Chickpeas	5	2	4.5	2	2	4	5	5	3.7
Corn / Maize	5	3.5	3	2	1.5	3	5	5	3.5
Pumpkins	5	2	2	2	2.5	3.5	4	3	3.0
Watermelons	5	2	2.5	2	2.5	3	4	3	3.0
Macadamias	5	2.5	4.5	4	4.5	4	3	4	3.9
Citrus	5	2.5	5	5	5	4	3	5	4.3
Stone Fruit (Peaches and nectarines)	5	3	2.5	4	4.5	3.5	5	5	4.1
Avocadoes	5	2	4	5	5	3	5	5	4.3
Wine Grapes (vertical integration)	5	2	1	3	3.5	3.5	3	5	3.3
Intensive Livestock (Piggery and Diary)		5		5	5	2.5	5	5	**4.6**
Meat Processing (Pigs)		5		5	5	2.5	5	5	**4.6**

6.11 CREATING JOBS THROUGH THE BOONDOOMA PIPELINE

Three projects have been identified and shown to be viable. Once built, and fully operational, the identified schemes will employ 296 people. To replace the jobs lost through Tarong's transition, a further 436 jobs need to be created.

As identified above, the transition of Tarong will make approximately 30,000 ML of water allocations available for an alternative use. Given the advantages that the region has for agricultural production, there is a strong opportunity to use some of this water for agricultural purposes and to create the jobs needed.

It is proposed to access water through the Boondooma pipeline that already runs through the area.



To create additional jobs, approximately 8,000 ML (out of 30,000 ML) is needed. There is 61,459 hectares of land suitable for horticulture, which is much more than is needed.

We have identified a range of crops and agricultural processes that could provide additional employment and sustainable agricultural production. Expansion of meat processing will provide additional employment and create substantial economic activity.

	Crop Suitability (Soil and Climate)	Domestic Market	Export Potential	Net Margins	Job creation	Sustainability	Existing Infrastructure and local knowledge	Benefits from scale / coordination	Average
Cotton	5	1	3.5	2	2	2.5	4	2	2.8
Peanuts	5	5	4	2.5	3	4.5	5	5	4.3
Beans (pulses)	5	2	4	2	2	4	5	5	3.6
Chickpeas	5	2	4.5	2	2	4	5	5	3.7
Corn / Maize	5	3.5	3	2	1.5	3	5	5	3.5
Pumpkins	5	2	2	2	2.5	3.5	4	3	3.0
Watermelons	5	2	2.5	2	2.5	3	4	3	3.0
Macadamias	5	2.5	4.5	4	4.5	4	3	4	3.9
Citrus	5	2.5	5	5	5	4	3	5	4.3
Stone Fruit (Peaches and nectarines)	5	3	2.5	4	4.5	3.5	5	5	4.1
Avocadoes	5	2	4	5	5	3	5	5	4.3
Wine Grapes (vertical integration)	5	2	1	3	3.5	3.5	3	5	3.3
Intensive Livestock (Piggery and Diary)		5		5	5	2.5	5	5	**4.6**
Meat Processing (Pigs)		5		5	5	2.5	5	5	**4.6**

Further investigation is required to determine the exact location of the water projects. However, given the amount of highly productive soil near the existing pipeline, it is envisaged that a number of small spurs could be added to create supply nodes.

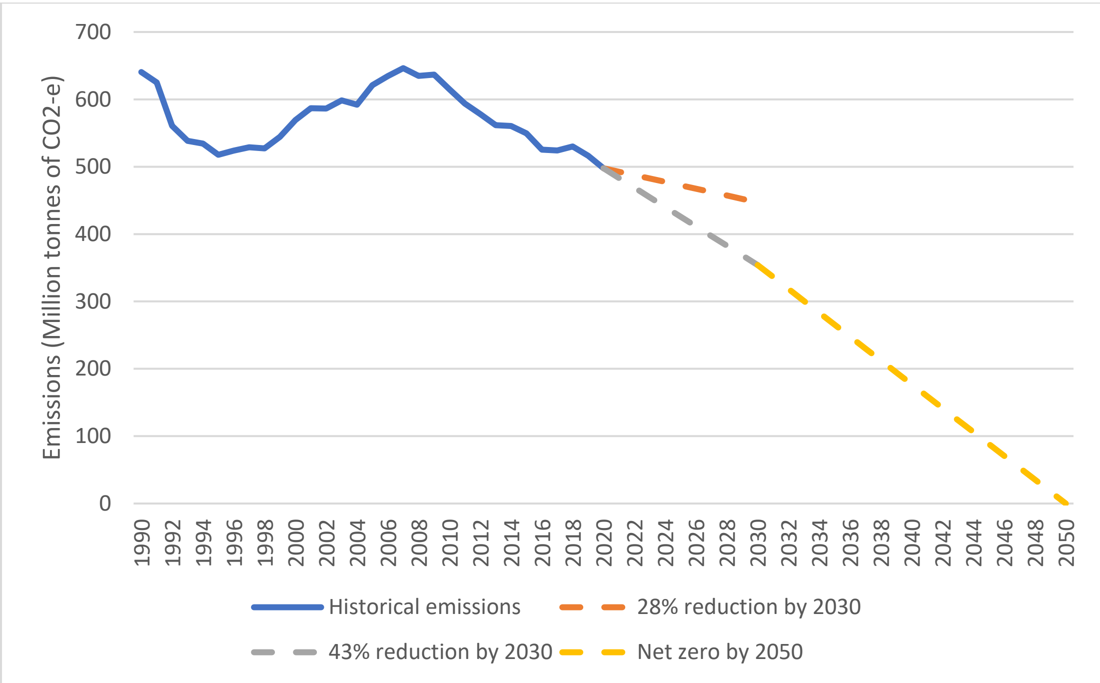
To meet the Government's commitments to Net Zero, these project can be built and operated on Net Zero principles, ensuring that these long life assets contribute to the Government's objectives.

6.12 NET ZERO AGRICULTURE

Currently, there is no formal requirement for infrastructure funded by the Australian Government, reviewed and recommended by Infrastructure Australia, to be net zero emissions.

However, the trajectory of emissions under the Australian Government's targets indicate that any project with a long project life (i.e. up to and beyond 2050) will have to be net zero so that it does not negatively impact the net zero target.

Figure 6.12 Australian emissions targets – previous 28% reduction target by 2030, new 43% reduction target by 2030 and net zero by 2050



It is likely that that new guidelines to align Infrastructure Australia with the national emissions target will include a net zero by 2050 requirement at a minimum.

Infrastructure projects that support the achievement of the 2030 and 2050 target through a reduction in emissions will also likely be prioritised.

Therefore, the annual emissions for each project has been calculated.

Table 6.6 Total emissions per year

	Blackbutt (t CO2-e)	Gordonbrook (t CO2-e)	Barlil and West Barambah weirs (t CO2-e)
Embodied (annualised over 50 years)	130	260	30
Operations (annual)	710	1,050	30
Enabled industry (annual)	2,320	17,960	4,740
Total	**3,160**	**19,270**	**4,800**

6.12.1 Achieving net zero

Net zero water infrastructure and enabled industry requires that all emissions are mitigate using the emissions mitigation framework:

1. Avoid emissions
2. Reduce emissions
3. Offset emissions

The following table provides potential mitigation measures for the key emissions identified in the preliminary emissions footprint.

Table 6.7 Infrastructure emissions

Categories	Description	Example of emissions mitigation
Embodied	Production of materials used in the construction of infrastructure, as well as those from the construction process itself	• Carbon neutral or recycled plastic pipes • Green steel • Electric construction vehicles using renewable energy • Carbon offsets
Operating	Ongoing operations of infrastructure assets	• Electricity sourced from renewable energy • Carbon offsets • On-site vehicles that use fossil fuels
Enabled	Activities of infrastructure's end-users	• Soil and tree carbon projects • Emissions reduction technologies for animal protein production • Electricity from renewable energy

A detailed net zero plan can be developed for the final composition of infrastructure and enabled industries.

6.13 COMMUNITY ASSETS AND URBAN WATER RESILIENCE PACKAGE

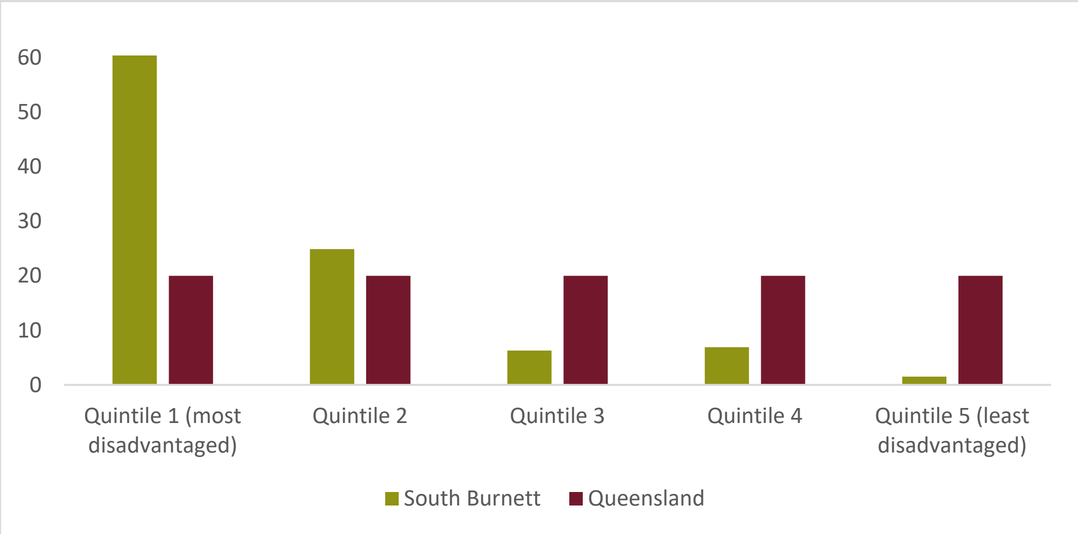
The South Burnett community will need to go through a period of social and community change during the transition period. The South Burnett already also has high socio-economic disadvantage relative to the total Queensland population. It is in the bottom third of the state for social disadvantage in the Socio-Economic Index for Areas (SEIFA)[13]. Residents are three times as likely to

[13] ABS, *Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2016*, cat no 2033.0.55.001, 2018, accessed August 2022.

be in the most disadvantaged quintile and 13 times less likely to be in the most advantaged quintile.

This already disadvantaged state will be exacerbated by the transition of Tarong. Without intervention, people's access to resources and their ability to participate in society, including factors such as income, education, employment, occupation and housing characteristics, will continue to decline.

Figure 6.13 Comparison of socio-economic disadvantage



Source: ABS, Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2016, cat no 2033.0.55.001 (Queensland Treasury derived).

To allow for community live to thrive during the transition period, it is essential that local clubs and community groups are able to manage some turnover in members, and be supported. In the Latrobe Valley, a Community and Facility Fund was developed to support community infrastructure projects and events, improving liveability, pride and local connection.

This fund generated local employment through use of local contractors, such as involvement of local sound and audio businesses in hall upgrades, and local tradesmen in energy efficiency upgrades and kitchen refurbishments. Major projects included refurbishment of six local scout halls, upgrades to Sale Memorial Hall and Sale Showgrounds, Future Morwell streetscape project, and Maffra's Cameron Sporting Complex redevelopment.

The Fund has also supported almost 50 local events including the Melbourne Food and Wine Festival Jindivick event and events supporting communities affected by drought or bushfire, youth and science activities, scouting and sporting activities, music, sculpture, cooking, culturally diverse communities and large community gatherings. Clubs supported report experiencing increased membership and participation - improved facilities have led to more event activity and increased visitation, which has improved their income significantly.

Funding for water and energy saving measures have led to significant cost savings – allowing clubs to invest these savings into facility improvements.

In addition, there was an investment in local sporting clubs to undertake strategic planning to build resilient, sustainable and inclusive sport and recreation organisations in the Latrobe Valley region.

Likewise, the South Burnett would benefit from a targeted investment in community assets that would embed a strong local culture.

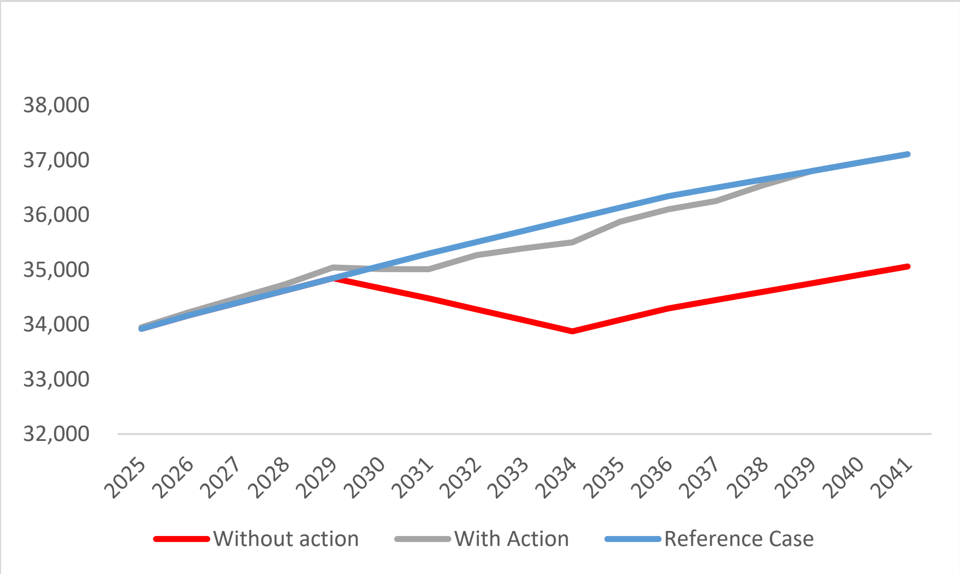
7 Conclusion and next steps

If no action is taken, the population of the South Burnett will decline by up to 10%, when Tarong Power Station closes. However, the Queensland Government's Energy Workers Charter and Jobs Security Guarantee will ensure that workers will continue to be employed, albeit in a different capacity.

The Premier has pledged to work with communities to develop regional economic futures strategies. The South Burnett seeks to leverage its advantages and expand its agricultural sector. This will rapidly create employment, by using some of the water currently used for energy generation.

Investing in the future of agriculture will prevent the regional decline that would be caused if Tarong Power Station was closed without a transition towards other indutries. This action will ensure that employment and population continues to grow.

Figure 7.1 Population in the South Burnett



The identified projects are all economically and financially viable. They are worthy of Government investment, irrespective of the broader regional imperative to provide economic support during the energy transition.

Table 7.1 Summary of new irrigation schemes

	Barlil Weir	Gordonbrook Dam	Blackbutt irrigation
Total benefits ($M)	24.0	33.6	34.4
Total costs ($M)	12.9	28.8	24.2
Net present value ($M)	11.1	4.8	10.2
New ongoing jobs	24	154	**116**
Benefit–cost ratio (BCR)	**1.86**	**1.17**	**1.42**

The implementation plan is summarised below.

Table 7.2 – Implementation plan

Action	Timing	Cost
Establish a local body to oversee transition works and to identify the additional water projects.	Commence in 2023 and operate until after the transition is complete	$4 million per year
Complete a detailed business case that examines the package of projects: • Barambah Creek Storage • Gordonbrook irrigation network • Blackbutt irrigation network If the project is determined to be viable, gain environmental and planning approvals	2022–24	$5 million for the detailed business case and approvals; $1 million for geotechnical investigations.
Commence preconstruction activities: • Finalise approvals • Complete a Detailed design • Prepare tendering documents • Tendering	2024–2025	$10 million
Construct schemes	2025–2030 It is proposed to stagger construction activities, to allow for a sustainable construction effort, with local contractors working on several projects across several years	$150 million
Worker transition	Assist energy workers and miners to transition into a future of clean energy and sustainable agriculture	$25 million
Community assets and urban water resilience package		$75 million
Total		**$300 million**

7.1 RECOMMENDATIONS

It is recommended that:

1. The Queensland and Commonwealth Government’s provide $300 million to allow for the South Burnett to invest in job creating water infrastructure and community projects.
2. South Burnett Regional Council continue negotiations with the State Government and Stanwell about acquiring 11,000 ML of Water Allocations. These allocations should be provided incrementally to allow for gradual increase in agricultural production during the period of transition
3. The Queensland Government apply to the Commonwealth for funding to allow for the completion of a regional Detailed Business Case to finalise investigations on additional storage on Barambah Creek, Gordonbrook Irrigation Network and Blackbutt Irrigation Network
4. The Queensland Government establish a regional body to oversee the transition. This body would have oversight of:
    a. The Detailed Business Case
    b. Identifying future water projects for job creation
    c. Pre-construction works for the projects
    d. Construction
    e. Worker transition assistance
    f. Community assets and urban water resilience.

ECONOMIC ROAD MAP

Attachment A: Barlil and West Barambah Weirs Demand Assessment

Barlil & West Barambah Weirs

Round 1 Demand Assessment Report

Prepared for:
South Burnett Regional Council

Prepared by:
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12 July 2022

Contents

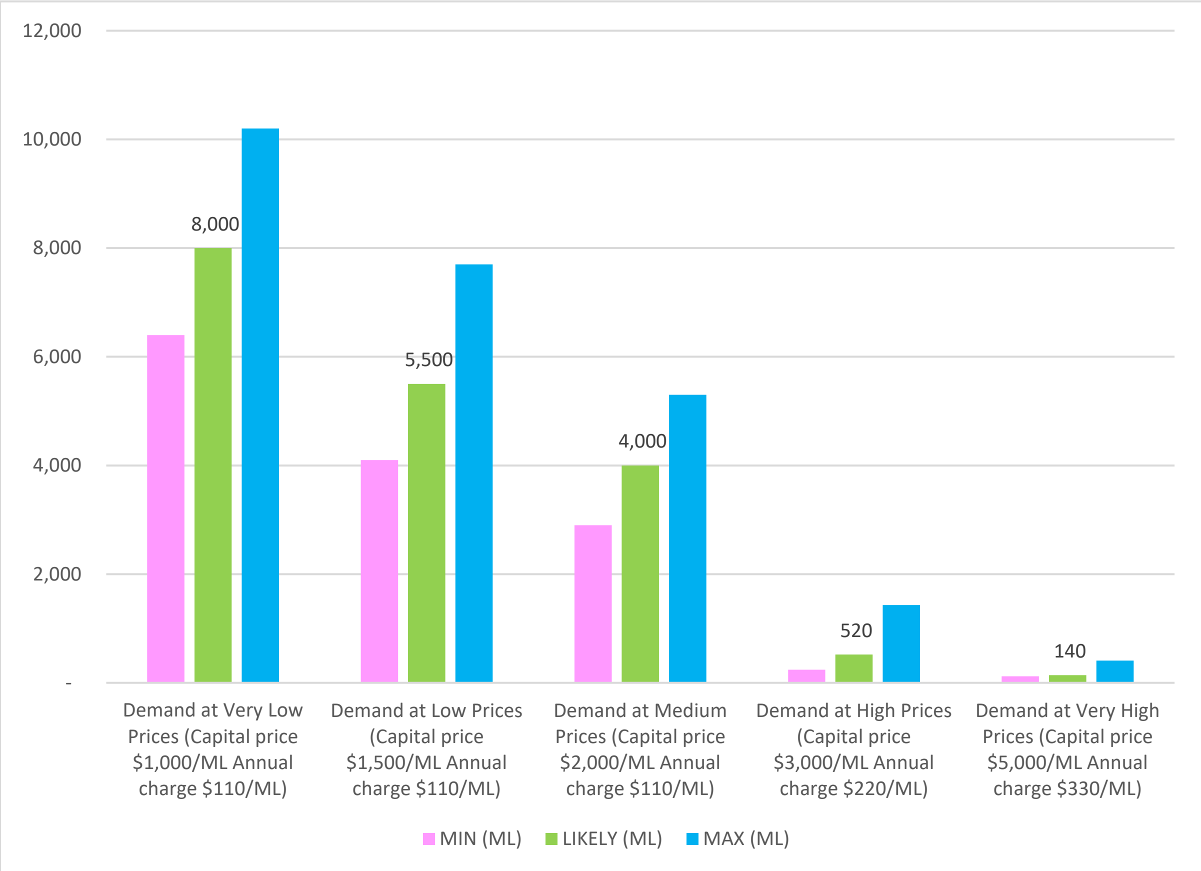
1 Executive summary

KBR was engaged to conduct a demand assessment for agricultural and other uses of the proposed Barlil Weir and potential West Barambah Weir.

There are 14 businesses interested in this water supplying 25 farms and other entities. Minimum, likely and maximum demand volumes are as follows. Likely demand at the optimal price will drive the engineering.

Demand and water uses

Figure 1 Demand for Barlil Weir and/or West Barambah Weir – Medium Priority Plus water allocations (ML)



The very low price has likely demand of 8,000 ML. The low price has likely demand of 5,500ML. The medium price has likely demand of 4,000 ML. Likely demand falls to 520 ML and 14 ML at high and very high prices.

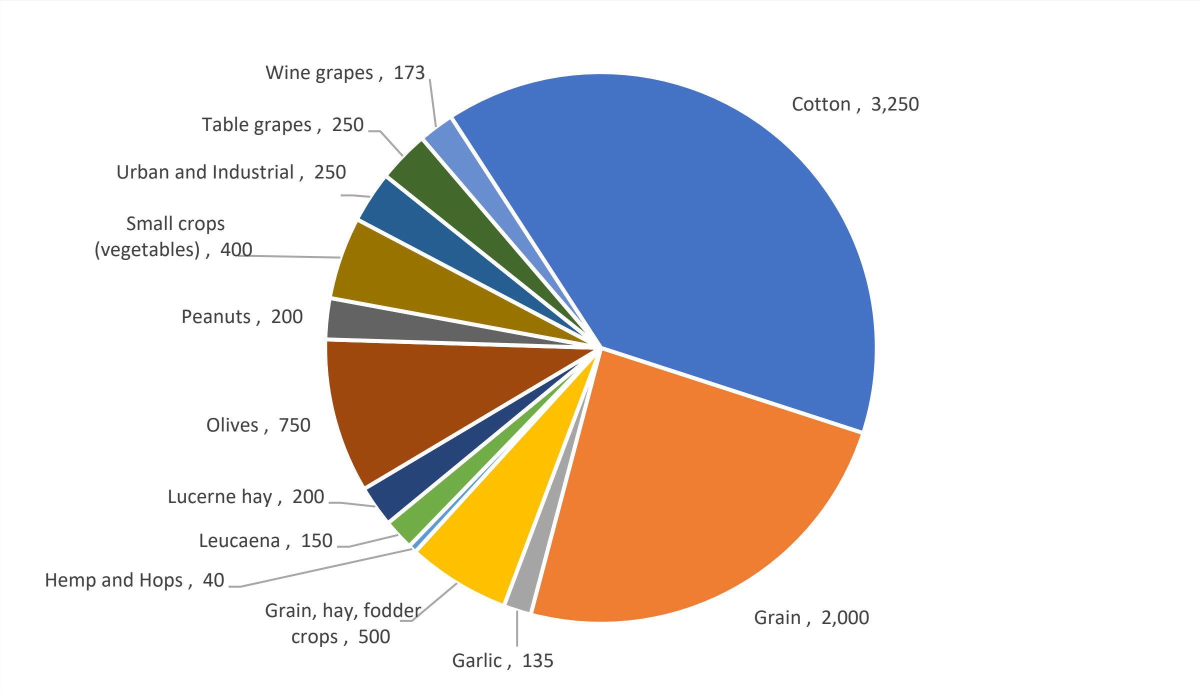
At very low to medium price scenarios, customer have provided evidence that they support annual charges of around $110/ML and a capital price of $1,000/ML to $2,000/ML.

Future water uses

Future economic water uses include a wide and delightfully diverse array of moderate to very high value enterprises. However, given current activities in the area, cotton and grains are purported to be the dominant future use of the new water product – Medium Priority Plus.

Of note, the future enterprise mix also includes garlic, hemp, hops, olives, peanuts, vegetables, and table and wine grapes. This will allow the profitability of locally made wine (referred to as the wine premium) to be included by KBR in our assessment / forecast of future economic benefits arising from this project/s.

Figure 2 Future water uses proposed by customers (ML)

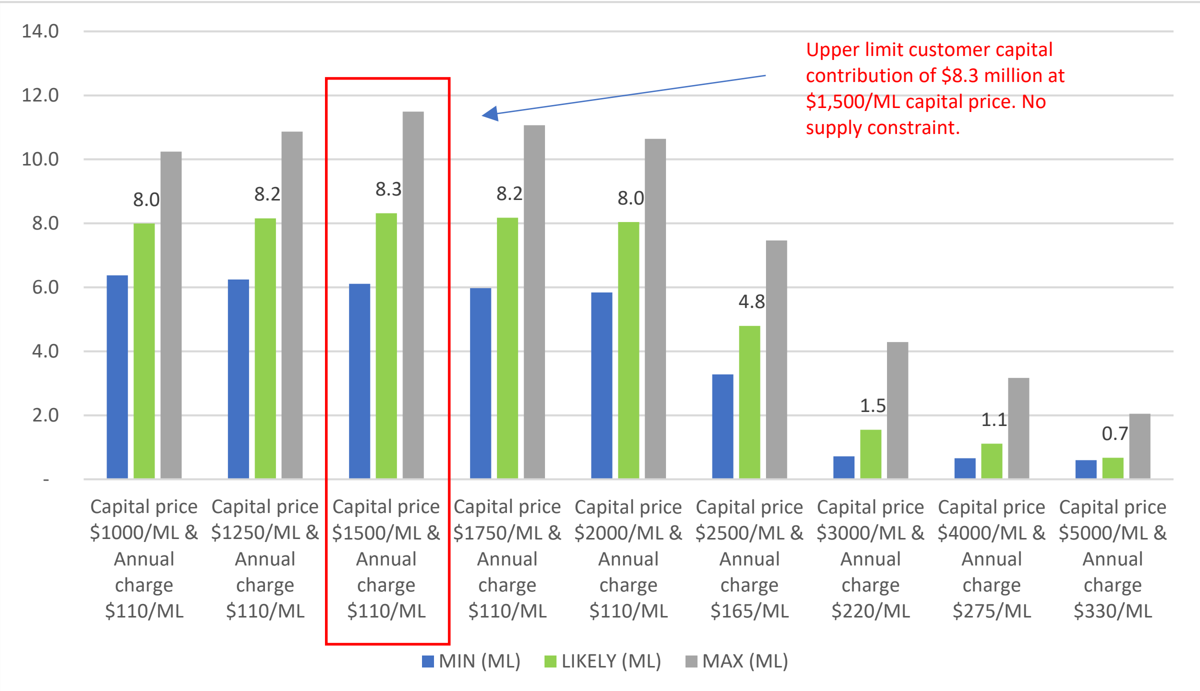


Forecast impacts of climate change on Wide Bay-Burnett strengthen the case for this project. For example, higher average temperatures and greater rainfall variability will led to frequent failure of dryland crops, underpinning the value of Council to progressing more reliable sources of water for agriculture.

Customer capital contributions – No supply constraint

Assuming no supply constraint, customer capital revenue and capital pricing options are set out below, which indicate that optimal revenue may be achieved at a customer capital price of $1,500/ML. It is possible to identify a customer capital contribution sweet spot if mid-point prices and revenues are also interpolated from the primary data. The figure below includes prices tested, mid-point prices and customer capital revenue.

Figure 3 Customer capital revenue at different prices (incl. interpolation) – No supply constraint ($ million)

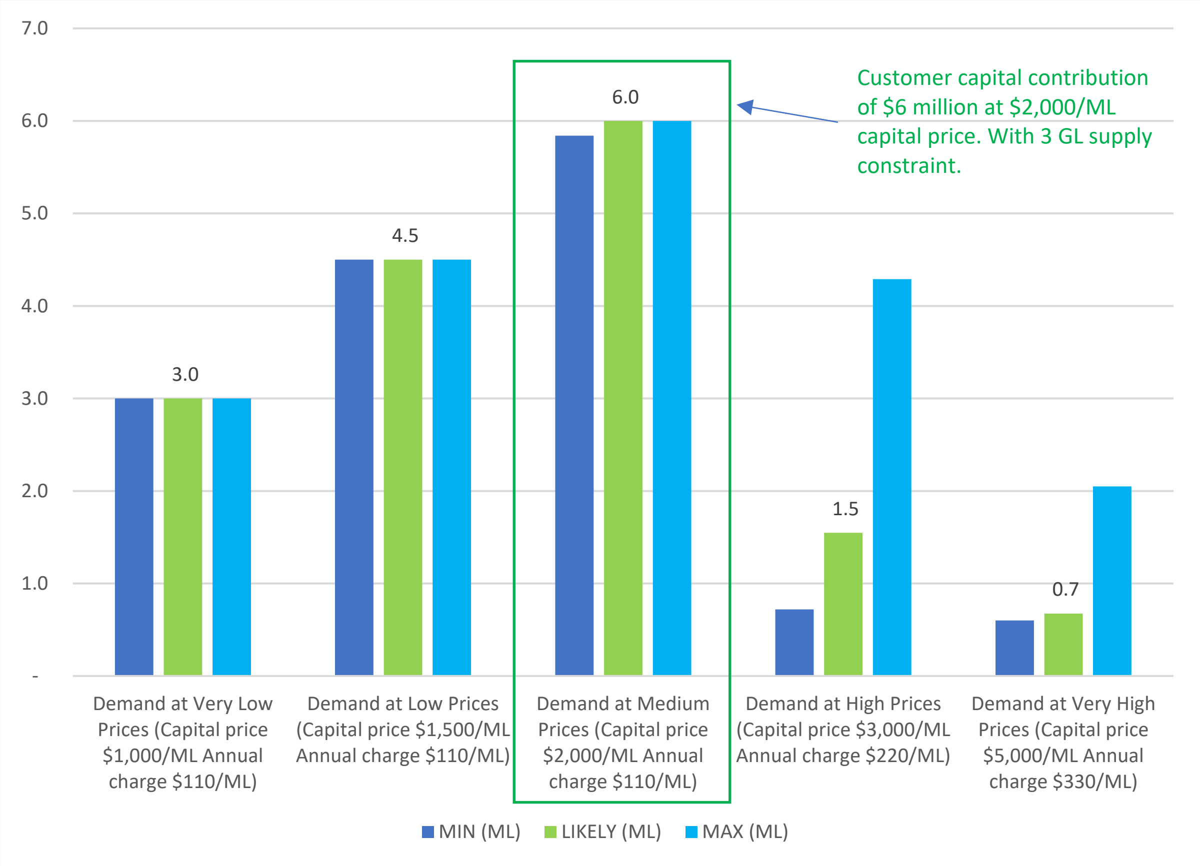


The figure above provides confidence that a customer capital price of $1,500/ML is likely to maximise customer capital contributions if total likely demand at this price of 5,500 ML can be met. However, the revenue of $8.3 million is based on there being no supply constraint (i.e. no limit on Medium Priority Plus).

Customer capital contributions – With 3 GL supply constraint

Given the how advanced Barlil Weir is as a project when compared to the West Barambah Weir concept, if a decision is made to progress Barlil Weir only – or Barlil Weir initially as a first stage – then the supply of new Medium Priority Plus water allocations for sale is 3,000 ML with a monthly reliability of about 91%. Assuming a supply constraint of 3,000 ML the forecast customer capital contributions at each price are set out below.

Figure 4 Barlil Weir Only – Customer capital contributions with 3 GL supply constraint ($ million)



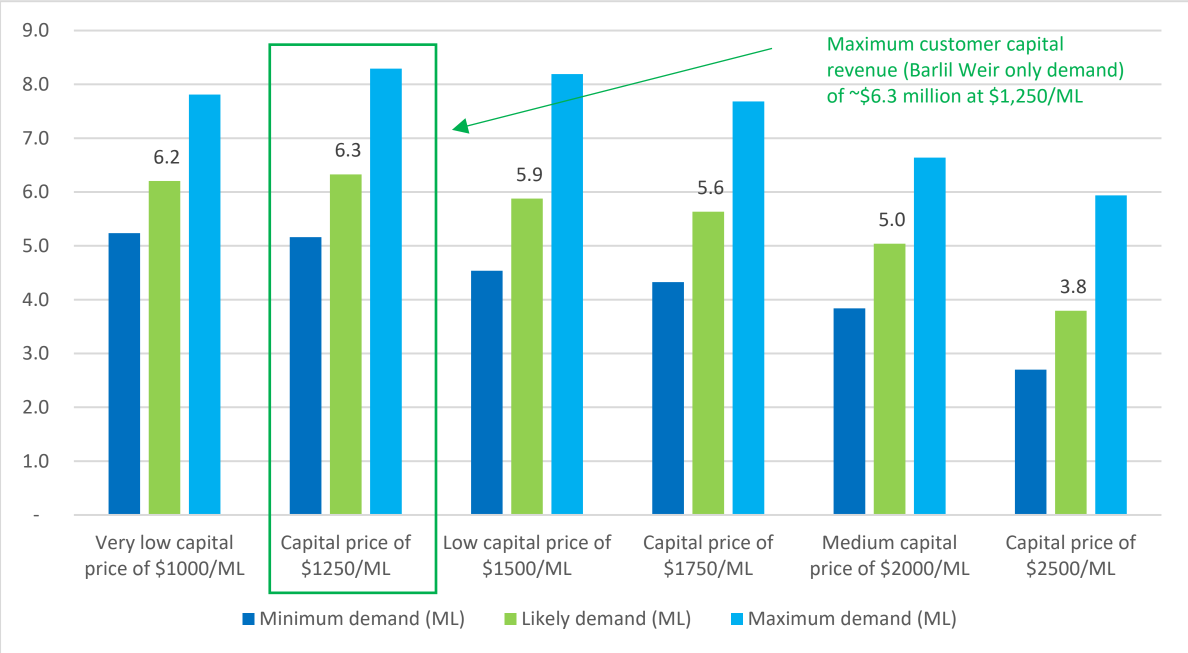
This analysis suggests that with a supply constraint – in a Barlil Weir only scenario – customer capital contributions are optimised at $6 million with a capital price of $2,000/ML.

Sensitivity analysis

KBR also considered what upstream demand 'drops out' if only Barlil Weir is developed – based on the self-exclusions nominated by respondents in their Expression of Interest forms. Two questions were considered: How much Barlil Weir only demand exists? And What size should be the larger version/s of the Barlil Weir?

KBR seeks to maximise customer capital contributions, because 'skin in the game' is what provides a project with its best chance of securing government approvals and funding. That is, maximising customer capital contributions gets projects built. Interpolated demand volumes and capital prices were used to forecast customer capital revenue in the figure below. The figure suggests that maximum revenue of about $6.3 million can be obtained a capital price of $1,250/ML paid upfront – assuming 5,100 ML of demand.

Figure 1.5 Barlil Weir only customer capital revenue (incl. selected interpolated capital prices) ($ million)



There are a few price and demand scenarios at which about $6 million of customer capital contributions may be secured. Lower prices mean higher demand certainty. To achieve low prices, higher volumes of sufficiently reliable water product are needed. Further investigations will determine the upper limit of Barlil Weir's ability to supply volumes above 3 GL, noting that 5 GL of demand is associated with the optimal price above.

Conclusions

As part of the broader economic road map being undertaken for Council, demand volumes exceeding Barlil Weir's yield could potentially be met by developing West Barambah Weir. However, the initial estimated combined yield of Barlil Weir and West Barambah Weir is 6 GL of Medium Priority Plus allocations. This is subject to change as further engineering and hydrological modelling are underway.

KBR consider that the larger more expensive West Barambah Weir would create up to 3 GL of additional water product, subject to its storage capacity being confirmed. West Barambah Weir is also forecast to negatively impact up to 2 GL of downstream users' water entitlements, which is not desirable. Whereas the 3 GL version of Barlil Weir receives a series of hydrological 'green lights' (Badu Advisory 2022).

Recommendations

KBR recommend that a 3 GL Barlil Weir be advanced via a detailed business case (DBC).

The complete set of Round 1 data forecasts a maximum customer capital contribution of about $6.0 million at $2,000/ML upfront capital price, assuming a 3 GL supply constraint. There is higher demand uncertainty at this moderate to high capital price, when compared to lower prices.

KBR also recommend that in the DBC, a larger version of Barlil Weir should be considered to meet additional Round 1 demand. The Round 1 demand data – for 'Barlil Weir only' demand as nominated by respondents – suggests the larger Barlil Weir should be between 4 and 6 GL. The sensitivity analysis revealed a maximum customer capital contribution of $6.3 million at $1,250/ML upfront capital price, assuming forecast likely demand can be met by 5 GL of supply. There is lower demand uncertainty at this low capital price, when compared to higher prices.

Once the base case (3 GL) and larger Barlil Weir option/s have been progressed as part of the DBC, a Round 2 demand assessment should take place incorporating new engineering design and costing information, and other assessments, for viable versions of the Barlil Weir. The DBC should be completed in a manner consistent with Queensland and Australian Government requirements.

2 Project overview

2.1 PURPOSE

The purpose of this report is to identify agricultural and other water demand for the Barlil Weir and potential West Barambah Weir water. The report outlines the process, findings and recommendations arising from the Round 1 demand assessment completed for these weirs.

2.2 NATIONALLY ENDORSED DEMAND ASSESSMENT PROCESS

KBR generally undertakes the following three phases of demand assessment using a process that emanated from Tasmanian Irrigation and is now a nationally endorsed approach:

- Round 1 – Expressions of Interest (non-binding) – the subject of this report
- Round 2 – Letters of Intent (non-binding) – part of a future detailed business case
- Round 3 – Water Sales – Legally binding water sales contracts with staged customer capital contributions, for example, made upon signing a contract, when government funding becomes unconditional and prior to completion of construction.

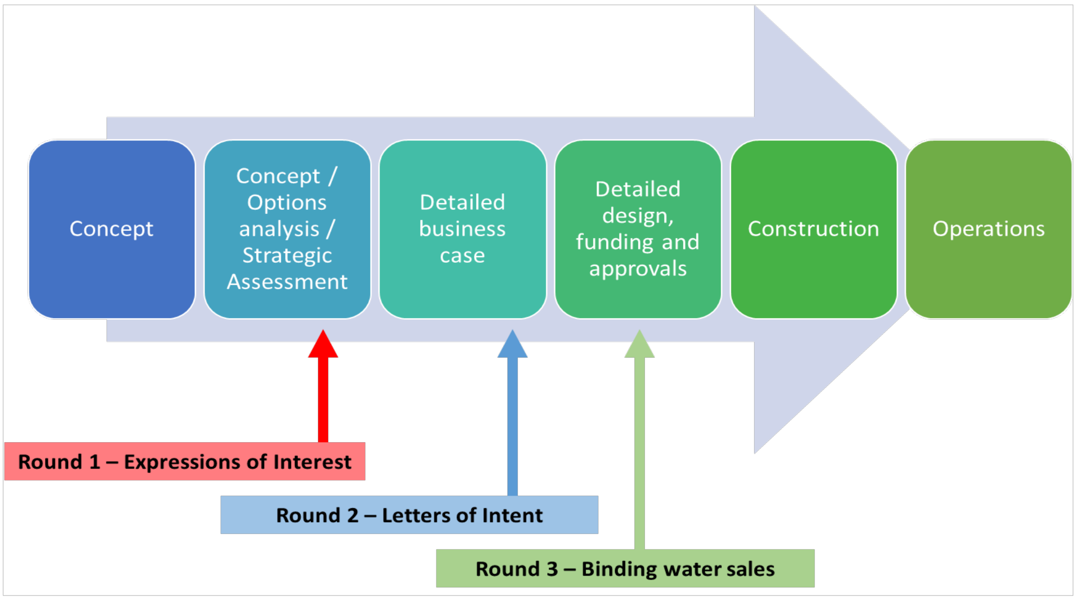
Round 1 and Round 2 are not legally binding, whereas Round 3 is legally binding to underpin funding. This approach demonstrates 'skin in the game' from customers and allows government to make a capital investment with a high degree of confidence that the project will succeed, and the forecast economic benefits arising from that investment will be realised to benefit the community.

2.3 METHODOLOGY

KBR's demand assessment strategy is iterative and connected to all stages of business case development. The demand assessment seeks written input from potential customers at each of these rounds. Demand assessment underpins each stage of business case development and is a major component of stakeholder engagement. This engagement was to undertake a Round 1 demand assessment.

Figure 2.1 outlines how Round 1 fits within a full demand assessment process.

Figure 2.1 Multi-stage Demand Process



Key stakeholders include a wide range of community members but for the purposes of demand assessment, KBR focuses on existing customers and potential new customers of any proposed infrastructure options. KBR utilises the client's contacts and its own.

Immersion/Service Need – KBR begins each business case project with an immersion into the local community. This includes meetings with stakeholders face-to-face for informal discussions to understand the wider context for the project and develop a strong understanding of the service need. It also includes supply infrastructure and farm visits.

Immersion meetings provided valuable input to the questions for the formal demand assessment form, including the range of price scenarios that were tested in the Round 1 Demand Assessment. Customers' and stakeholders' information is tested against other government sources, for example, crop yields, market prices, distribution or other supporting infrastructure.

Round 1 demand assessment – Information for Round 1 is collected in the form of non-binding expressions of interest. The formal demand process includes a public meeting/s and collection and detailed analysis of the forms including demand volumes at a wide range of prices. The form seeks interested parties to be thoughtful and realistic, but with no guarantees that the water become available. Products and prices are based on indicative modelling and/or expectations from previous experiences. Price ranges identify where the willingness-to-pay lies and very high prices rule out pricing and product options for future rounds.

Initial Engineering – Based on the Round 1 demand results initial engineering can then be undertaken to provide more specificity around infrastructure options that are able to be developed within the bounds of the likely demand. This will narrow-down the options for products and prices for the next stages of assessment.

2.3.1 Possible future stages

Round 2 Demand Assessment – This round seeks for customers to provide letters of intent along with their demand information. While this is not legally binding it is a strong show of good faith toward the intent to purchase water should it be made available under the types of products and prices in the demand assessment.

At this stage, the demand assessment is evaluated with only one price per product to give a solid picture for the potential customers to evaluate their demand for water volume. This is based on the more refined cost estimates and project details from the initial engineering.

Refined engineering – Based on the outcomes of the Round 2 Demand Assessment, there will be a firm idea of the volume of water demanded. This can be used to further refine the engineering of infrastructure options to reflect that level of demand (i.e. remove any excess capacity). This also provides the final options for finalization of the Detailed Business Case.

Detailed Business Case – developed according to the BCDF and PAF (method not detailed here).

Round 3 Demand Assessment – This round is where customers are requested to provide Binding Water Sales (incl. cash deposits) to cement their demand and provide formal reassurance that the infrastructure options being proposed have real, sufficient demand to provide the economic benefits that are being sought. This is the final stage prior to seeking approvals.

Approvals / Funding / Detailed Design / Construction – Final stages toward implementation.

3 Demand assessment process

3.1 METHODOLOGY

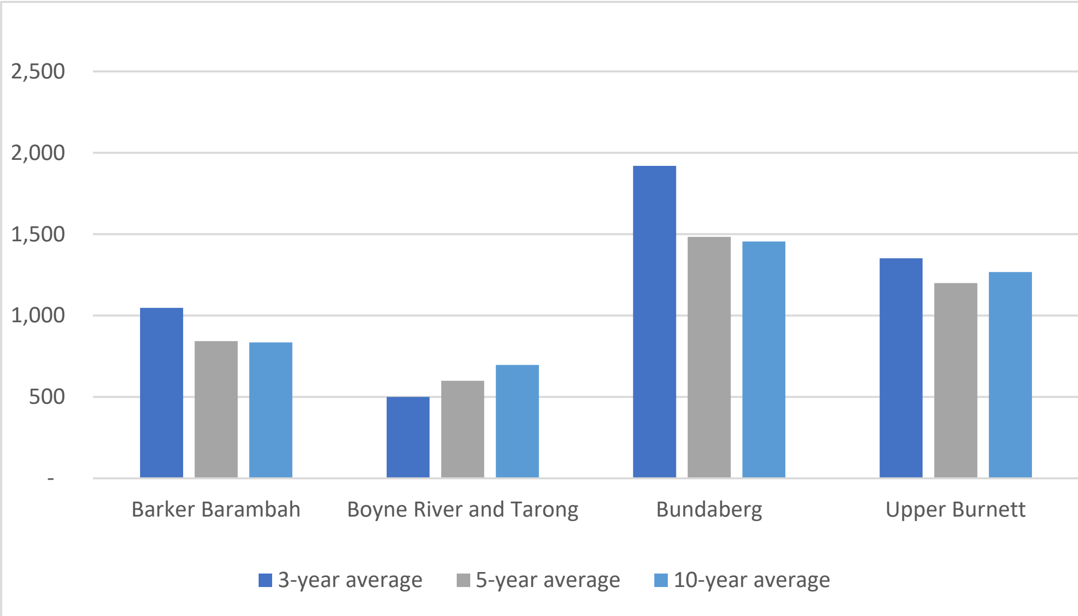
This section describes the key components of this water demand assessment and the process undertaken to develop a robust demand profile.

3.2 INPUT TO PRICE RANGES

The potential customers were presented with a wide, but realistic range of prices. This price range was developed having regard to the price of water in neighbouring schemes and the characteristics of the area.

Across the Bundaberg Burnett Region, the average price for medium priority water is approximately $800 to $1,000 per ML to purchase a Water Allocation.

Figure 3.1 Medium Priority - Weighted Average Price $/ML



Source: Business Queensland Permanent water trading data

Annual charges for Sunwater's existing schemes can be up to $100/ML.

3.3 PRICE RANGES AND WATER PRODUCT/S

KBR provided an annual charges price range that included the price of existing water as a low book-end and tested higher prices to accommodate the likely costs of new infrastructure.

We acknowledged that Government grants may be available to contribute to capital costs, but that ongoing annual charges recover all ongoing operating costs. We considered scenarios where:

- Customers paid the full cost
- Customer paid 50% and the Australian Government contributed 50%
- Customers paid 25%, the Australian Government contributed 50% and the Queensland Government contributed 25%.

Before customers are asked to provide their demand assessment responses, KBR gave a presentation outlining the overall project and providing context for the demand assessment.

This includes explaining any water products that are being tested in the demand assessment including reliability and price settings.

Price ranges are explained to ensure understanding of the differences between the upfront purchase price, ongoing fixed and variable/volumetric charges.

In addition, any assumptions made in the price points including potential government subsidies are made clear, and it is critical that at least one full cost recovery price point is included to ensure a fulsome understanding of the demand profile for each product.

Table 3.1 Upfront capital charges for Barlil Weir and West Barambah Weir Round 1 (subject to change)

Scenario	Very low	Low	Medium	High	Very High
Customer's one-off capital payment for new water ($/ML)	1,000	1,500	2,000	3,000	5,000

Table 3.2 Annual charges for Barlil Weir and West Barambah Weir Round 1 (subject to change)

Scenario	Very low	Low	Medium	High	Very High
Fixed annual charge ($/ML)	100	100	100	200	300
Water use charge ($/ML)	10	10	10	20	30
Total annual charge ($/ML)	**110**	**110**	**110**	**220**	**330**

In the absence of a specific water source, customers were asked to assume 90% monthly reliability for the Barlil Weir and potential West Barambah Weir water product.

3.4 ENGINEERING OPTIONS

Customers were informed that there are two options being considered:

- **Option 1:** Approximately 3,000ML of new Medium Priority Plus or 'high priority agricultural' water – with 90% monthly reliability – arising from the proposed construction of the Barlil Weir only for about $10 million.
- **Option 2:** Approximately 6,000ML of new Medium Priority Plus or 'high priority agricultural' water – with 90% monthly reliability – arising from the proposed construction of the Barlil Weir and West Barambah Weir for a combined capital cost of $30–60 million (noting that the capital cost of the latter weir is highly uncertain).

3.5 CUSTOMER COMMITMENT STRATEGY

Customers were informed that the process was a non-binding Expression of Interest, and that further rounds would have additional levels of commitment, as follows:

- Round 1 – non-binding expressions of interest
- Round 2 – non-binding but formal letters of intent
- Round 3 – binding water sales (including cash deposit).

3.6 ADDRESSING OPTIMISM BIAS, RISK AND UNCERTAINTY

We overcame the risk of optimism bias by:

- Providing detailed information to potential customers
- Spent a significant period consulting with customers to understand their businesses, build trust and allow for potential customers to understand the importance of an accurate demand assessment
- Asked for minimum, likely and maximum demand at a range of price points (see below).

This range of demand allows for a risk adjusted central demand profile to be established.

3.7 DEMAND SCENARIOS

Customers were asked for minimum, likely and maximum additional demand for new water from this project based on the above pricing assumptions. They were asked to exclude existing water use or existing irrigation supply and to follow the below guidelines.

Minimum demand	Likely demand	Maximum demand
Immediate need from 2025. Noting change in climate (e.g. average temperatures increasing). Improving your business.	Likely need for 10-20 years. Assume mid-range change in climate (e.g. average temperature increase of about 2 degrees C). Growing your business moderately.	Maximum need for 25-50 years. Assume pessimistic climate change (e.g. average temperature increase of 4 degrees C). Growing your business significantly.

3.8 CLIMATE CHANGE IMPACTS

Customers were informed that climate change forecasts should inform their long-term demand:

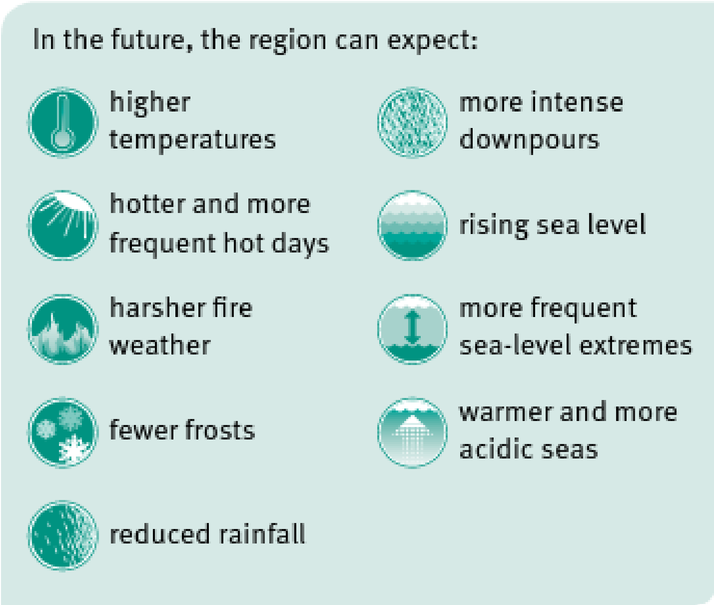
- Mid-range climate projections say average annual rainfall will be like current rainfall to 2050 and 2070
- Average temperatures are forecast to increase by 2.0 degrees Celsius by 2050
- Average temperatures are forecast to increase by 4.1 degrees Celsius by 2070.

The above is a summary of the following observations about climate change impacts on agricultural production in the South Burnett region as follows:

- Increased temperatures may lead to difficulties in supplying sufficient water to meet agricultural demand and heat damage to crops.
- Conditions may increase plant diseases, weeds and pests, and allow some pest species to move southwards into areas where they are currently excluded.
- Lower rainfall and increasing evaporation will cause more frequent depletion of soil moisture, reduced ground cover and lower livestock carrying capacity.
- Harsher fire weather poses a threat to the timber industry and broad-acre farming.

Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

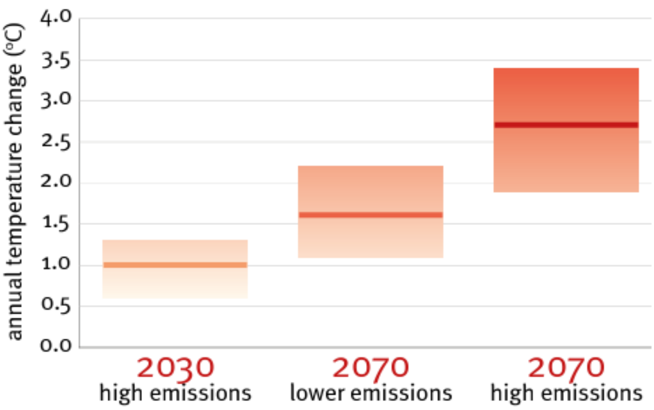
Figure 3.2 Impacts of climate change on for Wide Bay-Burnett region



Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

Maximum, minimum and average temperatures are projected to continue to rise. For the near future (2030), the annually average temperature increase is forecast to be 0.6 to 1.3°C above the climate of 1986–2005.

Figure 3.3 Temperature change for Wide Bay-Burnett region under different emissions scenarios



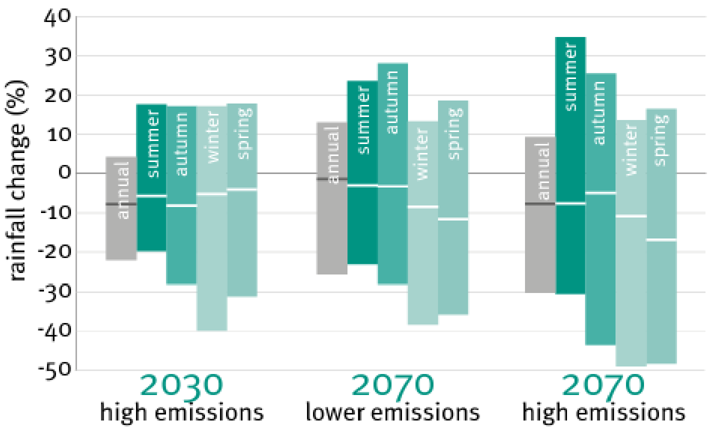
Projected annual average temperature changes for the Wide Bay–Burnett region. The horizontal line on each bar is the middle (median) projected temperature change. The extent of each bar indicates the range of projected changes.

Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

By 2070, forecast warming is 1.1 to 3.4°C, depending on future emissions. The region’s summer average temperature is 25°C. This could rise to over 26°C by 2030 and to over 28°C by 2070.

High climate variability is likely to be the major factor influencing rainfall changes in the next few decades. Rainfall projections for 2070 show little change or a decrease in average rainfall, particularly in winter and spring.

Figure 3.4 Climate forecasts



Projected annual and seasonal rainfall changes for the Wide Bay–Burnett region. The horizontal line on each bar is the middle (median) projected rainfall change. The extent of the bar indicates the range of projected changes.

Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

However, forecasts show high rainfall variability, and that rainfall intensity is expected to increase.

In summary, climate change will deliver to the Wide Bay-Burnett region higher average temperatures and greater rainfall variability (and intensity), which will drive deteriorating soil moisture and the need for a more reliable supply of water for irrigation as dry land crops will more frequently fail.

4 Round 1 demand results

4.1 OVERVIEW

This section summarises the results of the Round 1 questionnaire. Analysis and recommendations are based on these findings.

4.2 COMMUNITY ENGAGEMENT

The community was widely engaged during the process and most relevant stakeholders were very likely contacted via numerous channels. Community contact included:

- The council sent emails to its contact database
- The council advertised on its website
- KBR conducted a face-to-face community meeting with prospective customers.

4.3 ROUND 1 PARTICIPATION

Table 4.1 summarises customer participation in the Round 1 demand assessment.

Table 4.1 Round 1 number of participants

Item	Response
Number of respondents who attended KBR presentation	9
Number of responses received in Round 1	14
No. of properties / farms represented by respondents	25
Average no. of properties per respondent	1.8

4.4 QUESTION 1: DEMAND FOR WATER AT A RANGE OF PRICES

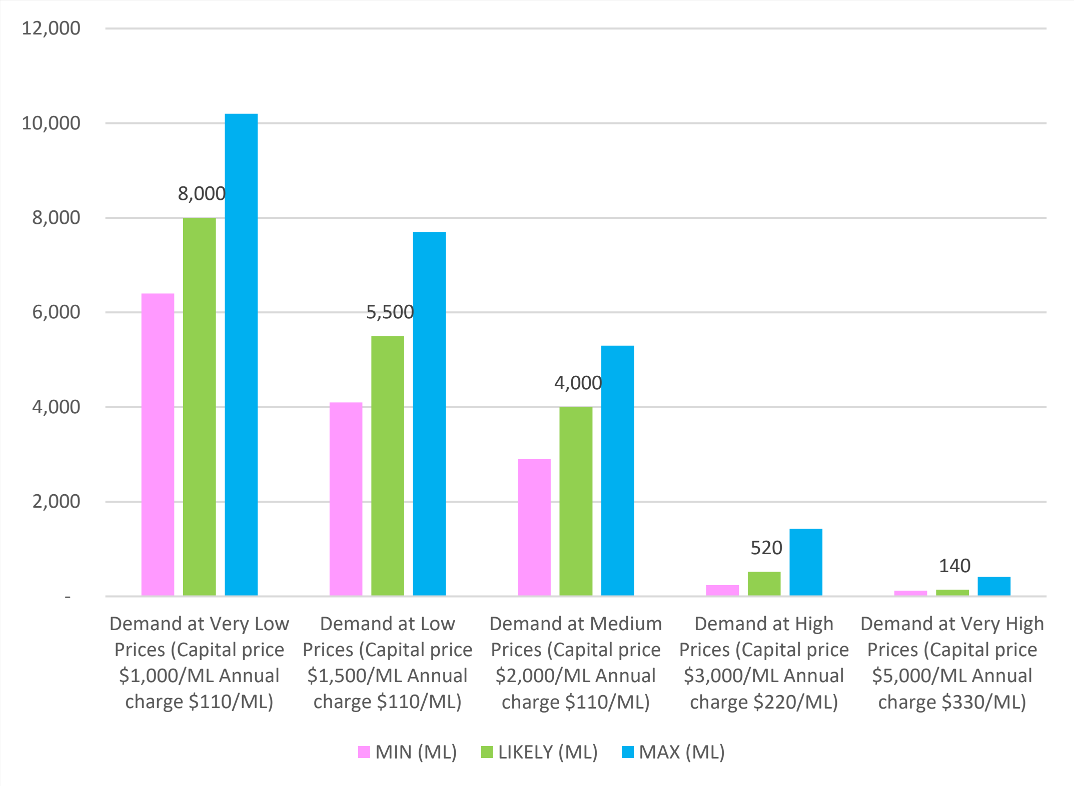
Respondents were asked to complete the following table to show minimum, likely and maximum volume of demand at each price point for the proposed 90% monthly reliability water product.

Table 4.2 Water price range

Water Price/s	Capital price ($/ML)	Annual charge ($/ML pa)	Minimum demand (ML)	Likely demand (ML)	Maximum demand (ML)
Very low	1,000	110			
Low	1,500	110			
Medium	2,000	110			
High	3,000	220			
Very high	5,000	330			

Demand at each price point is shown below.

Figure 4.1 Demand for Barlil and/or West Barambah Weirs – Medium Priority Plus water allocations (ML)



Demand drops as the price increases. The very low price has likely demand of 8,000 ML. The low price has likely demand of 5,500 ML. The medium price has likely demand of 4,000 ML.

At the high and very high prices, likely demand falls materially to 520 ML and 140 ML respectively.

4.5 QUESTION 2: INTENDED USES FOR WATER

Respondents were asked to provide delivery locations, the intended use for water and volumes assuming the very low price of $1,000/ML capital contribution and annual charge of $110/ML.

Table 4.3 Location of water and future uses based on very low price

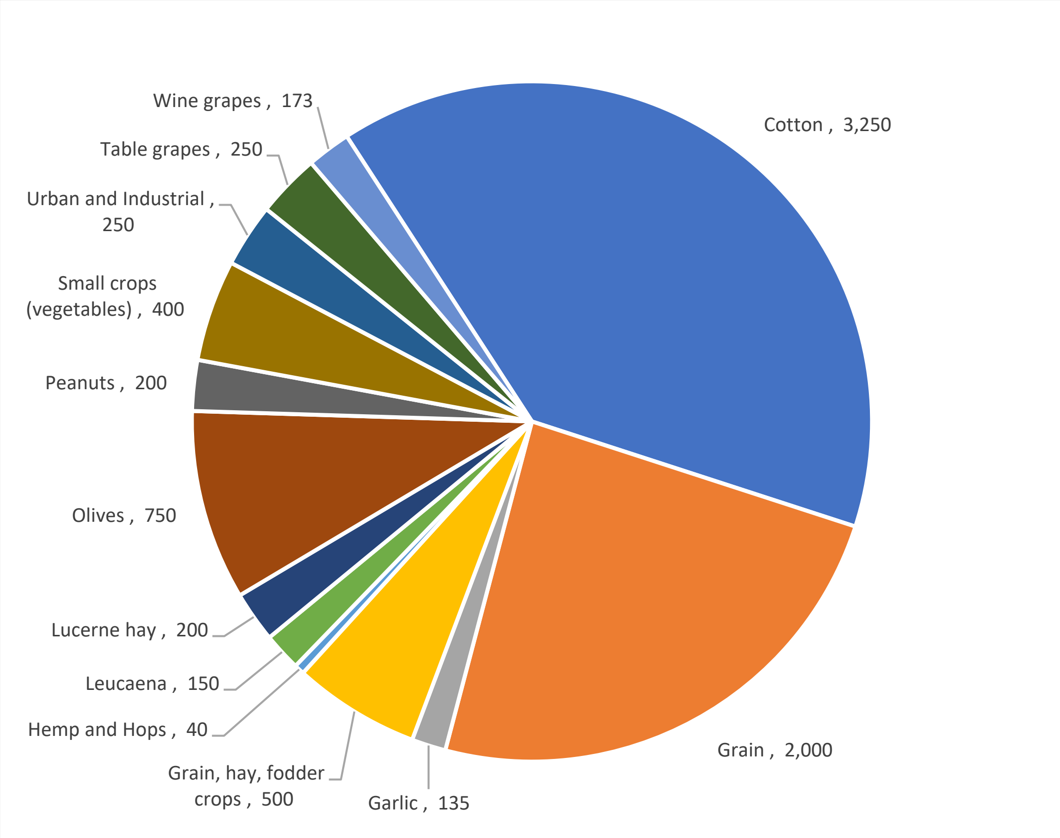
Property name, street address and (ideally) rates notice Lot and Plan No.	Intended use for water (e.g. Avocadoes, lemons, lucerne hay)	MIN (ML)	LIKELY (ML)	MAX (ML)

Responses to the delivery location component of this question will result in a webmap and inform the initial engineering design of a distribution scheme. This will also inform which customers can and cannot access water from each weir.

Responses to the future water uses question will allow us to identify the economic benefits of the additional water, which are covered in a separate report.

Figure 4.2 shows a summary of possible future uses of Barlil Weir and potential West Barambah Weir water at very low prices.

Figure 4.2 Future water uses proposed by customers (ML)



Future economic water uses include a wide and diverse array of moderate to very high value enterprises. However, given current activities in the area, cotton and grains are purported to be the dominant future use of the new water product – Medium Priority Plus.

Of note, the future enterprise mix also includes garlic, hemp, hops, olives, peanuts, vegetables, and table and wine grapes. This will allow the profitability of locally made wine (referred to as the wine premium) to be included by KBR in our assessment / forecast of future economic benefits arising from this project/s.

4.6 QUESTION 3: ATTENDANCE AT PUBLIC MEETING

Respondents were asked if they attended the KBR Round 1 public meeting for Barlil Weir and potential West Barambah Weir projects. Table 4.4 summarises customer participation in the Round 1 demand assessment meetings.

Table 4.4 Round 1 number of meeting attendees

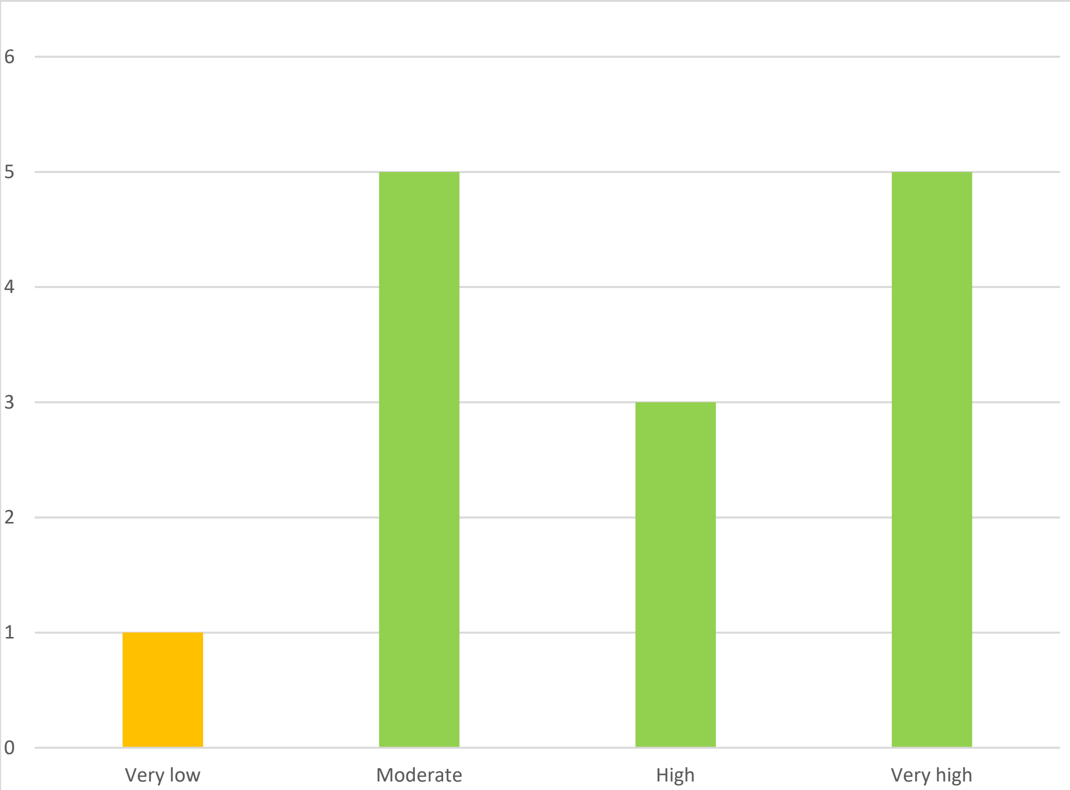
Response	Did you attend KBR's meeting on 29 March 2022?
Yes	9
No	5
Total	**14**

This result indicates that communication of the demand assessment reached potential customers outside of the group attending the presentations. It also demonstrates that people were willing to take the time to read the materials and complete the form, without the motivation of a public meeting.

4.7 QUESTION 4: SUPPORT FOR NEW WATER PRODUCT

Respondents were asked to what extent they support the proposed Medium Priority Plus or High Priority Agriculture product? The responses were as follows.

Figure 4.3 Customer support for the "MP Plus" Water Product



Most customers moderately to strongly support the proposed water product. The only person who did not, was unable to attend a meeting and is unlikely to understand the water product on offer. Eight of the nine attendees at the meeting provided high or very high support. The water product was developed in conjunction with those nine prospective customers in a workshop with KBR and Badu Advisory – it is the best way to address the identified service need for this area.

4.8 QUESTION 5: PREFERRED ENGINEERING OPTION

Customers were asked to rank the two engineering options (i.e. the weirs) to show their preference. The results are as follows.

Table 4.5 Preference for Barlil Weir only or both Barlil and West Barambah Weirs

Option	No. of times option ranked 1st
1. **Barlil Weir only** yielding approximately 3,000ML of new MP Plus water – with 90% monthly reliability – capital cost of about $10 million.	4
2. **Barlil Weir and West Barambah Weir** yielding approximately 6,000ML of new MP Plus water – with 90% monthly reliability – capital cost of $30–60 million. The construction cost of Barambah Weir was noted as being highly uncertain.	8

In summary, two thirds of respondents would prefer both weirs were built. One third are happy with just the Barlil Weir being constructed, given its relatively low cost and advanced approvals.

4.9 QUESTION 6: LIKELIHOOD OF INVESTMENT

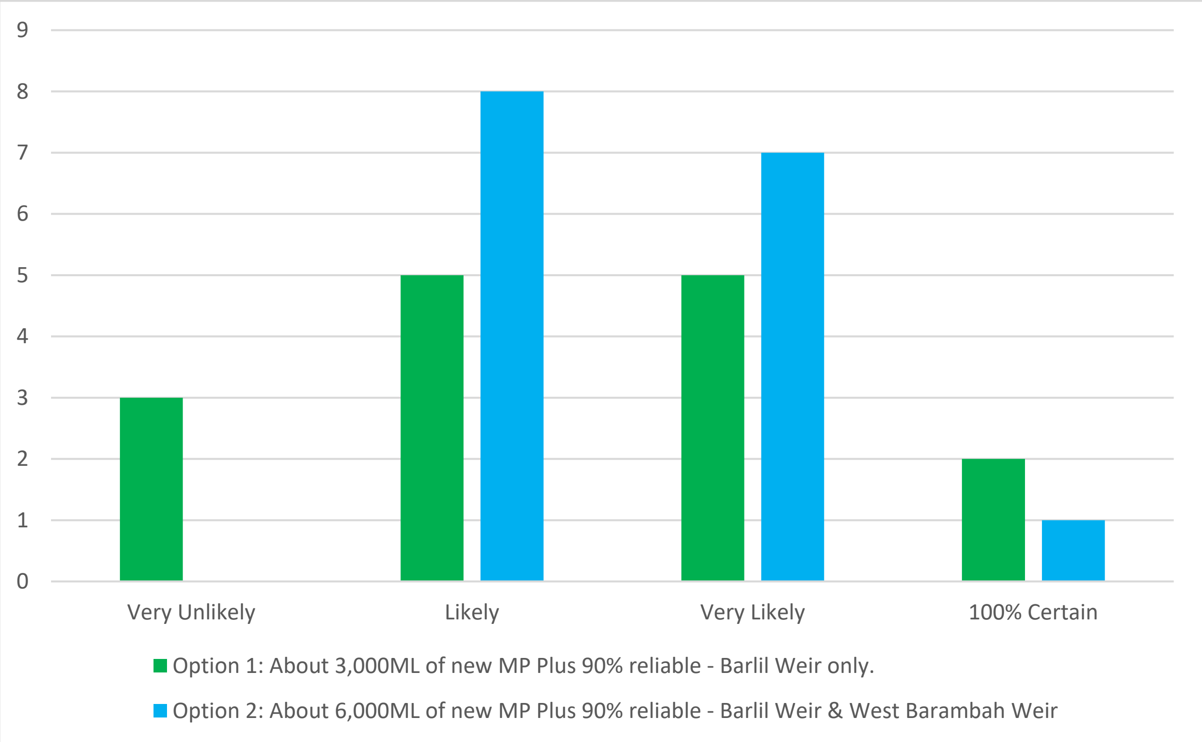
Customers were asked how likely are you to invest in this new water?

Table 4.6 Preference for Barlil Weir only or both Barlil and West Barambah Weirs

Level of certainty	Water prices	Very Unlikely	Unlikely	Likely	Very Likely	100% Certain
Option 1: About 3,000ML of new Medium Priority Plus or 'high priority agricultural' water – with 90% monthly reliability – arising from Barlil Weir only.	Very low, low or medium					
Option 2: About 6,000ML of new Medium Priority Plus or 'high priority agricultural' water – with 90% monthly reliability – arising from Barlil Weir and West Barambah Weir combined.	Medium, high or very high					

The result from the question above are presented in the figure below.

Figure 4.4 Likelihood of Investing in Option 1 versus Option 2



For Barlil Weir only, there are 12 responses from 15, that is, 80% of responses that have indicated investment in this option is likely, very likely or certain. For Barlil and West Barambah Weirs combined, 100% of responses indicated likely, very likely or certain investment in this option. The likely reason for the moderate difference in these responses, is that three or four respondents are located upstream in a location that they perceive would not benefit from Barlil Weir, whereas the potential West Barambah Weir would also be upstream and is perceived to benefit all customers.

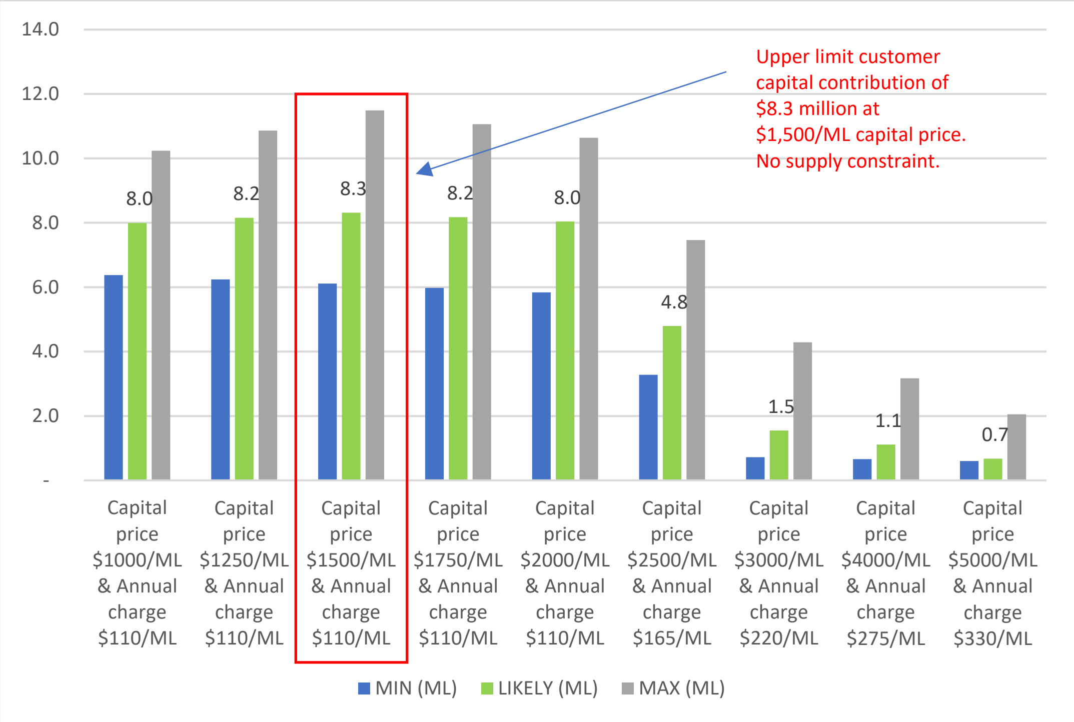
4.10 CUSTOMER CAPITAL REVENUE – NOT CONTRAINED BY SUPPLY

This section presents minimum, likely and maximum customer capital revenue at various prices.

Usually, particularly where supply is unconstrained, this analysis identifies a clear 'sweet spot' where customer capital revenue is maximised which is typically viewed as the capital price point that also maximises the schemes prospects of achieving funding and implementation success.

Figure 4.5 shows customer capital contributions at each price point (demand volume times capital price), noting that no supply constraint has been imposed at this point. The figure below includes customer capital contributions at the prices tested and derived mid-point prices.

Figure 4.5 Customer capital revenue at different prices (incl. interpolation) – No supply constraint ($M)

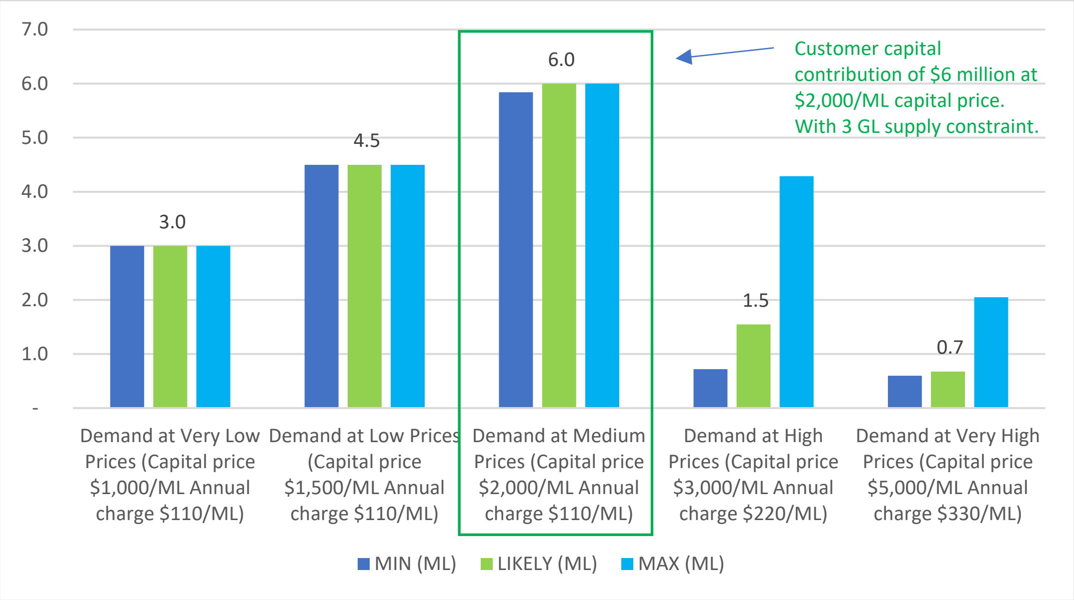


The figure above provides confidence that a customer capital price of $1,500/ML is likely to maximise absolute customer capital contributions if total likely demand of 5,500 ML can be met. However, the revenue of $8.3 million is based on there being no supply constraint (i.e. no limit on Medium Priority plus).

4.11 CUSTOMER CAPITAL REVENUE – CONSTRAINED BY SUPPLY / BARLIL WEIR ONLY

Given the how advanced Barlil Weir is as a project when compared to the West Barambah Weir concept, if a decision is made to progress Barlil Weir only – or Barlil Weir initially as a first stage – then the supply of new Medium Priority Plus water allocations for sale is 3,000 ML with a monthly reliability of about 91%. Assuming a supply constraint of 3,000 ML the forecast customer capital contributions at each price are set out below.

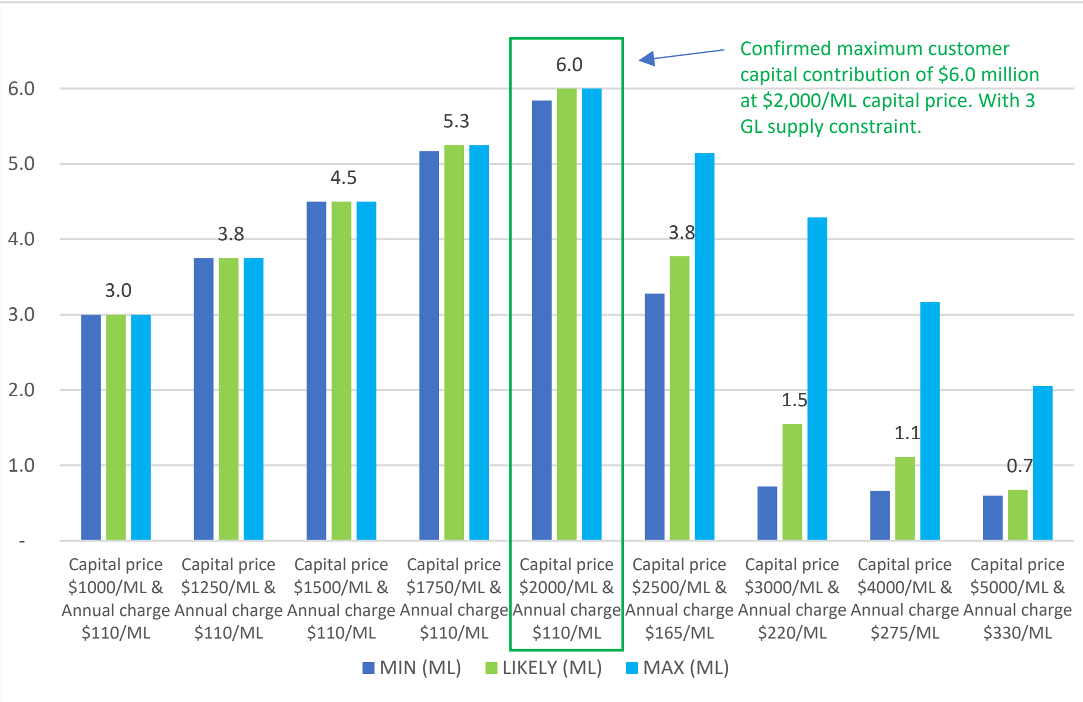
Figure 4.6 Barlil Weir customer capital contributions – 3 GL supply constraint ($ million)



This analysis suggests that with a supply constraint – in a Barlil Weir only scenario – customer capital contributions are optimised at $6 million with a capital price of $2,000/ML.

The following chart includes interpolated demand at derived mid-point prices for a Barlil Weir only project, with a supply constraint of 3,000 ML of Medium Priority Plus water allocations for sale.

Figure 4.7 Barlil Weir customer capital contributions – 3 GL supply constraint (incl. interpolation) ($ million)



4.12 SENSITIVITY ANALYSIS – BARLIL WEIR ONLY DEMAND AND THE SIZE OF A LARGER BARLIL WEIR

As a sensitivity analysis, based on the Round 1 data, KBR also considered what upstream demand 'drops out' if only Barlil Weir is developed – based on the self-exclusions nominated by respondents in their Expression of Interest forms. Having excluded that upstream demand, two questions were posed and answered below:

- How much Barlil Weir only demand exists?
- Therefore, what size should be the larger version/s of the Barlil Weir?

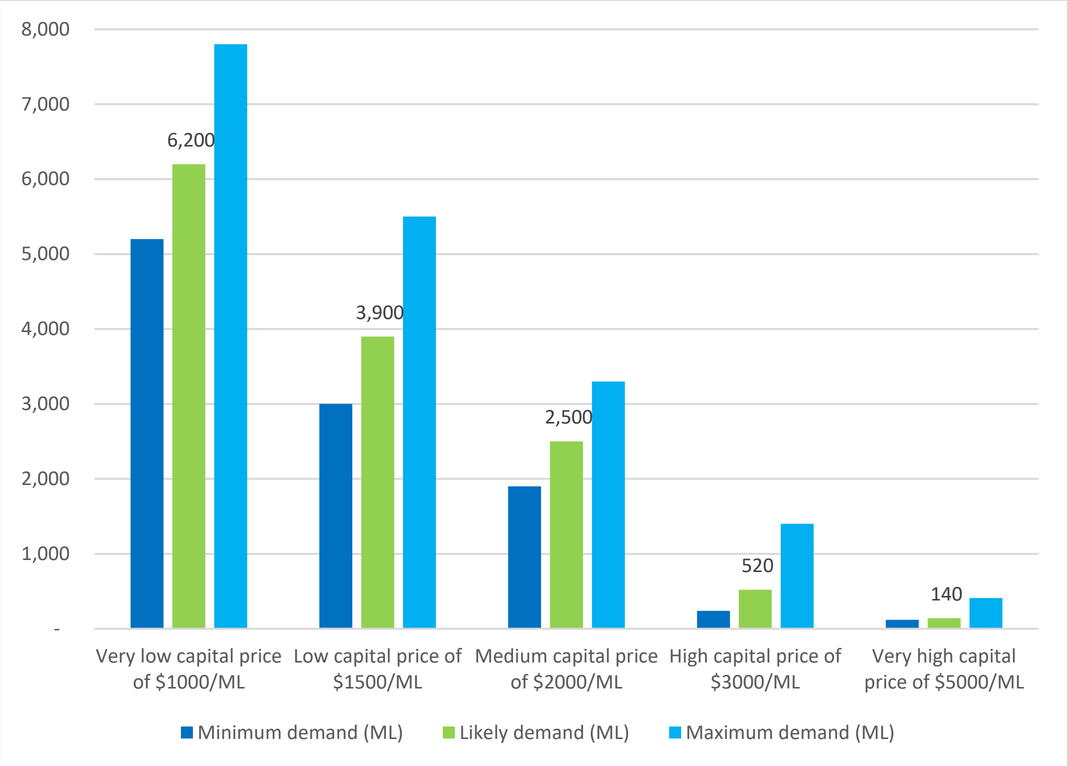
The next table provides demand, when three customers from upstream are removed.

Table 4.7 Barlil Weir only demand (excl. three customers based on their responses) (ML)

Rounded demand	Minimum demand (ML)	Likely demand (ML)	Maximum demand (ML)
Very low capital price of $1000/ML	5,200	6,200	7,800
Low capital price of $1500/ML	3,000	3,900	5,500
Medium capital price of $2000/ML	1,900	2,500	3,300
High capital price of $3000/ML	240	520	1,400
Very high capital price of $5000/ML	120	140	410

The figure below represents the same data as above graphically.

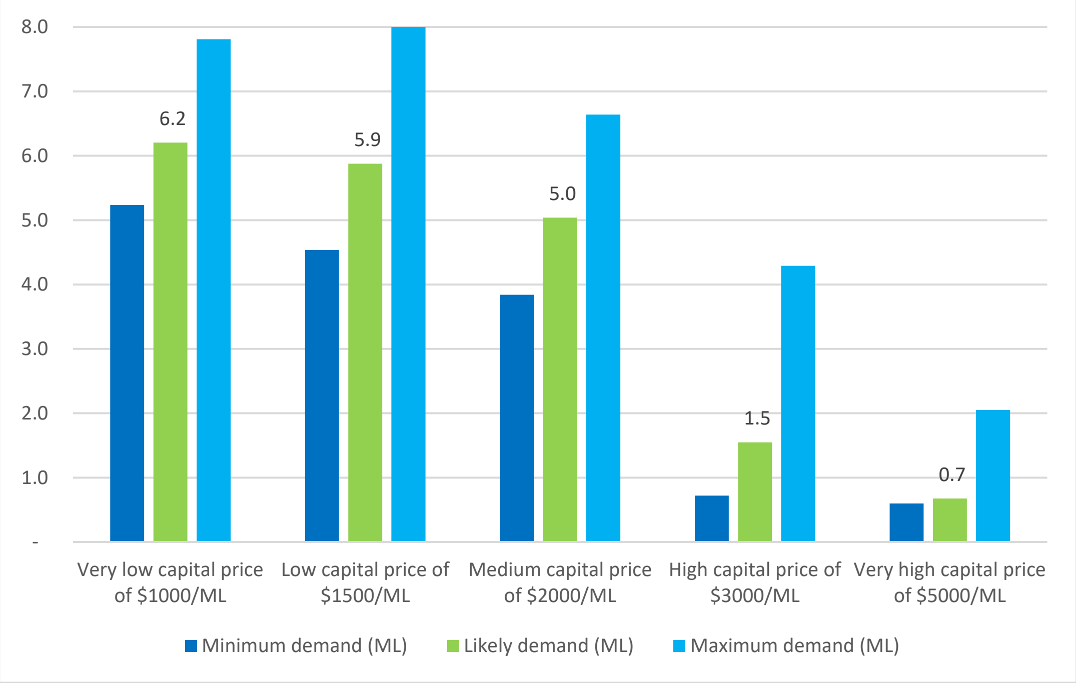
Figure 4.8 Barlil Weir only demand (excl. three customers based on their responses) (ML)



Before deciding that the larger versions of the Barlil Weir should be up to 6,200ML, it is worth considering the opportunity to maximise customer capital contributions, because 'skin in the game' is what provides a project with its best chance of securing government approvals support and funding. That is, maximising customer capital contributions gets projects built.

The following figure estimates the customer capital revenue that may arise at different prices points from 'Barlil Weir only' demand as nominated by respondents in Round 1.

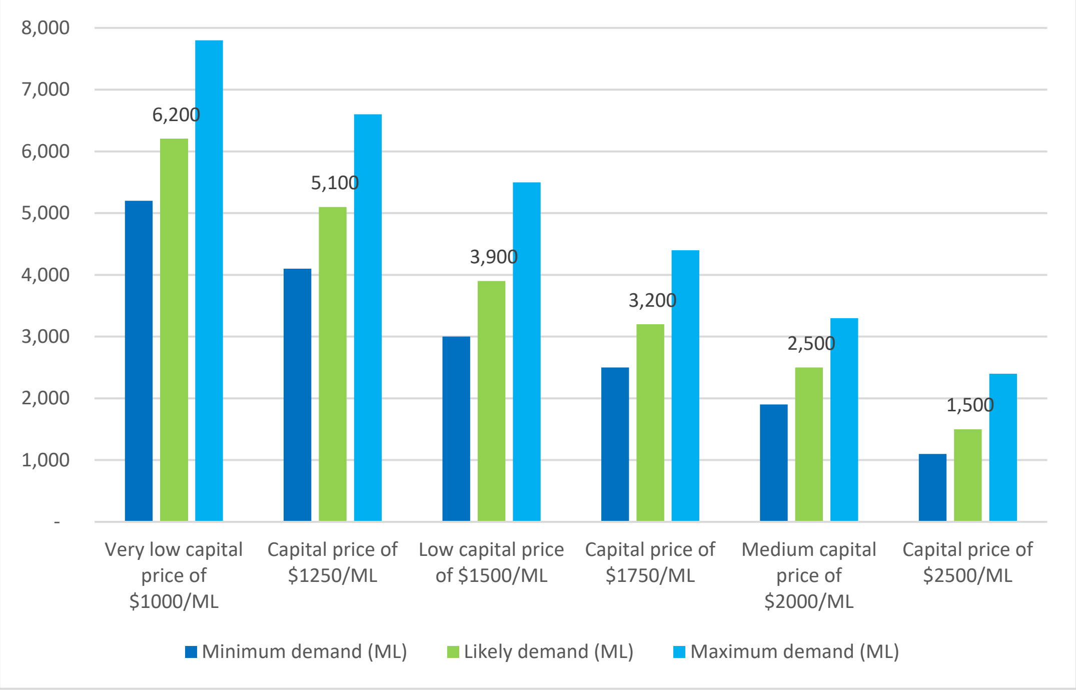
Figure 4.9 Barlil Weir only customer capital revenue (excl. three customers) ($ million)



The figure above – showing customer capital revenue at the prices in the Round 1 form – suggests that maximum revenue of about $6.2 million can be obtained a the very low price point including a capital price of $1,000/ML paid upfront – assuming 6,200 ML of demand.

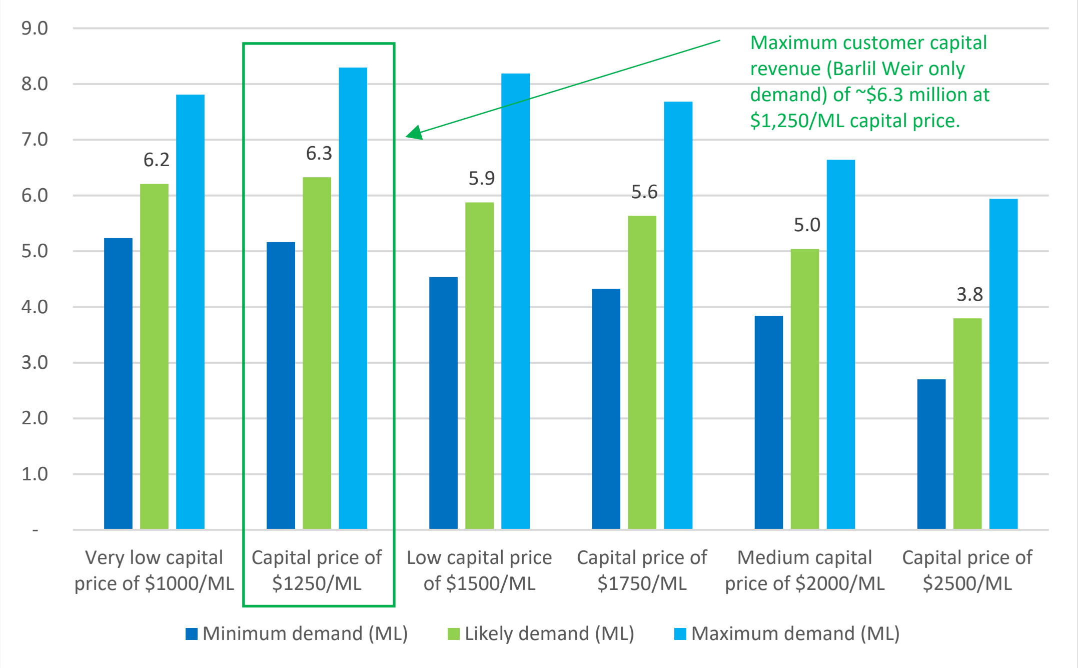
Interestingly, the next highest capital revenue price point is low including a capital price of $1,500/ML – assuming 3,900 ML of demand. Given the similarity of the revenues additional interpolated (derived) prices, volumes and revenue scenarios are considered below.

Figure 4.10 Barlil Weir only demand (incl. selected interpolated capital prices and demand volumes) (ML)



These interpolated demand volumes and capital prices have been used to forecast customer capital revenue in the figure below. The intention being to identify the optimal price point and volume for a Barlil Weir only demand scenario.

Figure 4.11 Barlil Weir only customer capital revenue (incl. selected interpolated capital prices) ($ million)



Keeping in mind the Round 1 Barlil Weir only demand volumes further above, and noting the opportunities to raise approximately $6 million of customer capital contributions at a:

- High volume of 6,200 ML likely demand at a $1,000/ML capital price – say 6 GL
- Medium volume of 5,100 ML likely demand at a $1,250/ML capital price – say 5 GL
- Low volume of 3,900 ML likely demand at a $1,500/ML capital price – say 4 GL

The base case Barlil Weir will be 3 GL as concluded in previous section, but the larger Barlil should be between 4 and 6 GL – with an optimal revenue raising capital price of $1,250/ML which predicts a likely demand volume of about 5 GL.

There are a few price and demand scenarios at which about $6 million of customer capital contributions may be secured. Lower prices mean higher demand certainty. To achieve low prices, higher volumes of sufficiently reliable water product are needed.

Further engineering and hydrological modelling investigations will determine the upper limit of Barlil Weir's ability to supply volumes above 3 GL, noting that 5 GL of demand is associated with the optimal price above.

5 Conclusions and Recommendations

5.1 CONCLUSIONS

As part of the broader economic road map being undertaken for Council, demand volumes exceeding Barlil Weir's yield could potentially be met by developing West Barambah Weir.

However, the initial estimated combined yield of Barlil Weir and West Barambah Weir is 6 GL of Medium Priority Plus allocations. This is subject to change as further engineering and hydrological modelling are underway. KBR consider that the larger more expensive second weir (West Barambah Weir) would create up to 3 GL of additional water product, subject to its storage capacity being confirmed.

West Barambah Weir is also forecast to negatively impact up to 2 GL of downstream users' water entitlements. This is not desirable. Whereas the 3 GL version of Barlil Weir receives a series of hydrological 'green lights', that is, modelled impacts are within the limitations of the Water Plan and/or are readily manageable. (Badu Advisory 2022)

5.2 RECOMMENDATIONS

KBR recommend that a 3 GL Barlil Weir be advanced via a detailed business case (DBC).

The complete set of Round 1 data forecasts a maximum customer capital contribution of about $6.0 million at $2,000/ML upfront capital price, assuming a 3 GL supply constraint. There is higher demand uncertainty at this moderate to high capital price, when compared to lower prices.

KBR also recommend that in the DBC, a larger version of Barlil Weir should be considered to meet additional Round 1 demand. The Round 1 demand data – for 'Barlil Weir only' demand as nominated by respondents – suggests the larger Barlil Weir should be between 4 and 6 GL. Sensitivity analysis revealed a maximum customer capital contribution of $6.3 million at a $1,250/ML upfront capital price, assuming forecast likely demand can be met by 5 GL of supply. There is lower demand uncertainty at this low capital price, when compared to higher prices.

Once the base case (3 GL) and larger Barlil Weir option/s have been progressed as part of the DBC, a Round 2 demand assessment should take place incorporating new engineering design and costing information, and other assessments, for viable versions of the Barlil Weir. The DBC should be completed in a manner consistent with Queensland and Australian Government requirements.

ECONOMIC ROAD MAP

Attachment B: Gordonbrook

Demand Assessment

Gordonbrook Dam Project

Round 1 Demand Assessment Report

Gordonbrook Dam Project

Round 1 Demand Assessment Report

Prepared for:
South Burnett Regional Council

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22 June 2022

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Contents

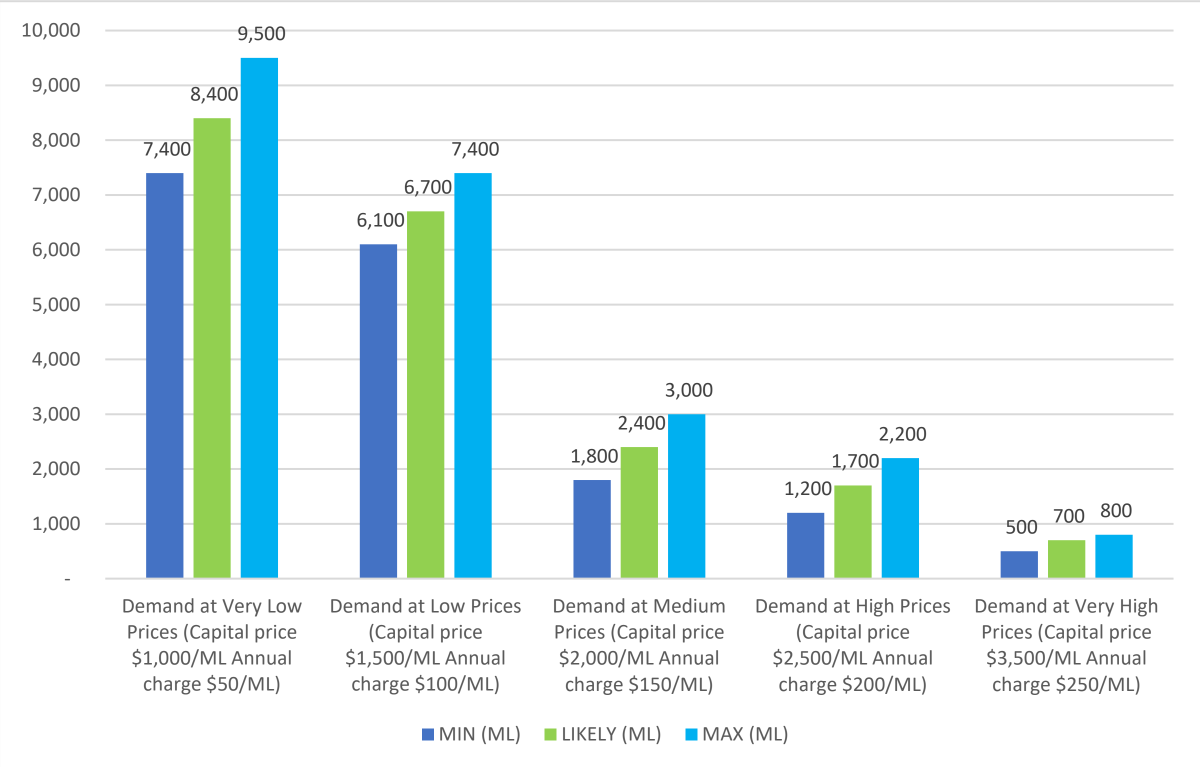
1 Executive summary

KBR was engaged to conduct a demand assessment for agricultural and other uses of the Gordonbrook Dam.

There are 25 businesses interested in this water supplying 48 farms and other entities. Minimum, likely and maximum demand volumes are as follows. Likely demand at the optimal price will drive the engineering.

Demand and water uses

Figure 1.1 Demand for Gordonbrook Dam (ML)



The very low price has likely demand of 8,400 ML. The low price has likely demand of 6,700ML. The medium price has likely demand of 2,400 ML. Likely demand falls below the available Gordonbrook Dam 1,800 ML of supply at the high and very high prices. Further hydrological modelling is required to develop a larger volume for sale that will still meet the agronomic, horticultural, livestock and commercial needs of customers.

Future economic water uses change as prices change. For example, peanut demand falls as prices rise. At higher prices intensive livestock, citrus and avocados reflect a higher proportion of the albeit significantly lower demand. A high priority product may be needed by intensive livestock, avocado and citrus growers. A medium priority product may be better suited to peanuts and other annual crops.

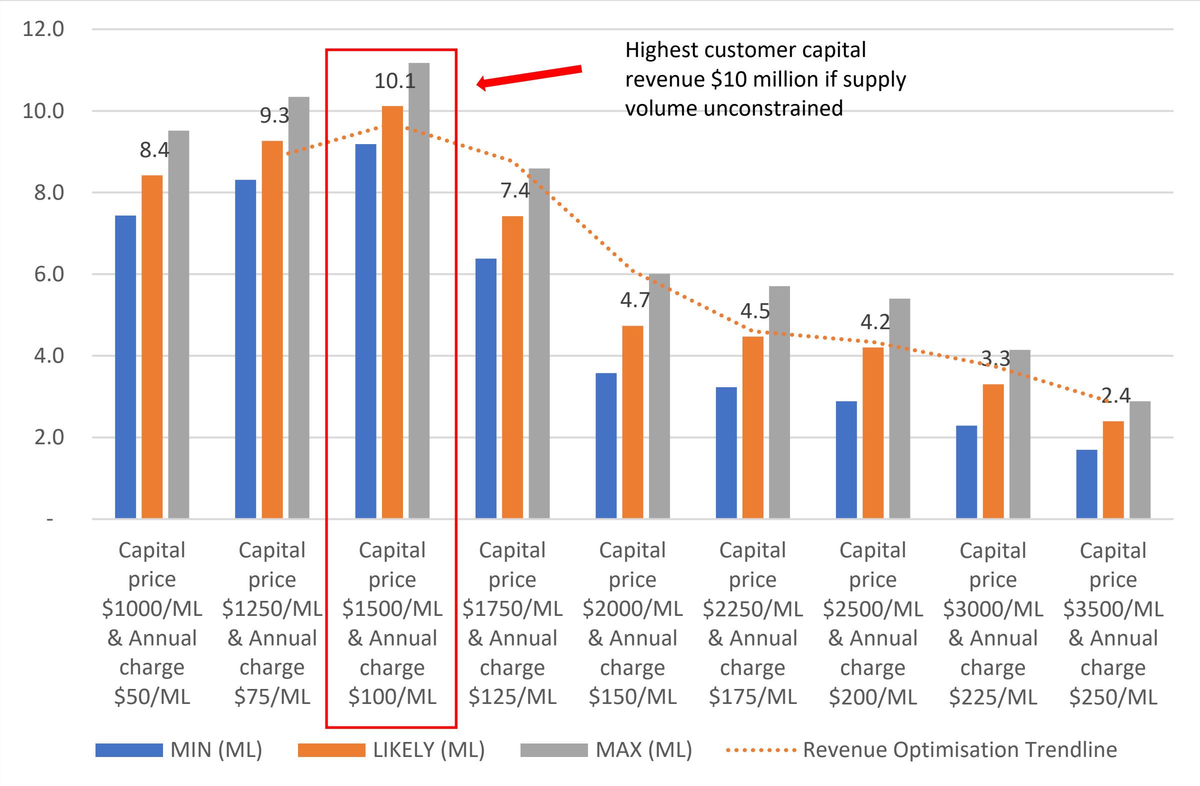
Forecast impacts of climate change on the Wide Bay-Burnett region strengthen the case for this project. For example, higher average temperatures and greater rainfall variability will led to frequent failure of dryland crops. This underpins the need for Council to progress a reliable source of irrigation and livestock water.

Customer capital contributions – No supply constraint

Assuming no supply constraint, customer capital revenue and capital pricing options are set out in Figure 1.2, which indicates that optimal revenue may be achieved at a customer capital price of $1,500/ML.

Experience has shown that it is possible to identify a more precise customer capital sweet spot if mid-point prices and revenues are also derived / interpolated from the primary demand data. The figure below includes prices tested and implied mid-point prices and customer capital revenue.

Figure 1.2 Customer capital revenue at different prices (incl. interpolation) ($ million)



The figure above provides confidence that a customer capital price of $1,500/ML is likely to maximise absolute customer capital contributions if all demand (i.e. 6,700 ML) can be met, giving the project its best chance of success. However, the revenue of $10 million is based on the likely demand with no supply constraint.

If a Round 2 demand assessment were to be undertaken at say $1,500/ML the forecast 6,700 ML demand volume may justify using all available water from Gordonbrook Dam (1,800 to 2,400 ML), with the balance of supply emanating from Boondooma Dam, combined into one potentially staged project.

Larger volumes of demand would justify developing a delivery network with greater capacity. Such a project would be more costly in absolute capital cost terms, but more affordable from a customer perspective. This is because supplying a higher volume lowers fixed annual charges ($/ML), due to the economies of scale.

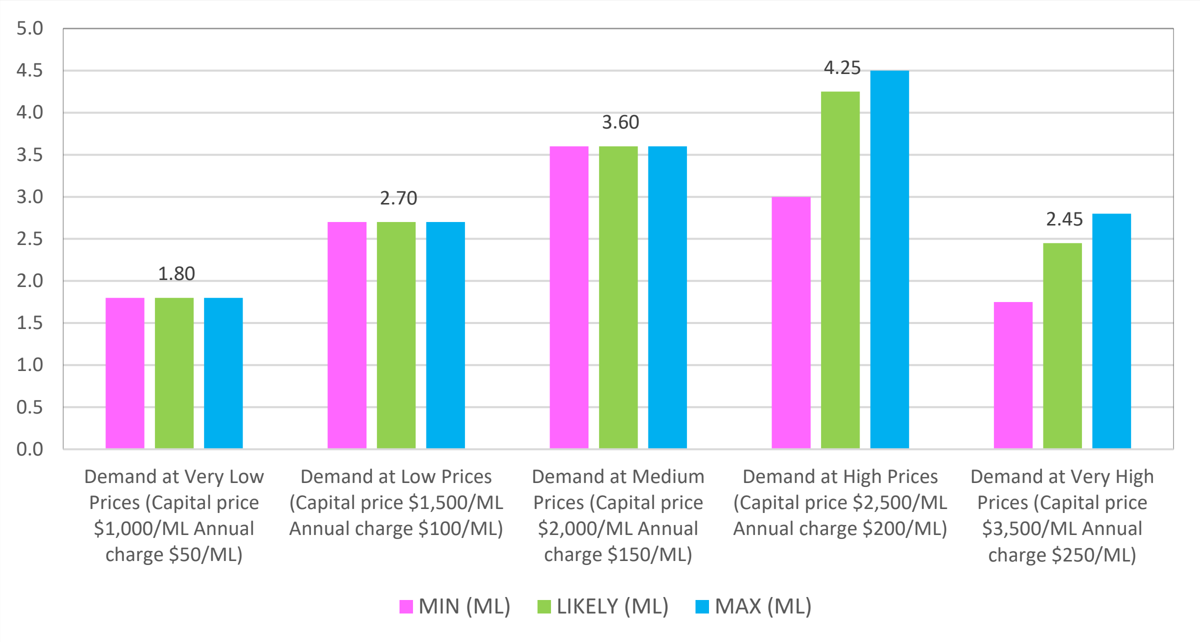
Customer capital contributions – With supply constraint

If Council confirms that it only holds 1,800 ML of water entitlements from Gordonbrook Dam, and ultimately no additional supply of water is found, assuming a supply constraint of 1,800 ML the forecast customer capital contributions and capital pricing options are in Figure 1.3. This analysis suggests customer contributions are optimised at a capital price of $2,500/ML.

The likely demand at this point is 1,700 ML, which may allow a higher reliability water product to be developed from Council's 1,800 ML. Alternatively, in a future demand assessment all 1,800 ML may be sold. As a result of adopting $2,500/ML as a capital price the revenue may be $4.25 million (1,700 ML) or $4.5 million (1,800 ML).

One consequence of adopting too high a capital price may be lower than expected demand in future demand assessments and therefore lower economic benefits. Moreover, the cost effectiveness of a low volume pipeline distribution network is not favourable due to poor economies of scale, as noted above. Volume is the key to reducing fixed annual charges per ML – and fixed annual charges can often drive demand at water sales.

Figure 1.3 Customer capital revenue at different prices with a supply constraint of 1,800 ML ($ million)



Recommendations

As part of the broader economic road map being undertaken for Council, demand volumes exceeding Gordonbrook Dam's available supply, will support the business case for Council to access other sources.

At very low, low and medium prices demand exceeds supply. This demand could be met by Gordonbrook and Boondooma dams combined. Depending on the available supply volume, our revenue analysis suggests an optimal customer capital price for a future demand assessment of:

- $1,500/ML if the project is not supply constrained, which would raise $10 million from customers, or
- $2,500/ML if the project is constrained to 1,800 ML supply, raising up to $4.5 million from customers.

The optimal capital price depends on the supply available, but also the reliability of the water product/s.

An early reading of the water regulations indicates a water product from Gordonbrook Dam alone may have about 80% monthly reliability. However, the Expression of Interest form tested demand with a monthly reliability of 90%, due to the possible inclusion of Boondooma Dam water in the supply mix.

Further hydrological assessments will be required to determine water product options and their reliability. It is recommended that further hydrological analysis establish the maximum volume of water that Gordonbrook Dam can supply, and the reliability of its water product/s. Consideration could be given to the development of a high and medium priority product given the high value future economic water uses proposed by customers.

Detailed consideration should be given to meeting additional demand from this process (e.g. by purchasing water from Boondooma Dam and connecting it to the proposed Gordonbrook Dam water delivery network). Engineering options for improving water quality (e.g. via blending or treatment) should be considered.

Councils proposed Part A and B bulk water charges are needed and should be developed.

Using the webmap that KBR has developed from this demand assessment, engineers should develop a delivery network design and cost for at least two demand scenarios. From that work the associated Part C and D annual charges should be developed to inform a future demand assessment.

Using the above information, a Round 2 demand assessment should be undertaken as part of a detailed business case or equivalent feasibility study. Our recommendations are justified given the strong demand revealed in this process and the likelihood that this project offers considerable economic benefits to the community, underpinned by customer willingness to pay $4 to $10 million of the capital costs.

2 Project overview

2.1 PURPOSE

In summary, the aim is to identify agricultural water demand for Gordonbrook Dam water.

The purpose of this report is to outline the process, findings and recommendations arising from the Round 1 demand assessment completed for the potential conversion of Gordonbrook Dam to an irrigation supply.

2.2 BACKGROUND

This report is the demand assessment, which will inform South Burnett Regional Council's investment decision.

The State's Regional water supply security assessment found that "Kingaroy could experience a water supply failure about once in 13 years". This frequency is unacceptably **high**, and the Queensland Government could be a partner in improving water reliability. The security assessment suggested that improvement to water security could be achieved by "access to additional water allocation from Boondooma Dam". This Gordonbrook Dam project may offer support.

As part of KBR's core scope, we will focus on the economic benefits of transitioning from urban use to irrigation use. This will focus on the benefits across the whole region. The economic will be reported separately or as an extension of this report. The economics is built on demand.

For this transition to be effective, water needs to be purchased from Stanwell. This will be an expensive exercise, and council needs to be persuaded that expenditure of council funds is reasonable. Council also needs to understand the implications from a council cash-flow perspective.

The Queensland Government will also need to be persuaded that the water needs of the South Burnett can be improved under this approach.

2.3 KINGAROY'S URBAN WATER SUPPLY AND WHAT IS AVAILABLE FROM GORDONBROOK DAM

Kingaroy's existing water supply is as follows:

- Council holds:
    - 1,809 ML of water allocations from Gordonbrook Dam with a reliability of 78-80%
    - 1,260 ML/a from Boondooma Dam that it uses for meeting the Kingaroy reticulation network's water demands.
- Council only accesses water from Gordonbrook Dam when Gordonbrook Dam is storing more than 3,250 ML (50% of its full supply volume). Any operational decision to use water when the dam is less than 50% full would reduce the 78-80% reliability.
- When Gordonbrook Dam is above 50% capacity, water is supplied to the Kingaroy WTP in the ratio of 30% from Gordonbrook Dam and 70% from Boondooma Dam.

2.4 KINGAROY'S URBAN DEMAND

Kingaroy's demand is approximately 1,800 ML per year. To supply the full 1,800 ML per year without Gordonbrook, a further 540 ML is required.

Over time, demand is predicted to increase by about 30 ML per year.

2.5 PROJECT SCOPE

This project will consider a range of topics, but is focussed on the demand assessment, the other elements will be the subject of separate advice. Table 2.1 outlines the full scope relevant to the Gordonbrook Dam portion of the Economic Road Map and if each is included in this report.

Table 2.1 Scope items associated with Gordonbrook Dam project

Step	Description	This Report?
Estimate demand	We will conduct a Round 1 demand assessment process. We will seek at least 1,809 ML of demand to match the water allocations held by Council in Gordonbrook Dam, which have a reliability of 78-80% if water used only when the dam is over half full.	Yes
Calculate revenue from irrigation customers	We understand that the price of Boondooma Dam water may be $4,000 to $6,000 per ML. Therefore, purchasing 540 ML will cost between $2.2 million and $3.2 million. Subject to the demand assessment, we initially expected that the Gordonbrook Dam water may be sold for approximately $5 million. This will be considered in this report. Irrigators will also be required to pay for ongoing costs (calculated as part of the core scope) and paid as a fixed and variable annual charge.	Yes (customer capital revenue)
Calculate costs associated with Gordonbrook Dam	We will work with council to understand the long-term costs of operating and maintaining Gordonbrook Dam. We will model these long-term costs and identify which costs will not be required when the transition takes place. For example, we expect water treatment costs to reduce if all water is sourced from Boondooma. We anticipate that council can provide a costed asset management plan and annual operating cost budget to inform these cash flows.	No
Risk assessment	This step will identify and assess the ongoing risks that might create, enhance, prevent, degrade, accelerate or delay the expected cash flows.	No
Overall cash flow	Compare costs and revenues, to determine ongoing cash-flow implications	No
Financial Model and Investment decision	We will prepare a financial model in Excel and an investment decision report to ensure that council is well placed to make an investment decision.	No

2.6 NATIONALLY ENDORSED DEMAND ASSESSMENT PROCESS

KBR generally undertakes the following three phases of demand assessment using a process that emanated from Tasmanian Irrigation and is now a nationally endorsed approach:

- Round 1 – Expressions of Interest (non-binding) – the subject of this report
- Round 2 – Letters of Intent (non-binding) – part of a future detailed business case
- Round 3 – Water Sales – Legally binding water sales contracts with staged customer capital contributions, for example, made upon signing a contract, when government funding becomes unconditional and prior to completion of construction.

Round 1 and Round 2 are not legally binding, whereas Round 3 is legally binding to underpin funding.

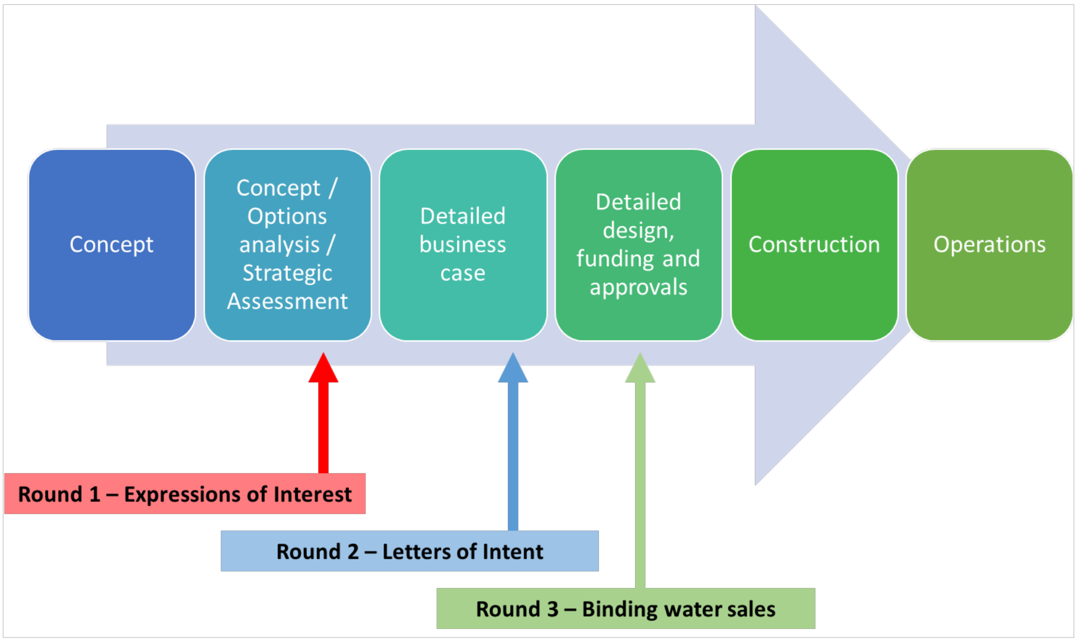
This approach demonstrates 'skin in the game' from customers and allows government to make a capital investment with a high degree of confidence that the project will succeed, and the forecast economic benefits arising from that investment will be realised for the benefit of the community.

2.7 METHODOLOGY

KBR's demand assessment strategy is iterative and connected to all stages of business case development. Refer to the figure below. The demand assessment seeks written input from potential customers at each of these rounds. Demand assessment underpins each stage of business case development and is a major component of stakeholder engagement.

This engagement was to undertake a Round 1 demand assessment. Figure 2.1 outlines how Round 1 fits within a full demand assessment process.

Figure 2.1 Multi-stage Demand Process



Key stakeholders include a wide range of community members but for the purposes of demand assessment, KBR focuses on existing customers and potential new customers of any proposed infrastructure options. KBR utilises the client's contacts and its own.

Immersion/Service Need – KBR begins each business case project with an immersion into the local community. This includes meetings with stakeholders face-to-face for informal discussions to understand the wider context for the project and develop a strong understanding of the service need. It also includes supply infrastructure and farm visits.

Immersion meetings provided valuable input to the questions for the formal demand assessment form, including the range of price scenarios that were tested in the Round 1 Demand Assessment. Customers' and stakeholders' information is tested against other government sources, for example, crop yields, market prices, distribution or other supporting infrastructure.

Round 1 demand assessment – Information for Round 1 is collected in the form of non-binding expressions of interest. The formal demand process includes a public meeting/s and collection and detailed analysis of the forms including demand volumes at a wide range of prices. The form seeks interested parties to be thoughtful and realistic, but with no guarantees that the water become available. Products and prices are based on indicative modelling and/or expectations from previous experiences. Price ranges identify where the willingness-to-pay lies and very high prices rule out pricing and product options for future rounds.

Initial Engineering – based on the Round 1 demand results initial engineering can then be undertaken to provide more specificity around infrastructure options that are able to be developed within the bounds of the likely demand. This will narrow-down the options for products and prices for the next stages of assessment.

2.7.1 Possible future stages

Round 2 Demand Assessment – This round seeks for customers to provide letters of intent along with their demand information. While this is not legally binding it is a strong show of good faith toward the intent to purchase water should it be made available under the types of products and prices in the demand assessment.

At this stage, the demand assessment is evaluated with only one price per product to give a solid picture for the potential customers to evaluate their demand for water volume. This is based on the more refined cost estimates and project details from the initial engineering.

Refined engineering – Based on the outcomes of the Round 2 Demand Assessment, there will be a firm idea of the volume of water demanded. This can be used to further refine the engineering of infrastructure options to reflect that level of demand (i.e. remove any excess capacity). This also provides the final options for finalization of the Detailed Business Case.

Detailed Business Case – developed according to the BCDF and PAF (method not detailed here).

Round 3 Demand Assessment – This round is where customers are requested to provide Binding Water Sales (incl. cash deposits) to cement their demand and provide formal reassurance that the infrastructure options being proposed have real, sufficient demand to provide the economic benefits that are being sought. This is the final stage prior to seeking approvals.

Approvals / Funding / Detailed Design / Construction – Final stages toward implementation.

3 Demand assessment process

3.1 METHODOLOGY

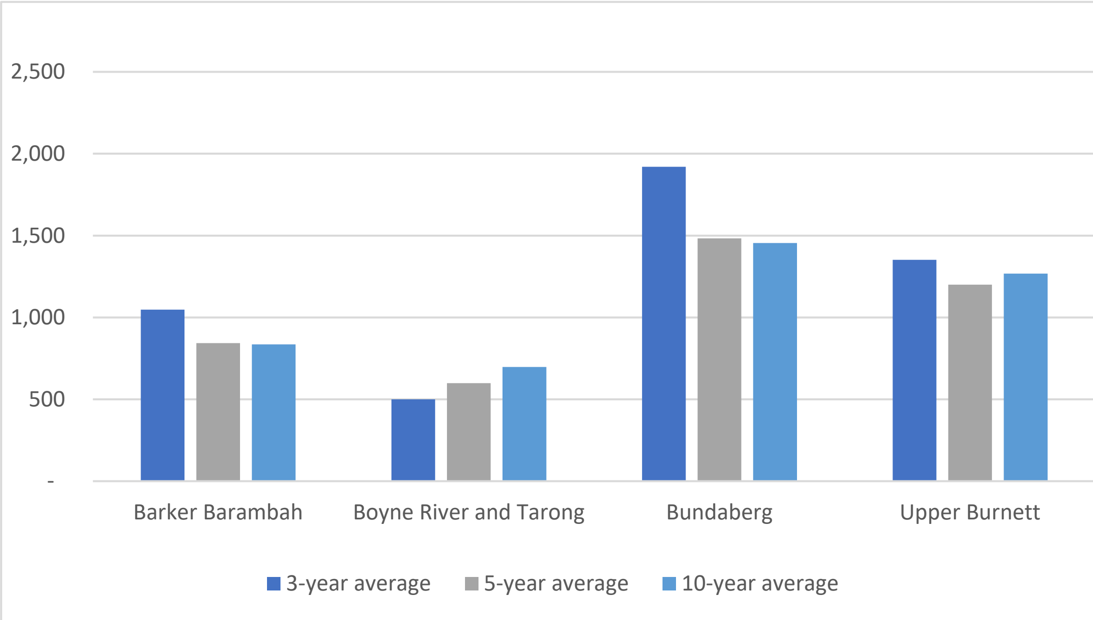
This section describes the key components of this water demand assessment and the process undertaken to develop a robust demand profile.

3.2 INPUT TO PRICE RANGES

The potential customers were presented with a wide, but realistic range of prices. This price range was developed having regard to the price of water in neighbouring schemes and the characteristics of the area.

Across the Bundaberg Burnett Region, the average price for medium priority water is approximately $800 to $1,000 per ML to purchase a Water Allocation.

Figure 3.1 Medium Priority - Weighted Average Price $/ML



Source: Business Queensland Permanent water trading data

Annual charges for Sunwater's existing schemes can be up to $100/ML.

3.3 PRICE RANGES AND WATER PRODUCT/S

KBR provided an annual charges price range that included the price of existing water as a low book-end and tested higher prices to accommodate the likely costs of new infrastructure.

We acknowledged that Government grants may be available to contribute to capital costs, but that ongoing annual charges recover all ongoing operating costs. We considered scenarios where:

- Customers paid the full cost
- Customer paid 50% and the Commonwealth contributed 50%
- Customers paid 25%, the Commonwealth contributed 50% and the Queensland Government contributed 25%.

Before customers are asked to provide their demand assessment responses, KBR gave a presentation outlining the overall project and providing context for the demand assessment.

This includes explaining any water products that are being tested in the demand assessment including reliability and price settings.

Price ranges are explained to ensure understanding of the differences between the upfront purchase price, ongoing fixed and variable/volumetric charges.

In addition, any assumptions made in the price points including potential government subsidies are made clear, and it is critical that at least one full cost recovery price point is included to ensure a fulsome understanding of the demand profile for each product.

Table 3.1 Upfront capital charges for Gordonbrook Dam Round 1 (subject to change)

Scenario	Very low	Low	Medium	High	Very High
Customer's one-off capital payment for new water ($/ML)	1,000	1,500	2,000	2,500	3,500

Table 3.2 Annual charges for Gordonbrook Dam Round 1 (subject to change)

Scenario	Very low	Low	Medium	High	Very High
Fixed annual charge ($/ML)	30	60	90	120	150
Water use charge ($/ML)	20	40	60	80	100
Total annual charge ($/ML)	50	100	150	200	250

In the absence of a specific water source, customers were asked to assume 90% monthly reliability for the Gordonbrook Dam water product.

3.4 CUSTOMER COMMITMENT STRATEGY

Customers were informed that the process was a non-binding Expression of Interest, and that further rounds would have additional levels of commitment, as follows:

- Round 1 – non-binding expressions of interest
- Round 2 – non-binding but formal letters of intent
- Round 3 – binding water sales (including cash deposit)

3.5 ADDRESSING OPTIMISM BIAS, RISK AND UNCERTAINTY

We overcame the risk of optimism bias by:

- Providing detailed information to potential customers
- Spent a significant period consulting with customers, so we can understand their businesses, build trust and allow for potential customers to understand the importance of an accurate demand assessment outcome
- Asked for minimum, likely and maximum demand at a range of price points.

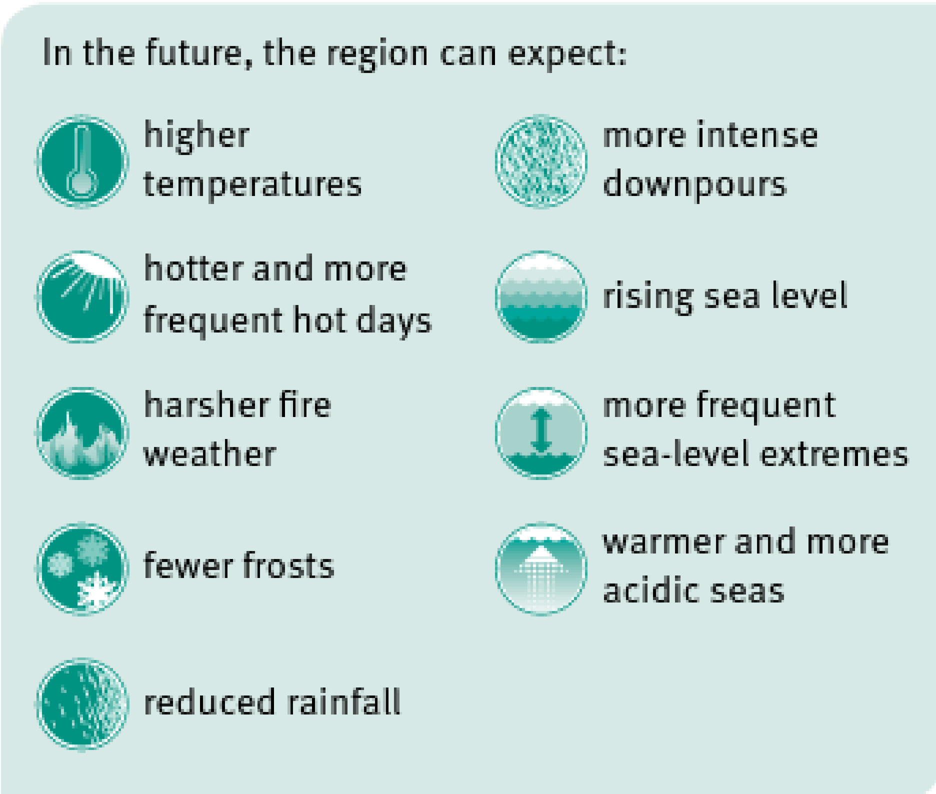
This range of demand allows for a risk adjusted central demand profile to be established.

3.6 CLIMATE CHANGE IMPACTS

Climate change will impact agricultural production in the South Burnett as follows:

- Increased temperatures may lead to difficulties in supplying sufficient water to meet agricultural demand and heat damage to crops.
- Conditions may increase plant diseases, weeds and pests, and allow some pest species to move southwards into areas where they are currently excluded.
- Lower rainfall and increasing evaporation will cause more frequent depletion of soil moisture, reduced ground cover and lower livestock carrying capacity.
- Harsher fire weather poses a threat to the timber industry and broad-acre farming.

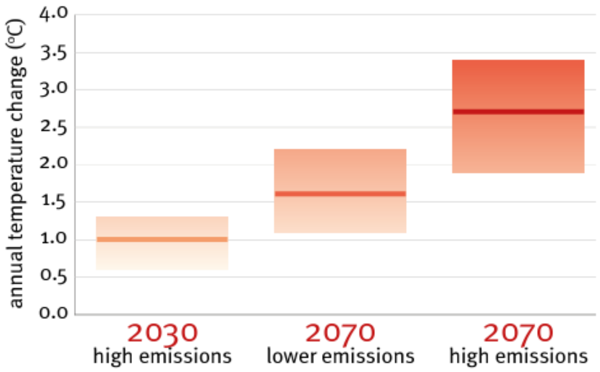
Figure 3.2 Impacts of climate change on for Wide Bay-Burnett region



Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

Maximum, minimum and average temperatures are projected to continue to rise. For the near future (2030), the annually average temperature increase is forecast to be 0.6 to 1.3°C above the climate of 1986–2005.

Figure 3.3 Temperature change for Wide Bay-Burnett region under different emissions scenarios



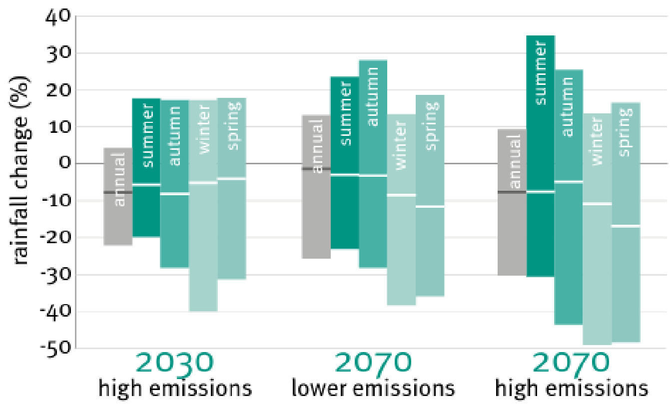
Projected annual average temperature changes for the Wide Bay–Burnett region. The horizontal line on each bar is the middle (median) projected temperature change. The extent of each bar indicates the range of projected changes.

Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

By 2070, forecast warming is 1.1 to 3.4°C, depending on future emissions. The region's summer average temperature is 25°C. This could rise to over 26°C by 2030 and to over 28°C by 2070.

High climate variability is likely to be the major factor influencing rainfall changes in the next few decades. Rainfall projections for 2070 show little change or a decrease in average rainfall, particularly in winter and spring.

Figure 3.4 Climate forecasts



Projected annual and seasonal rainfall changes for the Wide Bay–Burnett region. The horizontal line on each bar is the middle (median) projected rainfall change. The extent of the bar indicates the range of projected changes.

Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

However, forecasts show high rainfall variability, and that rainfall intensity is expected to increase.

In summary, climate change will deliver to the Wide Bay-Burnett region higher average temperatures and greater rainfall variability (and intensity), which will drive deteriorating soil moisture and the need for a more reliable supply of water for irrigation as dry land crops will more frequently fail.

4 Round 1 demand results

4.1 OVERVIEW

This section summarises the results of the Round 1 questionnaire. Analysis and recommendations are based on these findings.

4.2 COMMUNITY ENGAGEMENT

The community was widely engaged during the process and most relevant stakeholders were very likely contacted via numerous channels.

Community contact included:

- The council sent emails to its contact database
- The council advertised on its website
- KBR conducted a face-to-face community meeting with prospective customers.

4.3 ROUND 1 PARTICIPATION

Table 4.1 summarises customer participation in the Round 1 demand assessment.

Table 4.1 Round 1 number of participants

Item	Response
Number of respondents who attended KBR presentation	18
Number of responses received in Round 1	25
No. of properties / farms represented by respondents	48
Average no. of properties per respondent	1.9

4.4 QUESTION 1: DEMAND FOR WATER AT A RANGE OF PRICES

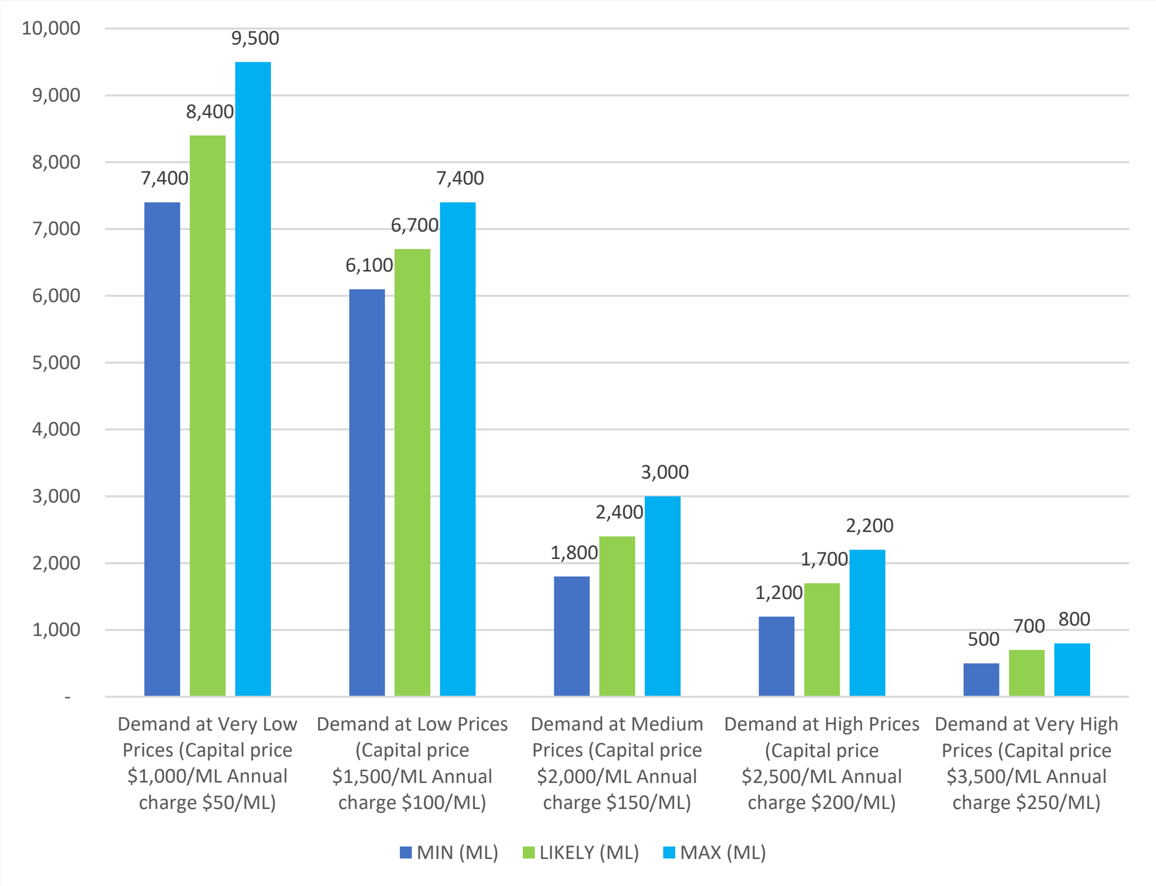
Respondents were asked to complete the following table to show minimum, likely and maximum volume of demand at each price point for the proposed 78-80% monthly reliability water product.

Table 4.2 Water price range

Water Price/s	Capital price ($/ML)	Annual charge ($/ML pa)	Minimum demand (ML)	Likely demand (ML)	Maximum demand (ML)
Very low	1,000	50			
Low	1,500	100			
Medium	2,000	150			
High	2,500	200			
Very high	3,500	250			

Demand at each price point is shown below.

Figure 4.1 Demand for water from Gordonbrook Dam (ML)



Demand drops as the price increases. The very low price has likely demand of 8,400 ML. The low price has likely demand of 6,700 ML. The medium price has likely demand of 2,400 ML.

Likely demand falls below the likely available Gordonbrook Dam 1,800 ML of 78-80% reliable supply at the high and very high prices.

4.5 QUESTION 2: INTENDED USES FOR WATER

Respondents were asked to provide delivery locations, the intended use for water and volumes assuming the very low price of $1,000/ML capital contribution and annual charge of $50/ML.

Table 4.3 Location of water and future uses based on very low price

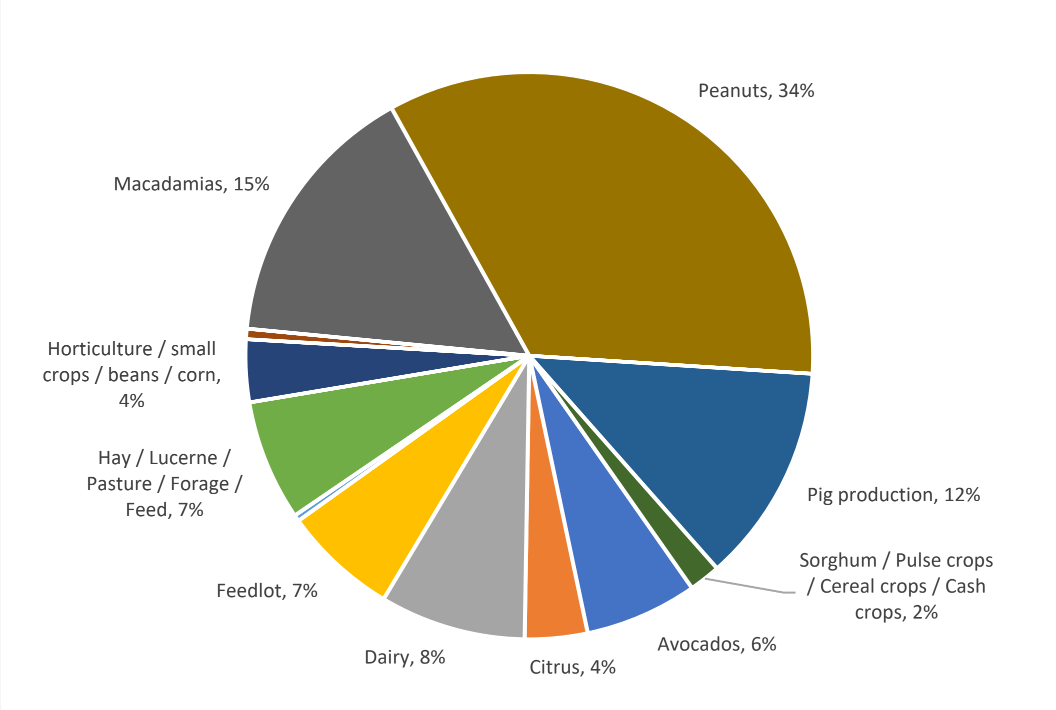
Property name, street address and (ideally) rates notice Lot and Plan No.	Intended use for water (e.g. Avocadoes, lemons, lucerne hay etc.)	MIN (ML)	LIKELY (ML)	MAX (ML)

Responses to the delivery location component of this question will result in a webmap and inform the initial engineering design of a distribution scheme. This will also inform which customers can and cannot viably be connected to the source using pipelines – depending on distance from source and elevation of delivery point.

Responses to the future use question will allow us to identify the economic benefits of the additional water, which will be covered in a separate report (or future extension of this report).

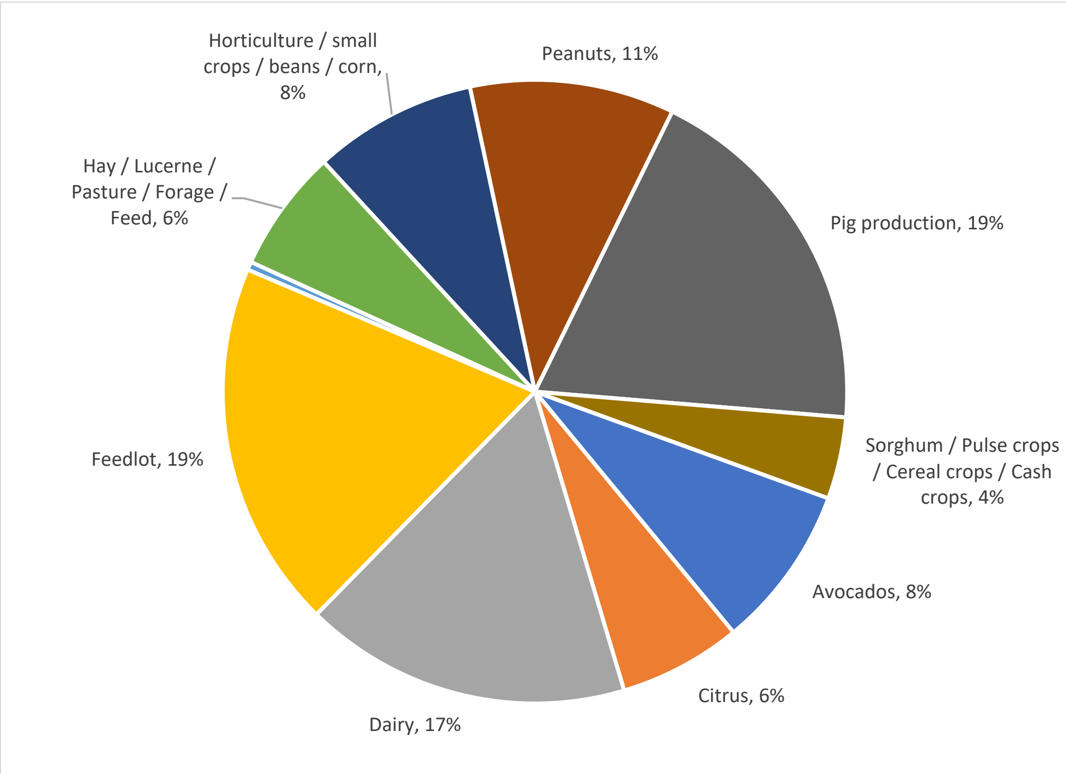
Figure 4.2 shows a summary of possible future uses of Gordonbrook Dam water at very low prices.

Figure 4.2 Share of likely demand allocated to future uses at very low price



Further analysis provided evidence of a changing crop mix as price rise (see figures below). Figure 4.3 shows a summary of possible future uses of Gordonbrook Dam water at medium prices.

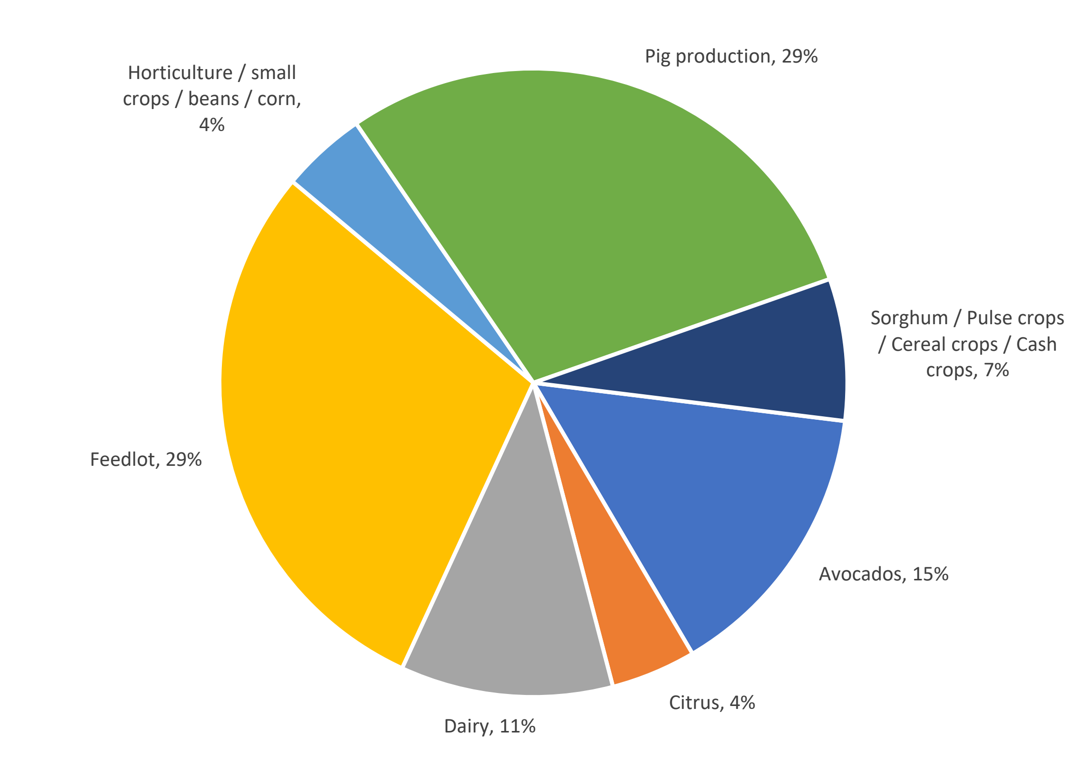
Figure 4.3 Share of likely demand allocated to future uses at medium price



Peanuts are prominent at low and very low prices but reduce to about 10% of demand at medium prices. Macadamias drop out of the mix at medium prices (but were also prominent at low prices). As the demand is falling the relative share of intensive animal industries increases.

Figure 4.4 shows a summary of possible future uses of Gordonbrook Dam water at very high prices noting the volumes are very low.

Figure 4.4 Share of likely demand allocated to future uses at very high price



Relatively speaking, at very high prices, citrus and avocados remain with intensive livestock.

Once possible implication of the above is that a high priority product may be needed by intensive livestock, avocado and citrus growers. A medium priority product may be better suited to peanuts and other annual crops. Consideration could be given to the development of a high and medium priority product in preparation for the next demand assessment.

4.6 QUESTION 3: ATTENDANCE AT PUBLIC MEETING

Respondents were asked if they attended the KBR Round 1 public meeting for Gordonbrook Dam. Table 4.4 summarises customer participation in the Round 1 demand assessment meetings.

Table 4.4 Round 1 number of meeting attendees

Response	Did you attend KBR's meeting on 29 March 2022?
Yes	19
No	6
Total	**25**

This result indicates that communication of the demand assessment reached potential customers outside of the group attending the presentations. It demonstrates that people were willing to take the time to read the materials and complete the form, without the motivation of a public meeting.

4.7 QUESTION 4: ONFARM STORAGE

Respondents were asked if they had on farm water storages. This is relevant as it means that water can be delivered over a longer period and stored onsite until needed. This reduces pipe diameters, which may help reduce water delivery costs and scheme capital costs. Most respondents (90%) do have existing on farm water storages.

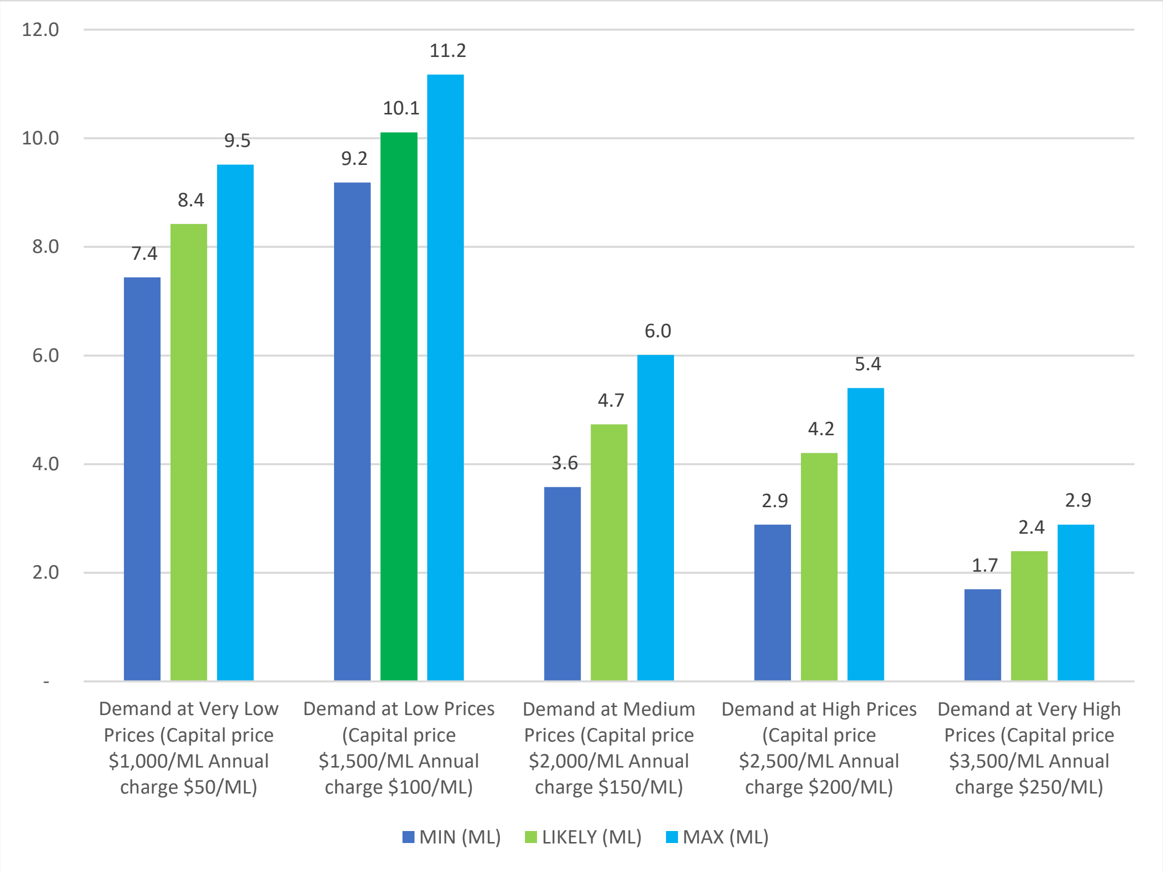
4.8 CUSTOMER CAPITAL REVENUE – NOT CONTRAINED BY SUPPLY

This section presents minimum, likely and maximum customer capital revenue at various prices.

Usually, particularly where supply is unconstrained, this analysis identifies a clear 'sweet spot' where customer capital revenue is maximised which is typically viewed as the capital price point that also maximises the schemes prospects of achieving funding and implementation success.

Figure 4.5 shows customer capital contributions at each price point (demand volume times capital price), noting that no supply constraint has been imposed at this point.

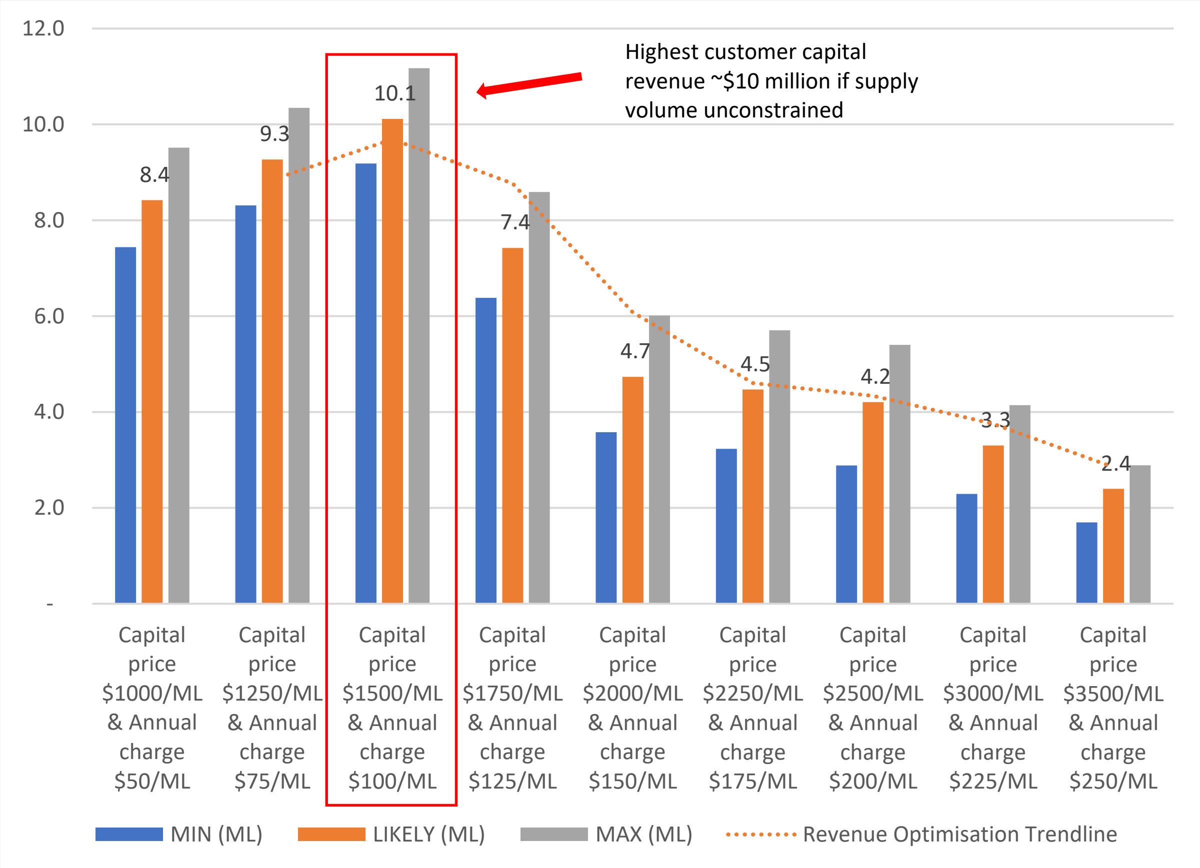
Figure 4.5 Customer capital revenue at different prices ($ million)



The above figure indicates that optimal revenue may be achieved at a customer capital price of $1,500/ML, assuming no supply constraint. Experience has shown that it is possible to identify a more precise customer capital sweet spot if mid-point prices and revenues are also derived / interpolated from the primary demand data.

Figure 4.6 shows customer capital contributions at each price point (volume times capital price) including interpolated / derived prices and volumes, assuming no supply constraint. In a greenfield project, or where supply exceeds demand, such analysis has historically been accurate.

Figure 4.6 **Customer capital revenue at different prices (incl. interpolation) ($ million)**



The figure above provides confidence that a customer capital price of $1,500/ML is likely to maximise absolute customer capital contributions if all demand (i.e. 6,700 ML) can be met, giving the project its best chance of success. However, the revenue of $10 million is based on the likely demand at these price points with no supply constraint.

4.9 CUSTOMER CAPITAL REVENUE – CONSTRAINED BY SUPPLY

The following table presents demand volumes at each price point.

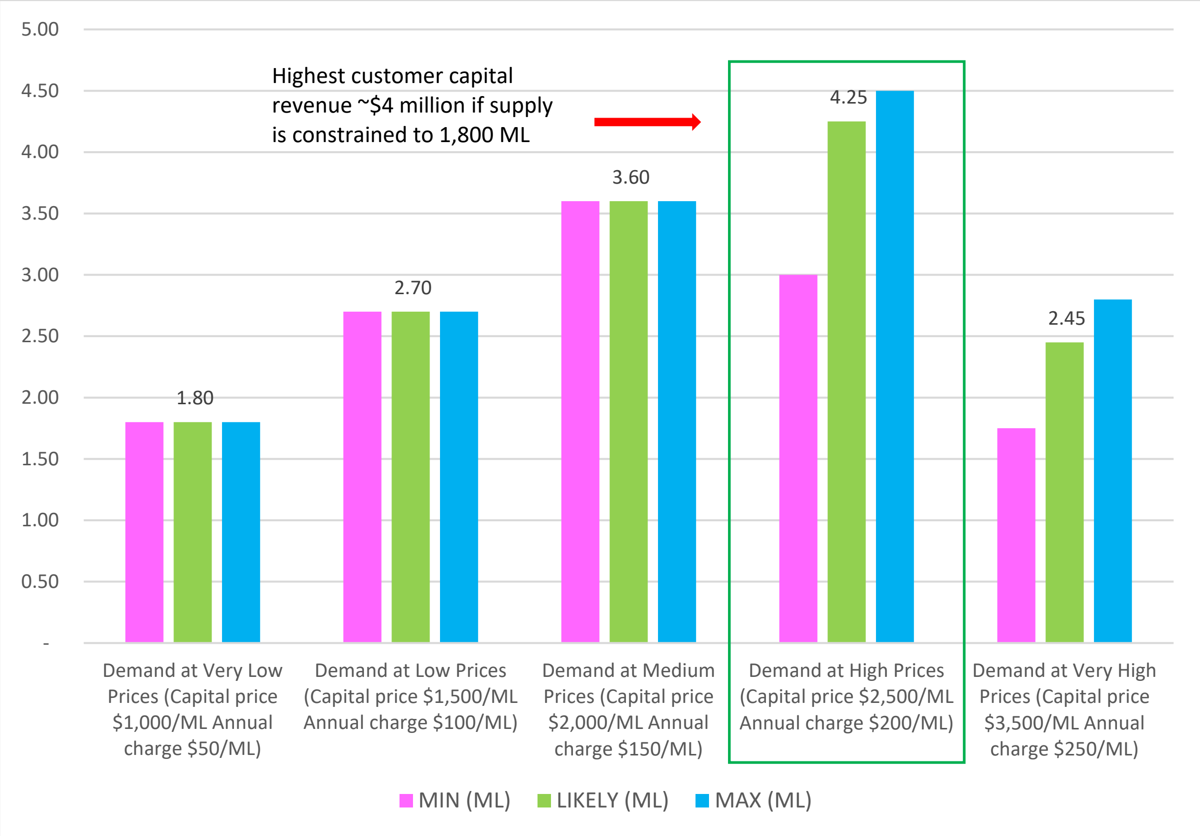
Table 4.5 **Round 1 demand at different prices (ML)**

Demand	Demand at Very Low Prices (Capital price $1,000/ML Annual charge $50/ML)	Demand at Low Prices (Capital price $1,500/ML Annual charge $100/ML)	Demand at Medium Prices (Capital price $2,000/ML Annual charge $150/ML)	Demand at High Prices (Capital price $2,500/ML Annual charge $200/ML)	Demand at Very High Prices (Capital price $3,500/ML Annual charge $250/ML)
MIN (ML)	7,400	6,100	1,800	1,200	500
LIKELY (ML)	8,400	6,700	2,400	1,700	700
MAX (ML)	9,500	7,400	3,000	2,200	800

Using the $1,500/ML capital price identified in the previous section, and assuming a supply limit of 1,800 ML of water entitlements, an initial estimate of capital revenue ($1,500/ML times 1,800 ML) is $2.7 million. This is too low and suggests that a higher customer capital contribution may be obtained by increasing the capital price until demand equals or only slightly exceeds supply (creating scarcity). This can be modelled by imposing a supply constraint.

Figure 4.7 presents estimated customer capital revenue based on a supply constraint of 1,800 ML.

Figure 4.7 Customer capital revenue at different prices with a supply constraint of 1,800 ML ($ million)



The figure above shows in a supply constrained environment that customer capital revenue is optimised at a capital price of $2,500/ML. The likely demand at this price point is 1,700 ML, which may allow a slightly higher reliability to be developed (from the 1,800 ML of available supply). Potentially in the future, at this low price, demand could rise to 1,800 ML due to water scarcity.

If a $2,500/ML customer capital price was adopted, revenue may be $4.25 million assuming 1,700 ML of demand. Or if 1,800 ML are sold in a future water sales process, then customer capital contributions are likely to be about $4.5 million.

4.10 IMPORTANCE OF SUPPLY VOLUMES AND WATER PRODUCT RELIABILITY

The revenue analysis suggests a customer capital price of $1,500/ML to $2,500/ML, depending on supply volume. Future demand also depends on water product reliability.

In the Expression of Interest form we suggested a notional water product with monthly reliability of 90%, noting that background information suggests 78-80% reliability. Willingness to pay may be lower for a lower reliability product (e.g. if we increased the volume available from Gordonbrook Dam but reduced the water product's reliability). Alternatively, with the introduction of Boondooma Dam water or HP, higher reliability products may elicit additional demand.

The consequence of charging too much (e.g. $2,500/ML) could be lower demand and therefore lower economic benefits. Moreover, the cost effectiveness of a low-volume distribution network is not favourable due to poor economies of scale. Higher volumes reduce fixed annual charges (lower costs per ML) and increase the certainty and likely volume of future water sales.

More hydrological analysis is needed, which accurately describes the volume/s of water available for sale, water products and the monthly reliability of those products. Consideration could be given to the development of a high and medium priority product from one or both sources.

5 Recommendations

As part of the broader economic road map being undertaken for Council, demand volumes exceeding Gordonbrook Dam's available supply, will support the business case for Council to access other sources.

At very low, low and medium prices demand exceeds supply. This demand could be met by Gordonbrook and Boondooma dams combined. Depending on the available supply volume, our revenue analysis suggests an optimal customer capital price for a future demand assessment of:

- $1,500/ML if the project is not supply constrained, which would raise $10 million from customers, or
- $2,500/ML if the project is constrained to 1,800 ML supply, raising up to $4.5 million from customers.

The optimal capital price depends on the supply available, but also the reliability of the water product/s.

An early reading of the water regulations indicates a water product from Gordonbrook Dam alone may have about 80% monthly reliability. However, the Expression of Interest form tested demand with a monthly reliability of 90%, due to the possible inclusion of Boondooma Dam water in the supply mix.

Further hydrological assessments will be required to determine water product options and their reliability. It is recommended that further hydrological analysis establish the maximum volume of water that Gordonbrook Dam can supply, and the reliability of its water product/s. Consideration could be given to the development of a high and medium priority product given the high value future economic water uses proposed by customers.

Detailed consideration should be given to meeting additional demand from this process (e.g. by purchasing water from Boondooma Dam and connecting it to the proposed Gordonbrook Dam water delivery network). Engineering options for improving water quality (e.g. via blending or treatment) should be considered.

Councils proposed Part A and B bulk water charges are needed and should be developed.

Using the webmap that KBR has developed from this demand assessment, engineers should develop a delivery network design and cost for at least two demand scenarios. From that work the associated Part C and D annual charges should be developed to inform a future demand assessment.

Using the above information, a Round 2 demand assessment should be undertaken as part of a detailed business case or equivalent feasibility study. Our recommendations are justified given the strong demand revealed in this process from 25 potential customers with 48 farms.

Moreover, further analysis appears warranted given the likelihood that this project offers considerable economic benefits to the community. Momentum for the project is underpinned by the fact that customers seem willing to pay $4 to $10 million of the capital costs, depending on the volume of water that can be supplied. We note that the higher the volume of supply, the more viable will be the project from a customer perspective, all other factors being equal.

ECONOMIC ROAD MAP

Attachment C: Blackbutt

Demand Assessment

Blackbutt Irrigation Project

Round 1 Demand Assessment Report

Blackbutt Irrigation Project

Round 1 Demand Assessment Report

Prepared for:
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8 August 2022

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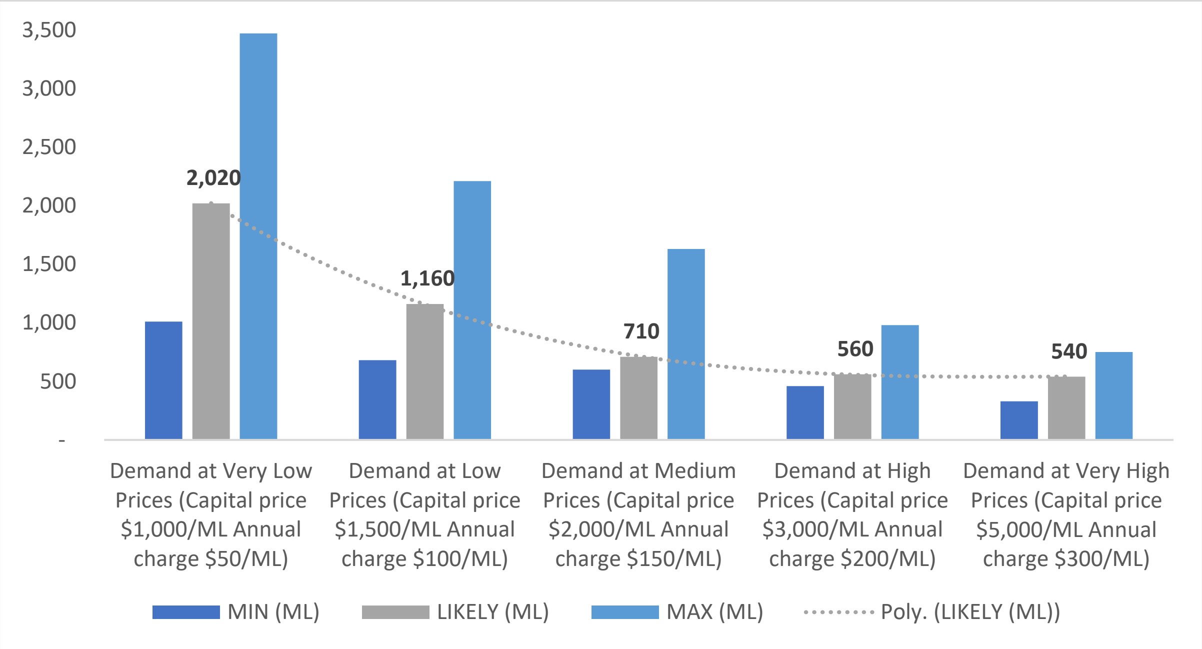
Contents

1 Executive summary

KBR undertook a demand assessment for the Blackbutt Irrigation Project. This assessment identified strong demand for new water across 24 properties. Likely demand was identified up to 2,020 ML.

Figure 1.1: Blackbutt Demand (ML)



As a result of responses received, demand ranges from 330 ML to 3,470 ML. However, likely demand ranges from 540 ML to 2,020 ML. As expected, demand drops as the price increases. However, the demand plateaus beyond $3,000 per ML, indicating a strong base of demand. Based on likely demand, across these price points, the project could raise between $2.0 and 2.7 million from customers.

Recommendations

Given the pattern of demand for various prices, KBR will focus on initial engineering to provide water across a range of demand. The Round 2 demand assessment in future will address different solutions and associated products to refine the understanding of what options would best suit the needs of the Blackbutt region.

Using the webmap that KBR will develop from this demand assessment, engineers should develop a delivery network design and cost for at least three price and demand scenarios (as noted above). From that work the associated fixed and variable annual charges should be developed to inform Round 2. To progress this project, KBR recommend that:

- A funding application should be made to conduct an Options Analysis
- A Round 2 demand assessment be undertaken as part of that Options Analysis.

KBR's recommendations are justified given the high economic value of the proposed new water using enterprises including avocados, avocado oil processing, lavender and macadamia nut orchards.

An Options Analysis is also warranted given this project offers economic benefits including $2.8 – 10.5 million of additional agricultural revenue annually, which will create 32 to 122 new ongoing jobs. The lower prices and higher demand scenarios result in the highest economic and employment benefits.

2 Project overview

2.1 PURPOSE

In summary, the aim is to identify agricultural water demand for Blackbutt Irrigation Project.

The purpose of this report is to outline the process, findings and recommendations arising from the Round 1 demand assessment completed for the Blackbutt Irrigation Project.

2.2 PROJECT SCOPE

Customer participation has been sought to determine the appetite for new water in Blackbutt.

2.3 NATIONALLY ENDORSED DEMAND ASSESSMENT PROCESS

This project will consider a range of topics, but is focussed on the demand assessment, the other elements will be the subject of separate advice. Nationally endorsed demand assessment process

KBR generally undertakes the following three phases of demand assessment using a process that emanated from Tasmanian Irrigation and is now a nationally endorsed approach:

- Round 1 – Expressions of Interest (non-binding) – the subject of this report
- Round 2 – Letters of Intent (non-binding) – part of a future detailed business case
- Round 3 – Water Sales – Legally binding water sales contracts with staged customer capital contributions, for example, made upon signing a contract, when government funding becomes unconditional and prior to completion of construction.

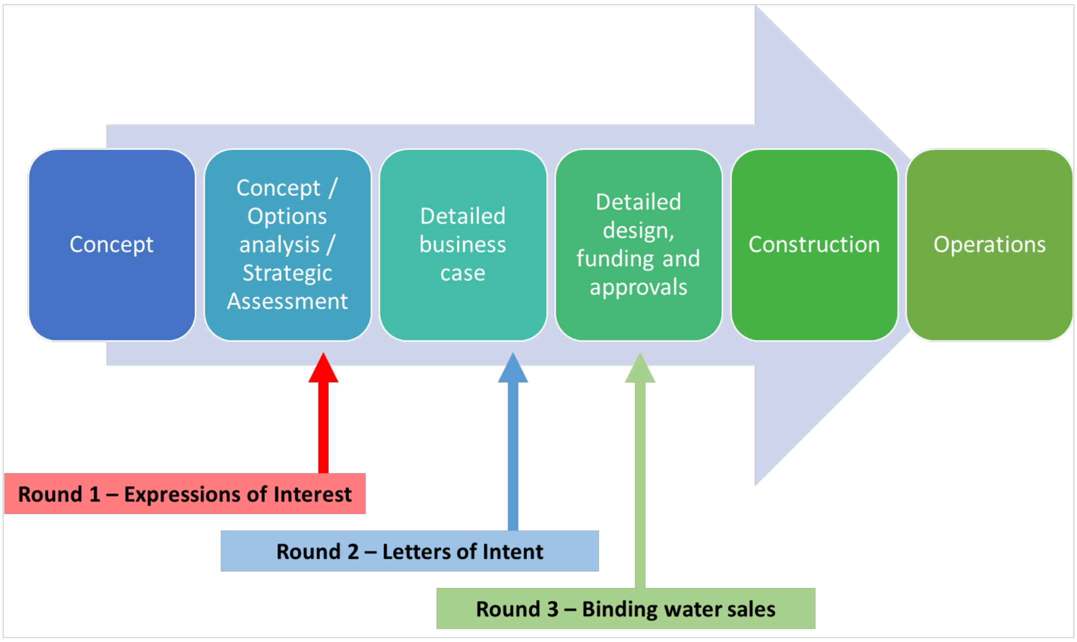
Round 1 and Round 2 are not legally binding, whereas Round 3 is legally binding to underpin funding. This approach demonstrates 'skin in the game' from customers and allows government to make a capital investment with a high degree of confidence that the project will succeed, and the forecast economic benefits arising from the investment will be realised by the community.

2.4 METHODOLOGY

KBR's demand assessment strategy is iterative and connected to all stages of business case development. Refer to the figure below. The demand assessment seeks written input from potential customers at each of these rounds. Demand assessment underpins each stage of business case development and is a major component of stakeholder engagement.

This engagement was to undertake a Round 1 demand assessment. Figure 2.1 outlines how Round 1 fits within a full demand assessment process.

Figure 2.1 Multi-stage Demand Process



Key stakeholders include a wide range of community members but for the purposes of demand assessment, KBR focuses on existing customers and potential new customers of any proposed infrastructure options. KBR utilises the client's contacts and its own.

Immersion/Service Need – KBR begins each business case project with an immersion into the local community. This includes meetings with stakeholders face-to-face for informal discussions to understand the wider context for the project and develop a strong understanding of the service need. It also includes supply infrastructure and farm visits.

Immersion meetings provided valuable input to the questions for the formal demand assessment form, including the range of price scenarios that were tested in the Round 1 Demand Assessment. Customers' and stakeholders' information is tested against other government sources, for example, crop yields, market prices, distribution or other supporting infrastructure.

Round 1 demand assessment – Information for Round 1 is collected in the form of non-binding expressions of interest. The formal demand process includes a public meeting/s and collection and detailed analysis of the forms including demand volumes at a wide range of prices. The form seeks interested parties to be thoughtful and realistic, but with no guarantees that the water become available. Products and prices are based on indicative modelling and/or expectations from previous experiences. Price ranges identify where the willingness-to-pay lies and very high prices rule out pricing and product options for future rounds.

Initial Engineering – based on the Round 1 demand results initial engineering can then be undertaken to provide more specificity around infrastructure options that are able to be developed within the bounds of the likely demand. This will narrow-down the options for products and prices for the next stages of assessment.

2.4.1 Possible future stages

Round 2 Demand Assessment – This round seeks for customers to provide letters of intent along with their demand information. While this is not legally binding it is a strong show of good faith toward the intent to purchase water should it be made available under the types of products and prices in the demand assessment.

At this stage, the demand assessment is evaluated with only one price per product to give a solid picture for the potential customers to evaluate their demand for water volume. This is based on the more refined cost estimates and project details from the initial engineering.

Refined engineering – Based on the outcomes of the Round 2 Demand Assessment, there will be a firm idea of the volume of water demanded. This can be used to further refine the engineering of infrastructure options to reflect that level of demand (i.e. remove any excess capacity). This also provides the final options for finalization of the Detailed Business Case.

Detailed Business Case – developed according to the BCDF and PAF (method not detailed here).

Round 3 Demand Assessment – This round is where customers are requested to provide Binding Water Sales (incl. cash deposits) to cement their demand and provide formal reassurance that the infrastructure options being proposed have real, sufficient demand to provide the economic benefits that are being sought. This is the final stage prior to seeking approvals.

Approvals / Funding / Detailed Design / Construction – Final stages toward implementation.

3 Demand assessment process

3.1 METHODOLOGY

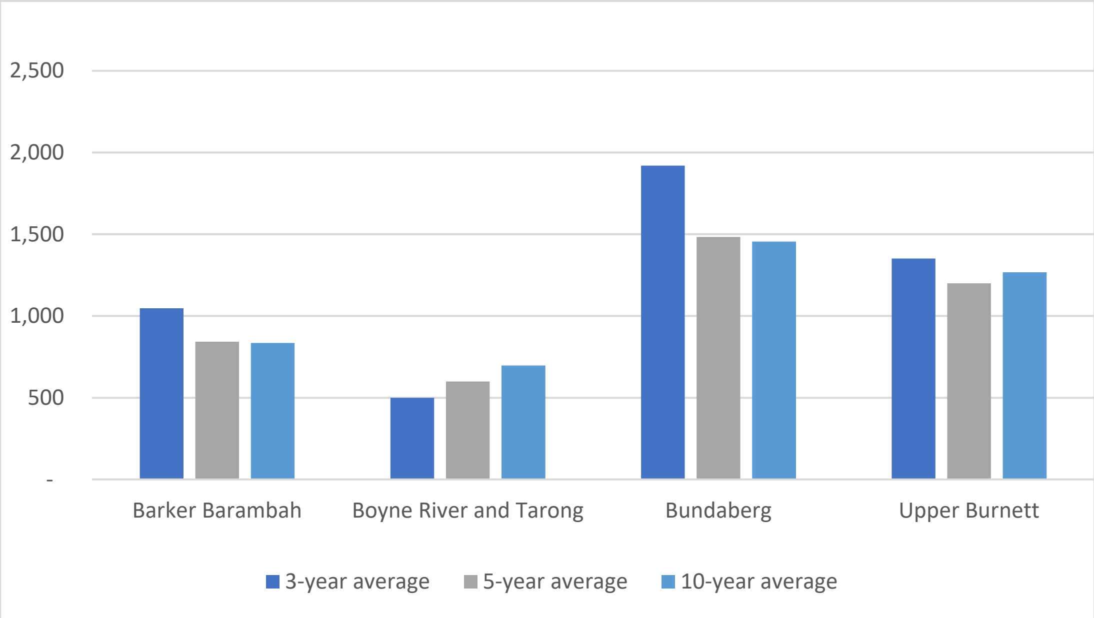
This section describes the key components of this water demand assessment and the process undertaken to develop a robust demand profile.

3.2 INPUT TO PRICE RANGES

The potential customers were presented with a wide, but realistic range of prices. This price range was developed having regard to the price of water in neighbouring schemes and the characteristics of the area.

Across the Bundaberg Burnett Region, the average price for medium priority water is approximately $800 to $1,000 per ML to purchase a Water Allocation.

Figure 3.1 Medium Priority - Weighted Average Price $/ML



Source: Business Queensland Permanent water trading data

Annual charges for Sunwater's existing schemes can be up to $100/ML.

3.3 PRICE RANGES AND WATER PRODUCT/S

KBR provided an annual charges price range that included the price of existing water as a low book-end and tested higher prices to accommodate the likely costs of new infrastructure.

We acknowledged that Government grants may be available to contribute to capital costs, but that ongoing annual charges recover all ongoing operating costs. We considered scenarios where:

- Customers paid the full cost
- Customer paid 50% and the Commonwealth contributed 50%
- Customers paid 25%, the Commonwealth contributed 50% and the Queensland Government contributed 25%.

Before customers are asked to provide their demand assessment responses, KBR gave a presentation outlining the overall project and providing context for the demand assessment.

This includes explaining any water products that are being tested in the demand assessment including reliability and price settings.

Price ranges are explained to ensure understanding of the differences between the upfront purchase price, ongoing fixed and variable/volumetric charges.

In addition, any assumptions made in the price points including potential government subsidies are made clear, and it is critical that at least one full cost recovery price point is included to ensure a fulsome understanding of the demand profile for each product.

Table 3.1 Upfront capital charges for Blackbutt Irrigation Project Round 1 (subject to change)

Scenario	Very low	Low	Medium	High	Very High
Customer's one-off capital payment for new water ($/ML)	1,000	1,500	2,000	3,000	5,000

Table 3.2 Annual charges for Blackbutt Irrigation Project Round 1 (subject to change)

Scenario	Very low	Low	Medium	High	Very High
Fixed annual charge ($/ML)	25	50	75	100	150
Water use charge ($/ML)	25	50	75	100	150
Total annual charge ($/ML)	50	100	150	200	300

In the absence of a specific water source, customers were asked to assume 90% monthly reliability for the Blackbutt Irrigation Project water product.

3.4 CUSTOMER COMMITMENT STRATEGY

Customers were informed that the process was a non-binding Expression of Interest, and that further rounds would have additional levels of commitment, as follows:

- Round 1 – non-binding expressions of interest
- Round 2 – non-binding but formal letters of intent
- Round 3 – binding water sales (including cash deposit).

3.5 ADDRESSING OPTIMISM BIAS, RISK AND UNCERTAINTY

We overcame the risk of optimism bias by:

- Providing detailed information to potential customers
- Spent a significant period consulting with customers, so we can understand their businesses, build trust and allow for potential customers to understand the importance of an accurate demand assessment outcome
- Asked for minimum, likely and maximum demand at a range of price points.

This range of demand allows for a risk adjusted central demand profile to be established.

3.6 EXISITNG WATER SUPPLIES

Blackbutt irrigators rely on overland flow, groundwater and rainfall for irrigation.

The Blackbutt region is connected via pipeline to both Wivenhoe Dam / Western Corridor Water Recycling Scheme and Boondooma Dam. These pipelines are primarily for the purpose of supplying water to the Tarong power station. However, three irrigators have access through these pipelines to water through council's Water Allocation.

Blackbutt is within the Bundaberg Burnett Region and could have access to surrounding schemes. According to the Queensland bulk water opportunities statement Part B: 2021 Program update, there is water available in the Barker Barambah WSS, Bundaberg WSS, and Upper Burnett WSS.

Table 3.3: Availability of water allocations

Water Supply Scheme	Total water storage capacity (ML)	Water allocations held by customers (ML)	Uncommitted water allocations (ML)
Barker Barambah	136,190	34,305	793
Boyne River and Tarong	204,200	41,785	0
Bundaberg[1]	809,045	375,163	15,590
Central Brisbane and Stanley River	1,356,409	286,041	0
Three Moon Creek	89,325	15,228	0
Upper Burnett	188,429	48,700	6,763

Source: QBWOS (2021).

The volume of water in the Barker Barambah would not meet Blackbutt demand, and is some distance away.

While Bundaberg WSS does have a substantial volume of water, and may have more once the Paradise Dam raising is complete, its distance from Bundaberg to Blackbutt (240 km) would make this unviable. Likewise, the Upper Burnett WSS is 200km away.

The only viable options for supply from existing sources would be to use the existing pipelines. The Tarong Power station is schedule to close in 2037. The power station can source water from both the SEQ manufactured water sources, and from Borumba Dam. Once the power station closes, this water will be available for other purposes.

There have been no local processes for the release of unsupplemented water allocations.

3.7 EVIDENCE OF WATER SUPPLY ACTING AS A CONSTRAINT ON ECONOMIC ACTIVITY

Agricultural output in Blackbutt is constrained by the access to reliable water.

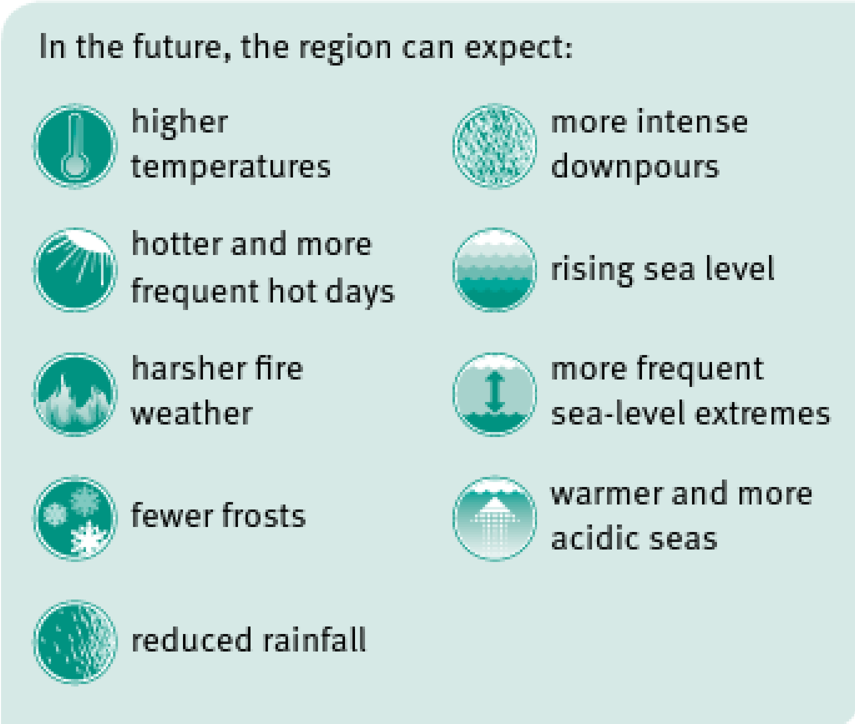
This was confirmed during the North and South Burnett Options Analysis. Refer to Appendix E.7 of the North and South Burnett Options Analysis.

3.8 CLIMATE CHANGE IMPACTS

Climate change will impact agricultural production in the South Burnett as follows:

- Increased temperatures may lead to difficulties in supplying sufficient water to meet agricultural demand and heat damage to crops.
- Conditions may increase plant diseases, weeds and pests, and allow some pest species to move southwards into areas where they are currently excluded.
- Lower rainfall and increasing evaporation will cause more frequent depletion of soil moisture, reduced ground cover and lower livestock carrying capacity.
- Harsher fire weather poses a threat to the timber industry and broad-acre farming.

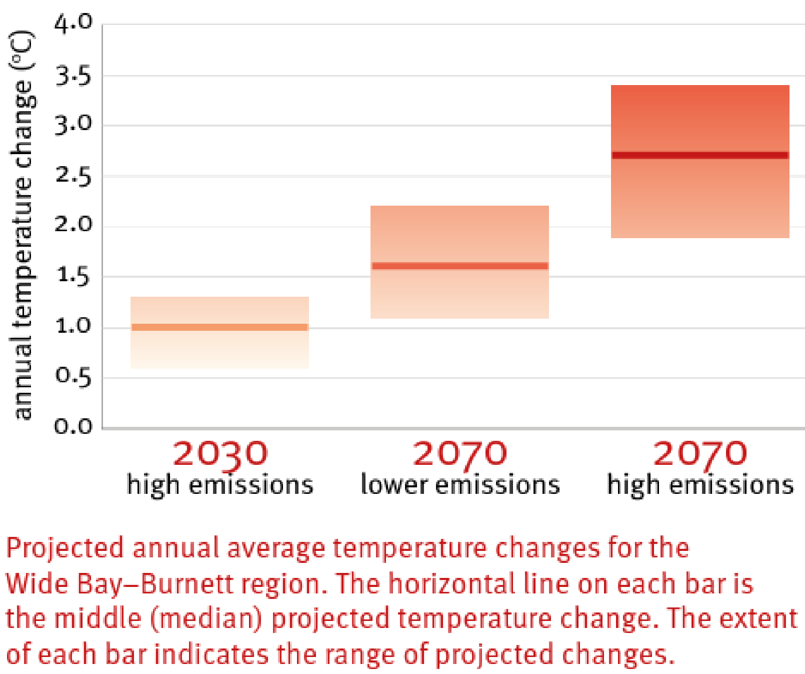
Figure 3.2 Impacts of climate change on for Wide Bay-Burnett region



Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

Maximum, minimum and average temperatures are projected to continue to rise. For the near future (2030), the annually average temperature increase is forecast to be 0.6 to 1.3°C above the climate of 1986–2005.

Figure 3.3 Temperature change for Wide Bay-Burnett region under different emissions scenarios

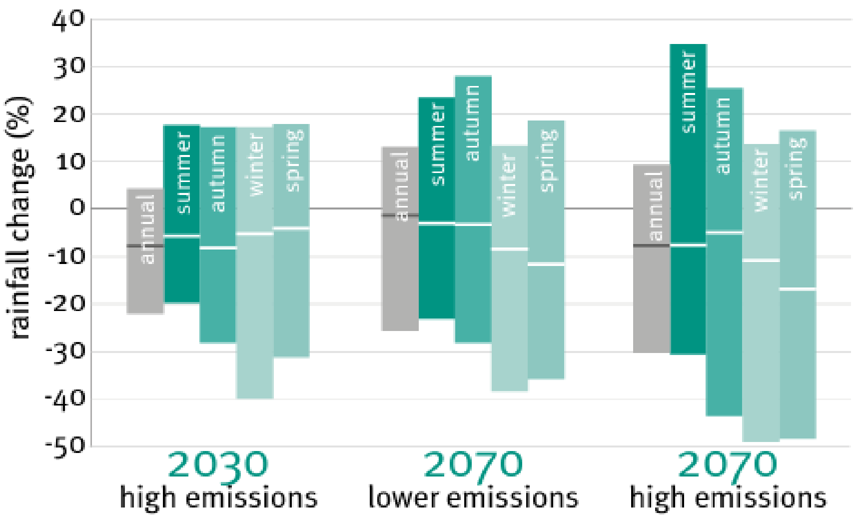


Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

By 2070, forecast warming is 1.1 to 3.4°C, depending on future emissions. The region's summer average temperature is 25°C. This could rise to over 26°C by 2030 and to over 28°C by 2070.

High climate variability is likely to be the major factor influencing rainfall changes in the next few decades. Rainfall projections for 2070 show little change or a decrease in average rainfall, particularly in winter and spring.

Figure 3.4 Climate forecasts



Projected annual and seasonal rainfall changes for the Wide Bay–Burnett region. The horizontal line on each bar is the middle (median) projected rainfall change. The extent of the bar indicates the range of projected changes.

Source: https://www.qld.gov.au/__data/assets/pdf_file/0024/68550/wide-bay-burnett-climate-change-impact-summary.pdf

However, forecasts show high rainfall variability, and that rainfall intensity is expected to increase.

In summary, climate change will deliver to the Wide Bay-Burnett region higher average temperatures and greater rainfall variability (and intensity), which will drive deteriorating soil moisture and the need for a more reliable supply of water for irrigation as dry land crops will more frequently fail.

4 Round 1 demand results

4.1 OVERVIEW

This section summarises the results of the Round 1 questionnaire. Analysis and recommendations are based on these findings.

4.2 COMMUNITY ENGAGEMENT

The community was widely engaged during the process and most relevant stakeholders were very likely contacted via numerous channels.

Community contact included:

- The council sent emails to its contact database
- The council advertised on its website
- KBR conducted a face-to-face community meeting with prospective customers.

4.3 ROUND 1 PARTICIPATION

Table 4.1 summarises customer participation in the Round 1 demand assessment.

Table 4.1 Round 1 number of participants

Item	Response
Number of respondents who attended KBR presentation	5
Number of responses received in Round 1	11
No. of properties / farms represented by respondents	24
Average no. of properties per respondent	2.2

4.4 QUESTION 1: DEMAND FOR WATER AT A RANGE OF PRICES

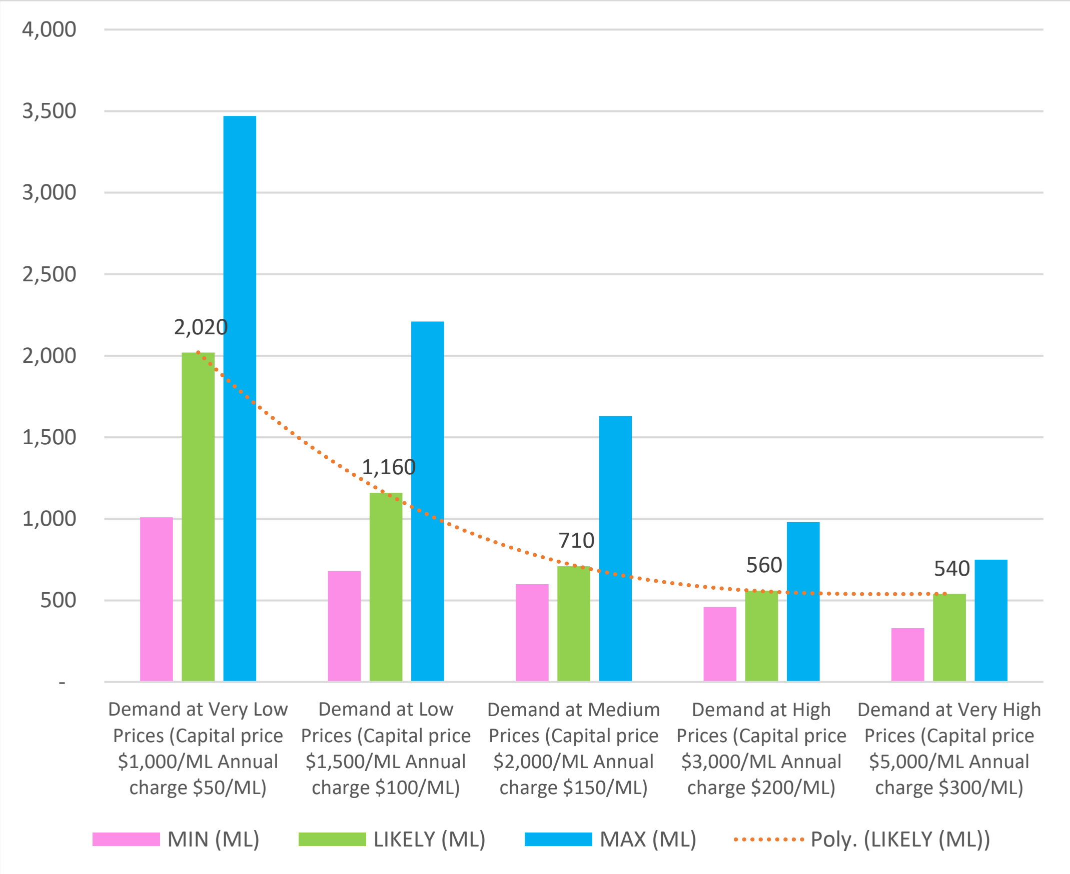
Respondents were asked to complete the following table to show minimum, likely and maximum volume of demand at each price point for the proposed 78-80% monthly reliability water product.

Table 4.2 Water price range

Water Price/s	Capital price ($/ML)	Annual charge ($/ML pa)	Minimum demand (ML)	Likely demand (ML)	Maximum demand (ML)
Very low	1,000	50			
Low	1,500	100			
Medium	2,000	150			
High	3,000	200			
Very high	5,000	300			

Demand at each price point is shown below.

Figure 4.1 New demand for water from Blackbutt Irrigation Project (ML)



Demand reduces as the price increases. The very low price has likely demand of 2,020 ML. The low price has likely demand of 1,160 ML. The medium price has likely demand of 710 ML. However, the demand plateaus beyond $3,000 per ML, indicating that there is a very strong base of demand at or above 540-560 ML.

4.5 QUESTION 2: INTENDED USES FOR WATER

Respondents were asked to provide delivery locations, the intended use for water and volumes assuming the very low price of $1,000/ML capital contribution and annual charge of $50/ML.

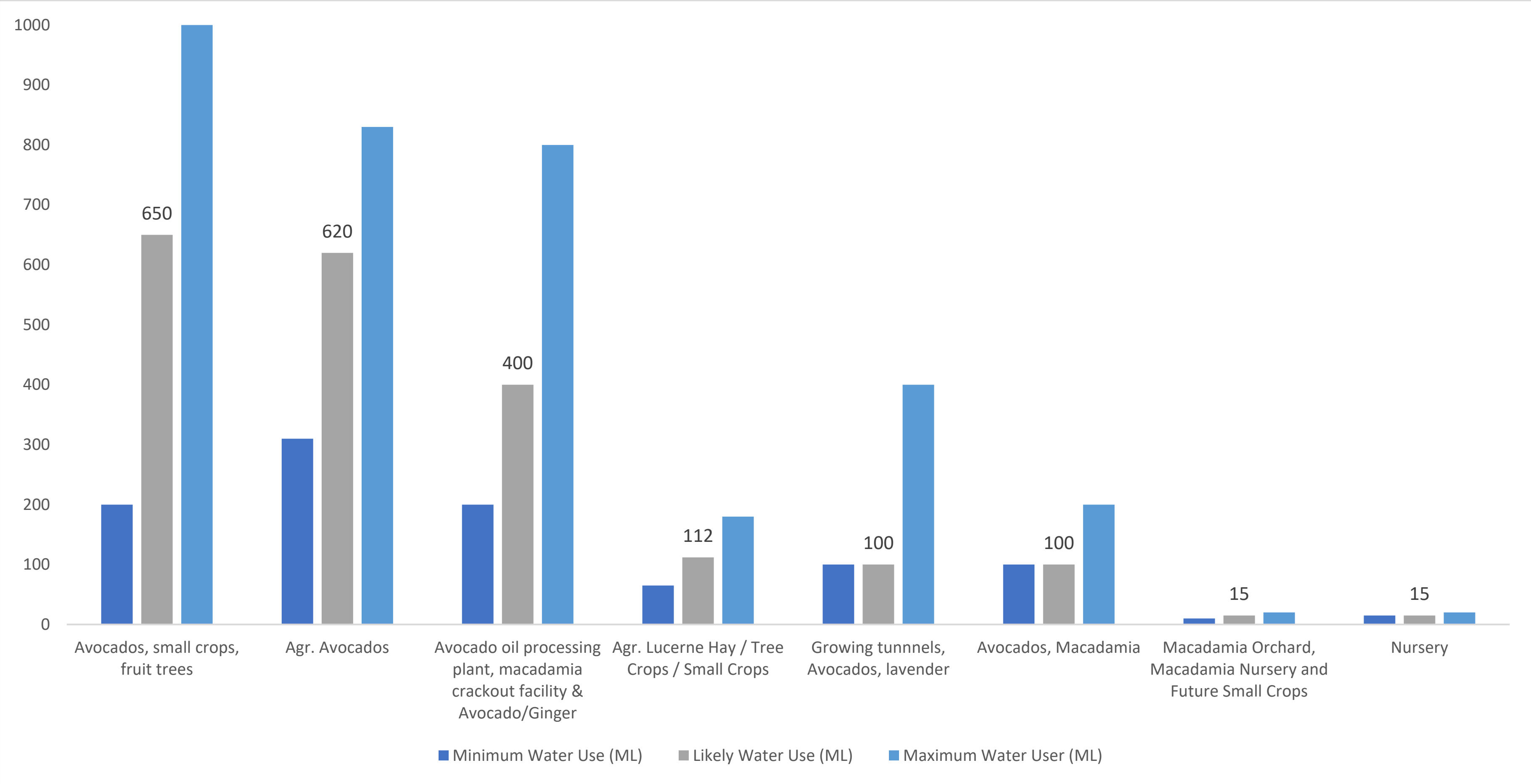
Table 4.3 Location of water and future uses based on very low price

Property name, street address and (ideally) rates notice Lot and Plan No.	Intended use for water (e.g. Avocados, lemons, lucerne hay)	MIN (ML)	LIKELY (ML)	MAX (ML)

Responses to the delivery location component of this question will result in a webmap and inform the initial engineering design of a distribution scheme. This will also inform which customers can and cannot viably be connected to the source using low-dimension pipelines – depending on distance from source and elevation of delivery point.

Responses to the future use question (Figure 4.2) allowed a forecast of project economic benefits. Appendix A shows that access to new water can produce a direct economic benefit up to $66.5 million and deliver an additional 209 new permanent jobs in agriculture and supporting industries.

Figure 4.2: Round 1 Water Demand per enterprise



Note: This chart is based on customer supplied data which did not always break down water use into single commodities. For example, avocadoes are combined with other commodities.

4.6 QUESTION 3: ATTENDANCE AT PUBLIC MEETING

Respondents were asked if they attended the KBR Round 1 public meeting for this project. Table 4.4 summarises customer participation in the Round 1 demand assessment meetings.

Table 4.4 Round 1 number of meeting attendees

Response	Did you attend KBR's meeting on 29 March 2022?
Yes	5
No	6
Total	**11**

This result indicates that communication of the demand assessment reached potential customers outside of the group attending the presentations. It demonstrates that people were willing to take the time to read the materials and complete the form, without the motivation of a public meeting.

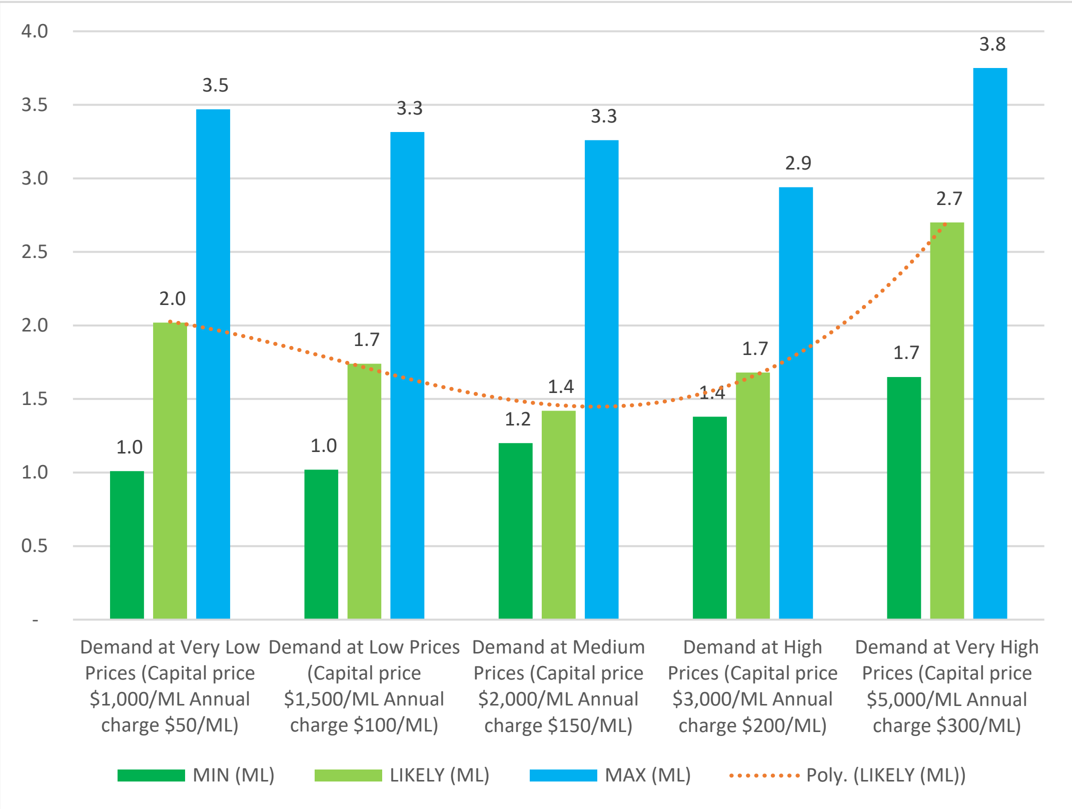
4.7 CUSTOMER CAPITAL REVENUE – NOT CONTRAINED BY SUPPLY

This section presents minimum, likely and maximum customer capital revenue at various prices.

Usually, particularly where supply is unconstrained, this analysis identifies a clear 'sweet spot' where customer capital revenue is maximised which is typically viewed as the capital price point that also maximises the schemes prospects of achieving funding and implementation success.

Figure 4.5 shows customer capital contributions at each price point (demand volume times capital price), noting that no supply constraint was imposed.

Figure 4.3 Customer capital revenue at different prices ($ million)



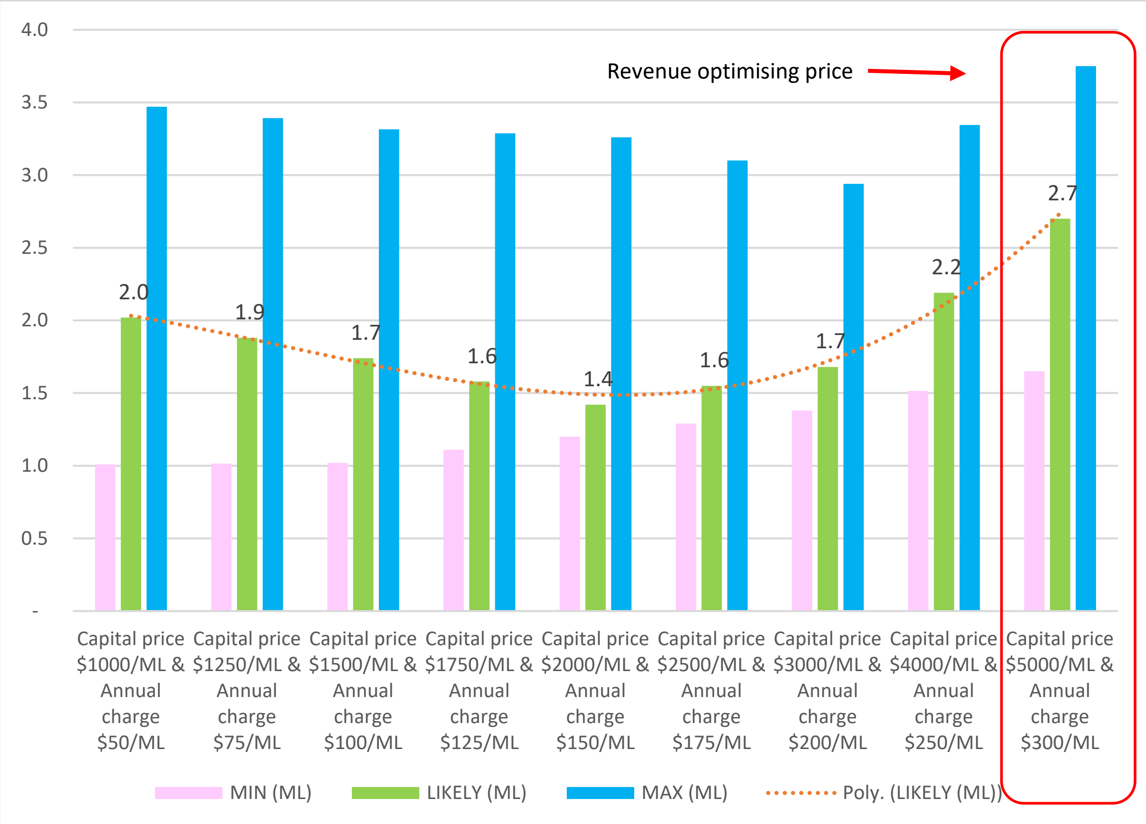
Capital revenue is maximised at the very high price of $5,000 per ML. This indicates that there is a small volume of water for which there are customers that are highly motivated to buy.

As the price reduces the volume demanded is not proportionally increased, and therefore the capital revenue is reduced. When the price is reduced to $2,000 per ML the capital revenue begins to increase again, albeit not reaching the maximum which is achieved at the high price.

This suggests it may be a suitable option to supply only a small volume of water and attract a high price from highly motivated customers. Alternatively, to supply a larger volume of water (and thereby achieve greater economic benefits for the region) an option would need to be viable within the smaller capital revenue resulting from a very low price.

Figure 4.6 shows customer capital contributions at each price point (volume times capital price) including interpolated / derived prices and volumes, assuming no supply constraint. In a greenfield project, or where supply exceeds demand, such analysis has historically been accurate.

Figure 4.4 Customer capital revenue at different prices (incl. interpolation) ($ million)



The figure indicates that a customer capital price of $5,000 per ML is forecast to maximise absolute customer capital contributions at $2.7 million. However, this price is very high, which may see a failure in Round 3 binding water sales, when growers consider alternative capital investments.

It is relevant therefore to consider two other revenue optimising scenarios:

- $2.2 million may be raised at $4,000/ML
- $2.0 million may be raised at $1,000/ML – which will have the highest certainty of Round 3 success.

KBR recommend that for the next phase of investigation, different solutions are progressed for initial engineering for this wide range of price, demand and revenue scenarios.

4.8 IMPORTANCE OF SUPPLY VOLUMES AND WATER PRODUCT RELIABILITY

The revenue analysis suggests a customer capital price of $1,000 per ML to $5,000 per ML, depending on the proponents view on the risks associated with achieving Round 3 binding water contract success. The higher the price, the lower the chance of signed up demand and vice versa.

The consequence of charging too much (e.g. $4,000 to $5,000 per ML) could be lower demand and therefore lower economic benefits. Moreover, the cost effectiveness of a low-volume distribution network is not favourable due to poor economies of scale.

A lower price (e.g. $1,000 to $2,000 per ML) with higher demand volumes reduces fixed annual charges (lower costs per ML) and increase the certainty and likely volume of future water sales.

More analysis is needed to ascertain the volume/s of water available for sale, water products and the monthly reliability of those products.

4.9 RECOMMENDATIONS

Given the pattern of demand for various prices, KBR will focus on initial engineering to provide water across a range of demand. The Round 2 demand assessment in future will address different solutions and associated products to refine the understanding of what options would best suit the needs of the Blackbutt region.

Using the webmap that KBR will develop from this demand assessment, engineers should develop a delivery network design and cost for at least three price and demand scenarios (as noted above). From that work the associated fixed and variable annual charges should be developed to inform Round 2. To progress this project, KBR recommend that:

- A funding application should be made to conduct an Options Analysis
- A Round 2 demand assessment be undertaken as part of that Options Analysis.

KBR’s recommendations are justified given the high economic value of the proposed new water using enterprises including avocados, avocado oil processing, lavender and macadamia nut orchards.

An Options Analysis is also warranted given this project offers economic benefits including $2.8 – 10.5 million of additional agricultural revenue annually, which will create 32 to 122 new ongoing jobs. The lower prices and higher demand scenarios result in the highest economic and employment benefits.

ECONOMIC ROAD MAP

Attachment D:West

Barambah Weir

Environmental report

KBR

Appendix 1

Barambah Demand Assessment

October 2022

West Barambah Weir

Environmental Report

West Barambah Weir

Environmental Report

Prepared by:
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9 September 2022

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Limitations Statement

The sole purpose of this report and the associated services performed by Kellogg Brown & Root Pty Ltd (KBR) is to deliver in accordance with the scope of services set out in the contract between KBR and Coalstoun Lakes Water ('the Client'). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

KBR derived the data in this report primarily from visual inspections, examination of records in the public domain, interviews with individuals with information about the site. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, KBR has relied upon and presumed accurate certain information (or absence thereof) relative to the site, provided by government officials and authorities, the Client and others identified herein. Except as otherwise stated in the report, KBR has not attempted to verify the accuracy or completeness of any such information.

The findings, observations and conclusions expressed by KBR in this report are not, and should not be considered, an opinion. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon information in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between KBR and the Client. KBR accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

Revision History

Revision	Date	Comment	Signatures			
			Originated by	Checked by	Technical Approval	Project Approval
1	8 Sep 22	Draft	Simon Costanzo		Adrian Volders	
2	9 Sep 22	Final	Simon Costanzo			

Contents

1 Key points

- The reference project (West Barambah Weir) proposes the construction of a weir across Barambah Creek, approximately 25 km upstream from the confluence of Barker Creek in the South Burnett District.
- Following construction of the 280 m long weir, approximately 200 ha of predominantly pastoral land will be inundated, resulting in a storage volume of approximately 5,000 ML of water.
- A search of Federal and State databases identified that the area of interest contains:
  - a number of threatened, vulnerable and critically endangered ecological communities and species including the koala
  - areas of high to very high conservation significance
  - regulated vegetation including endangered remnant vegetation
- Impacts are expected to water quality, hydrology and fish passage during construction, inundation and the life history of the impounded water
- This desktop assessment has identified a number of environmental values that will be impacted by the construction of West Barambah Weir. On ground investigations to confirm or deny these impacts will need to be completed. Development impacts similar to these have been previously approved with conditions and there is the potential to offset these impacts.
- If required, the minimum financial settlement for environmental offsets, based on a high-level desktop assessment of the project using the Department of Environment and Science Offsets Calculator, would be $2,642,284.80.

2 Introduction

West Barambah Weir is a proposed structure to be located on Barambah Creek in the wider Burnett District of Queensland. The purpose of the weir is to store water and allow expansion of irrigation in the Moffatdale area and increase drought and climate resilience into the future.

The weir is proposed to be located approximately 25 km upstream from the confluence with Barker Creek. Bjelke-Petersen Dam is located 1.5 km upstream of this confluence. A locality plan is shown in Figure 1.

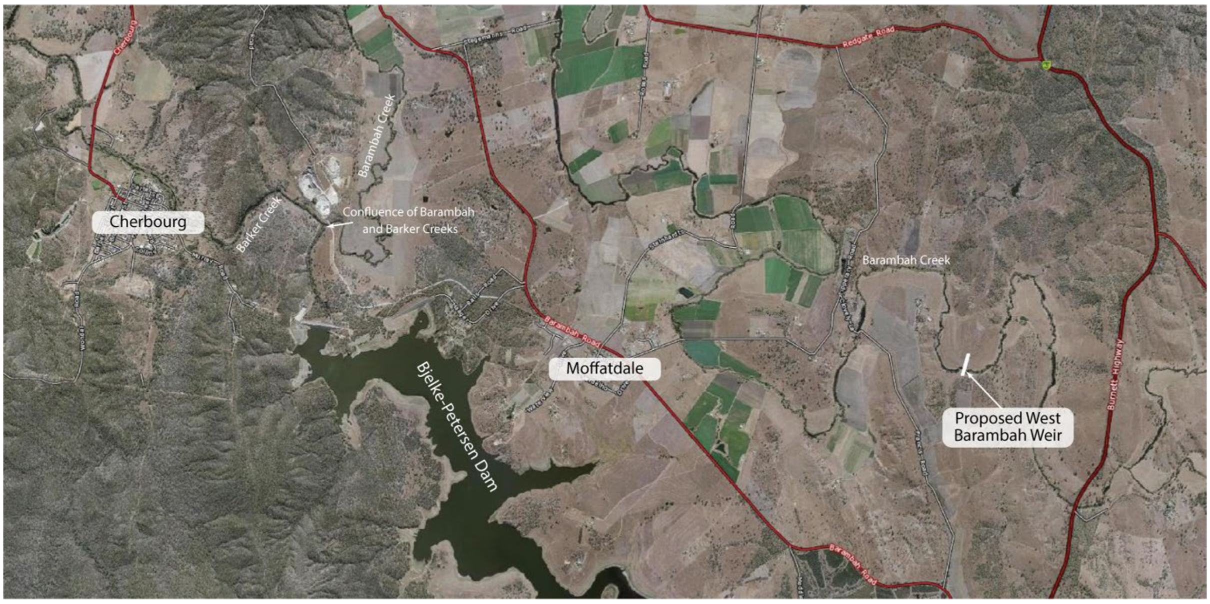

Figure 1 - Location of proposed West Barambah Weir

Following construction of the 280 m long weir and at full capacity, approximately 200 ha of land will be inundated, resulting in a storage volume of approximately 5,000 ML of water (storage ratio 140:1). The proposed weir inundation area is shown in Figure 2.

The concept design describes the following infrastructure:

- a 280 m long and 12 m high earthen embankment perpendicular to Barambah Creek
- a side excavated concreted spillway as the main flood routing structure.

The inundation area shows a wide and relatively shallow basin, expected to inundate land approximately 6 km upstream from the weir at full capacity.

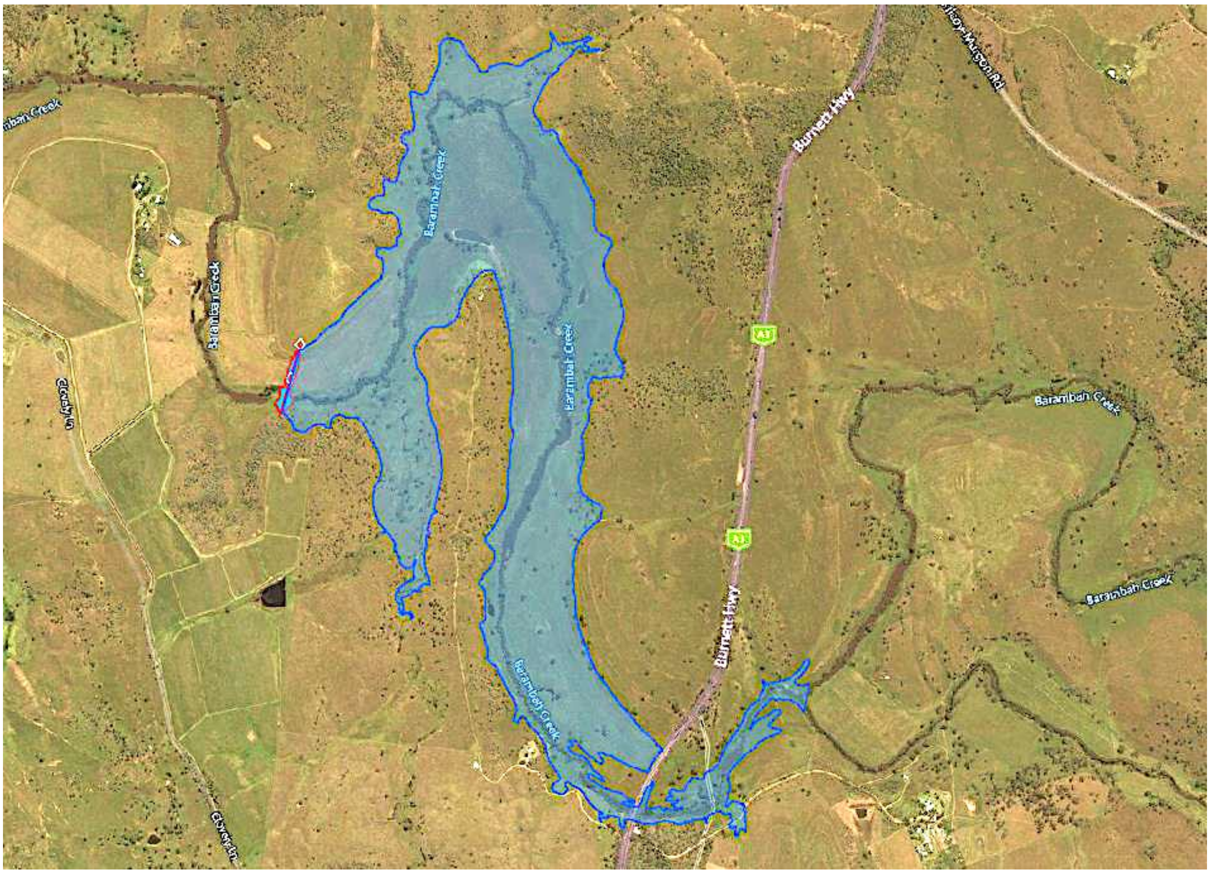

Figure 2 - Proposed weir inundation area[1]

[1] Pinion Advisory. West Barambah Weir – Concept Assessment Memo Report. 2 August 2022.

3 Environmental considerations

3.1 FAUNA, FLAURA AND HABITAT

3.1.1 EPBC Act Protected Matters (Federal)

The Protected Matters Search Tool was used to identify what, within the inundation area (+250 m buffer), is protected under the Environment Protection and Biodiversity Conservation Act 1999 (Figure 3). This area is referred to as the Area of Interest (AOI). The full report can be found in Attachment I.

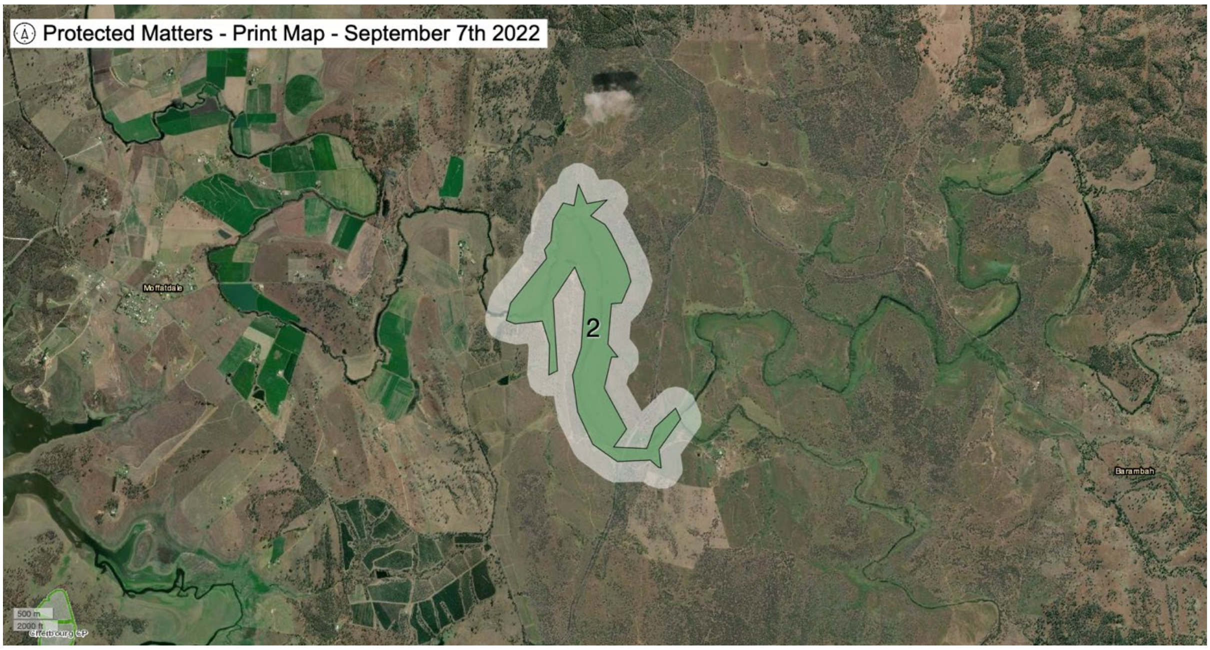

Figure 3 – Map showing area of inundation (green highlight) and 250 m buffer (white) used in the Protected Matters Search Tool.

Matters of National Environmental Significance

Table 1 shows listed threatened ecological communities within the AOI including two critically endangered communities that are mapped as potentially occurring in the area.

Table 1 Listed Threatened Ecological Communities

Community ID	Community Name	Threatened Category
141	Poplar Box Grassy Woodland on Alluvial Plains	Endangered
101	Lowland Rainforest of Subtropical Australia	Critically Endangered
43	White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically Endangered

Table 2 shows listed threatened species within the AOI including six critically endangered species that are mapped as potentially occurring in the area.

Table 2 Listed Threatened Species

Species ID	Scientific name	Common name	Class	Threatened category
847	*Numenius madagascariensis*	Eastern Curlew, Far Eastern Curlew	Bird	Critically Endangered
19162	*Rhodomyrtus psidioides*	Native Guava	Plant	Critically Endangered

Species ID	Scientific name	Common name	Class	Threatened category
744	*Lathamus discolor*	Swift Parrot	Bird	Critically Endangered
856	*Calidris ferruginea*	Curlew Sandpiper	Bird	Critically Endangered
81648	*Elseya albagula*	Southern Snapping Turtle, White-throated Snapping Turtle	Reptile	Critically Endangered
15763	*Rhodamnia rubescens*	Scrub Turpentine, Brown Malletwood	Plant	Critically Endangered
77037	*Rostratula australis*	Australian Painted Snipe	Bird	Endangered
75184	*Dasyurus maculatus maculatus (SE mainland population)*	Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population)	Mammal	Endangered
25960	*Mixophyes fleayi*	Fleay's Frog	Frog	Endangered
331	*Dasyurus hallucatus*	Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu]	Mammal	Endangered
14035	*Lepidium peregrinum*	Wandering Pepper-cress	Plant	Endangered
3066	*Cossinia australiana*	Cossinia	Plant	Endangered
254	*Petauroides volans*	Greater Glider (southern and central)	Mammal	Endangered
81869	*Phebalium distans*	Mt Berryman Phebalium	Plant	Endangered
85104	*Phascolarctos cinereus (combined populations of Qld, NSW and the ACT)*	Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory)	Mammal	Endangered
9828	*Cadellia pentastylis*	Ooline	Plant	Vulnerable
18106	*Denhamia parvifolia*	Small-leaved Denhamia	Plant	Vulnerable
87600	*Petaurus australis australis*	Yellow-bellied Glider (south-eastern)	Mammal	Vulnerable
16839	*Haloragis exalata subsp. velutina*	Tall Velvet Sea-berry	Plant	Vulnerable
15202	*Thesium australe*	Austral Toadflax, Toadflax	Plant	Vulnerable
67036	*Calyptorhynchus lathami lathami*	South-eastern Glossy Black-Cockatoo	Bird	Vulnerable
64440	*Geophaps scripta scripta*	Squatter Pigeon (southern)	Bird	Vulnerable
186	*Pteropus poliocephalus*	Grey-headed Flying-fox	Mammal	Vulnerable
1656	*Delma torquata*	Adorned Delma, Collared Delma	Reptile	Vulnerable
16091	*Bosistoa transversa*	Three-leaved Bosistoa, Yellow Satinheart	Plant	Vulnerable
14159	*Dichanthium setosum*	bluegrass	Plant	Vulnerable
9338	*Arthraxon hispidus*	Hairy-joint Grass	Plant	Vulnerable
174	*Macroderma gigas*	Ghost Bat	Mammal	Vulnerable
183	*Chalinolobus dwyeri*	Large-eared Pied Bat, Large Pied Bat	Mammal	Vulnerable
1420	*Egernia rugosa*	Yakka Skink	Reptile	Vulnerable
470	*Grantiella picta*	Painted Honeyeater	Bird	Vulnerable
83395	*Nyctophilus corbeni*	Corben's Long-eared Bat, South-eastern Long-eared Bat	Mammal	Vulnerable
942	*Erythrotriorchis radiatus*	Red Goshawk	Bird	Vulnerable
929	*Falco hypoleucos*	Grey Falcon	Bird	Vulnerable
59254	*Furina dunmalli*	Dunmall's Snake	Reptile	Vulnerable
923	*Turnix melanogaster*	Black-breasted Button-quail	Bird	Vulnerable
682	*Hirundapus caudacutus*	White-throated Needletail	Bird	Vulnerable

Table 3 shows listed migratory species within the AOI including six critically endangered species that are mapped as potentially occurring in the area.

Table 3 Listed Migratory Species

Species ID	Scientific name	Common name	Class	Threatened category
83946	*Symposiachrus trivirgatus*	Spectacled Monarch	Bird	Critically Endangered
847	*Numenius madagascariensis*	Eastern Curlew, Far Eastern Curlew	Bird	Critically Endangered
863	*Gallinago hardwickii*	Latham's Snipe, Japanese Snipe	Bird	Critically Endangered
678	*Apus pacificus*	Fork-tailed Swift	Bird	Critically Endangered
612	*Myiagra cyanoleuca*	Satin Flycatcher	Bird	Critically Endangered
609	*Monarcha melanopsis*	Black-faced Monarch	Bird	Critically Endangered
592	*Rhipidura rufifrons*	Rufous Fantail	Bird	Endangered
86651	*Cuculus optatus*	Oriental Cuckoo, Horsfield's Cuckoo	Bird	Endangered
874	*Calidris acuminata*	Sharp-tailed Sandpiper	Bird	Endangered
858	*Calidris melanotos*	Pectoral Sandpiper	Bird	Endangered
856	*Calidris ferruginea*	Curlew Sandpiper	Bird	Endangered
59309	*Actitis hypoleucos*	Common Sandpiper	Bird	Endangered
644	*Motacilla flava*	Yellow Wagtail	Bird	Endangered
682	*Hirundapus caudacutus*	White-throated Needletail	Bird	Endangered

Other Matters Protected by the EPBC Act

Table 4 shows listed marine species within the AOI including three critically endangered species that are mapped as potentially occurring in the area. The listed species are classified as marine as they migrate across marine environments.

Table 4 - Listed Marine Species

Species ID	Scientific name	Common name	Class	Category
83946	*Symposiachrus trivirgatus*	Spectacled Monarch	Bird	Migratory
77037	*Rostratula australis*	Australian Painted Snipe	Bird	Endangered
847	*Numenius madagascariensis*	Eastern Curlew, Far Eastern Curlew	Bird	Critically Endangered
863	*Gallinago hardwickii*	Latham's Snipe, Japanese Snipe	Bird	Migratory
678	*Apus pacificus*	Fork-tailed Swift	Bird	Migratory
612	*Myiagra cyanoleuca*	Satin Flycatcher	Bird	Migratory
609	*Monarcha melanopsis*	Black-faced Monarch	Bird	Migratory
943	*Haliaeetus leucogaster*	White-bellied Sea-Eagle	Bird	Migratory
592	*Rhipidura rufifrons*	Rufous Fantail	Bird	Migratory
670	*Merops ornatus*	Rainbow Bee-eater	Bird	Migratory
66521	*Bubulcus ibis*	Cattle Egret	Bird	Migratory
744	*Lathamus discolor*	Swift Parrot	Bird	Critically Endangered
978	*Anseranas semipalmata*	Magpie Goose	Bird	Migratory
874	*Calidris acuminata*	Sharp-tailed Sandpiper	Bird	Migratory
858	*Calidris melanotos*	Pectoral Sandpiper	Bird	Migratory
83425	*Chalcites osculans*	Black-eared Cuckoo	Bird	Migratory

Species ID	Scientific name	Common name	Class	Category
856	*Calidris ferruginea*	Curlew Sandpiper	Bird	Critically Endangered
59309	*Actitis hypoleucos*	Common Sandpiper	Bird	Migratory
644	*Motacilla flava*	Yellow Wagtail	Bird	Migratory
682	*Hirundapus caudacutus*	White-throated Needletail	Bird	Vulnerable

3.1.2 State Biodiversity and Conservation Values

A search of the Queensland Government Environmental Reports Online for terrestrial biodiversity and aquatic conservation values was performed within a 2 km radius around the centre of the reference project's inundation area (AOI) (see map of AOI in Attachment II). Table 5 shows the area and classification of remnant regional ecosystems within the AOI which upon inspection of satellite imagery appears to be riparian vegetation. Further detail on the composition of these areas can be found Attachment II.

Table 5 - Remnant regional ecosystems within the AOI as per the Qld Herbarium's 'biodiversity status'

Biodiversity Status	Area (Ha)
Endangered	0.33
Of concern	26.17
No concern at present	13.31

Table 6 shows the area within the AOI mapped as being of "State", "Regional" or "Local" significance via application of the Queensland Department of Environment and Science's Biodiversity Assessment and Mapping Methodology (BAMM). This includes 8.71 ha of remnant vegetation forming part of a bioregional corridor. Further detail on the composition of these areas can be found in Attachment II.

Table 6 – Areas of biodiversity significance within the AOI.

Biodiversity significance	Area (Ha)
State Habitat for EVNT taxa	0.0
State	8.71
Regional	0.0
Local or Other Values	5.94

Table 7 shows areas within the AOI mapped as being of "Very High", "High", "Medium", "Low", or "Very Low" aquatic conservation value for riverine and non-riverine wetlands via application of the Queensland Department of Environment and Science's Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM). It shows over 1000 ha of high-very high conservation significance. Further detail on the composition of these areas can be found in Attachment II.

Table 7 - Areas of aquatic conservation significance within the AOI.

Aquatic conservation significance (riverine wetlands)	Area (Ha)
Very High	916.49
High	340.06
Medium	0.0
Low	0.0
Very Low	0.0

Table 8 shows threatened species which are classified as "Endangered" (E) or "Vulnerable" (VE) under the Environment Protection and Biodiversity Conservation Act 1999 or "Endangered", "Vulnerable" or "Near threatened" (NT) under the Nature Conservation Act 1992. Koalas have been recorded on, or within approximately 4km of the AOI. A number of other Biodiversity Planning Assessment (BPA) and Aquatic Conservation Assessment (ACA) Priority species have also been recorded on, or within approximately 4km of the AOI (see Attachment II).

Table 8 - Threatened species recorded on, or within 4 km of the AOI.

Species	Common name	NCA status	EPBC status
Phascolarctos cinereus	koala	E	E

3.1.3 Matters of State Environmental Significance

A search of the Queensland Government Environmental Reports Online for Matters of Environmental Significance was performed within a 2 km radius around the centre of the reference project's inundation area (AOI) (see map of AOI in Attachment III). Table 9 shows a summary of the MSES values present in the AOI which includes Threatened Wildlife (see also Figure 4) and a diversity of Regulated Vegetation classifications including Endangered/Of Concern remnant vegetation (see also Figure 5). Further detail on the composition of these areas can be found in Attachment III.

Table 9 - Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha
1b Protected Areas- nature refuges	0.0 ha
1c Protected Areas- special wildlife reserves	0.0 ha
2 State Marine Parks- highly protected zones	0.0 ha
3 Fish habitat areas (A and B areas)	0.0 ha
4 Strategic Environmental Areas (SEA)	0.0 ha
5 High Ecological Significance wetlands on the map of Referable Wetlands	0.0 ha
6a High Ecological Value (HEV) wetlands	0.0 ha
6b High Ecological Value (HEV) waterways	0.0 km
7a Threatened (endangered or vulnerable) wildlife	24.62 ha
7b Special least concern animals	0.0 ha
7c i Koala habitat area - core (SEQ)	0.0 ha
7c ii Koala habitat area - locally refined (SEQ)	0.0 ha
7d Sea turtle nesting areas	0.0 km
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	13.94 ha
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	6.55 ha
8c Regulated Vegetation - Category R (GBR riverine regrowth)	43.84 ha
8d Regulated Vegetation - Essential habitat	18.04 ha
8e Regulated Vegetation - intersecting a watercourse	30.4 km
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	0.0 ha
9a Legally secured offset areas- offset register areas	0.0 ha
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha

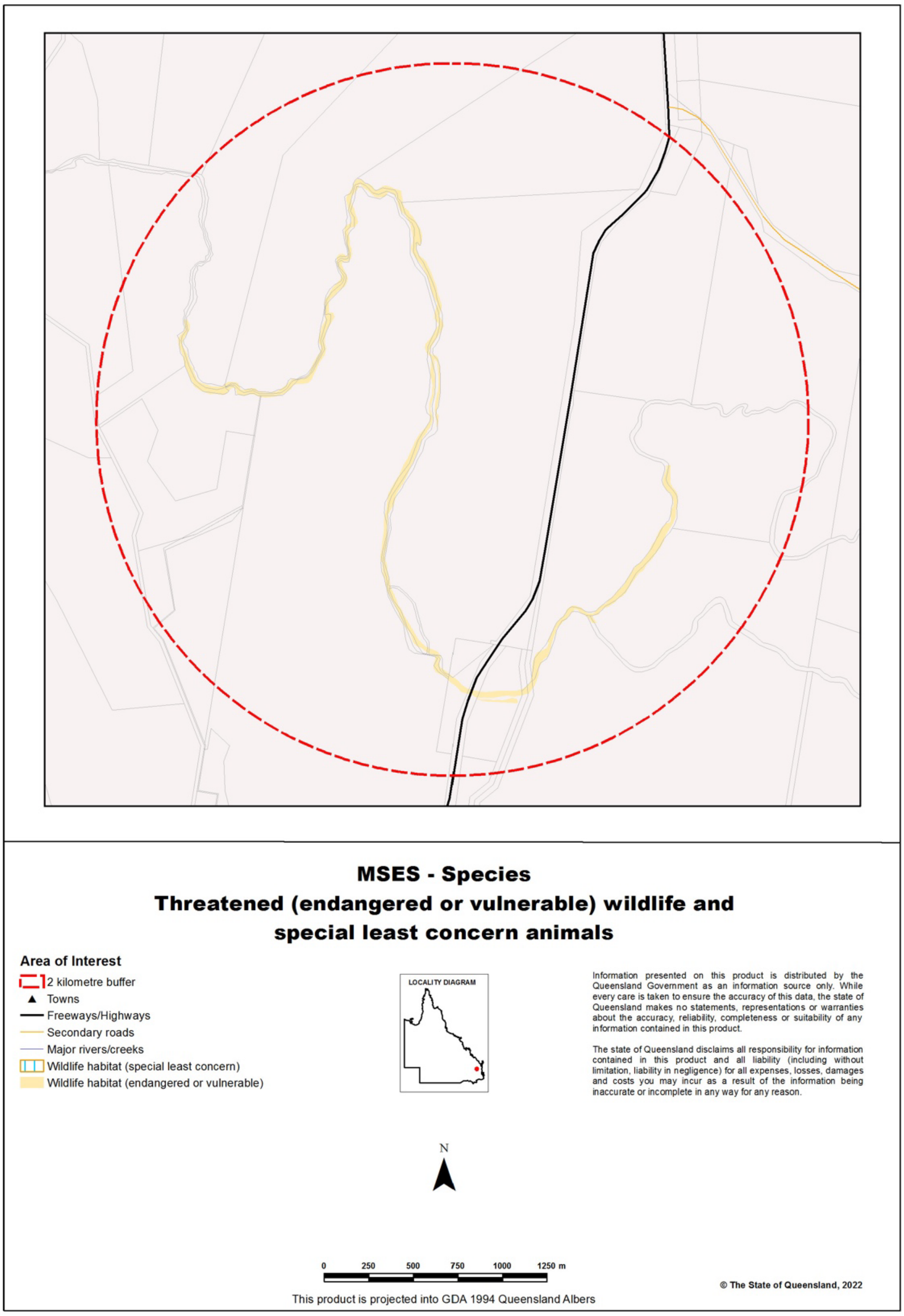

Figure 4 – Map of threatened (endangered or vulnerable) wildlife and special least concern animals within the AOI.

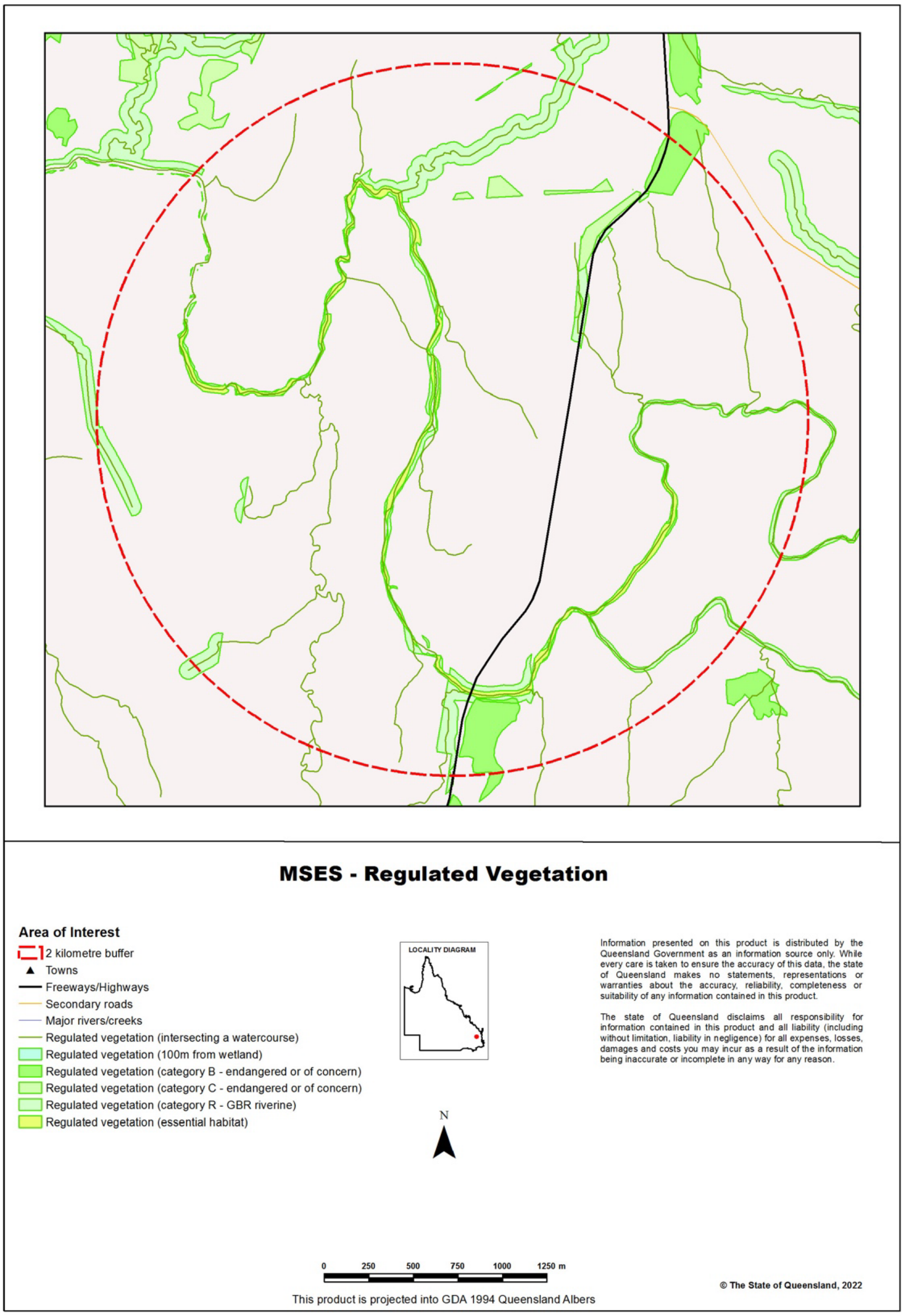

Figure 5 - Map of regulated vegetation within the AOI.

3.1.4 Regional Ecosystems

A search of the Queensland Government Environmental Reports Online for Regional Ecosystems was performed within a 2 km radius around the centre of the reference project's inundation area (AOI) (see map of AOI in Attachment IV). Table 9 shows a summary of biodiversity status of regional ecosystems present in the AOI which includes "Endangered" and "Of Concern" remnant vegetation (see also Figure 6 and Figure 7). Further detail on the composition of these areas can be found in Attachment IV.

Table 10 – Summary table of biodiversity status of regional ecosystems within the AOI.

Biodiversity Status	Area (Ha)
Endangered	0.33
Of concern	26.17
No concern at present	13.31
Total remnant vegetation	39.81

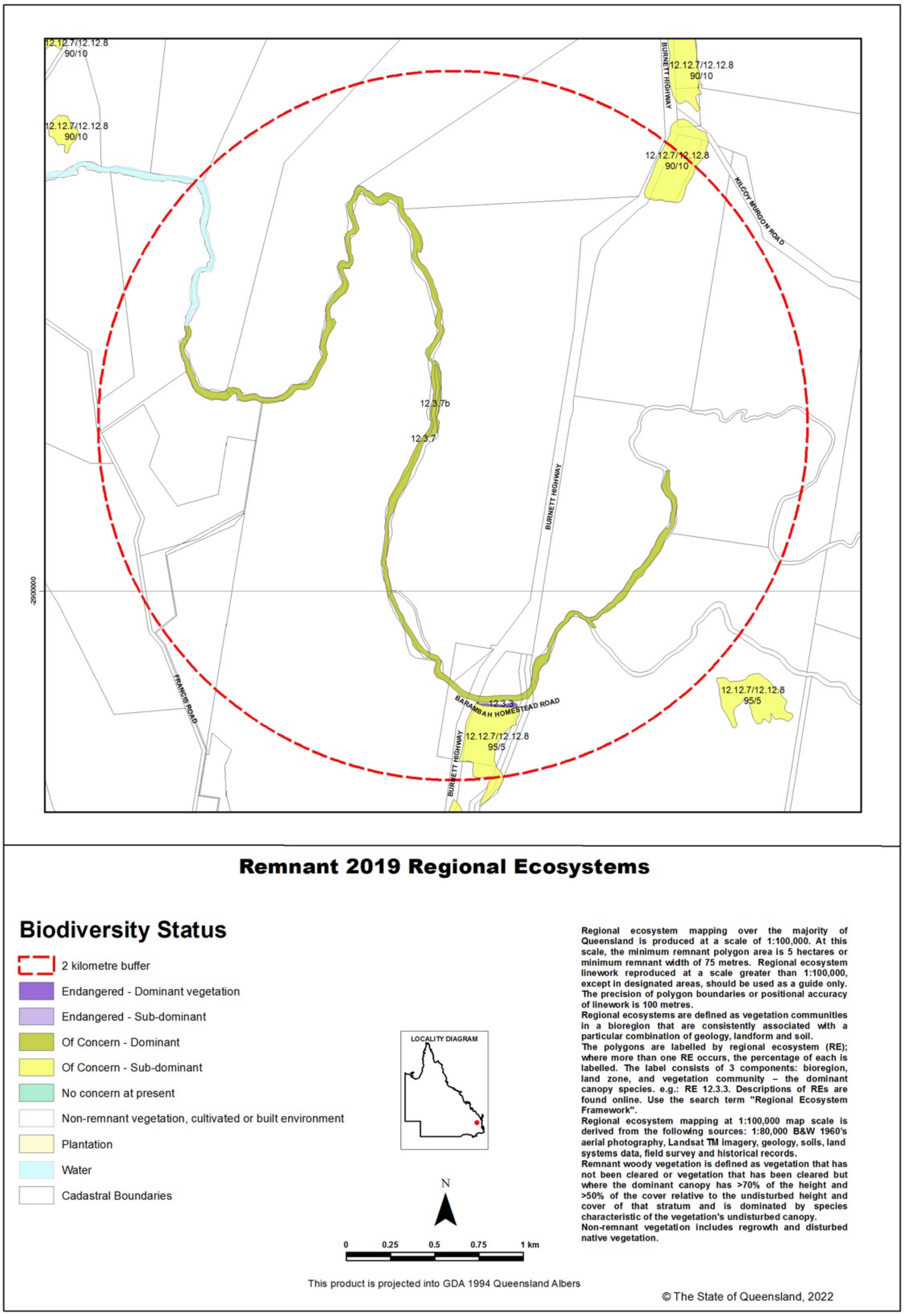

Figure 6 – Remnant 2019 Regional Ecosystems

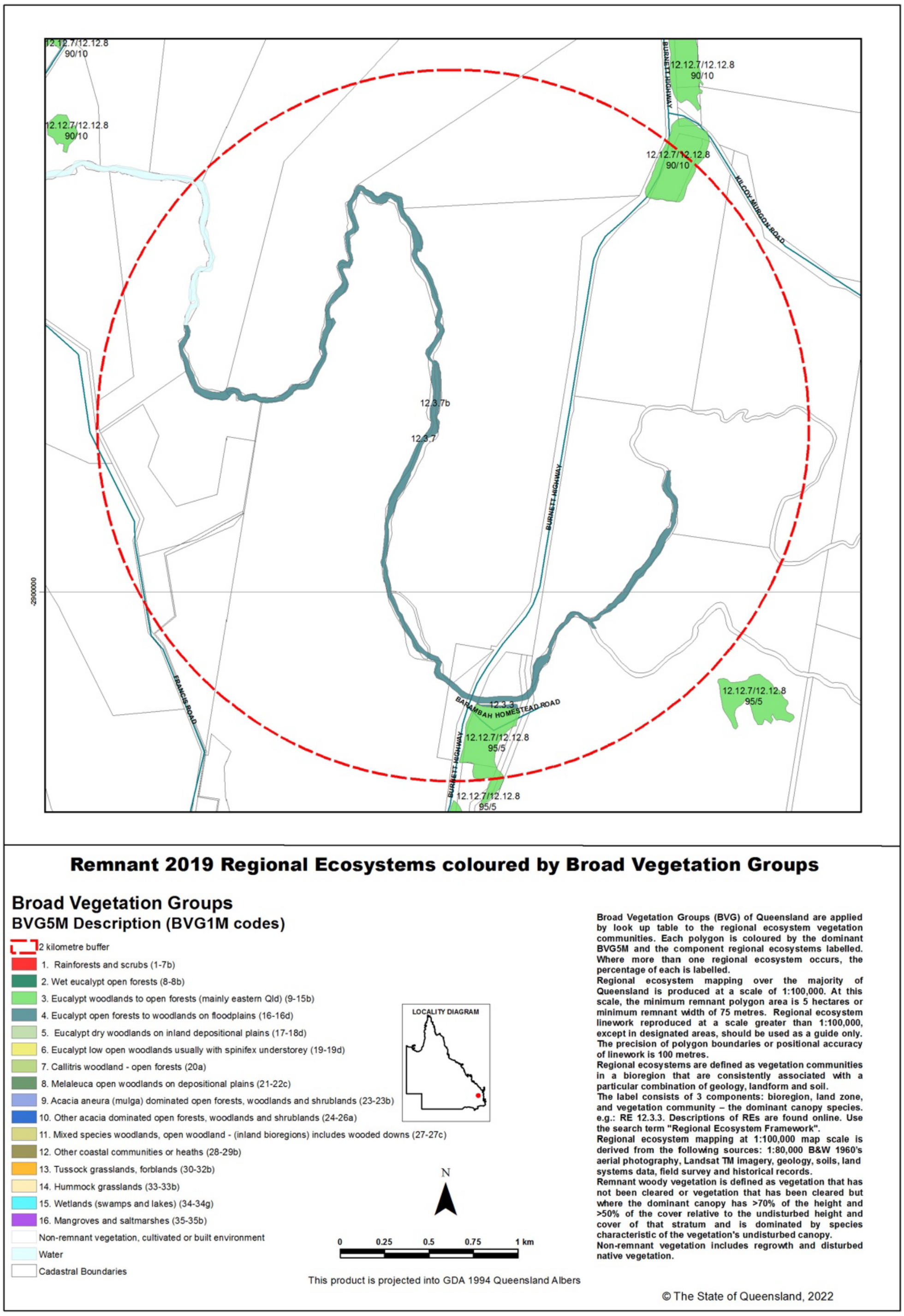

Figure 7 - Remnant 2019 Regional Ecosystems coloured by Broad Vegetation groups

3.2 WATER QUALITY

Water quality impacts have been described below reflecting the three stages of the project: weir construction, inundation, and post-inundation.

- Impacts to water quality at the site of weir construction and downstream of the weir are likely to occur due to disturbance of soil and sediment within the creek bed and banks. Best practice soil and sediment management will be required.
- Impacts to water quality may occur during the filling (inundation) behind the weir from an increase in nutrients and a decline in dissolved oxygen levels due to decaying vegetation within the submerged zone, for which offsets may be required. This will likely be a cyclical pattern as the storage area grows and shrinks over time in response to varying rainfall patterns. Management of vegetation, predicted to be inundated, will need to be considered.
- Impacts to water quality post inundation upstream of the weir may include the following:
    - potential for algal blooms that can be potentially toxic to livestock (e.g. cyanobacterial blooms) and cause a recreational hazard; and declined dissolved oxygen levels during and following algal bloom decay.
    - potential for water stratification and development of an anoxic zone (depletion of oxygen) at the bottom of the storage that will impact benthic organisms and potentially result in the release of nutriments and metals from the inundated soil into the overlying water column.
    - potential for water temperature to increase during low flow periods which can affect sensitive species.

3.3 HYDROLOGY

Construction of the weir will impact the volume, velocity and timing of flow in Baramabah Creek. It is acknowledged that two weirs exist downstream from the reference project and the confluence of Barambah and Barker Creeks. Irrespective, consideration will need to be given to understanding and managing environmental flows and downstream extraction requirements.

Construction of the weir will impede fish passage in Baramabah Creek. All native fish need to move between habitat areas at some stage in their life cycle to spawn, seek food, or find shelter; and for many species migrations over long extended distances are required to complete their life cycle[2] [3]. Consideration of fish passage across the weir will need to be considered.

[2] Thorncraft G.A. and Harris J.H. (1996). Assessment of rock-ramp fishways. Report for the Environmental Trusts, NSW Environmental Protection Authority, Border Rivers Commission, Department of Land and Water Resources, and Wyong Council. Fisheries Research Institute, Cronulla.

[3] Smith, A.K, and Pollard, D.A. (1998). Policy and guidelines. NSW Fisheries Office of Conservation, Sydney. 76 pp.

4 Potential environmental offset costs

4.1 METHODOLOGY

The extent and range of environmental offset costs are to a large extent unknown at this stage and will be highly dependent on the findings of the detailed ecological survey and the outcomes of the regulatory approvals process. The method of providing offsets either through direct delivery by the project proponent or by financial settlement with the State government will also have a large impact on costs. As a high-level guide for potential offsets costs the loss of mapped koala habitat in the inundation area using the financial settlement method is used.

The Queensland Government's Financial Settlement Offset Calculator was used to estimate a range of potential environmental offset costs for the West Barambah Weir and inundation area. Table 11 outlines the criteria was used in estimating a financial settlement for the West Barambah Weir based on the dominant regional ecosystem type that will be inundated as shown in Figure 6, Table 12 and described in Table 13.

Table 11 - Criteria used in the Financial Settlement Offset Calculator for the West Barambah Weir project.

Question	Selection
Section	Terrestrial / Southern Burnett Regional Council
Bioregion	Southeast Queensland
Subregion	Brisbane - Barambah Volcanics
Distinct matter area	24.3 ha*
Matter group	Regional ecosystem /*Eucalyptus tereticornis*, *Casuarina cunninghamiana* subsp. *cunninghamiana* +/- *Melaleuca spp*. Fringing woodland
DMA notional offset area	97.2 ha

*based on regional ecosystem 12.3.7 - Habitat for an extensive range of aquatic flora and fauna. This ecosystem is known to provide suitable habitat for koalas (*Phascolarctos cinereus*). 12.3.7a: This ecosystem is known to provide suitable habitat for koalas (*Phascolarctos cinereus*). 12.3.7c: This ecosystem is known to provide suitable habitat for koalas (*Phascolarctos cinereus*). 12.3.7d: This ecosystem is known to provide suitable habitat for koalas (*Phascolarctos cinereus*).

Table 12 - Remnant regional ecosystems, description, and status within the AOI.

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
12.12.7	Eucalyptus crebra woodland on Mesozoic to Proterozoic igneous rocks	No concern at present	13.31	1.06
12.12.8	Eucalyptus melanophloia woodland on Mesozoic to Proterozoic igneous rocks	Of concern	1.01	0.08
12.3.3	Eucalyptus tereticornis woodland on Quaternary alluvium	Endangered	0.33	0.03
12.3.7	Eucalyptus tereticornis, Casuarina cunninghamiana subsp. cunninghamiana +/- Melaleuca spp. fringing woodland	Of concern	24.3	1.93
12.3.7b	Eucalyptus tereticornis, Casuarina cunninghamiana subsp. cunninghamiana +/- Melaleuca spp. fringing woodland	Of concern	0.86	0.07
non-remnant	None	None	1,213.64	96.58
water	None	None	3.11	0.25

Source: Regional Ecosystems Report (Attachment IV)

Table 13 - Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
12.12.7	Potential habitat for NCA listed species: Callitris baileyi, Cycas megacarpa. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
12.12.8	Potential habitat for NCA listed species: Coleus omissus. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
12.3.3	Habitat for threatened plant species including Rhaponticum australe. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.3a: Habitat for threatened plant species including occasional Rhaponticum australe. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.3b: Habitat for threatened flora species including Melaleuca irbyana. 12.3.3c: Habitat for threatened flora species including Melaleuca irbyana and Marsdenia coronata. 12.3.3d: Habitat for threatened plant species including Rhaponticum australe. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
12.3.7	Habitat for an extensive range of aquatic flora and fauna. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7a: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7c: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7d: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
12.3.7b	Habitat for an extensive range of aquatic flora and fauna. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7a: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7c: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7d: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
non-remnant	None
water	None

Source: Regional Ecosystems Report (Attachment IV)

4.2 FINANCIAL SETTLEMENT

An indicative financial settlement to offset the inundation of 24.3 ha of regional ecosystem /*Eucalyptus tereticornis*, *Casuarina cunninghamiana* subsp. *cunninghamiana* +/- *Melaleuca spp*. Fringing woodland is estimated to be $2,642,284.80 (Table 14).

Table 14 - Environmental offsets calculator results

Payment details	Cost
Non-protected area cost	
On ground cost	$1,944,000.00
Landholder incentive payment	$212,284.80
Administrative costs	$486,000.00
Total non-protected area cost	$2,642,284.80
Protected area cost	
Total protected area costs	$0.00
Total cost	
Grand total	$2,642,284.80

Appendix I EPBC Act Protected Matters Report

Australian Government
Department of Agriculture, Water and the Environment

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 07-Sep-2022

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	3
Listed Threatened Species:	37
Listed Migratory Species:	14

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	20
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	1
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text
Lowland Rainforest of Subtropical Australia	Critically Endangered	Community may occur within area
Poplar Box Grassy Woodland on Alluvial Plains	Endangered	Community may occur within area
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically Endangered	Community may occur within area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text
BIRD		
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calyptorhynchus lathami lathami		
South-eastern Glossy Black-Cockatoo [67036]	Vulnerable	Species or species habitat may occur within area
Erythrotriorchis radiatus		
Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area
Falco hypoleucos		
Grey Falcon [929]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Geophaps scripta scripta Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat may occur within area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat may occur within area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat likely to occur within area
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Turnix melanogaster Black-breasted Button-quail [923]	Vulnerable	Species or species habitat likely to occur within area
FROG		
Mixophyes fleayi Fleay's Frog [25960]	Endangered	Species or species habitat may occur within area
MAMMAL		
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area
Dasyurus maculatus maculatus (SE mainland population) Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Macroderma gigas		
Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area
Nyctophilus corbeni		
Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable	Species or species habitat may occur within area
Petauroides volans		
Greater Glider (southern and central) [254]	Endangered	Species or species habitat likely to occur within area
Petaurus australis australis		
Yellow-bellied Glider (south-eastern) [87600]	Vulnerable	Species or species habitat may occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT)		
Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Endangered	Species or species habitat likely to occur within area
Pteropus poliocephalus		
Grey-headed Flying-fox [186]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
PLANT		
Arthraxon hispidus		
Hairy-joint Grass [9338]	Vulnerable	Species or species habitat may occur within area
Bosistoa transversa		
Three-leaved Bosistoa, Yellow Satinheart [16091]	Vulnerable	Species or species habitat may occur within area
Cadellia pentastylis		
Ooline [9828]	Vulnerable	Species or species habitat may occur within area
Cossinia australiana		
Cossinia [3066]	Endangered	Species or species habitat likely to occur within area
Denhamia parvifolia		
Small-leaved Denhamia [18106]	Vulnerable	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Dichanthium setosum bluegrass [14159]	Vulnerable	Species or species habitat likely to occur within area
Haloragis exalata subsp. velutina Tall Velvet Sea-berry [16839]	Vulnerable	Species or species habitat may occur within area
Lepidium peregrinum Wandering Pepper-cress [14035]	Endangered	Species or species habitat may occur within area
Phebalium distans Mt Berryman Phebalium [81869]	Endangered	Species or species habitat likely to occur within area
Rhodamnia rubescens Scrub Turpentine, Brown Malletwood [15763]	Critically Endangered	Species or species habitat may occur within area
Rhodomyrtus psidioides Native Guava [19162]	Critically Endangered	Species or species habitat may occur within area
Thesium australe Austral Toadflax, Toadflax [15202]	Vulnerable	Species or species habitat likely to occur within area
REPTILE		
Delma torquata Adorned Delma, Collared Delma [1656]	Vulnerable	Species or species habitat may occur within area
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat may occur within area
Elseya albagula Southern Snapping Turtle, White-throated Snapping Turtle [81648]	Critically Endangered	Species or species habitat likely to occur within area
Furina dunmalli Dunmall's Snake [59254]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text
Migratory Marine Birds		
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cuculus optatus		
Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Hirundapus caudacutus		
White-throated Needletail [682]	Vulnerable	Species or species habitat likely to occur within area
Monarcha melanopsis		
Black-faced Monarch [609]		Species or species habitat likely to occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca		
Satin Flycatcher [612]		Species or species habitat likely to occur within area
Rhipidura rufifrons		
Rufous Fantail [592]		Species or species habitat likely to occur within area
Symposiachrus trivirgatus as Monarcha trivirgatus		
Spectacled Monarch [83946]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area

Scientific Name	Threatened Category	Presence Text
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text
Bird		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area overfly marine area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat likely to occur within area overfly marine area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat likely to occur within area overfly marine area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat likely to occur within area overfly marine area
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat may occur within area overfly marine area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area overfly marine area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area

Scientific Name	Threatened Category	Presence Text
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat likely to occur within area overfly marine area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat likely to occur within area overfly marine area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area overfly marine area
Symposiachrus trivirgatus as Monarcha trivirgatus Spectacled Monarch [83946]		Species or species habitat may occur within area overfly marine area

Extra Information

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status
Not controlled action			
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Appendix II Biodiversity and Conservation Values

Queensland Government

Department of Environment and Science

Environmental Reports

Biodiversity and Conservation Values

Biodiversity Planning Assessments and Aquatic Conservation Assessments

For the selected area of interest
Longitude: 152.068547 Latitude: -26.309792 with 2 kilometre radius

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or Area of Interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "Central co-ordinates" option, the resulting assessment area encompasses an area extending from 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: biodiversity.planning@des.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

Table of Contents

Summary Information

Tables 1 to 8 provide an overview of the AOI with respect to selected topographic and environmental values.

Table 1: Area of interest details: Longitude: 152.068547 Latitude: -26.309792

Size (ha)	1,256.55
Local Government(s)	Gympie Regional, South Burnett Regional
Bioregion(s)	Southeast Queensland
Subregion(s)	Brisbane - Barambah Volcanics
Catchment(s)	Burnett

The following table identifies available Biodiversity Planning Assessments (BPAs) and Aquatic Conservation Assessments (ACAs) with respect to the AOI.

Table 2: Available Biodiversity Planning and Aquatic Conservation Assessments

Assessment Type	Assessment Area and Version
Biodiversity Planning Assessment(s)	Southeast Queensland v4.1
Aquatic Conservation Assessment(s) (riverine)	Wide Bay-Burnett Catchments v1.1
Aquatic Conservation Assessment(s) (non-riverine)	Wide Bay-Burnett Catchments v1.1

Table 3: Remnant regional ecosystems within the AOI as per the Qld Herbarium's 'biodiversity status'

Biodiversity Status	Area (Ha)	% of AOI
Endangered	0.33	0.03
Of concern	26.17	2.08
No concern at present	13.31	1.06

The following table identifies the extent and proportion of the user specified area of interest (AOI) which is mapped as being of "State", "Regional" or "Local" significance via application of the Queensland Department of Environment and Science's *Biodiversity Assessment and Mapping Methodology* (BAMM).

Table 4: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	0.0	0.0
State	8.71	0.69
Regional	0.0	0.0
Local or Other Values	5.94	0.47

Table 5: Non-riverine wetlands intersecting the AOI

Non-riverine wetland types intersecting the area of interest	#
(No Records)	

NB. The figures presented in the table above are derived from the relevant non-riverine Aquatic Conservation Assessment(s). Later releases of wetland mapping produced via the Queensland Wetland Mapping Program may provide more recent *information in regards to wetland extent.*

Table 6: Named waterways intersecting the AOI

Name	Permanency
BARAMBAH CREEK	Non-perennial

Refer to **Map 1** for general locality information.

The following two tables identify the extent and proportion of the user specified AOI which is mapped as being of "Very High", "High", "Medium", "Low", or "Very Low" aquatic conservation value for riverine and non-riverine wetlands via application of the Queensland Department of Environment and Science's *Aquatic Biodiversity Assessment and Mapping Method* (AquaBAMM).

Table 7: Summary table, aquatic conservation significance (riverine)

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	916.49	72.94
High	340.06	27.06
Medium	0.0	0.0
Low	0.0	0.0
Very Low	0.0	0.0

Table 8: Summary table, aquatic conservation significance (non-riverine)

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
(No Records)		

Biodiversity Planning Assessments

Introduction

The Department of Environment and Science (DES) attributes biodiversity significance on a bioregional scale through a Biodiversity Planning Assessment (BPA). A BPA involves the integration of ecological criteria using the *Biodiversity assessment and Mapping Methodology* (BAMM) and is developed in two stages: 1) **diagnostic criteria**, and 2) **expert panel criteria**. The diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion, while the expert panel criteria allows for the refinement of the mapped information from the diagnostic output by incorporating local knowledge and expert opinion.

The BAMM methodology has application for identifying areas with various levels of significance solely for biodiversity reasons. These include threatened ecosystems or taxa, large tracts of habitat in good condition, ecosystem diversity, landscape context and connection, and buffers to wetlands or other types of habitat important for the maintenance of biodiversity or ecological processes. While natural resource values such as dryland salinity, soil erosion potential or land capability are not dealt with explicitly, they are included to some extent within the biodiversity status of regional ecosystems recognised by the DES.

Biodiversity Planning Assessments (BPAs) assign three levels of overall biodiversity significance.

- **State significance** - areas assessed as being significant for biodiversity at the bioregional or state scales. They also include areas assessed by other studies/processes as being significant at national or international scales. In addition, areas flagged as being of State significance due to the presence of endangered, vulnerable and/or near threatened taxa, are identified as "State Habitat for EVNT taxa".
- **Regional significance** - areas assessed as being significant for biodiversity at the subregional scale. These areas have lower significance for biodiversity than areas assessed as being of State significance.
- **Local significance and/or other values** - areas assessed as not being significant for biodiversity at state or regional scales. Local values are of significance at the local government scale.

For further information on released BPAs and a copy of the underlying methodology, go to:

http://www.qld.gov.au/environment/plants-animals/biodiversity/planning/

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

The following table identifies the extent and proportion of the user specified AOI which is mapped as being of "State", "Regional" or "Local" significance via application of the BAMM.

Table 9: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	0.0	0.0
State	8.71	0.69
Regional	0.0	0.0
Local or Other Values	5.94	0.47

Refer to **Map 2** for further information.

Diagnostic Criteria

Diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion. These criteria are diagnostic in that they are used to filter the available data and provide a "first-cut" or initial determination of biodiversity significance. This initial assessment is then combined through a second group of other essential criteria.

A description of the individual diagnostic criteria is provided in the following sections.

Criteria A. Habitat for EVNT taxa: Classifies areas according to their significance based on the presence of endangered, vulnerable and/or rare (EVNT) taxa. EVNT taxa are those scheduled under the *Nature Conservation Act 1992* and/or the

Environment Protection and Biodiversity Conservation Act 1999. It excludes highly mobile fauna taxa which are instead considered in Criterion H and brings together information on EVNT taxa using buffering of recorded sites or habitat suitability models (HSM) where available.

Criteria B. Ecosystem value: Classifies on the basis of biodiversity status of regional ecosystems, their extent in protected areas (presence of poorly conserved regional ecosystems), the presence of significant wetlands; and areas of national importance such as the presence of Threatened Ecological Communities, World Heritage areas and Ramsar sites. Ecosystem value is applied at a bioregional (**B1**) and regional (**B2**) scale.

Criteria C. Tract size: Measures the relative size of tracts of vegetation in the landscape. The size of any tract is a major indicator of ecological significance, and is also strongly correlated with the long-term viability of biodiversity values. Larger tracts are less susceptible to ecological edge effects and are more likely to sustain viable populations of native flora and fauna than smaller tracts.

Criteria D. Relative size of regional ecosystems: Classifies the relative size of each regional ecosystem unit within its bioregion (**D1**) and its subregion (**D2**). Remnant units are compared with all other occurrences with the same regional ecosystem. Large examples of a regional ecosystem are more significant than smaller examples of the same regional ecosystem because they are more representative of the biodiversity values particular to the regional ecosystem, are more resilient to the effects of disturbance, and constitute a significant proportion of the total area of the regional ecosystem.

Criteria F. Ecosystem diversity: Is an indicator of the number of regional ecosystems occurring within an area. An area with high ecosystem diversity will have many regional ecosystems and ecotones relative to other areas within the bioregion.

Criteria G. Context and connection: Represents the extent to which a remnant unit incorporates, borders or buffers areas such as significant wetlands, endangered ecosystems; and the degree to which it is connected to other vegetation.

A summary of the biodiversity status based upon the diagnostic criteria is provided in the following table.

Table 10: Summary of biodiversity significance based upon diagnostic criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
Local or Other Values	Refer to diagnostic data for additional information	14.65	1.17

Assessment of diagnostic criteria with respect to the AOI

The following table reflects an assessment of the individual diagnostic criteria noted above in regards to the AOI.

Table 11: Assessment of individual diagnostic criteria with respect to the AOI

Diagnostic Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
A: Habitat for EVNT Taxa					14.65	1.2		
B1: Ecosystem Value (Bioregion)					14.65	1.2		
B2: Ecosystem Value (Subregion)			14.65	1.2				
C: Tract Size							14.65	1.2
D1: Relative RE Size (Bioregion)							14.65	1.2
D2: Relative RE Size (Subregion)							14.65	1.2
F: Ecosystem Diversity							14.65	1.2
G: Context and Connection	5.21	0.4			3.5	0.3	5.94	0.5

Other Essential Criteria

Other essential criteria (also known as expert panel criteria) are based on non-uniform information sources and which may rely more upon expert opinion than on quantitative data. These criteria are used to provide a "second-cut" determination of biodiversity significance, which is then combined with the diagnostic criteria for an overall assessment of relative biodiversity significance. A summary of the biodiversity status based upon the other essential criteria is provided in the following table.

Table 12: Summary of biodiversity significance based upon other essential criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Remnant forms part of a bioregional corridor (J)	8.71	0.69

A description of each of the other essential criteria and associated assessment in regards to the AOI is provided in the following sections.

Criteria H. Essential and general habitat for priority taxa: Priority taxa are those which are at risk or of management concern, taxa of scientific interest as relictual (ancient or primitive), endemic taxa or locally significant populations (such as a flying fox camp or heronry), highly specialised taxa whose habitat requirements are complex and distributions are not well correlated with any particular regional ecosystem, taxa important for maintaining genetic diversity (such as complex spatial patterns of genetic variation, geographic range limits, highly disjunct populations), taxa critical for management or monitoring of biodiversity (functionally important or ecological indicators), or economic and culturally important taxa.

Criteria I. Special biodiversity values: areas with special biodiversity values are important because they contain multiple taxa in a unique ecological and often highly biodiverse environment. Areas with special biodiversity values can include the following:

- Ia - centres of endemism - areas where concentrations of taxa are endemic to a bioregion or subregion are found.
- Ib - wildlife refugia (Morton *et al*. 1995), for example, islands, mound springs, caves, wetlands, gorges, mountain ranges and topographic isolates, ecological refuges, refuges from exotic animals, and refuges from clearing. The latter may include large areas that are not suitable for clearing because of land suitability/capability.
- Ic - areas with concentrations of disjunct populations.
- Id - areas with concentrations of taxa at the limits of their geographic ranges.
- Ie - areas with high species richness.
- If - areas with concentrations of relictual populations (ancient and primitive taxa).
- Ig - areas containing REs with distinct variation in species composition associated with geomorphology and other environmental variables.
- Ih - an artificial waterbody or managed/manipulated wetland considered by the panel/s to be of ecological significance.
- Ii - areas with a high density of hollow-bearing trees that provide habitat for animals.
- Ij - breeding or roosting sites used by a significant number of individuals.
- Ik - climate change refuge.

The following table identifies the value and extent area of the Other Essential Criteria H and I within the AOI.

Table 13: Relative importance of expert panel criteria (H and I) used to access overall biodiversity significance with respect to the AOI

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
H: Core Habitat Priority Taxa					4.92	0.4	9.73	0.8
Ia: Centres of Endemism								
Ib: Wildlife Refugia								
Ic: Disjunct Populations								
Id: Limits of Geographic Ranges								
Ie: High Species Richness								
If: Relictual Populations								
Ig: Variation in Species Composition								
Ih: Artificial Wetland								

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
Ii: Hollow Bearing Trees								
Ij: Breeding or Roosting Site								
Ik: Climate Refugia								

NB. Whilst biodiversity values associated with Criteria I may be present within the site (refer to tables 12 and 15), for the New England Tableland and Central Queensland Coast BPAs, area and % area figures associated with Criteria Ia through to Ij cannot be listed in the table above (due to slight variations in data formats between BPAs).

Criteria J. Corridors: areas identified under this criterion qualify either because they are existing vegetated corridors important for contiguity, or cleared areas that could serve this purpose if revegetated. Some examples of corridors include riparian habitats, transport corridors and "stepping stones".

Bioregional and subregional conservation corridors have been identified in the more developed bioregions of Queensland through the BPAs, using an intensive process involving expert panels. Map 3 displays the location of corridors as identified under the Statewide Corridor network. The Statewide Corridor network incorporates BPA derived corridors and for bioregions where no BPA has been assessed yet, corridors derived under other planning processes. *Note: as a result of updating and developing a statewide network, the alignment of corridors may differ slightly in some instances when compared to those used in individual BPAs.*

The functions of these corridors are:

- **Terrestrial** Bioregional corridors, in conjunction with large tracts of remnant vegetation, maintain ecological and evolutionary processes at a landscape scale, by:

  • Maintaining long term evolutionary/genetic processes that allow the natural change in distributions of species and connectivity between populations of species over long periods of time;

  • Maintaining landscape/ecosystems processes associated with geological, altitudinal and climatic gradients, to allow for ecological responses to climate change;

  • Maintaining large scale seasonal/migratory species processes and movement of fauna;

  • Maximising connectivity between large tracts/patches of remnant vegetation;

  • Identifying key areas for rehabilitation and offsets; and

- **Riparian** Bioregional Corridors also maintain and encourage connectivity of riparian and associated ecosystems.

The location of the corridors is determined by the following principles:

- Terrestrial

  • Complement riparian landscape corridors (i.e. minimise overlap and maximise connectivity);

  • Follow major watershed/catchment and/or coastal boundaries;

  • Incorporate major altitudinal/geological/climatic gradients;

  • Include and maximise connectivity between large tracts/patches of remnant vegetation;

  • Include and maximise connectivity between remnant vegetation in good condition; and

- Riparian

  • Located on the major river or creek systems within the bioregion in question.

The total extent of remnant vegetation triggered as being of "State", "Regional" or "Local" significance due to the presence of an overlying BPA derived terrestrial or riparian corridor within the AOI, is provided in the following table. For further information on how remnant vegetation is triggered due to the presence of an overlying BPA derived corridor, refer to the relevant landscape BPA expert panel report(s).

Table 14: Extent of triggered remnant vegetation due to the presence of BPA derived corridors with respect to the AOI

Biodiversity Significance	Area (Ha)	% of AOI
State	8.71	0.69
Regional	0.0	0.0
Local	0.0	0.0

NB: area figures associated with the extent of corridor triggered remnant vegetation are only available for those bioregions where a BPA has been undertaken.

Refer to **Map 3** for further information.

Threatening process/condition (Criteria K) - areas identified by experts under this criterion may be used to amend (upgrade or downgrade) biodiversity significance arising from the "first-cut" analysis. The condition of remnant vegetation is affected by threatening processes such as weeds, ferals, grazing and burning regime, selective timber harvesting/removal, salinity, soil erosion, and climate change.

Assessment of Criteria K with respect to the AOI is not currently included in the "Biodiversity and Conservation Values" report, as it has not been applied to the majority of Queensland due to data/information limitations and availability.

Special Area Decisions

Expert panel derived "Special Area Decisions" are used to assign values to Other Essential Criteria. The specific decisions which relate to the AOI in question are listed in the table below.

Table 15: Expert panel decisions for assigning levels of biodiversity significance with respect to the AOI

Decision Number	Description	Panel Recommended Significance	Criteria Values
seqn_l_13	Riparian bioregional corridors	State	Criterion J

Expert panel decision descriptions:

seqn_l_13

The riparian bioregional corridors provide connectivity through lowland areas of SEQ.

See Table 4 for list of waterways considered riparian corridors.

For further information, refer to sections 2.3.2 and 3.2 of this report.

Aquatic Conservation Assessments

Introduction

The Aquatic Biodiversity Assessment and Mapping Method or AquaBAMM (Clayton *et al.* 2006), was developed to assess conservation values of wetlands in queensland, and may also have application in broader geographical contexts. It is a comprehensive method that uses available data, including data resulting from expert opinion, to identify relative wetland conservation/ecological values within a specified study area (usually a catchment). The product of applying this method is an Aquatic Conservation Assessment (ACA) for the study area.

An ACA using AquaBAMM is non-social, non-economic and identifies the conservation/ecological values of wetlands at a user-defined scale. It provides a robust and objective conservation assessment using criteria, indicators and measures that are founded upon a large body of national and international literature. The criteria, each of which may have variable numbers of indicators and measures, are naturalness (aquatic), naturalness (catchment), diversity and richness, threatened species and ecosystems, priority species and ecosystems, special features, connectivity and representativeness. An ACA using AquaBAMM is a powerful decision support tool that is easily updated and simply interrogated through a geographic information system (GIS).

Where they have been conducted, ACAs can provide a source of baseline wetland conservation/ecological information to support natural resource management and planning processes. They are useful as an independent product or as an important foundation upon which a variety of additional environmental and socio-economic elements can be added and considered (i.e. an early input to broader 'triple-bottom-line' decision-making processes). An ACA can have application in:

- determining priorities for protection, regulation or rehabilitation of wetlands and other aquatic ecosystems
- on-ground investment in wetlands and other aquatic ecosystems
- contributing to impact assessment of large-scale development (e.g. dams)
- water resource and strategic regional planning prcesses

For a detailed explanation of the methodology please refer to the summary and expert panel reports relevant to the ACA utilised in this assessment. These reports can be accessed at Wetland *Info*:

http://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

Explanation of Criteria

Under the AquaBAMM, eight criteria are assessed to derive an overall conservation value. Similar to the Biodiversity Assessment and Mapping Methodology, the criteria may be primarily diagnostic (quantitative) or primarily expert opinion (qualitative) in nature. The following sections provide a brief description of each of the 8 criteria.

Criteria 1. Naturalness - Aquatic: This attribute reflects the extent to which a wetland's (riverine, non-riverine, estuarine) aquatic state of naturalness is affected through relevant influencing indicators which include: presence of exotic flora and fauna; presence of aquatic communities; degree of habitat modification and degree of hydrological modification.

Criteria 2. Naturalness - Catchment: The naturalness of the terrestrial systems of a catchment can have an influence on many wetland characteristics including: natural ecological processes e.g. nutrient cycling, riparian vegetation, water chemistry, and flow. The indicators utilised to assess this criterion include: presence of exotic flora and/or fauna; riparian, catchment and flow modification.

Criteria 3. Naturalness - Diversity and Richness: This criterion is common to many ecological assessment methods and can include both physical and biological features. It includes such indicators as species richness, riparian ecosystem richness and geomorphological diversity.

Criteria 4. Threatened Species and Ecosystems: This criterion evaluates ecological rarity characteristics of a wetland. This includes both species rarity and rarity of communities / assemblages. The communities and assemblages are best represented by regional ecosystems. Species rarity is determined by NCA and EPBC status with Endangered, Vulnerable or Near-threatened species being included in the evaluation. Ecosystem rarity is determined by regional ecosystem biodiversity status i.e. Endangered, Of Concern, or Not of Concern.

Criteria 5. Priority Species and Ecosystems: Priority flora and fauna species lists are expert panel derived. These are aquatic, semi-aquatic and riparian species which exhibit at least 1 particular trait in order to be eligible for consideration. For flora species the traits included:

- It forms significant macrophyte beds (in shallow or deep water).
- It is an important food source.
- It is important/critical habitat.
- It is implicated in spawning or reproduction for other fauna and/or flora species.
- It is at its distributional limit or is a disjunct population.
- It provides stream bank or bed stabilisation or has soil binding properties.
- It is a small population and subject to threatening processes.

Fauna species are included if they meet at least one of the following traits:

- It is endemic to the study area (>75 per cent of its distribution is in the study area/catchment).
- It has experienced, or is suspected of experiencing, a serious population decline.
- It has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area/catchment.
- It is currently a small population and threatened by loss of habitat.
- It is a significant disjunct population.
- It is a migratory species (other than birds).
- A significant proportion of the breeding population (>one per cent for waterbirds, >75 per cent other species) occurs in the waterbody (see Ramsar criterion 6 for waterbirds).
- Limit of species range.

See the individual expert panel reports for the priority species traits specific to an ACA.

Criteria 6. Special Features: Special features are areas identified by flora, fauna and ecology expert panels which exhibit characteristics beyond those identified in other criteria and which the expert panels consider to be of the highest ecological importance. Special feature traits can relate to, but are not solely restricted to geomorphic features, unique ecological processes, presence of unique or distinct habitat, presence of unique or special hydrological regimes e.g. spring-fed streams. Special features are rated on a 1 - 4 scale (4 being the highest).

Criteria 7. Connectivity: This criterion is based on the concept that appropriately connected aquatic ecosystems are healthy and resilient, with maximum potential biodiversity and delivery of ecosystem services.

Criteria 8. Representativeness: This criterion applies primarily to non-riverine assessments, evaluates the rarity and uniqueness of a wetland type in relation to specific geographic areas. Rarity is determined by the degree of wetland protection within "protected Areas" estate or within an area subject to the *Fisheries Act 1994*, *Coastal Protection and Management Act 1995*, or *Marine Parks Act 2004*. Wetland uniqueness evaluates the relative abundance and size of a wetland or wetland management group within geographic areas such as catchment and subcatchment.

Riverine Wetlands

Riverine wetlands are all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created, periodically or continuously contain moving water, or connecting two bodies of standing water. AquaBAMM, when applied to riverine wetlands uses a discrete spatial unit termed subsections. A subsection can be considered as an area which encompasses discrete homogeneous stream sections in terms of their natural attributes (i.e. physical, chemical, biological and utilitarian values) and natural resources. Thus in an ACA, an aquatic conservation significance score is calculated for each subsection and applies to all streams within a subsection, rather than individual streams as such.

Please note, the area figures provided in Tables 16 and 17, are derived using the extent of riverine subsections within the AOI. Refer to **Map 5** for further information. A summary of the conservation significance of riverine wetlands within the AOI is provided in the following table.

Table 16: Overall level/s of riverine aquatic conservation significance

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	916.49	72.94

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
High	340.06	27.06
Medium	0.0	0.0
Low	0.0	0.0
Very Low	0.0	0.0

The individual aquatic conservation criteria ratings for riverine wetlands within the AOI are listed below.

Table 17: Level/s of riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic	340.06	27.1	916.49	72.9				
2. Naturalness catchment	1,174.14	93.4	82.41	6.6				
3. Diversity and richness					1,256.55	100.0		
4. Threatened species and ecosystems			916.49	72.9	257.65	20.5		
5. Priority species and ecosystems	916.49	72.9	257.65	20.5				
6. Special features	916.49	72.9						
7. Connectivity	340.06	27.1					916.49	72.9
8. Representative-ness								

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to riverine wetlands within the AOI.

Table 18: Expert panel decisions for assigning overall levels of riverine aquatic conservation significance

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
bu_r_fa_09	Flowing streams between impoundments	Burnett	6.3.1	4

4 is the highest rating/value

Expert panel decision descriptions:

bu_r_fa_09

The remaining fish diversity and the majority of the **Elseya sp.** and the Australian lungfish (**Neoceratodus forsteri**) populations will be retained in these flowing river sections in the future.

Note: This decision was taken from the previous Burnett River ACA (decision number afep_burn_5).

Non-riverine Wetlands

Non-riverine wetlands include both lacustrine and palustrine wetlands, however, do not currently incorporate estuarine, marine or subterranean wetland types. A summary of the conservation significance of non-riverine wetlands within the AOI is provided in the following table. Refer to **Map 6** for further information.

Table 19: Overall level/s of non-riverine aquatic conservation significance

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
(No Records)		

The following table provides an assessment of non-riverine wetlands within the AOI and associated aquatic conservation criteria values.

Table 20: Level/s of non-riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
(No Records)								

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to non-riverine wetlands within the AOI.

Table 21: Expert panel decisions for assigning overall levels of non-riverine aquatic conservation significance.

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
(No Records)				

4 is the highest rating/value

Expert panel decision descriptions:

(No Records)

Threatened and Priority Species

Introduction

This chapter contains a list of threatened and priority flora and/or fauna species that have been recorded on, or within 4km of the Assessment Area.

The information presented in this chapter with respect to species presence is derived from compiled databases developed primarily for the purpose of BPAs and ACAs. Data is collated from a number of sources and is updated periodically.

It is important to note that the list of species provided in this report, may differ when compared to other reports generated from other sources such as the State government's WildNet, Herbrecs or the federal government's EPBC database for a number of reasons.

Records for threatened and priority species are filtered and checked based on a number of rules including:

- Taxonomic nomenclature - current scientific names and status,
- Location - cross-check co-ordinates with location description,
- Taxon by location - requires good knowledge of the taxon and history of the record,
- Duplicate records - identify and remove,
- Expert panels - check records and provide new records,
- Flora cultivated records excluded,
- Use precise records less than or equal to 2000m,
- Use recent records greater than or equal to 1975 animals, greater than or equal to 1950 plants.

Threatened Species

Threatened species are those species classified as "Endangered" or "Vulnerable" under the *Environment Protection and Biodiversity Conservation Act 1999* or "Endangered", "Vulnerable" or "Near threatened" under the *Nature Conservation Act 1992*.

The following threatened species have been recorded on, or within approximately 4km of the AOI.

Table 22: Threatened species recorded on, or within 4km of the AOI

Species	Common name	NCA status	EPBC status	Back on Track rank	Migratory species*	Wetland species**	Identified flora/fauna
Phascolarctos cinereus	koala	E	E	Low			FA

NB. Please note that the threatened species listed in this section are based upon the most recently compiled DES internal state-wide threatened species dataset. This dataset may contain additional records that were not originally available for inclusion in the relevant individual BPAs and ACAs.

**JAMBA - Japan-Australia Migratory Bird Agreement; CAMBA - China-Australia Migratory Bird Agreement; ROKAMBA - Republic of Korea-Australia Migratory Bird Agreement; CMS - Convention on the Conservation of Migratory Species*.

***I - wetland indicator species; D - wetland dependent species.*.

BPA Priority Species

A list of BPA priority species that have been recorded on, or within approximately 4km of the AOI is contained in the following table.

Table 23: Priority species recorded on, or within 4km of the AOI

Species	Common name	Back on Track rank	Identified flora/fauna
Beyeria lasiocarpa	None	L	FL
Pomatostomus temporalis	Grey-crowned Babbler	None	FA

NB. Please note that the list of priority species is based on those species identified in the BPAs, however records for these species may be more recent than the originals used. furthermore, the BPA priority species databases are updated from time to time. At each update, the taxonomic details for all species are amended as necessary to reflect current taxonomic name and/or status changes.

ACA Priority Species

A list of ACA priority species used in riverine and non-riverine ACAs that have been recorded on, or within approximately 4km of the AOI are contained in the following tables.

Table 24: Priority species recorded on, or within 4 km of the AOI - riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Acrocephalus australis	Australian Reed-Warbler	Low	FA
Ardea alba modesta	Eastern Great Egret	Low	FA
Bacopa monnieri	None	None	FL
Haliaeetus leucogaster	White-bellied Sea-Eagle	Low	FA

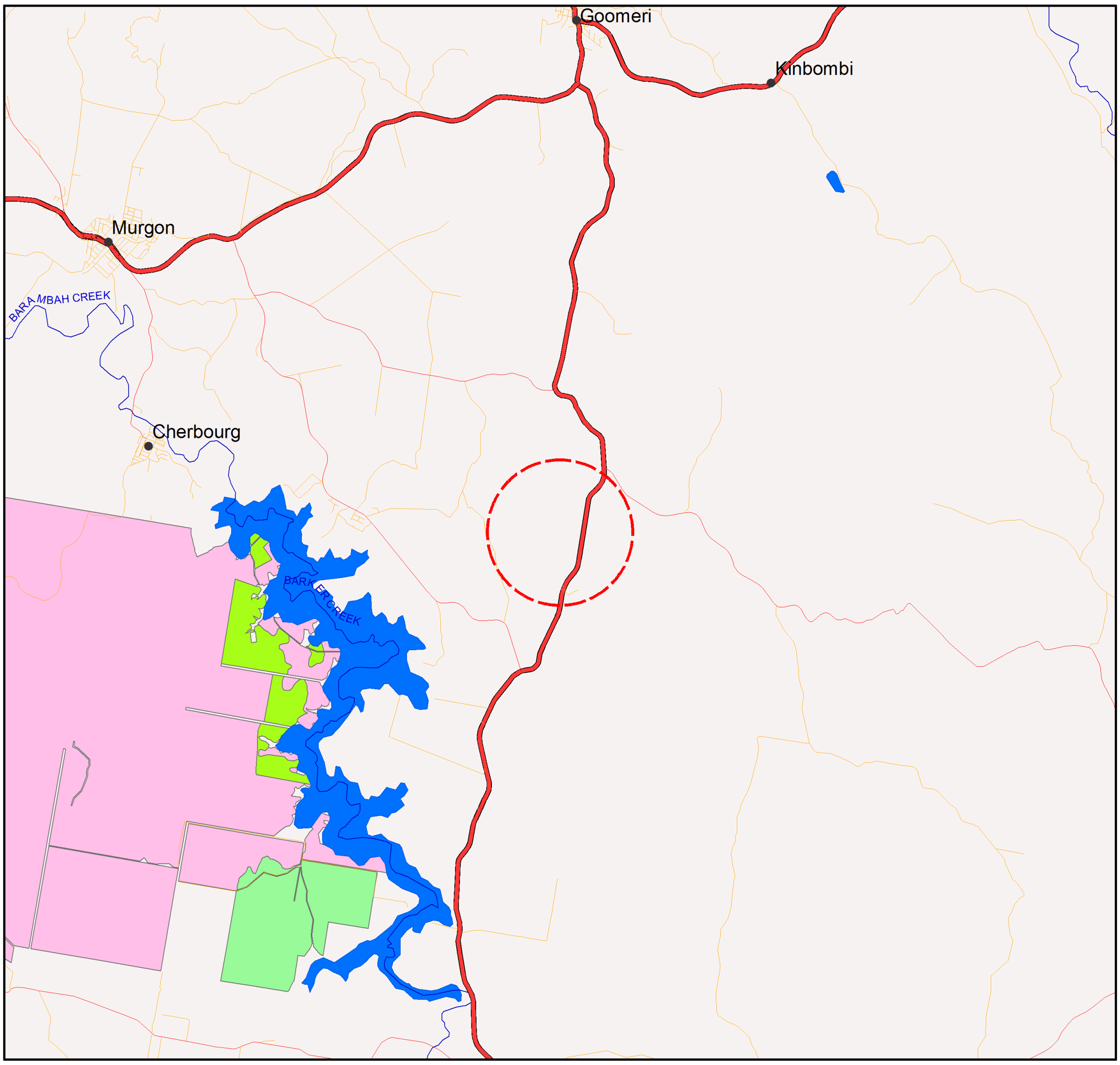
Table 25: Priority species recorded on, or within 4 km of the AOI - non-riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Acrocephalus australis	Australian Reed-Warbler	Low	FA
Ardea alba modesta	Eastern Great Egret	Low	FA
Bacopa monnieri	None	None	FL
Haliaeetus leucogaster	White-bellied Sea-Eagle	Low	FA

NB. Please note that the priority species records used in the above two tables are comprised of those adopted for the released individual ACAs. The ACA riverine and non-riverine priority species databases are updated from time to time to reflect new release of ACAs. At each update, the taxonomic details for all ACAs records are amended as necessary to reflect current taxonomic name and/or status changes.

Maps

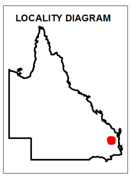
Map 1 - Locality Map



Locality Map

Legend

- 2 kilometre buffer
- Towns
- Highway
- Connector
- Street/Local Road
- Reservoirs
- Lakes
- National Park (Scientific)
- National Park
- National Park (CYPAL)
- Conservation Park
- Resources Reserve
- Forest Reserve
- State Forest
- Timber Reserve
- Nature Refuges
- Coordinated Conservation Areas
- Major rivers/creeks
- Queensland



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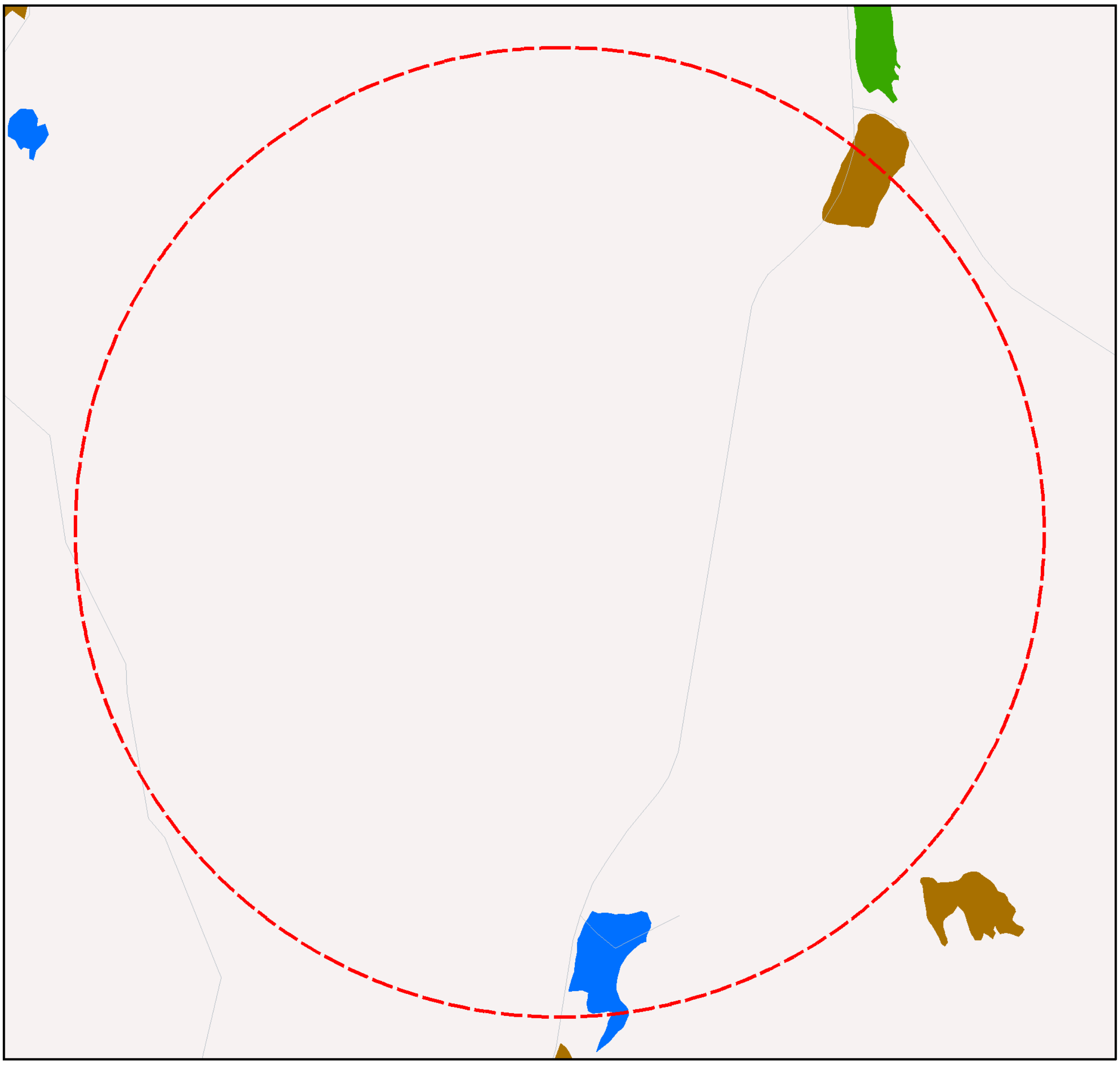
Map 2 - Biodiversity Planning Assessment (BPA)



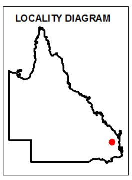
Biodiversity Planning Assessments

Legend

- 2 kilometre buffer
- Towns
- Roads
- Major rivers/creeks
- Queensland

Biodiversity Planning Assessment

- State Habitat for EVNT taxa
- State
- Regional
- Local or Other Values
- Non Bioregion Ecosystem



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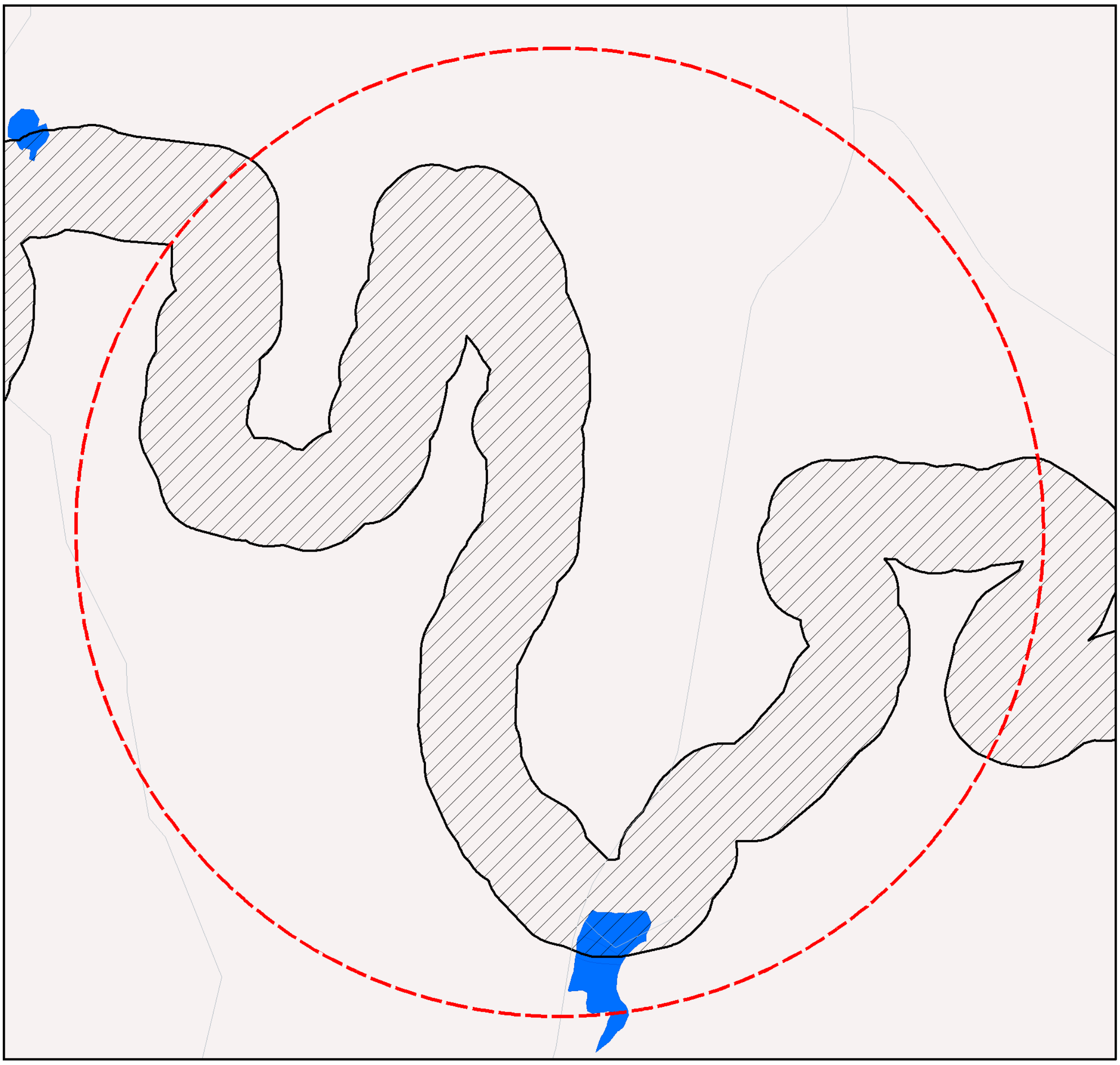
Map 3 - Corridors



Corridors

Legend

- 2 kilometre buffer
- Towns
- Roads
- Major rivers/creeks
- Queensland

Corridors

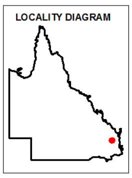
- State
- Regional

Corridor Triggered Vegetation

- State
- Regional
- Local

Core Area Vegetation

- Brigalow Belt only



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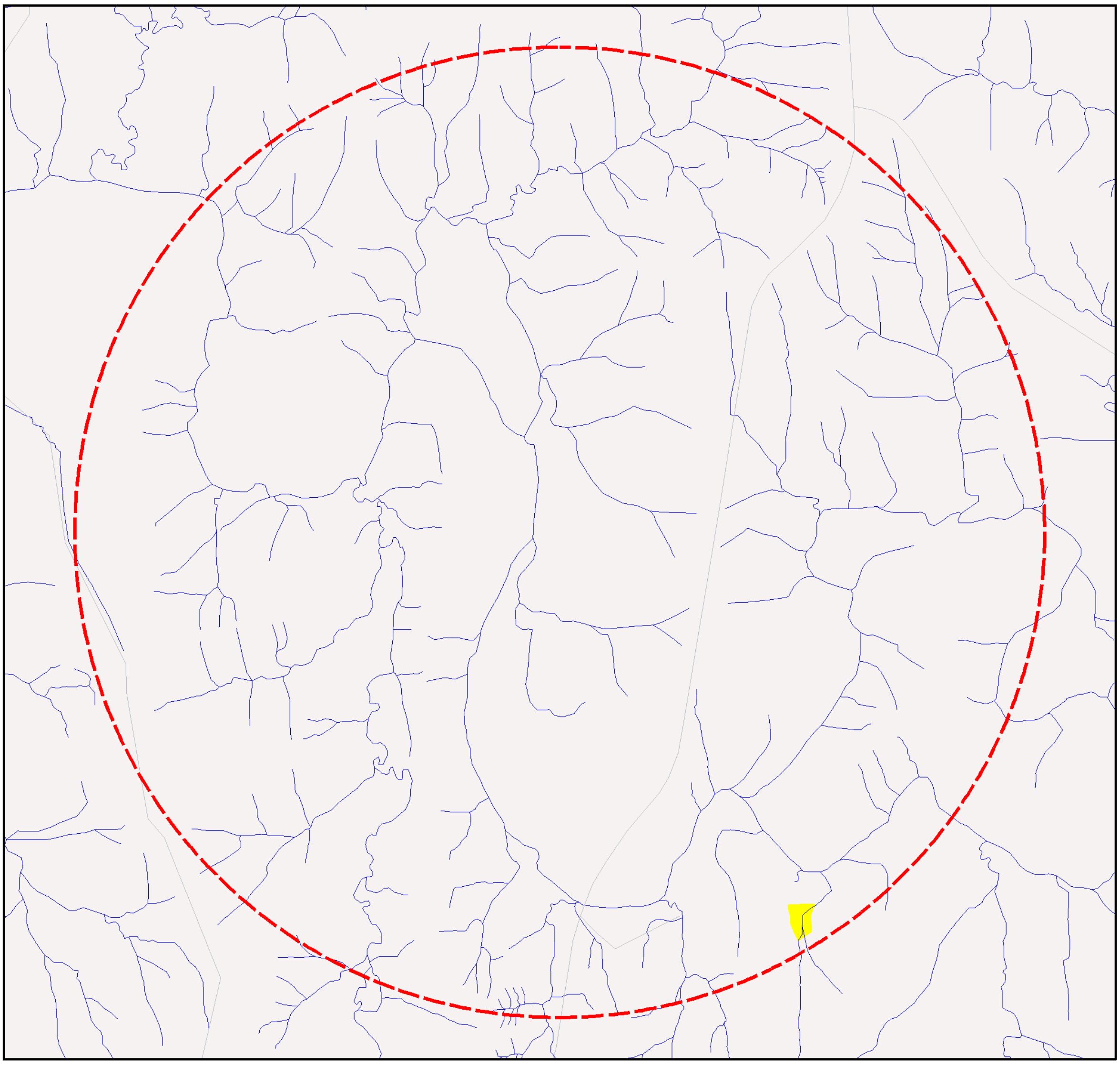
Map 4 - Wetlands and waterways



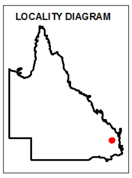
Wetlands and Waterways

Legend

- 2 kilometre buffer
- Towns
- Roads
- Springs
- Rivers/Creeks
- Directory of Important Wetlands
- Ramsar Sites - QLD
- Queensland

Wetland Type

- Marine Waterbodies
- Estuarine Waterbodies
- Riverine Waterbodies
- Lacustrine Waterbodies
- Palustrine Waterbodies
- Marine RE
- Estuarine RE
- Riverine RE
- Lacustrine RE
- Palustrine RE
- RE 51-80% wetland (mosaic units)
- RE 1-50% wetland (mosaic units)



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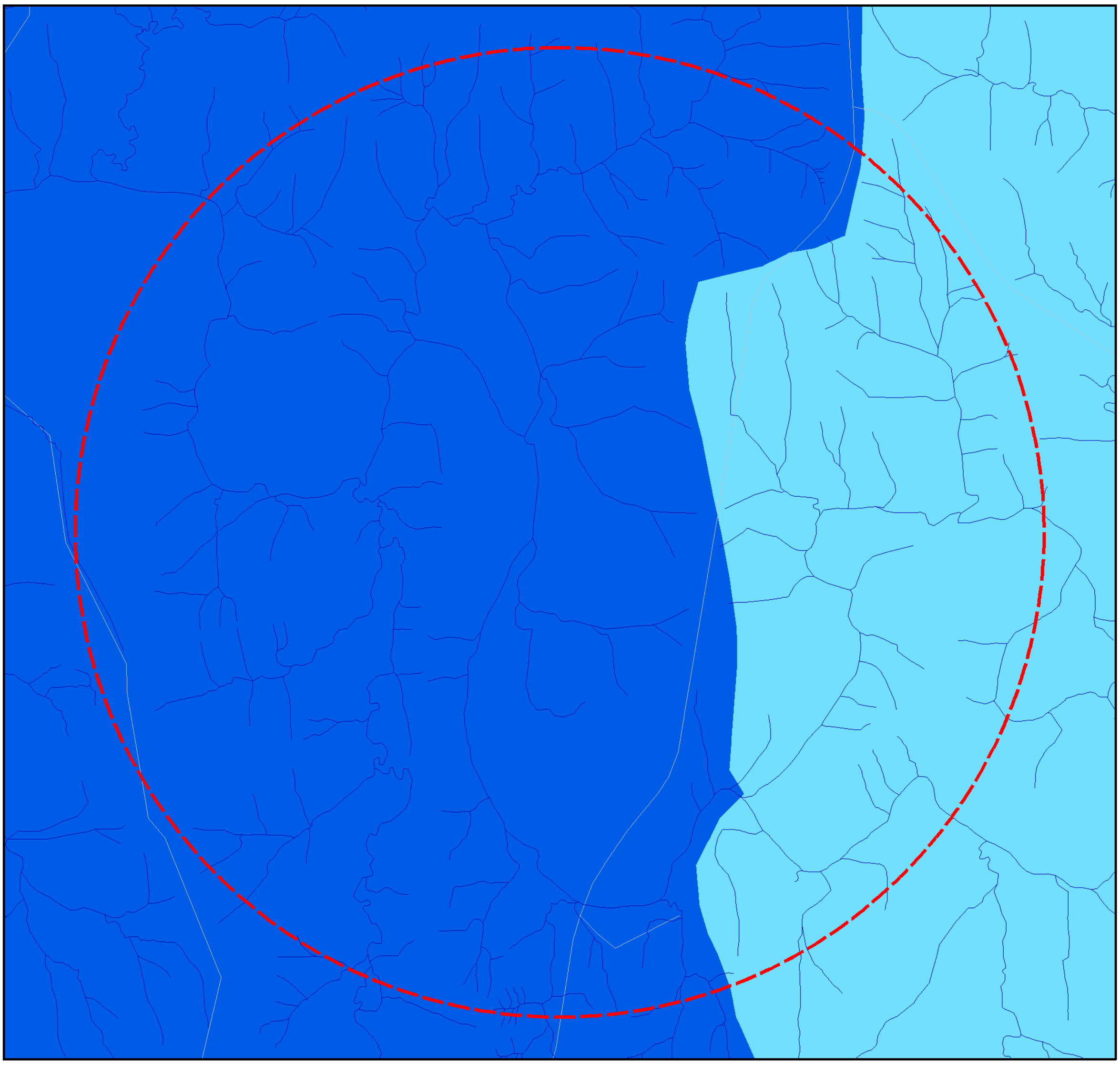
Map 5 - Aquatic Conservation Assessment (ACA) - riverine



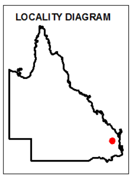
Aquatic Conservation Assessment (ACA) - riverine

Legend

- 2 kilometre buffer
- Towns
- Roads
- Rivers/Creeks
- Queensland

ACA Riverine - Subcatchment Significance

- Very High
- High
- Medium
- Low
- Very Low



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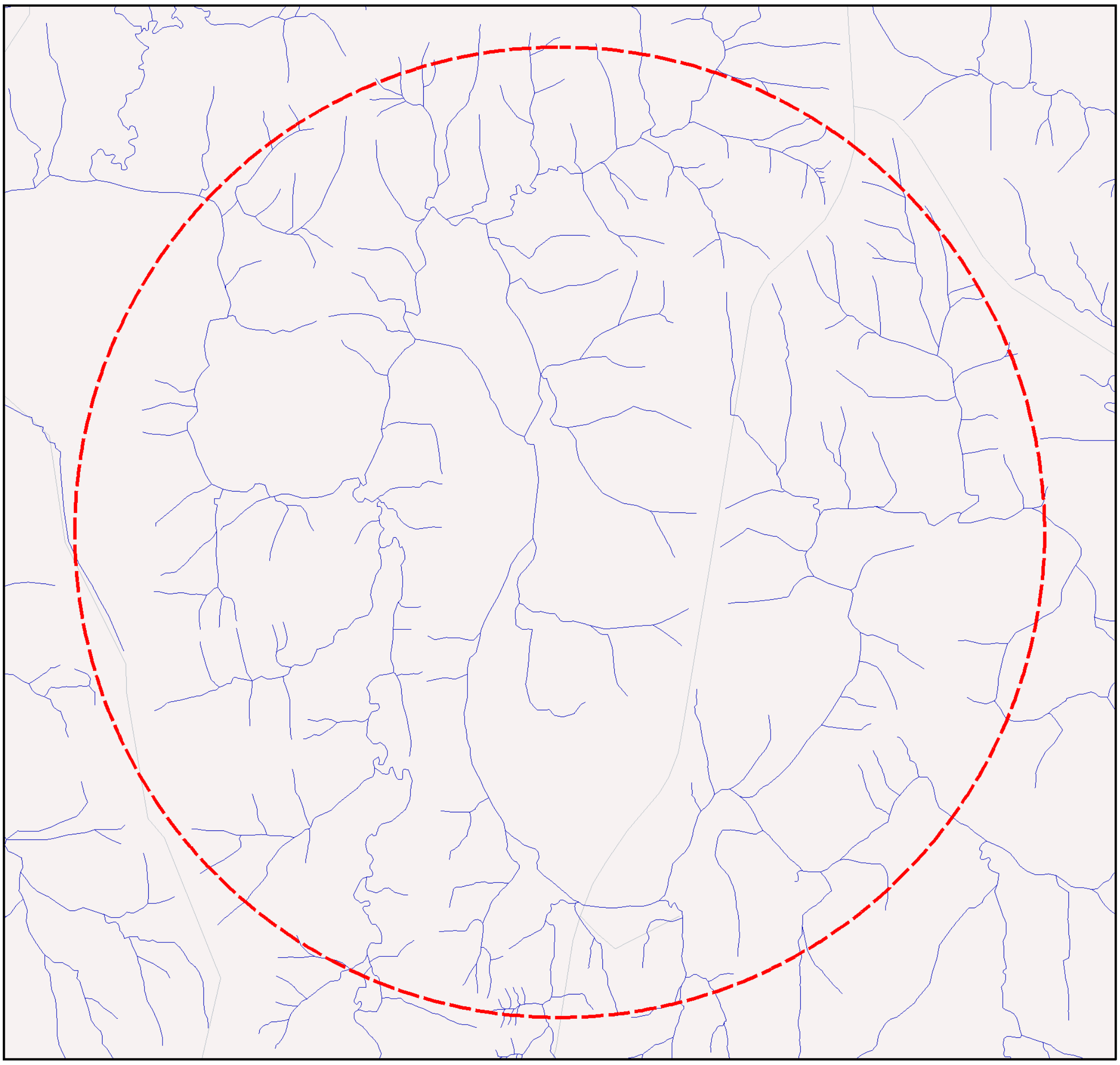
Map 6 - Aquatic Conservation Assessment (ACA) - non-riverine



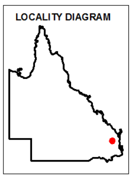
Aquatic Conservation Assessment (ACA) - nonriverine

Legend

- 2 kilometre buffer
- Towns
- Roads
- Rivers/Creeks
- Queensland

ACA Non-riverine

- Very High
- High
- Medium
- Low
- Very Low



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References

Clayton, P.D., Fielder, D.F., Howell, S. and Hill, C.J. (2006) *Aquatic biodiversity assessment and mapping method (AquaBAMM): a conservation values assessment tool for wetlands with trial application in the Burnett River catchment.* Published by the Environmental Protection Agency, Brisbane. ISBN 1-90928-07-3. Available at

http://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca/

Environmental Protection Agency (2002) *Biodiversity Assessment and Mapping Methodology. Version 2.1, July 2002.* (Environmental Protection Agency, Brisbane).

Morton, S. R., Short, J. and Barker, R. D. with an Appendix by G.F. Griffin and G. Pearce (1995). *Refugia for Biological Diversity in Arid and Semi-arid Australia. Biodiversity Series* , Paper No. 4, Biodiversity Unit, Environment Australia.

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

Theme	Datasets
Aquatic Conservation Assessments Non-riverine*	Combination of the following datasets: Cape York Peninsula Non-riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Non-riverine v1.3 Lake Eyre and Bulloo Basins v1.1 QMDB Non-riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Non-riverine ACA v1.1 Southern Gulf Catchments Non-riverine ACA v1.1
Aquatic Conservation Assessments Riverine*	Combination of the following datasets: Cape York Peninsula Riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Riverine v1.1 Lake Eyre and Bulloo Basins v1.1 QMDB Riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Riverine ACA v1.1 Southern Gulf Catchments Riverine ACA v1.1
Biodiversity Planning Assessments*	Combination of the following datasets: Brigalow Belt BPA v2.1 Cape York Peninsula BPA v1.1 Central Queensland Coast BPA v1.3 Channel Country BPA v1.1 Desert Uplands BPA v1.3 Einasleigh Uplands BPA v1.1 Gulf Plains BPA v1.1 Mitchell Grass Downs BPA v1.1 Mulga Lands BPA v1.4 New England Tableland v2.3 Northwest Highlands v1.1 Southeast Queensland v4.1 Wet Tropics v1.1
Statewide BPA Corridors*	Statewide corridors v1.6
Threatened Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
BPA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
ACA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.

***These datasets are available at:**

http://dds.information.qld.gov.au/DDS

Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
ACA	- Aquatic Conservation Assessment
AQUABAMM	- Aquatic Biodiversity Assessment and Mapping Methodology
BAMM	- Biodiversity Assessment and Mapping Methodology
BoT	- Back on Track
BPA	- Biodiversity Planning Assessment
CAMBA	- China-Australia Migratory Bird Agreement
DES	- Department of Environment and Science
EPBC	- *Environment Protection and Biodiversity Conservation Act 1999*
EVNT	- Endangered, Vulnerable, Near Threatened
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
JAMBA	- Japan-Australia Migratory Bird Agreement
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
ROKAMBA	- Republic of Korea-Australia Migratory Bird Agreement

Appendix III Matters of State Environmental Significance Report

Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
Longitude: 152.068547 Latitude: -26.309792 with 2 kilometre radius

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@des.qld.gov.au

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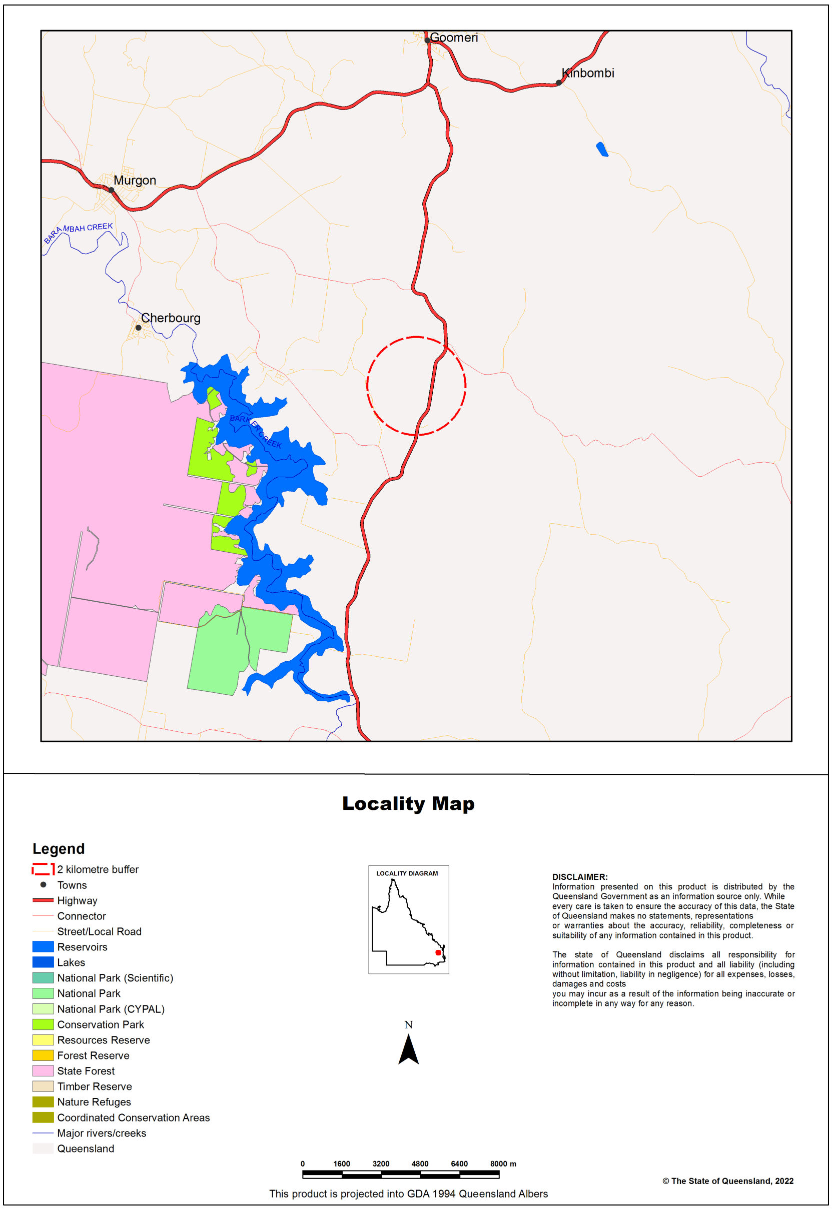
Table of Contents

Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI Longitude: 152.068547 Latitude: -26.309792

Size (ha)	1,256.55
Local Government(s)	Gympie Regional, South Burnett Regional
Bioregion(s)	Southeast Queensland
Subregion(s)	Brisbane - Barambah Volcanics
Catchment(s)	Burnett



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992* ;

- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004* ;

- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;

- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;

- Regulated vegetation under the *Vegetation Management Act 1999* that is:

  • Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;

  • Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;

  • Category R areas on the regulated vegetation management map;

  • Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;

  • Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;

- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Queensland Wetland Environmental Values under the Environment Protection Regulation 2019;

- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;

- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha	0.0 %
1b Protected Areas- nature refuges	0.0 ha	0.0 %
1c Protected Areas- special wildlife reserves	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	0.0 ha	0.0 %
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	0.0 ha	0.0 %
6a High Ecological Value (HEV) wetlands	0.0 ha	0.0 %
6b High Ecological Value (HEV) waterways	0.0 km	Not applicable
7a Threatened (endangered or vulnerable) wildlife	24.62 ha	2.0%
7b Special least concern animals	0.0 ha	0.0 %
7c i Koala habitat area - core (SEQ)	0.0 ha	0.0 %
7c ii Koala habitat area - locally refined (SEQ)	0.0 ha	0.0 %
7d Sea turtle nesting areas	0.0 km	Not applicable
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	13.94 ha	1.1%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	6.55 ha	0.5%
8c Regulated Vegetation - Category R (GBR riverine regrowth)	43.84 ha	3.5%
8d Regulated Vegetation - Essential habitat	18.04 ha	1.4%
8e Regulated Vegetation - intersecting a watercourse	30.4 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	0.0 ha	0.0 %
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(no results)

1b. Protected Areas - nature refuges

(no results)

1c. Protected Areas - special wildlife reserves

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

(no results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values

(no results)

6a. Wetlands in High Ecological Value (HEV) waters

(no results)

6b. Waterways in High Ecological Value (HEV) waters

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7a. Threatened (endangered or vulnerable) wildlife

Values are present

7b. Special least concern animals

Not applicable

7c i. Koala habitat area - core (SEQ)

Not applicable

7c ii. Koala habitat area - locally refined (SEQ)

Not applicable

7d. Wildlife habitat (sea turtle nesting areas)

Not applicable

Threatened (endangered or vulnerable) wildlife habitat suitability models

Species	Common name	NCA status	Presence
Boronia keysii		V	None
Calyptorhynchus lathami	Glossy black cockatoo	V	None
Casuarius casuarius johnsonii	Sthn population cassowary	E	None
Crinia tinnula	Wallum froglet	V	None
Denisonia maculata	Ornamental snake	V	None
Litoria freycineti	Wallum rocketfrog	V	None
Litoria olongburensis	Wallum sedgefrog	V	None
Macadamia integrifolia		V	None
Macadamia ternifolia		V	None
Macadamia tetraphylla		V	None
Melaleuca irbyana		E	None
Petaurus gracilis	Mahogany Glider	E	None
Petrogale persephone	Proserpine rock-wallaby	E	None
Pezoporus wallicus wallicus	Eastern ground parrot	V	None
Phascolarctos cinereus	Koala - outside SEQ*	V	Core
Taudactylus pleione	Kroombit tinkerfrog	E	None
Xeromys myoides	Water Mouse	V	None

**For koala model, this includes areas outside SEQ. Check 7c SEQ koala habitat for presence/absence.*

Threatened (endangered or vulnerable) wildlife species records

(no results)

Special least concern animal species records

(no results)

Shorebird habitat (critically endangered/endangered/vulnerable)

Not applicable

Shorebird habitat (special least concern)

Not applicable

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

Migratory status (M) - China and Australia Migratory Bird Agreement (C), Japan and Australia Migratory Bird Agreement (J), Republic of Korea and Australia Migratory Bird Agreement (R), Bonn Migratory Convention (B), Eastern Flyway (E)

To request a species list for an area, or search for a species profile, access Wildlife Online at:
https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals, Map 3b - MSES - Species - Koala habitat area (SEQ)** and **Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)** for an overview of the relevant MSES.

MSES - Regulated Vegetation

For further information relating to regional ecosystems in general, go to:
https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/
For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:
https://environment.ehp.qld.gov.au/regional-ecosystems/

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
12.12.7/12.12.8	O-subdom	rem_oc
12.3.3	E-dom	rem_end

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Regional ecosystem	Vegetation management polygon	Vegetation management status
12.12.7/12.12.8/12.12.12	O-subdom	hvr_oc

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Regulated vegetation map category	Map number
R	9345

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Not applicable

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

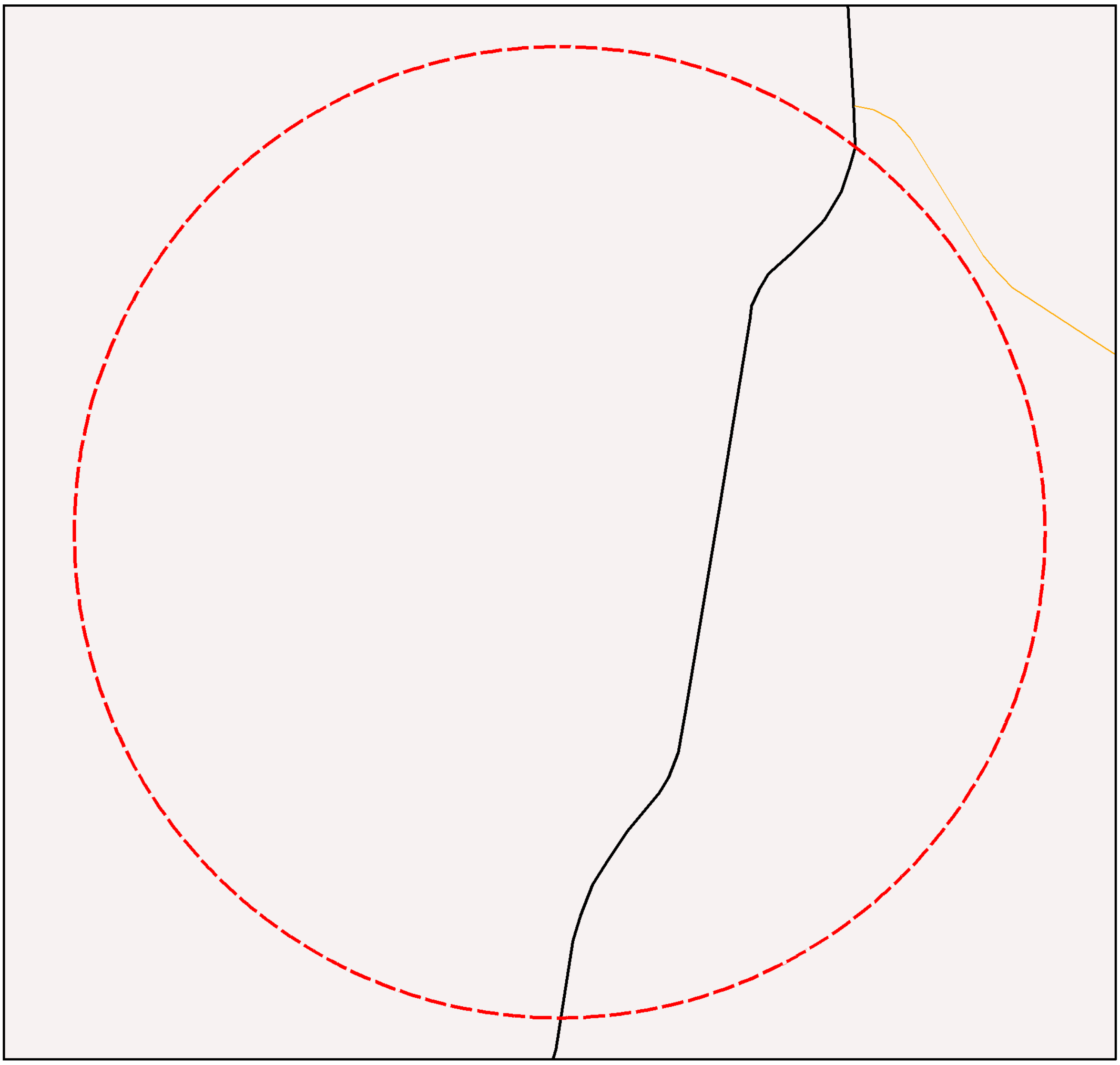
(no results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

(no results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

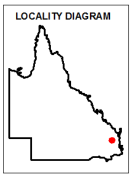
Map 1 - MSES - State Conservation Areas



MSES - State Conservation Areas

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Protected area (estates, nature refuges, special wildlife reserves)
- Declared fish habitat area (A and B areas)
- Marine park (highly protected)



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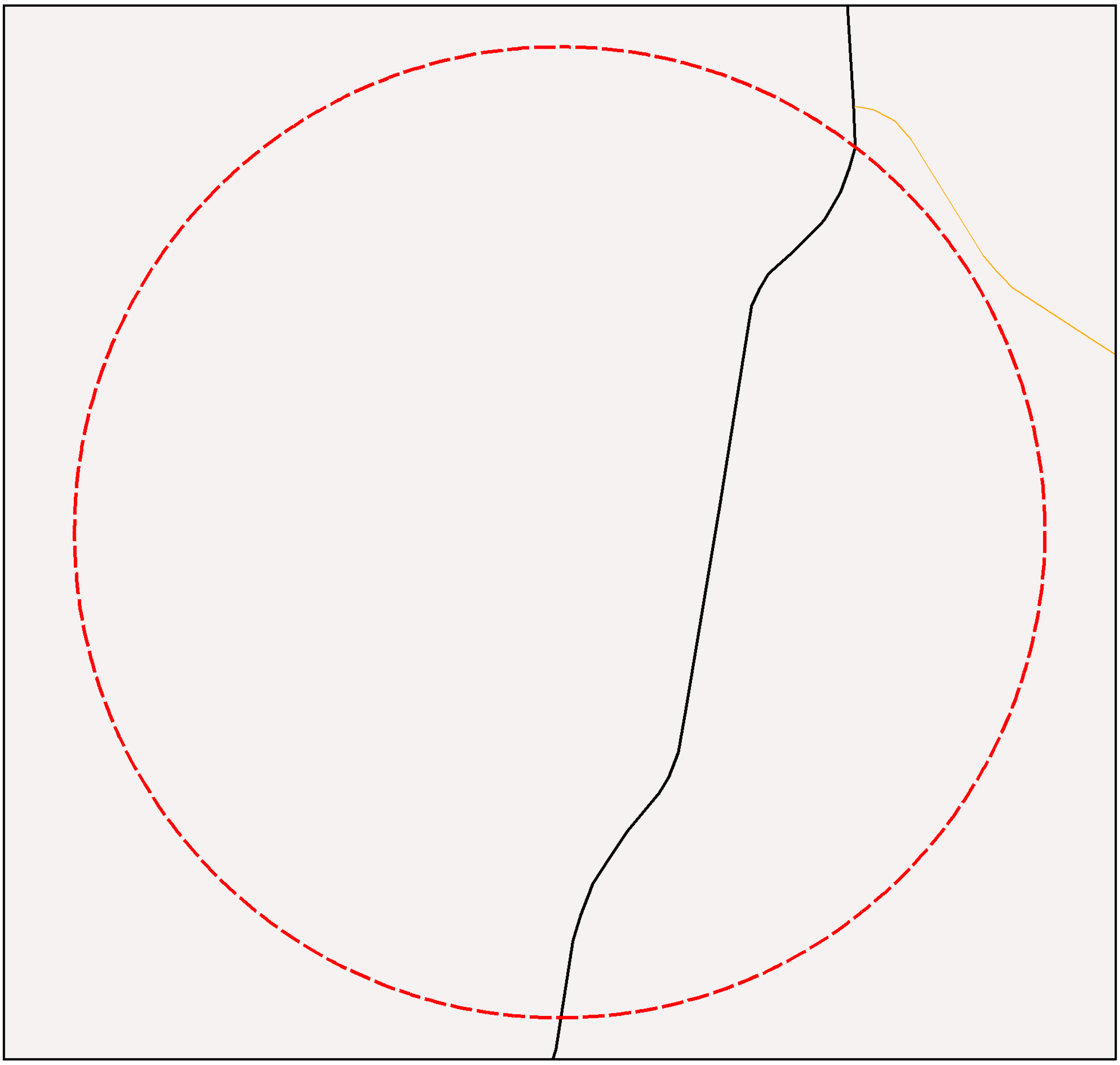
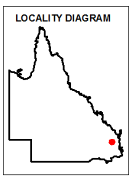
Map 2 - MSES - Wetlands and Waterways



MSES - Wetlands and Waterways

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Declared high ecological value waters (watercourse)
- Strategic environmental area (designated precinct)
- Declared high ecological value waters (wetland)
- High ecological significance wetlands



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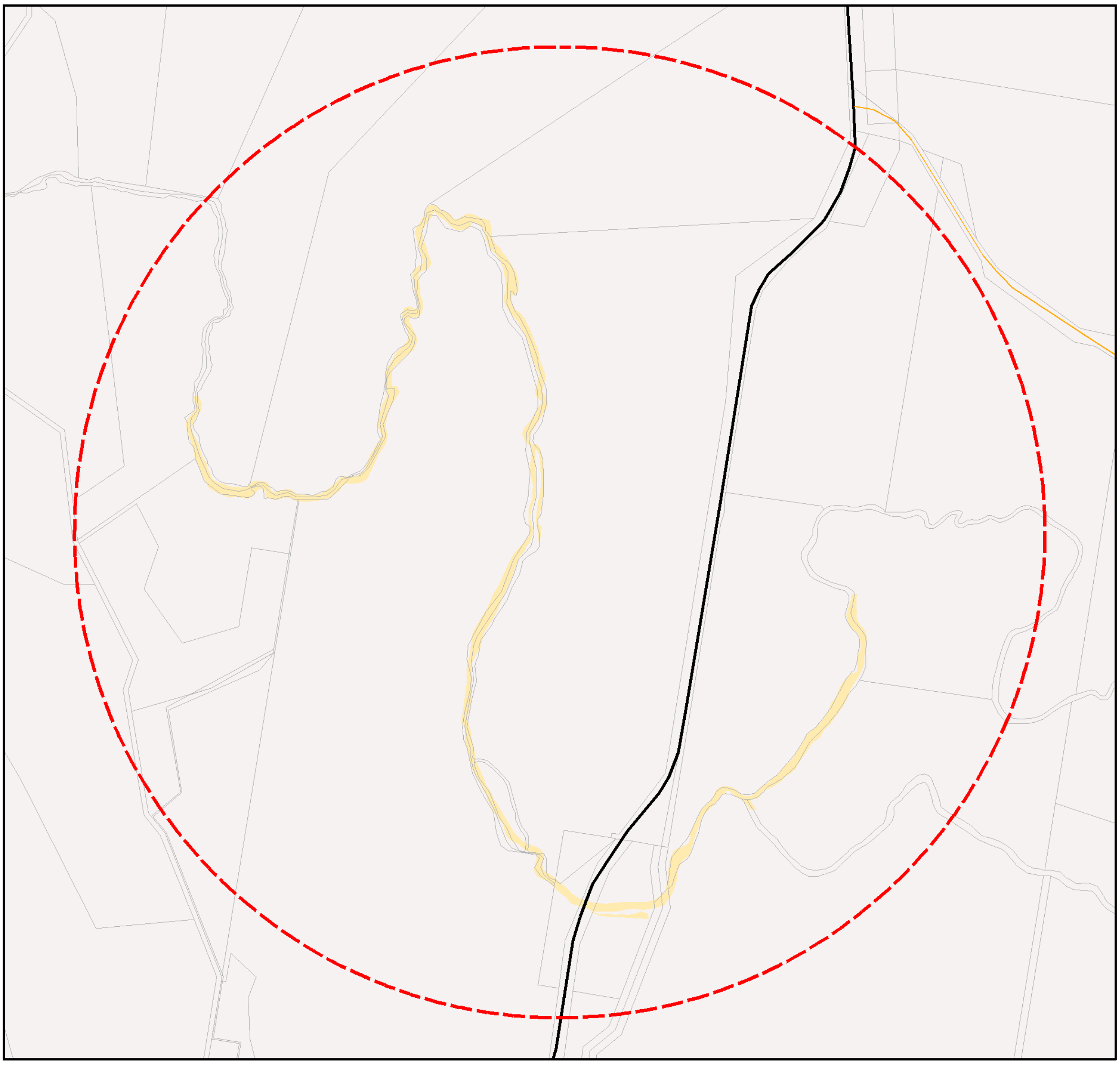
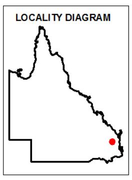
Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals



MSES - Species
Threatened (endangered or vulnerable) wildlife and special least concern animals

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Wildlife habitat (special least concern)
- Wildlife habitat (endangered or vulnerable)



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0 250 500 750 1000 1250 m

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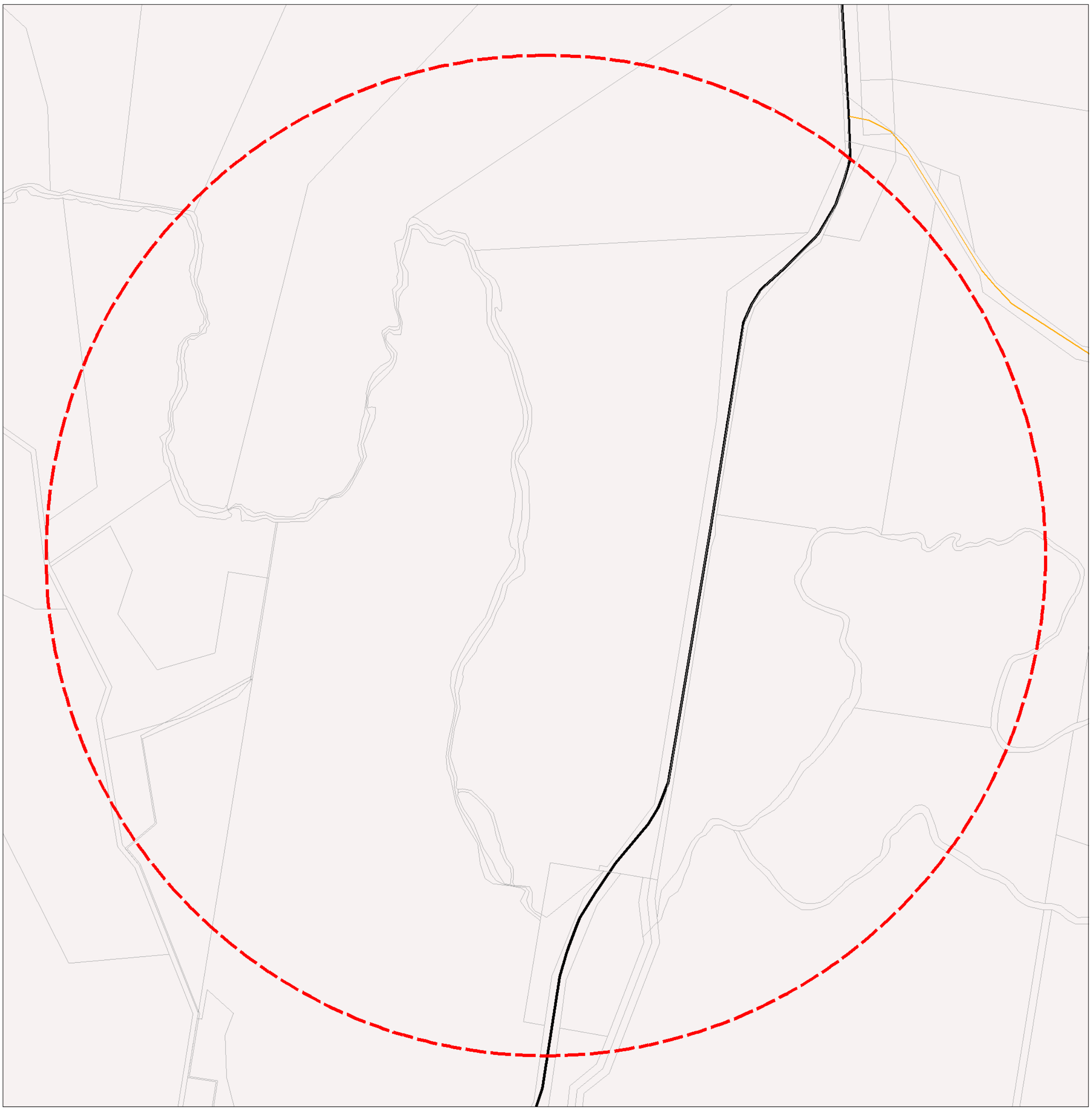
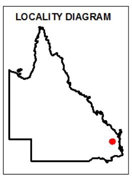
Map 3b - MSES - Species - Koala habitat area (SEQ)



MSES - Species
Koala habitat area (SEQ)

Area of Interest
- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Koala habitat area (core)
- Koala habitat area (locally refined)



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The represented layers for SEQ 'koala habitat area-core' and 'koala habitat area- locally refined' in MSES are sourced directly from the regulatory mapping under the Nature Conservation (Koala) Conservation Plan 2017. Whilst every effort is made to ensure the information remains current, there may be delays between updating versions. Please refer to the original mapping for the most recent version. See https://environment.des.qld.gov.au/wildlife/animals/living-with/koalas/mapping

The koala habitat mapping within South East Queensland uses regional ecosystem linework compiled at a scale varying from 1:25,000 to 1:100,000. Linework should be used as a guide only. The positional accuracy of regional ecosystem data mapped at a scale of 1:100,000 is +/- 100 metres.

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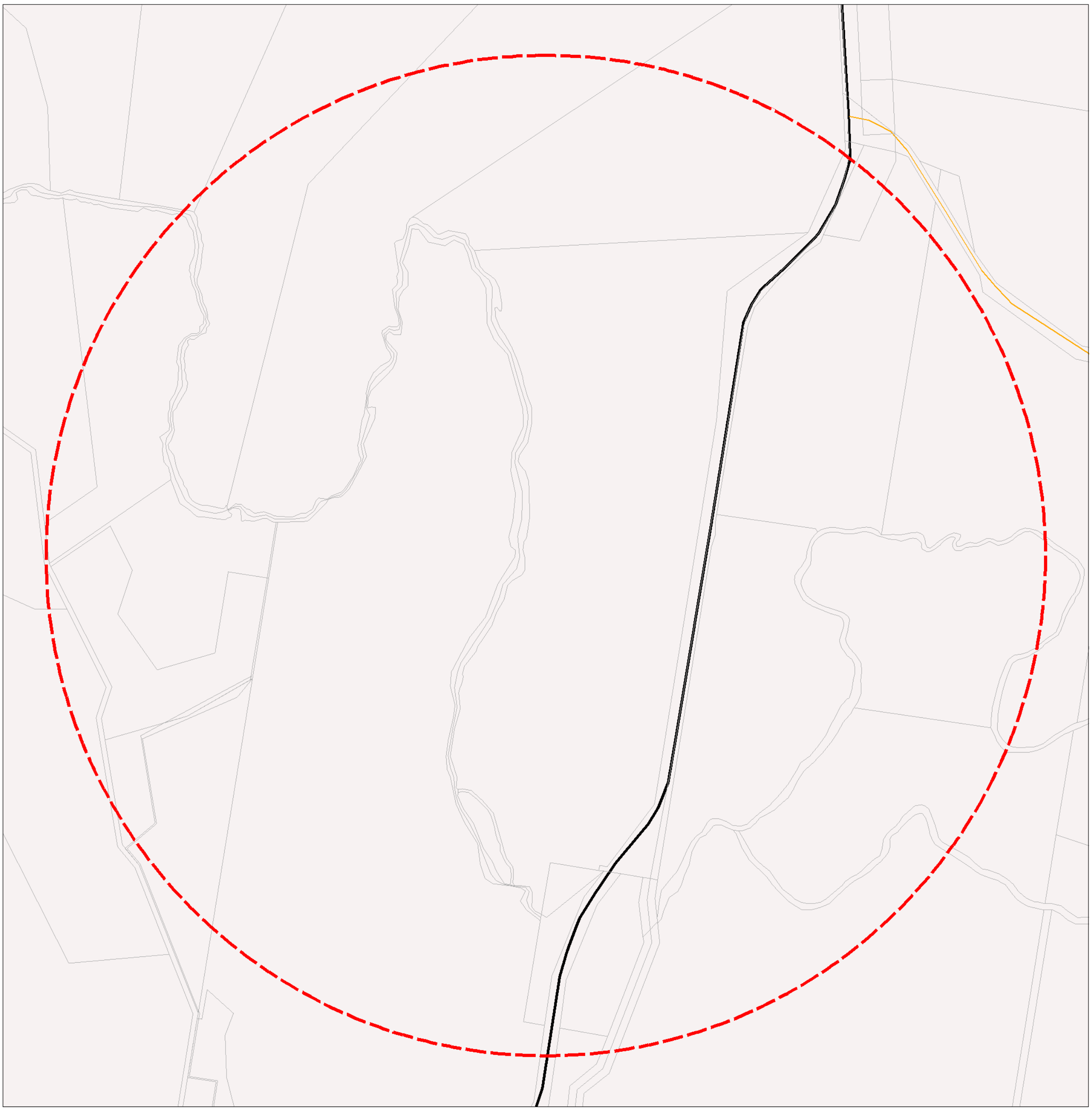
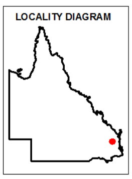
Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)



MSES - Wildlife habitat (sea turtle nesting areas)

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Wildlife habitat (sea turtle nesting areas)



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MSES mapping of sea turtle nesting areas identifies beaches where the recorded number of turtle nests are over 1% of the turtle species or genetic stock. The linework is also deliberately extended along nearby rocky coastlines and headlands to recognise that significant numbers of nesting adults and hatchlings can become disoriented by light pollution from development on rocky coastlines and headlands while navigating offshore from nesting beaches.

0 225 450 675 900 1,125 m

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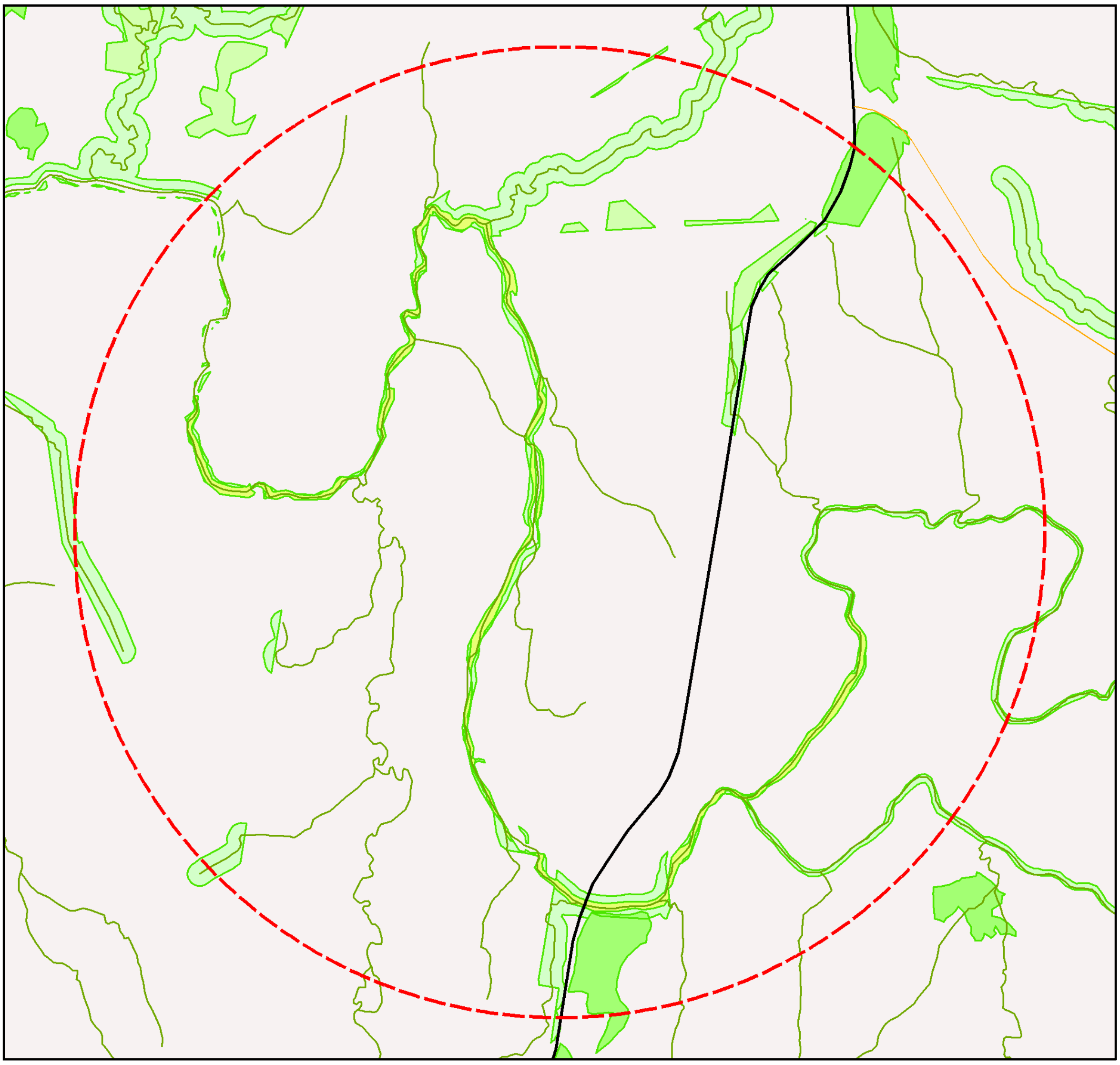
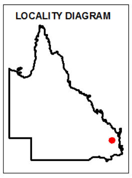
Map 4 - MSES - Regulated Vegetation



MSES - Regulated Vegetation

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Regulated vegetation (intersecting a watercourse)
- Regulated vegetation (100m from wetland)
- Regulated vegetation (category B - endangered or of concern)
- Regulated vegetation (category C - endangered or of concern)
- Regulated vegetation (category R - GBR riverine)
- Regulated vegetation (essential habitat)



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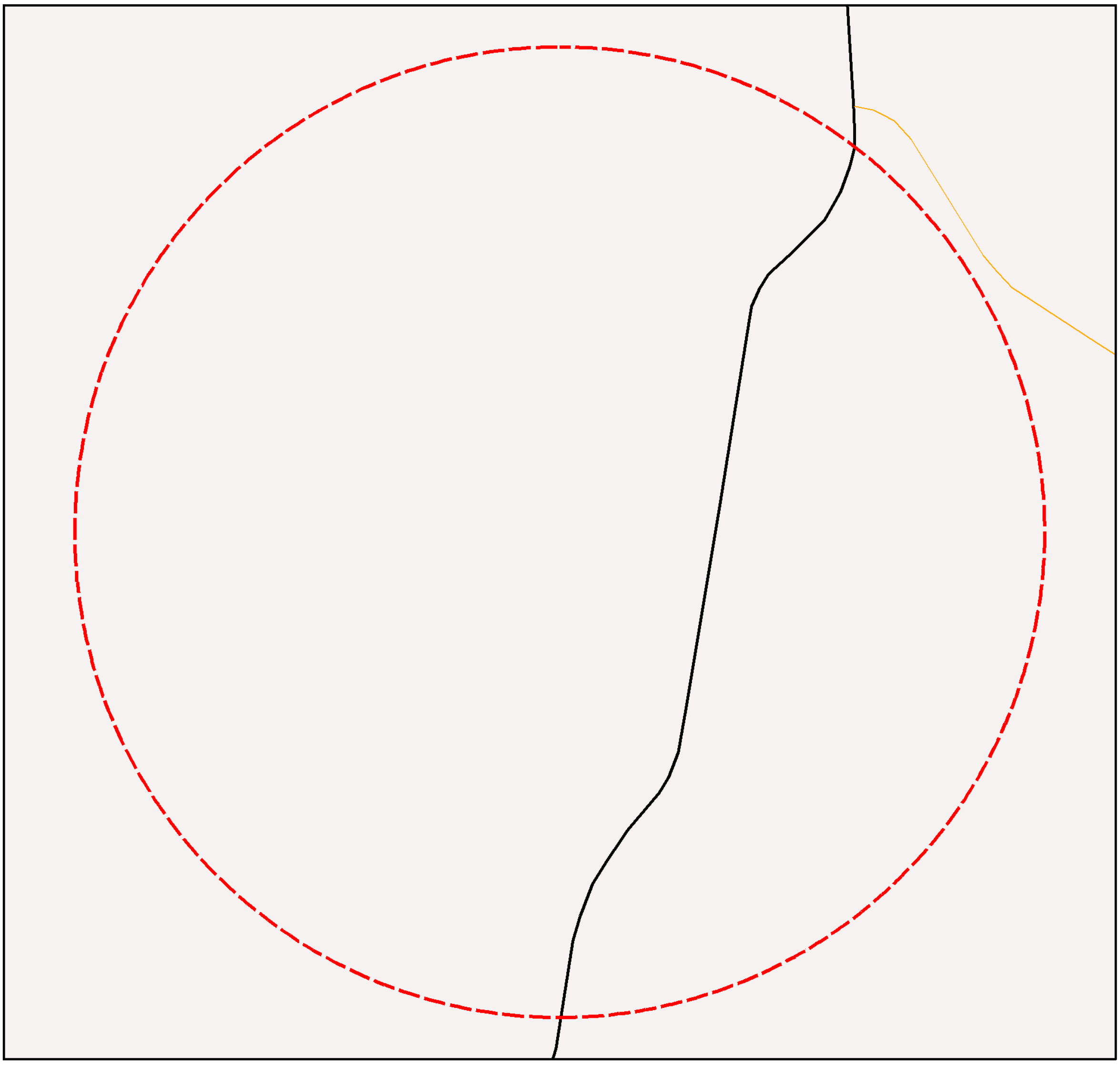
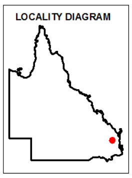
Map 5 - MSES - Offset Areas



MSES - Offsets

Area of Interest

- 2 kilometre buffer
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Legally secured offset area (offset register)
- Legally secured offset area (vegetation offsets)



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Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	current QSpatial data (http://qspatial.information.qld.gov.au)
Protected Areas-Estates, Nature Refuges, Special Wildlife Reserves	- Protected areas of Queensland - Nature Refuges - Queensland - Special Wildlife Reserves- Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Queensland Wetland Environmental Values
Wetlands in HEV waters	HEV waters: - EPP Water intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 5) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000)
Wildlife habitat (threatened and special least concern)	- WildNet database species records - habitat suitability models (various) - SEQ koala habitat areas under the Koala Conservation Plan 2019 - Sea Turtle Nesting Areas records
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map
VMA Essential Habitat	Vegetation management - essential habitat map
VMA Wetlands	Vegetation management wetlands map
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- *Environmental Protection Act 1994*
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- *Vegetation Management Act 1999*

Appendix IV Regional Ecosystems Report

Queensland Government

Department of Environment and Science

Environmental Reports

Regional Ecosystems

Biodiversity Status

For the selected area of interest
Longitude: 152.068547 Latitude: -26.309792 with 2 kilometre radius

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the input coordinates.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no matters of interest have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the Queensland Herbarium's Regional Ecosystem framework. The Biodiversity Status has been used to depict the extent of "Endangered", "Of Concern" and "No Concern at Present" regional ecosystems in all cases, rather than the classes used for the purposes of the *Vegetation Management Act 1999* (VMA). Mapping and figures presented in this document reflect the Queensland Herbarium's Remnant and Pre-clearing Regional Ecosystem Datasets, and not the certified mapping used for the purpose of the VMA.

For matters relevant to vegetation management under the VMA, please refer to the Department of Resources website https://www.dnrme.qld.gov.au/

Please direct queries about these reports to: Queensland.Herbarium@qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

Table of Contents

Summary Information

The following table provides an overview of the AOI with respect to selected topographic and environmental themes. Refer to **Map 1** for locality information.

Table 1: Area of interest details: Longitude: 152.068547 Latitude: -26.309792 with 2 kilometre radius

Size (ha)	1,256.55
Local Government(s)	Gympie Regional, South Burnett Regional
Bioregion(s)	Southeast Queensland
Subregion(s)	Brisbane - Barambah Volcanics
Catchment(s)	Burnett

The table below summarizes the extent of remnant vegetation classed as "Endangered", "Of concern" and "No concern at present" regional ecosystems classified by Biodiversity Status within the area of interest (AOI).

Table 2: Summary table, biodiversity status of regional ecosystems within the AOI

Biodiversity Status	Area (Ha)	% of AOI
Endangered	0.33	0.03
Of concern	26.17	2.08
No concern at present	13.31	1.06
Total remnant vegetation	39.81	3.17

Refer to **Map 2** for further information.

Regional Ecosystems

1. Introduction

Regional ecosystems are vegetation communities in a bioregion that are consistently associated with particular combinations of geology, landform and soil (Sattler and Williams 1999). Descriptions of Queensland's Regional ecosystems are available online from the Regional Ecosystem Description Database (REDD). Descriptions are compiled from a broad range of information sources including vegetation, land system and geology survey and mapping and detailed vegetation site data. The regional ecosystem classification and descriptions are reviewed as new information becomes available. A number of vegetation communities may form a single regional ecosystem and are usually distinguished by differences in dominant species, frequently in the shrub or ground layers and are denoted by a letter following the regional ecosystem code (e.g. a, b, c). Vegetation communities and regional ecosystems are amalgamated into a higher level classification of broad vegetation groups (BVGs).

A published methodology for survey and mapping of regional ecosystems across Queensland (Neldner et al 2020) provides further details on regional ecosystem concepts and terminology.

This report provides information on the type, status, and extent of vegetation communities, regional ecosystems and broad vegetation groups present within a user specified area of interest. Please note, for the purpose of this report, the Biodiversity Status is used. This report has not been developed for application of the *Vegetation Management Act 1999* (VMA). Additionally, information generated in this report has been derived from the Queensland Herbarium's Regional Ecosystem Mapping, and not the regulated mapping certified for the purposes of the VMA. If your interest/matter relates to regional ecosystems and the VMA, users should refer to the Department of Resources website.

https://www.dnrme.qld.gov.au/

With respect to the Queensland Biodiversity Status,

"Endangered" regional ecosystems are described as those where:

- remnant vegetation is less than 10 per cent of its pre-clearing extent across the bioregion; or 10-30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 hectares, or
- less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss*, or
- 10-30 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or
- it is a rare** regional ecosystem subject to a threatening process.***

"Of concern" regional ecosystems are described as those where:

- the degradation criteria listed above for 'Endangered' regional ecosystems are not met and,
- remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 20 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares, or
- 10-30 percent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.****

and "No concern at present" regional ecosystems are described as those where:

- remnant vegetation is over 30 per cent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and
- the degradation criteria listed above for 'Endangered' or 'Of concern' regional ecosystems are not met.

**Severe degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 50 years even with the removal of threatening processes; or soil surface is severely degraded, for example, by loss of A horizon, surface expression of salinity; surface compaction, loss of organic matter or sheet erosion.*

***Rare regional ecosystem: pre-clearing extent (1000 ha); or patch size (100 ha and of limited total extent across its range).*

****Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development.*

*****Moderate degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 20 years even with the removal of threatening processes; or soil surface is moderately degraded.*

2. Remnant Regional Ecosystems

The following table identifies the remnant regional ecosystems and vegetation communities mapped within the AOI and provides their short descriptions, Biodiversity Status, and remnant extent within the selected AOI. Please note, where heterogeneous vegetated patches (mixed patches of remnant vegetation mapped as containing multiple regional ecosystems) occur within the AOI, they have been split and listed as individual regional ecosystems (or vegetation communities where present) for the purposes of the table below. In such instances, associated area figures have been generated based upon the estimated proportion of each regional ecosystem (or vegetation community) predicted to be present within the larger mixed patch.

Table 3: Remnant regional ecosystems, description and status within the AOI

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
12.12.7	Eucalyptus crebra woodland on Mesozoic to Proterozoic igneous rocks	No concern at present	13.31	1.06
12.12.8	Eucalyptus melanophloia woodland on Mesozoic to Proterozoic igneous rocks	Of concern	1.01	0.08
12.3.3	Eucalyptus tereticornis woodland on Quaternary alluvium	Endangered	0.33	0.03
12.3.7	Eucalyptus tereticornis, Casuarina cunninghamiana subsp. cunninghamiana +/- Melaleuca spp. fringing woodland	Of concern	24.3	1.93
12.3.7b	Eucalyptus tereticornis, Casuarina cunninghamiana subsp. cunninghamiana +/- Melaleuca spp. fringing woodland	Of concern	0.86	0.07
non-remnant	None	None	1,213.64	96.58
water	None	None	3.11	0.25

Refer to **Map 2** for further information. **Map 3** also provides a visual estimate of the distribution of regional ecosystems present before clearing.

Table 4 provides further information in regards to the remnant regional ecosystems present within the AOI. Specifically, the extent of remnant vegetation remaining within the bioregion, the 1:1,000,000 broad vegetation group (BVG) classification, whether the regional ecosystem is identified as a wetland, and extent of representation in Queensland's Protected Area Estate. For a description of the vegetation communities within the AOI and classified according to the 1:1,000,000 BVG, refer to **Table 6**.

Table 4: Remnant regional ecosystems within the AOI, additional information

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
12.12.7	Pre-clearing 171000 ha; Remnant 2019 56000 ha	13c	Not a Wetland	Medium
12.12.8	Pre-clearing 139000 ha; Remnant 2019 29000 ha	17b	Not a Wetland	Low
12.3.3	Pre-clearing 436000 ha; Remnant 2019 39000 ha	16c	Not a Wetland	Low
12.3.7	Pre-clearing 124000 ha; Remnant 2019 68000 ha	16a	Riverine	Low

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
12.3.7b	Pre-clearing 124000 ha; Remnant 2019 68000 ha	16d	Riverine	Low
non-remnant	None	None	None	None
water	None	None	None	None

Representation in Protected Area Estate: High greater than 10% of pre-clearing extent is represented; Medium 4 - 10% is represented; Low less than 4% is represented, No representation.

The distribution of mapped wetland systems within the area of interest is displayed in **Map 6**.

The following table lists known special values associated with a regional ecosystem type.

Table 5: Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
12.12.7	Potential habitat for NCA listed species: Callitris baileyi, Cycas megacarpa. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
12.12.8	Potential habitat for NCA listed species: Coleus omissus. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
12.3.3	Habitat for threatened plant species including Rhaponticum australe. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.3a: Habitat for threatened plant species including occasional Rhaponticum australe. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.3b: Habitat for threatened flora species including Melaleuca irbyana. 12.3.3c: Habitat for threatened flora species including Melaleuca irbyana and Marsdenia coronata. 12.3.3d: Habitat for threatened plant species including Rhaponticum australe. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
12.3.7	Habitat for an extensive range of aquatic flora and fauna. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7a: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7c: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7d: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
12.3.7b	Habitat for an extensive range of aquatic flora and fauna. This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7a: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7c: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus). 12.3.7d: This ecosystem is known to provide suitable habitat for koalas (Phascolarctos cinereus).
non-remnant	None
water	None

3. Remnant Regional Ecosystems by Broad Vegetation Group

BVGs are a higher-level grouping of vegetation communities. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid climatic zones. BVGs provide an overview of vegetation communities across the state or a bioregion and allow comparison with other states. There are three levels of BVGs which reflect the approximate scale at which they are designed to be used: the 1:5,000,000 (national), 1:2,000,000 (state) and 1:1,000,000 (regional) scales.

A comprehensive description of BVGs is available at:

https://publications.qld.gov.au/dataset/redd/resource/

The following table provides a description of the 1:1,000,000 BVGs present and their associated extent within the AOI.

Table 6: Broad vegetation groups (1 million) within the AOI

BVG (1 Million)	Description	Area (Ha)	% of AOI
None	None	1,216.75	96.83
13c	Woodlands of Eucalyptus crebra (sens. lat.) (narrow-leaved red ironbark), E. drepanophylla (grey ironbark), E. fibrosa (dusky-leaved ironbark), E. shirleyi (shirley's silver-leaved ironbark) on granitic and metamorphic ranges (land zones 12, 11, 9, [5]) (BRB, EIU, SEQ, NET, CQC)	13.31	1.06
16a	Open forest and woodlands dominated by Eucalyptus camaldulensis (river red gum) (or E. tereticornis (blue gum)) and/or E. coolabah (coolabah) (or E. microtheca (coolabah)) fringing drainage lines. Associated species may include Melaleuca spp., Corymbia tessellaris (carbeen), Angophora spp., Casuarina cunninghamiana (riveroak). Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded. (land zone 3) (MGD, BRB, GUP, CHC, MUL, DEU, EIU, NWH, SEQ, [NET, WET]) (All bioregions except CYP and CQC)	24.3	1.93
16c	Woodlands and open woodlands dominated by Eucalyptus coolabah (coolabah) or E. microtheca (coolabah) or E. largiflorens (black box) or E. tereticornis (blue gum) or E. chlorophylla on floodplains. Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded. (land zone 3) (All bioregions except WET, principally GUP, BRB, MUL).	0.33	0.03
16d	River beds, open water or sand, or rock, frequently unvegetated. (land zone 3) (GUP, EIU, BRB, CYP, DEU, [CQC, MUL])	0.86	0.07
17b	Woodlands to open woodlands dominated by Eucalyptus melanophloia (silver-leaved ironbark) (or E. shirleyi (shirley's silver-leaved ironbark)) on sand plains and footslopes of hills and ranges. (land zones 5, 12, 3, 11, 9, 7) (BRB, DEU, EIU, SEQ, NET, GUP, NWH)	1.01	0.08

Refer to **Map 4** for further information. **Map 5** also provides a representation of the distribution of vegetation communities as per the 1:5,000,000 BVG believed to be present prior to European settlement.

4. Technical and BioCondition Benchmark Descriptions

Technical descriptions provide a detailed description of the full range in structure and floristic composition of regional ecosystems (e.g. 11.3.1) and their component vegetation communities (e.g. 11.3.1a, 11.3.1b). See:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

The descriptions are compiled using site survey data from the Queensland Herbarium's CORVEG database. Distribution maps, representative images (if available) and the pre-clearing and remnant extent (hectares) of each vegetation community derived from the regional ecosystem mapping data are included. The technical descriptions should be used in conjunction with the fields from the regional ecosystem description database (REDD) for a full description of the regional ecosystem.

Technical descriptions include data on canopy height, canopy cover and native plant species composition of the predominant layer, which are attributes relevant to assessment of the remnant status of vegetation under the *Vegetation Management Act*

1999. However, as technical descriptions reflect the full range in structure and floristic composition across the climatic, natural disturbance and geographic range of the regional ecosystem, local reference sites should be used for remnant assessment where possible (Neldner et al. 2020 (PDF))* section 3.3 of:

https://publications.qld.gov.au/dataset/redd/resource/

The technical descriptions are subject to review and are updated as additional data becomes available.

When conducting a BioCondition assessment, these technical descriptions should be used in conjunction with BioCondition benchmarks for the specific regional ecosystem, or component vegetation community.

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

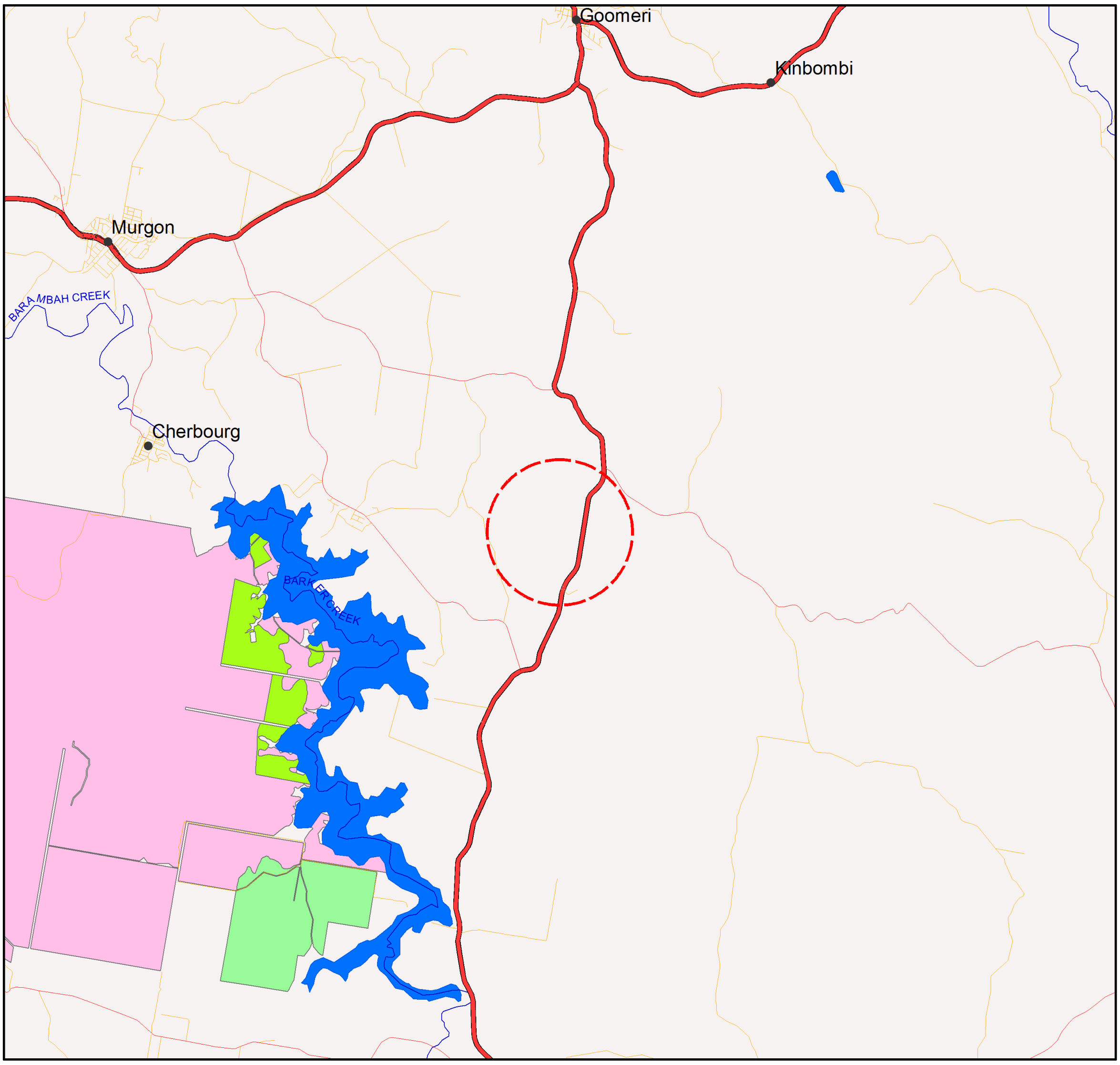
Benchmarks are based on a combination of quantitative and qualitative information and should be used as a guide only. Benchmarks are specific to one regional ecosystem vegetation community, however, the natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes has been considered throughout the geographic extent of the regional ecosystem. Local reference sites should be used for this spatial and temporal (seasonal and annual) variability.

Table 7: List of remnant regional ecosystems within the AOI for which technical and biocondition benchmark descriptions are available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
12.12.7	Not currently available	Available
12.12.8	Not currently available	Not currently available
12.3.3	Available	Available
12.3.7	Available	Available
12.3.7b	Not currently available	Not currently available
non-remnant	Not currently available	Not currently available
water	Not currently available	Not currently available

Maps

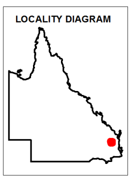
Map 1 - Location



Locality Map

Legend

- 2 kilometre buffer
- Towns
- Highway
- Connector
- Street/Local Road
- Reservoirs
- Lakes
- National Park (Scientific)
- National Park
- National Park (CYPAL)
- Conservation Park
- Resources Reserve
- Forest Reserve
- State Forest
- Timber Reserve
- Nature Refuges
- Coordinated Conservation Areas
- Major rivers/creeks
- Queensland



N

0 1600 3200 4800 6400 8000 m

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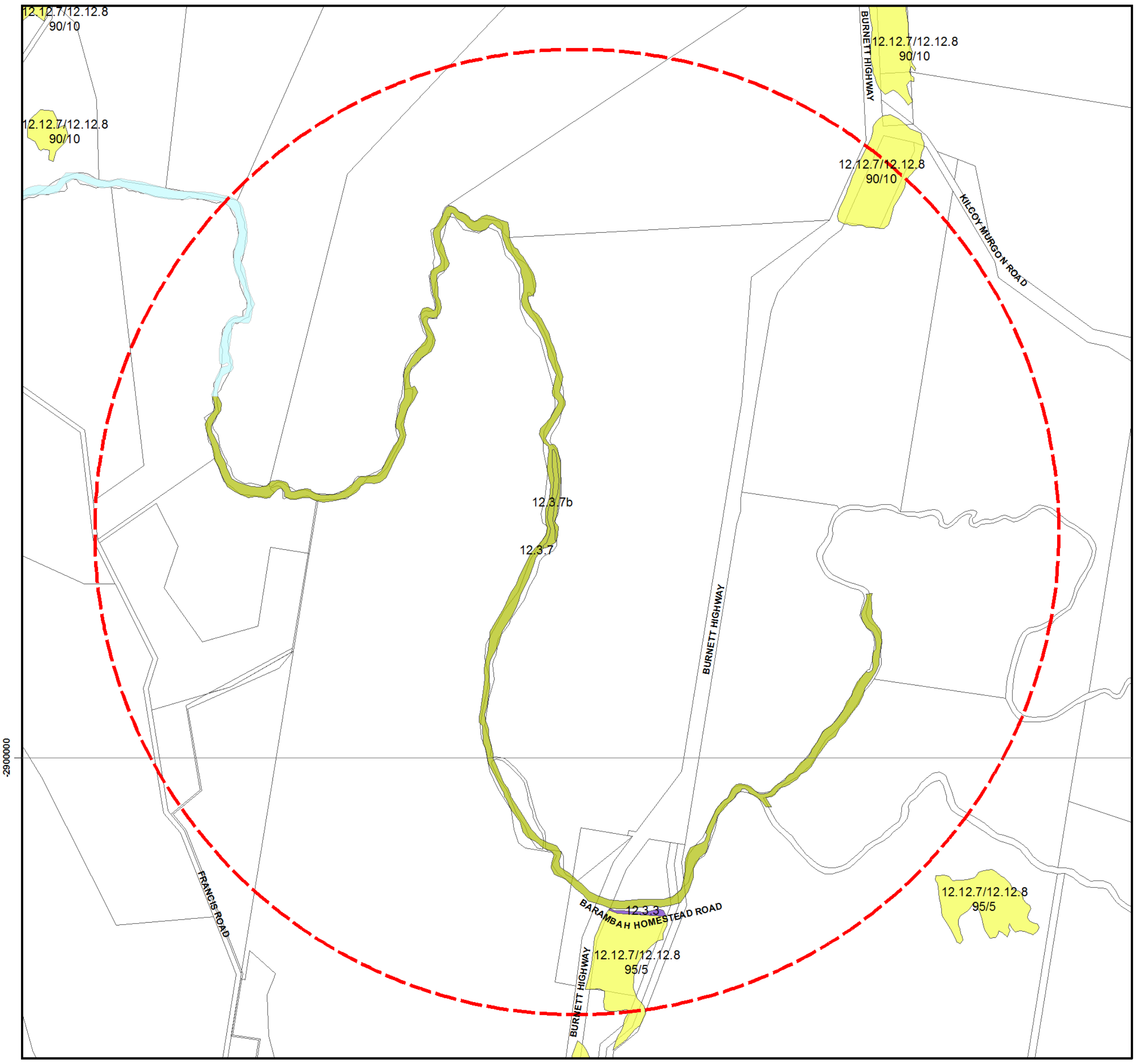
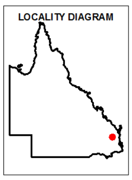
Map 2 - Remnant 2019 regional ecosystems

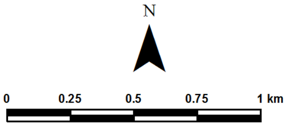


Remnant 2019 Regional Ecosystems

Biodiversity Status

- 2 kilometre buffer
- Endangered - Dominant vegetation
- Endangered - Sub-dominant
- Of Concern - Dominant
- Of Concern - Sub-dominant
- No concern at present
- Non-remnant vegetation, cultivated or built environment
- Plantation
- Water
- Cadastral Boundaries





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Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
The polygons are labelled by regional ecosystem (RE); where more than one RE occurs, the percentage of each is labelled. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.
Remnant woody vegetation is defined as vegetation that has not been cleared or vegetation that has been cleared but where the dominant canopy has >70% of the height and >50% of the cover relative to the undisturbed height and cover of that stratum and is dominated by species characteristic of the vegetation's undisturbed canopy.
Non-remnant vegetation includes regrowth and disturbed native vegetation.

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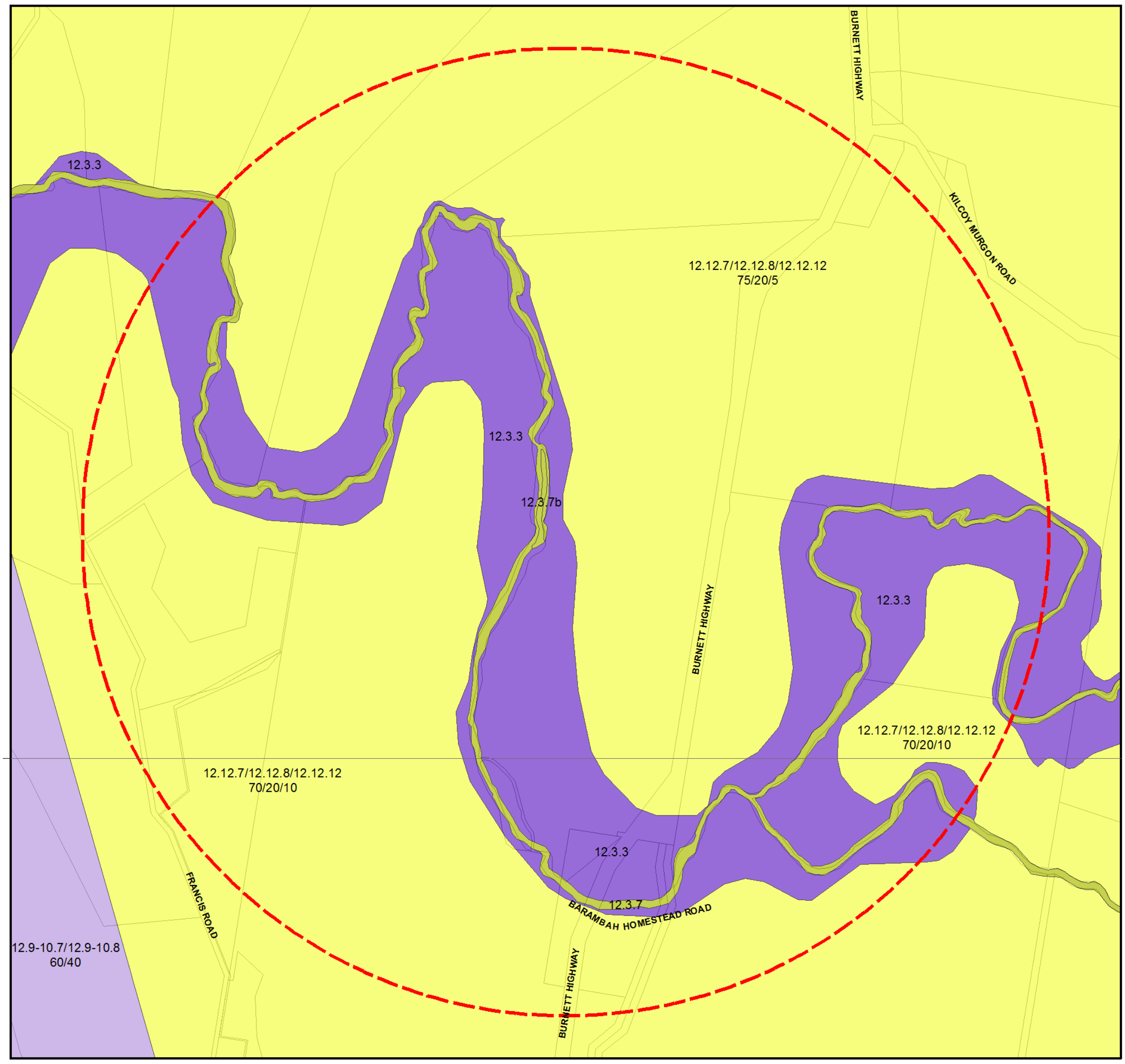
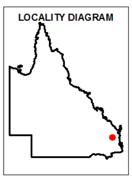
Map 3 - Pre-clearing regional ecosystems



Pre-clearing Regional Ecosystems

Biodiversity Status

- 2 kilometre buffer
- Endangered - Dominant vegetation
- Endangered - Sub-dominant
- Of Concern - Dominant
- Of Concern - Sub-dominant
- No concern at present
- Water
- Cadastral Boundaries



N

0 0.25 0.5 0.75 1 km

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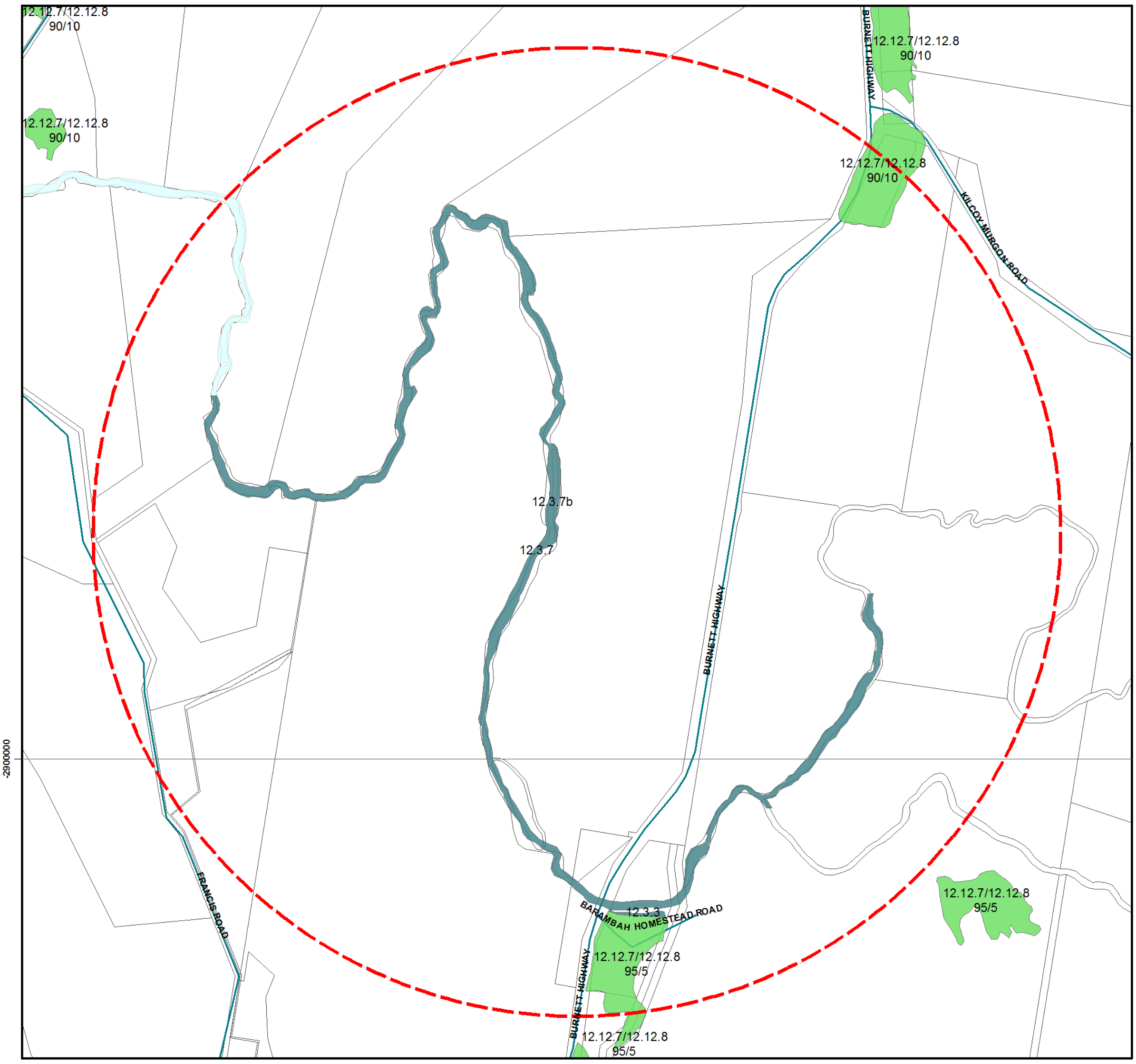
Map 4 - Remnant 2019 regional ecosystems by BVG (5M)

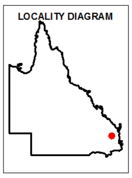


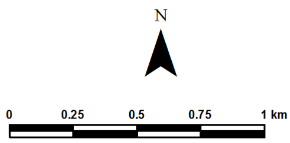
Remnant 2019 Regional Ecosystems coloured by Broad Vegetation Groups

Broad Vegetation Groups

BVG5M Description (BVG1M codes)

- 2 kilometre buffer
- 1. Rainforests and scrubs (1-7b)
- 2. Wet eucalypt open forests (8-8b)
- 3. Eucalypt woodlands to open forests (mainly eastern Qld) (9-15b)
- 4. Eucalypt open forests to woodlands on floodplains (16-16d)
- 5. Eucalypt dry woodlands on inland depositional plains (17-18d)
- 6. Eucalypt low open woodlands usually with spinifex understorey (19-19d)
- 7. Callitris woodland - open forests (20a)
- 8. Melaleuca open woodlands on depositional plains (21-22c)
- 9. Acacia aneura (mulga) dominated open forests, woodlands and shrublands (23-23b)
- 10. Other acacia dominated open forests, woodlands and shrublands (24-26a)
- 11. Mixed species woodlands, open woodland - (inland bioregions) includes wooded downs (27-27c)
- 12. Other coastal communities or heaths (28-29b)
- 13. Tussock grasslands, forblands (30-32b)
- 14. Hummock grasslands (33-33b)
- 15. Wetlands (swamps and lakes) (34-34g)
- 16. Mangroves and saltmarshes (35-35b)
- Non-remnant vegetation, cultivated or built environment
- Water
- Cadastral Boundaries





This product is projected into GDA 1994 Queensland Albers

Broad Vegetation Groups (BVG) of Queensland are applied by look up table to the regional ecosystem vegetation communities. Each polygon is coloured by the dominant BVG5M and the component regional ecosystems labelled. Where more than one regional ecosystem occurs, the percentage of each is labelled.
Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
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The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
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Non-remnant vegetation includes regrowth and disturbed native vegetation.

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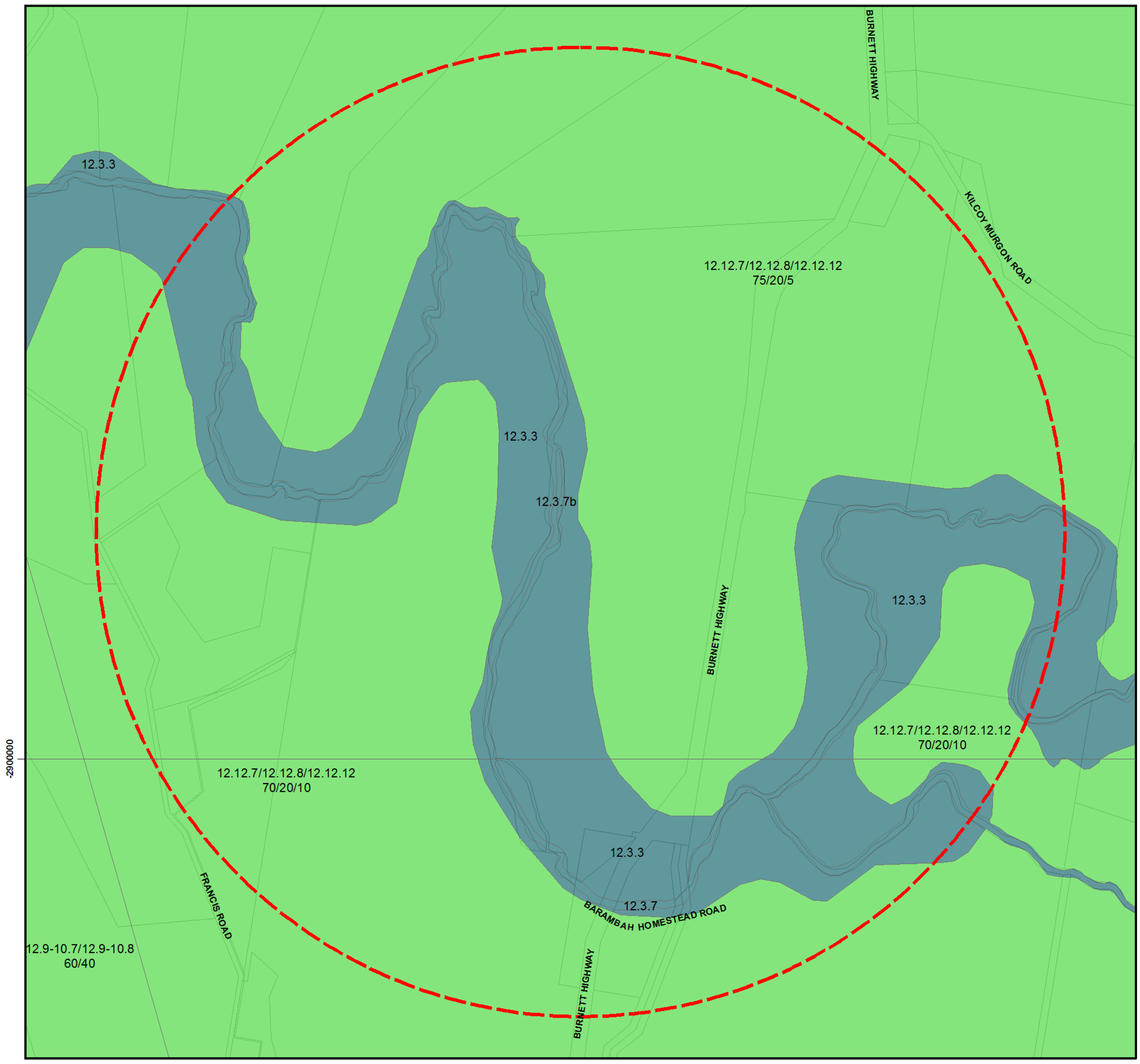
Map 5 - Pre-clearing regional ecosystems by BVG (5M)



Pre-clearing Regional Ecosystems coloured by Broad Vegetation Groups

Broad Vegetation Groups

BVG5M Description (BVG1M codes)

- 2 kilometre buffer
- 1. Rainforests and scrubs (1-7b)
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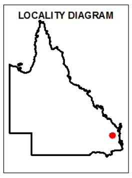
- 14. Hummock grasslands (33-33b)
- 15. Wetlands (swamps and lakes) (34-34g)
- 16. Mangroves and saltmarshes (35-35b)
- Water
- Cadastral Boundaries

LOCALITY DIAGRAM



N

0 0.25 0.5 0.75 1 km

This product is projected into GDA 1994 Queensland Albers

Broad Vegetation Groups (BVG) of Queensland are applied by look up table to the regional ecosystem vegetation communities. Each polygon is coloured by the dominant BVG5M and the component regional ecosystems labelled. Where more than one regional ecosystem occurs, the percentage of each is labelled.
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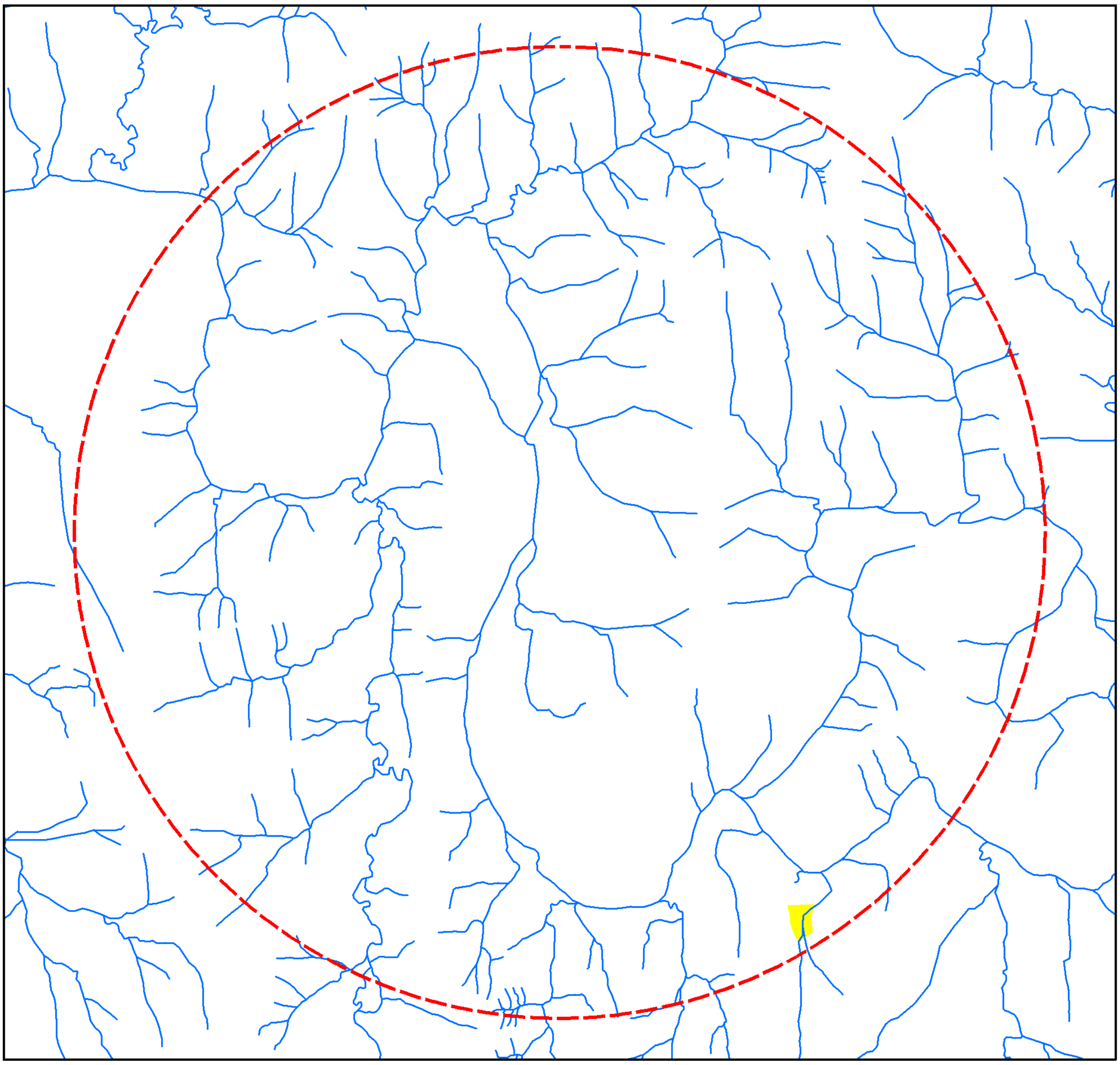
Map 6 - Wetlands and waterways



Queensland Wetland Data

Legend

2 kilometre buffer
Towns

Queensland Wetland Data

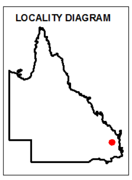
Riverine Drainage Lines
Springs

Wetland System - Water Bodies

Marine Waterbodies
Estuarine Waterbodies
Riverine Waterbodies
Lacustrine Waterbodies
Palustrine Waterbodies

Wetland System - Regional Ecosystems

Marine RE
Estuarine RE
Riverine RE
Lacustrine RE
Palustrine RE
RE 51-80% wetland (mosaic units)
RE 1-50% wetland (mosaic units)



N

0 250 500 750 1000 1250 m

Accuracy information: The positional accuracy of wetland data mapped at a scale of 1:100,000 is +/-100m with a minimum polygon size of 5ha or 75m wide for linear features, except for areas along the east coa st which are mapped at the 1:50,000 scale with a positional accuracy of +/-50m, with a minimum polygon size of 1ha or 35m wide for linear features. Wetlands smaller than 1ha are not delineated on the wetland data. Consideration of the effects of mapped scale is necessary when interpret ing data at a larger scale, e.g. 1:25,000. For property assessment, digital linework should be used as a guide only. The extent of wetlands depicted on this map is based on rectified 2013 Landsat ETM+ imagery supplied by Statewide Landcover and Trees Study (SLATS), Department of Environment and Science. The extent of water bodies is based on the maximum extent of inundation derived from available Landsat imagery up to and including the 2013 imagery.

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Links and Other Information Sources

The Department of Environment and Science's Website -

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/

provides further information on the regional ecosystem framework, including access to links to the Regional Ecosystem Database, Broad Vegetation Group Definitions, Regional Ecosystem and Land zone descriptions.

Descriptions of the broad vegetation groups of Queensland can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

The methodology for mapping regional ecosystems can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

Technical descriptions for regional ecosystems can be obtained from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

Benchmarks can be obtained from:

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

For further information associated with the remnant regional ecosystem dataset used by this report, refer to the metadata associated with the Biodiversity status of pre-clearing and Remnant Regional Ecosystems of Queensland dataset (version listed in **Appendix 1**) which is available through the Queensland Government Information System portal,

http://dds.information.qld.gov.au/dds/

The Queensland Globe is a mapping and data application. As an interactive online tool, Queensland Globe allows you to view and explore Queensland maps, imagery (including up-to-date satellite images) and other spatial data, including regional ecosystem mapping. To further view and explore regional ecosystems over an area of interest, access the Biota Globe (a component of the Queensland Globe). The Queensland Globe can be accessed via the following link:

http://www.dnrm.qld.gov.au/mapping-data/queensland-globe

References

Neldner, V.J., Niehus, R.E., Wilson, B.A., McDonald, W.J.F., Ford, A.J. and Accad, A. (2019). The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 4.0. Queensland Herbarium, Department of Environment and Science.

(https://publications.qld.gov.au/dataset/redd/resource/78209e74-c7f2-4589-90c1-c33188359086)

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S., Butler, D.W., McDonald, W.J.F, Addicott, E.P. and Appelman, C.N. (2020). Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland. Version 5.1. Updated March 2020. Queensland Herbarium, Queensland Department of Environment and Science, Brisbane.

(https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4)

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

The dataset listed below is available for download from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/download/

- Regional Ecosystem Description Database

The datasets listed below are available for download from:

http://dds.information.qld.gov.au/dds/

- Biodiversity status of pre-clearing and 2019 remnant regional ecosystems of Queensland
- Pre-clearing Vegetation Communities and Regional Ecosystems of Queensland
- Queensland Wetland Data Version - Wetland lines
- Queensland Wetland Data Version - Wetland points
- Queensland Wetland Data Version - Wetland areas

Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
VMA	- *Vegetation Management Act 1999*

ECONOMIC ROAD MAP

Attachment E: Crop Feasibility study

Peritus Ag Advisory

KBR – Boondooma Dam to Tarong Pipeline Project

Feasibility Study for Irrigated Cropping

18 August 2022

Contents

Appendices

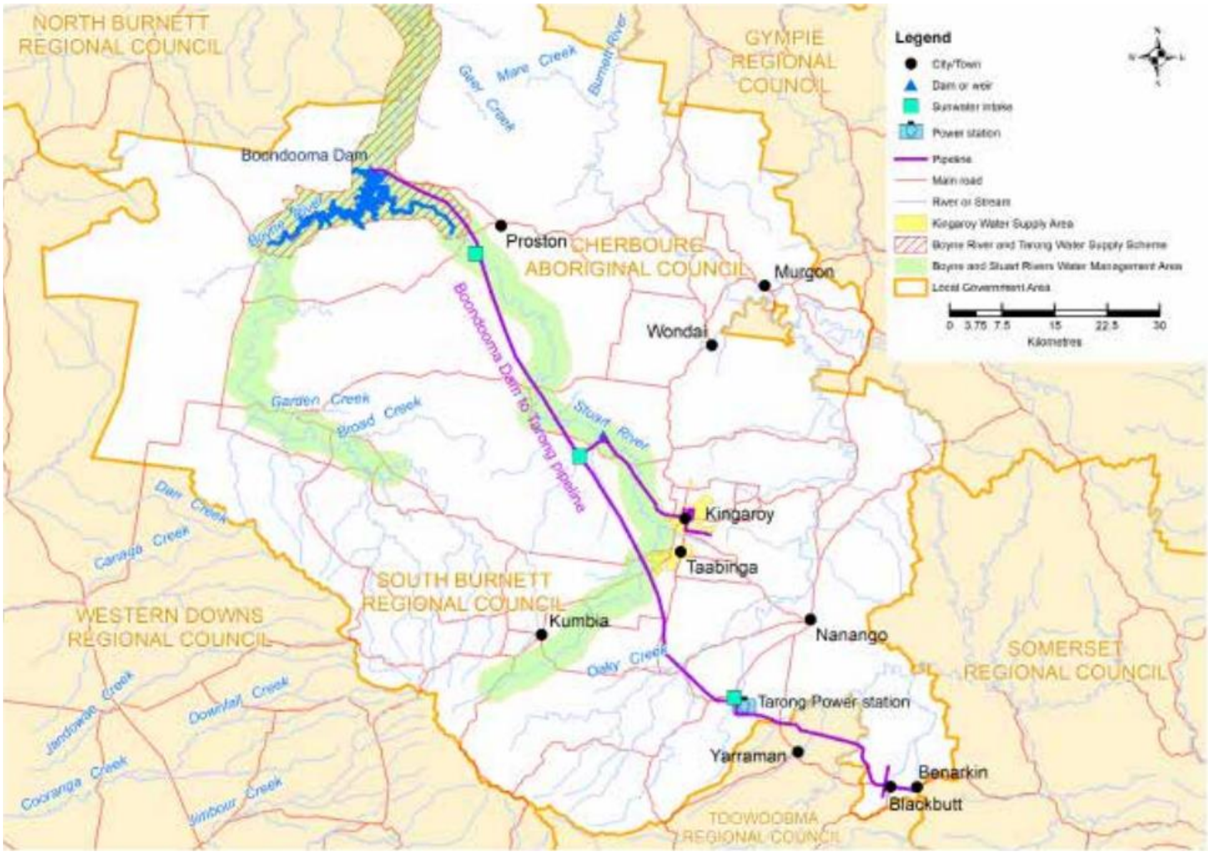
Tables

Images

1 Instructions

PeritusAg has been requested by KBR to assist with the Boondooma Dam to Tarong pipeline project. The project's objective is to proactively position the agriculture industry in the region to be ready to use the additional water that will become available from the Boondooma Dam once the Tarong Power Station is shut down. The closing power station will leave behind 30,000ML of high priority water that can be used for other purposes including urban requirements and agricultural production. The location of the current pipeline from the Boondooma Dam to the Tarong Power Station is presented as ***Image 1.1***.

Image 1.1: Boondooma to Tarong pipeline location



We have been requested to provide a feasibility study review of the potential crops that could be grown in the region when the additional water is made available. This study will consider the following parameters:

- suitability of the climate
- suitability of the soils
- review of the water quality from Boondooma Dam and Gordonbrook Dam
- current crop production in the region (dryland and irrigated)
- regionally suitable crops

Following on from this review, we will participate in a KBR led workshop to consider the irrigated crop production opportunities for the region in line with other factors, which are being reviewed by KBR staff, including the following:

- domestic markets
- export markets
- net margins, profitability, and capacity to pay
- existing infrastructure

2 Executive Summary

Based on the instructions provided by KBR, we have conducted a feasibility study for the potential for irrigated crop production in the farming region adjacent to the Boondooma Dam to Tarong pipeline.

This study reviewed the future opportunity for increasing irrigated crop production, when additional water allocation from the Boondooma Dam will become available. The additional water allocation will become available following the shutdown of the Tarong Power Station in 10-15 years' time.

We reviewed several factors that would have an influence on the potential for expanding irrigated crop production in the region, including the following:

- climate
- climate change risk
- soil types
- soil suitability factors
- carbon emissions and soil carbon

The climate review identified the following critical considerations that may have an influence on suitable crops, including:

- Air temperature
  - Average range: 3.8C – 30.9C
  - Max: 41C
  - Min: -6C
  - ≥35C: 12.6 days per year
  - ≥40C: 0.2 days per year
  - ≤2C: 39.2 days per year
  - ≤0C: 19.5 days per year
- Rainfall
  - Average: 645mm/yr
  - Median: 577mm/yr

The risk of frost in the region is significant, although, according to local knowledge, more elevated sites have less risk of frost and are suitable for frost sensitive crops.

The maximum high temperatures also pose a challenge for many high value perennial crops.

Both the risk of frost and high temperatures can be managed by careful consideration of site selection, mitigation measures (tree guards, shade structures etc) and crop management.

Climate change is likely to result in an increase in both the maximum and minimum temperatures although based on Bureau of Meteorology (BOM) predictions. The expected changes would not require any additional temperature mitigation/management strategies other than what would currently be required.

The annual rainfall is likely to become more variable with climate change and supports the value that irrigated crop production can bring to a region around increased reliability of production of irrigated crops.

There was an extensive soil survey conducted by the Department of Primary Industries in 2001, and that we have referenced in this feasibility study.

The study found that of the 126,608ha in the study area, there was approximately 61,459ha that could be suitable for perennial horticulture. This suitable area equates to 49% of the total area in the study.

We have identified the following factors that would need to be assessed to evaluate a site to be considered suitable.

- frost risk
- soil type
- rooting depth and sub-soil parameters
- access to proposed delivery network
- area of land available at the site

Irrigated crop production has the potential to lift production and provide reliable production regardless of the rainfall received in any given year. These factors will assist producers to reduce their carbon emissions and store more carbon in the soil by the following measures:

a) Irrigation enables a high level of confidence in yield potential. This means that nitrogen applications can be more accurately calculated to improve nitrogen use efficiency.

b) N2O losses can be reduced by applying nitrogen fertilisers more often throughout the crop growing cycle. Many irrigation systems, such as centre pivots or lateral move irrigators enable in-crop applications of fertiliser. With higher yield potential crops, growers are also more likely to change fertiliser application practices to maximise yield, which can involve more split applications of nitrogen fertiliser.

c) Incorporating fertiliser below the soil surface or applying fertiliser with irrigation water can reduce the potential losses of nitrogen as N2O, and increase nitrogen use efficiency.

d) The ability to produce consistently higher yielding crops with higher plant biomass each season can result in more carbon being stored in the soil. Irrigated crops with consistent biomass production each season can avoid the yield and biomass fluctuations that occur in dry-land cropping where soil carbon can accumulate during ‘wet’ years and previous years gains lost during a ‘dry’ year.

Based on the review of current annual and perennial crops grown in the region, we consider the following crops to be opportunities for irrigated crop production.

- Annual crops
    - Cotton
    - Peanuts
    - Beans
    - Chickpeas
    - Corn/maize
    - Pumpkins
    - Watermelons
- Perennial crops
    - macadamias
    - avocados
    - citrus
    - stone fruit
    - wine grapes

Based on the current irrigated crop production in the region, we assessed the potential water demand for annual and perennial crops as the following:

- Annual grain, cereal & forage crops: 4.5ML/ha/yr
- Adzuki beans, cotton & corn crops: 7ML/ha/crop cycle
- Perennial crops: 8ML/ha/yr

Based on the assumption that there would be 20 – 30GL of water allocation made available from the Tarong pipeline, we have calculated the potential area of land that could be converted into irrigated crop production ranging from 2,500 – 6,667ha.

The potential irrigation areas correspond to 2 – 5% of the total area in the DPI study area or 4 – 10% of the area identified as suitable for perennial horticulture crops.

3 Climate Review

This section will review the climate for the region based on weather data from the Bureau of Meteorology (BOM) weather station located at the Kingaroy Airport. The data has been collated from all available data collected since 2001 (21 years). The BOM location of Kingaroy was chosen based on the following assumptions:

- Current crop production operations are centred around Kingaroy.
- Kingaroy is the only BOM location in the region.
- New water allocations are likely to be taken up by existing farming operations from along the Tarong pipeline that runs adjacent to the red soil plateau situated around Kingaroy, where existing farming operations currently operate.

The climate review will consider the following parameters:

- temperature
- humidity
- rainfall
- climate change

Review of air temperature variability

In this section we will address the historical temperature variability. The air temperature data has been sourced from the BOM website and is summarised in ***Table 3.1,*** with all data presented in degrees Celsius.

Table 3.1: Kingaroy historical air temperature data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Max (C)	30.90	29.80	28.30	25.80	22.50	19.80	19.80	21.70	25.10	27.50	29.20	30.30
Mean Min (C)	18.00	17.70	16.30	12.10	7.40	5.80	3.80	4.10	8.10	11.80	14.50	16.80
Highest Max (C)	41.00	41.60	38.20	35.00	31.80	27.00	27.20	33.30	36.70	39.00	38.90	40.50
Lowest Min (C)	11.00	11.10	4.40	-0.60	-3.00	-5.00	-6.00	-4.90	-2.10	0.30	2.40	6.50

The key temperature statistics from this data are as follows:

a) Average maximum temperature ranges from 19.8C in June/July through to 30.3 – 30.9C in December/January.

b) Average minimum temperature ranges from 3.8C in July through to 18C in January.

c) The highest maximum temperature is 40.5 - 41C in December/January.

d) The lowest minimum temperature is -6C in July.

The average historical maximum temperature by month from Table 3.1 would be categorised as moderate, with a range of 20 – 30C. However, the highest maximum temperature is the factor that can impact crop production and the monthly data indicates;

a) that historically from September through to April, the temperature can peak at 35 – 41C.

b) Many crops will start to show a negative plant response as temperatures go higher than 33 – 35C.

c) Temperature mitigation practices will need to be considered for some crops to be successfully grown in the region and not be impacted by these high temperatures.

Historically, the average number of days where the temperature has reached high values where a negative crop response may occur are:

- ≥35C: 12.6 days per year
- ≥40C: 0.2 days per year

Our analysis of historical high temperatures in the Kingaroy region indicates that they have occurred approximately 13 days per year where the temperature will be higher than 35C and 0.2 days per year where the temperature can reach higher than 40C. Managing temperatures from 35 – 40C can often be achieved with a range of measures such as cooling misters/sprinklers or shade structures for example. Managing temperatures over 40C can be achieved with the same systems/structures but are typically less effective.

The average minimum historical temperature by month from Table 3.1 shows a range of 5.8C in June through to 18C in January. Historically, the lowest minimum temperature ranges from -6C in July through to 11C in January, with a risk of frost (sub-zero temperatures) from April to September.

The risk of frost will need to be considered during the crop selection process, as well as the possible crop management or mitigation options that will be required (frost fans, irrigation systems etc). Historically, the average number of days where the temperature can reach low values resulting in a potential negative crop response are:

- ≤2C: 39.2 days per year
- ≤0C: 19.5 days per year

The risk of frost in the Kingaroy region indicates that historically they can achieve approximately 20 days per year where the temperature will drop below 0C and result in a minor or major frost event. Appropriate frost mitigation strategies will be required to manage any crops that are sensitive to frost damage.

During stakeholder engagement sessions with local growers and agronomists, when raising the risk of frost, local knowledge suggests that frosts can be both patchy and very site specific. There are frost sensitive crops grown in the region, but the growers have used local knowledge to locate them in elevated sites, where frost event are not common. This local knowledge has been considered in relation to developing the list of crops that could be grown in the region. Further investigation work would need to be conducted by any potential investor or grower developing a plan to diversify their business. This will ensure they are confident of the risk of frost for a specific location.

Review of humidity variability

The historical humidity data has been sourced from the BOM website and is summarised in ***Table 3.2,*** with all data presented as percent moisture (%).

Table 3.2: Kingaroy historical humidity data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean 9am (%)	67.00	72.00	71.00	71.00	70.00	76.00	74.00	64.00	61.00	57.00	60.00	64.00
Mean 3pm (%)	47.00	52.00	48.00	45.00	43.00	49.00	44.00	36.00	35.00	33.00	41.00	43.00

The data in Table 3.2 indicates that the historical average humidity at 9am ranges between 57 – 71% with the highest average values from February to July of 70 – 76%. The 3pm average humidity data ranges from 33 – 52% with the lowest values from August to October of 33 – 36%.

As humidity levels drop, the evaporative loss of water from plants increases, thereby increasing the requirement for applying irrigation. The humidity values are lowest in later winter/early spring (August – October). In combination with a typical increase in vegetative growth during this period, low humidity will have a strong influence on the water use of most irrigated perennial crops and annual crops.

When considering an irrigation demand budget, in conjunction with crop stage and rainfall, humidity should also be considered as a key influence on daily water demand.

Review of rainfall variability

The historical rainfall data has been sourced from the BOM website and is summarised in ***Table 3.3,*** with all data presented as millimetres (mm) of rain.

Table 3.3: Kingaroy historical rainfall data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Mean (mm)	87.40	92.10	71.20	21.60	32.90	41.90	23.70	26.90	25.20	62.30	63.60	96.20	***645.00***

The Kingaroy region has an official historical average rainfall of 645mm per year. The months with the highest rainfall are October to March with a range of 62 – 92mm average per month. The rainfall pattern is consistent with a dominance of summer rainfall. A summer rainfall pattern is suited to irrigated perennial crops or summer grown annual crops, as rainfall will occur during peak water demand for these crop types.

The average rainfall data provides broad insight into the rainfall patterns of a region. ***Table 3.4*** provides additional historical rainfall statistics to enable a broader understanding of the expected rainfall for the Kingaroy region, with the referenced data attached as;

Appendix A: Historical climate statistics for Kingaroy

Table 3.4: Additional historical Kingaroy rainfall data

Statistic	Annual Total Rainfall (mm)
Mean	635.1
Median	576.8
Highest	1079.0
Lowest	295.8

The average annual rainfall data value from Table 3.4, averages the actual annual rainfall totals. The value in Table 3.3 is the total rainfall from the average monthly rainfall figures, resulting in a difference of 10mm between the two figures (Note: all data sourced from BOM).

The total annual rainfall varies significantly from 295 – 1079mm/yr. This significant variability will influence the calculated water allocation. The calculated allocation will need to ensure that perennial crops are supplied with water to match the range of annual demands. Assuming rainfall efficiency of 50%, the driest years would require an additional water allocation of up to 1.5ML/ha to compensate for the lack of rainfall.

In calculating the water allocation requirements for a specific crop based on the historical data, the use of the median value of 577mm/yr should be used as this will represent the midpoint of annual total rainfall in the past 21 years.

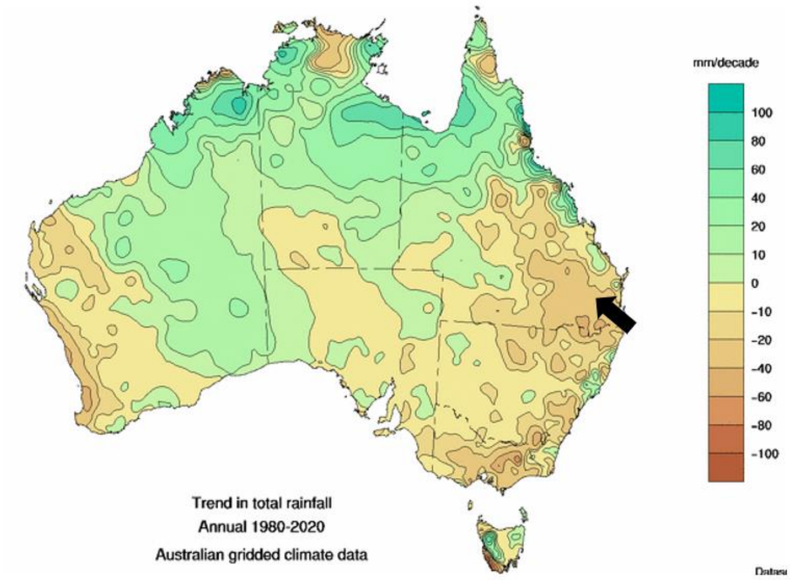
Climate change

With any new irrigated agriculture project, the risk and impact of climate change needs to be considered along with historical climate data. Climate change can impact crop management and performance in the following:

- air temperature
- soil temperature
- humidity
- rainfall
- extreme weather events
- altered risk of frost and heat waves

The BOM website provides a range of predictive maps of the expected changes to climate across Australia. The following BOM climate change maps (***Image 3.1, 3.2 and 3.3***) present the predicted changes in rainfall and air temperature.

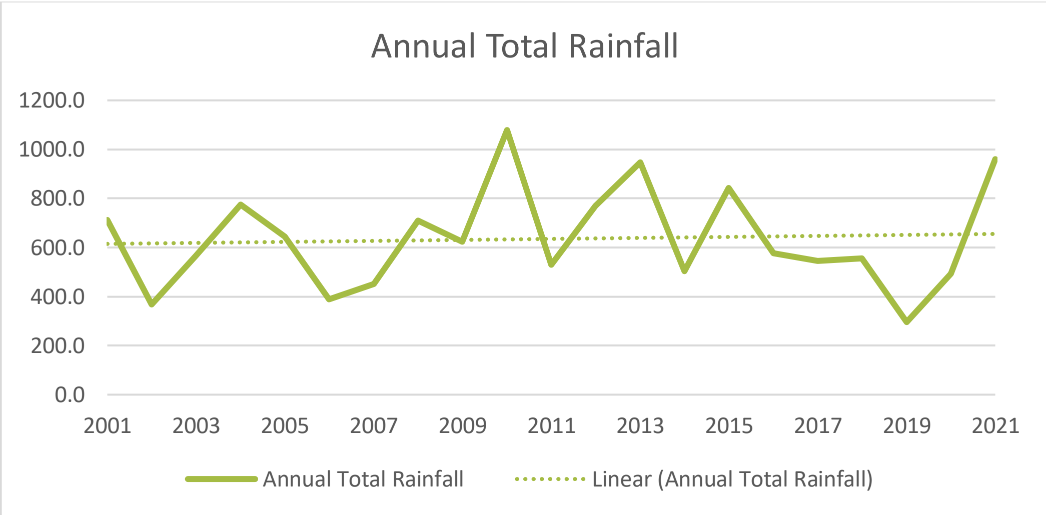
Image 3.1: Climate change map – trend in total rainfall



The black arrow points to the approximate location of Kingaroy. This predictive BOM map indicates that the region will be impacted by an expected reduction in rainfall of 20-40mm per decade. Over a 30-year period, the rainfall in this region may reduce by 60 – 120mm and assuming a 50% rainfall efficiency rate, would increase the irrigation demand by 0.3 – 0.6ML/ha. The initial irrigation demand calculations should take this risk into account.

A review of the historical data for the past 21 years, as shown in ***Graph 3.1***, shows a trend of a slight increase in annual rainfall over this period.

Graph 3.1: Historical trend in annual rainfall for Kingaroy



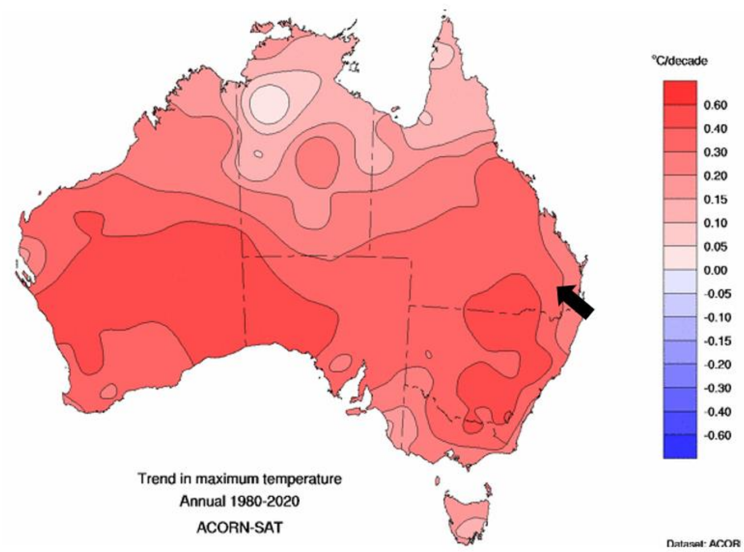
The linear trend line in Graph 3.1 over the past 21 years is presented as a dotted line and is showing a slight upward trend of approximately 20mm/decade or 40mm over the past 21 years. However, 21 years is a short timescale to consider rainfall cycles and the predicted future impact of climate change.

The impact of climate change on rainfall patterns can also increase the variability of annual rainfall, even if the average is not directly impacted.

It would be advisable to use historical trends, BOM predicted future trends for total annual rainfall, as well as the risk of increased variability, to calculate the required water allocation for a new irrigation crop production operation.

Image 3.2 presents the BOM predictive map for the increase in the maximum temperature because of climate change.

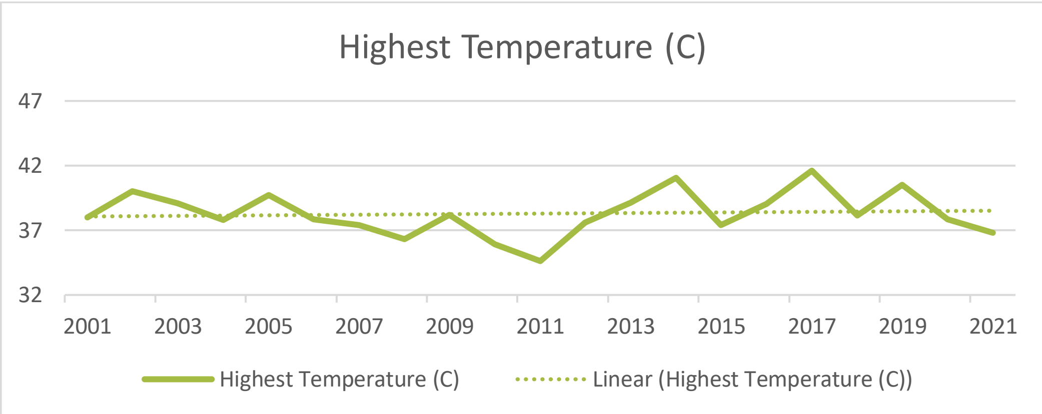
Image 3.2: Climate change map – trend in maximum temperature



The black arrow points towards the approximate location of the Kingaroy region. This predictive BOM map indicates that the region will be impacted by an increase in the maximum temperature of 0.3 – 0.4C per decade. Over a 30-year period, the maximum temperature in this region may increase by 0.9 – 1.2C. Based on review of air temperature earlier in this section, if the prediction is correct, the number of days per year with temperatures in the 35 – 40C range will likely increase from the historical average of 12.6/yr. The number of days >40C will also likely increase from the historical average of 0.2/yr.

In reviewing the historical data for the past 21 years, as shown in ***Graph 3.2***, the trend is showing a slight increase in the highest temperature over this period.

Graph 3.2: Historical trend in highest temperature for Kingaroy

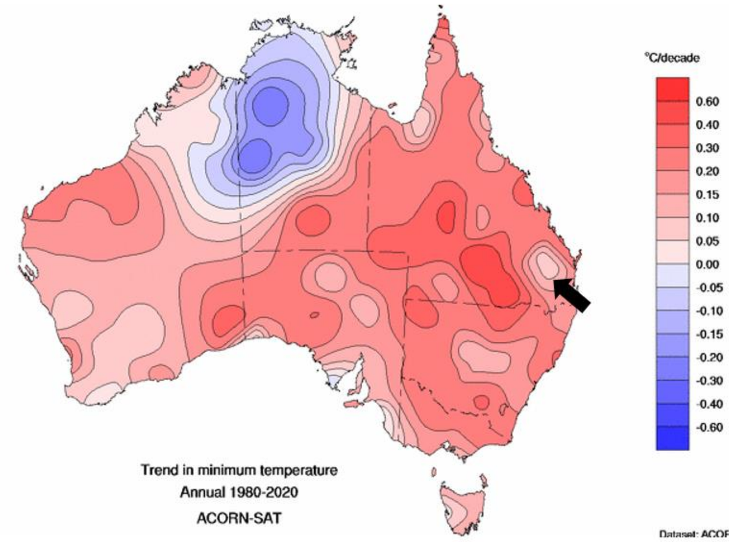


The linear trend line in Graph 3.2 over the past 21 years is presented as a dotted line and is showing a slight upward trend of approximately 0.22C/decade or 0.44C over the past 21 years. This increase in maximum temperature is broadly in line with the BOM predictions.

If the long-term temperature predictions are correct, then the decision around crop choice may not change, but the mitigation strategies being considered to manage high temperatures should be factored in during the design and setup stage, as well as the potential influence on daily crop water use.

Image 3.3 presents the BOM predictive map for the increase in the minimum temperature because of climate change.

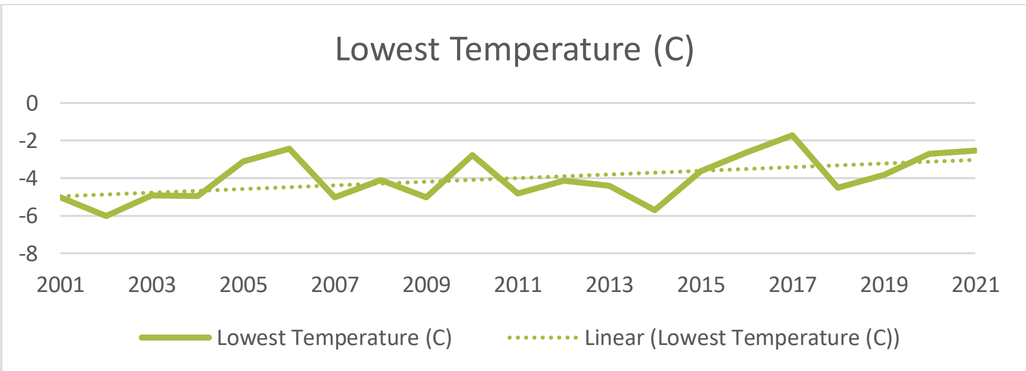
Image 3.3: Climate change map – trend in minimum temperature



The black arrow points towards the approximate location of the Kingaroy region. This predictive BOM map indicates that the region will be impacted by an increase in the minimum temperature of 0.05 – 0.1C per decade. Over a 30-year period, the minimum temperature in this region may increase by 0.15 – 0.3C.

In reviewing the historical data for the past 21 years, as shown in ***Graph 3.3***, the trend is showing an increase in the lowest temperature over this period.

Graph 3.3: Historical trend in lowest temperature for Kingaroy



The linear trend line in Graph 3.3 over the past 21 years is presented as a dotted line and is showing a slight upward trend of approximately 0.97C/decade or 1.94C over the past 21 years. This increase in minimum temperature is broadly in line with the BOM predictions.

Based on review of air temperature earlier in this section, if the prediction is correct, the number of days per year with temperatures at or below 0C is not likely to change significantly over the next 30 years. Any frost mitigation strategies being considered in the design and setup stage for an irrigation project will likely be required even with a slight increase in the minimum temperature.

4 Soils Review

This section will review the available data on the soils of the South Burnett region and the suitability of these soils for irrigated crop production.

There have been broad studies of the soils of the South Burnett region with a focus on the region between Barker-Barambah Creek in the north down to the Bunya Mountains in the south. The documents referenced in this section are attached as;(MF

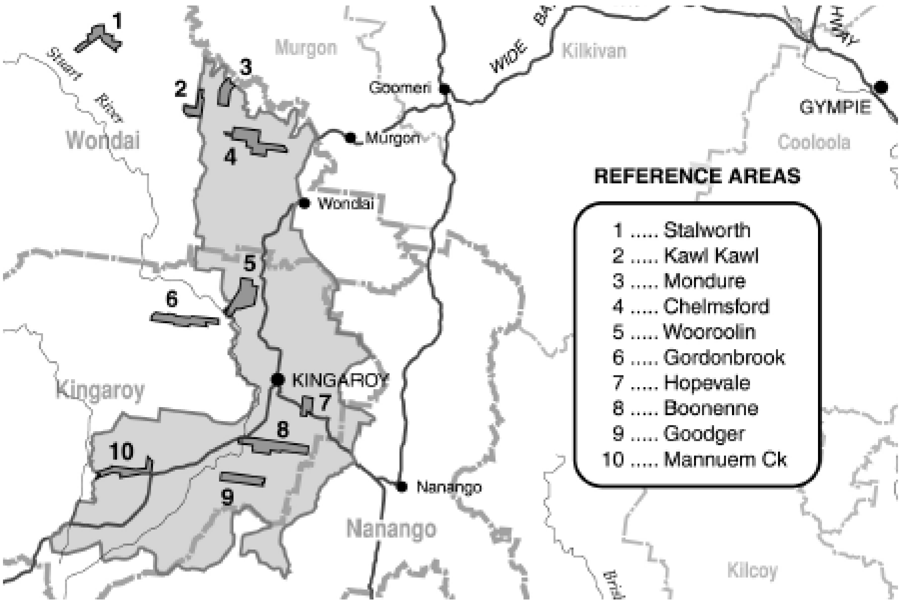
Appendix B: South Burnett soil and land suitability report

Appendix C: South Burnett area soils map

Appendix D: South Burnett dryland crop suitability map

Image 4.1 presents the study area that is covered by Appendix B.

Image 4.1: Soil mapping study area



The study area represents approximately 126,608ha of total land area and identified 49 distinct soil profile classes that combine the following attributes:

- soil classification
- geology
- landform
- vegetation

The study identified the following soil types across the study area:

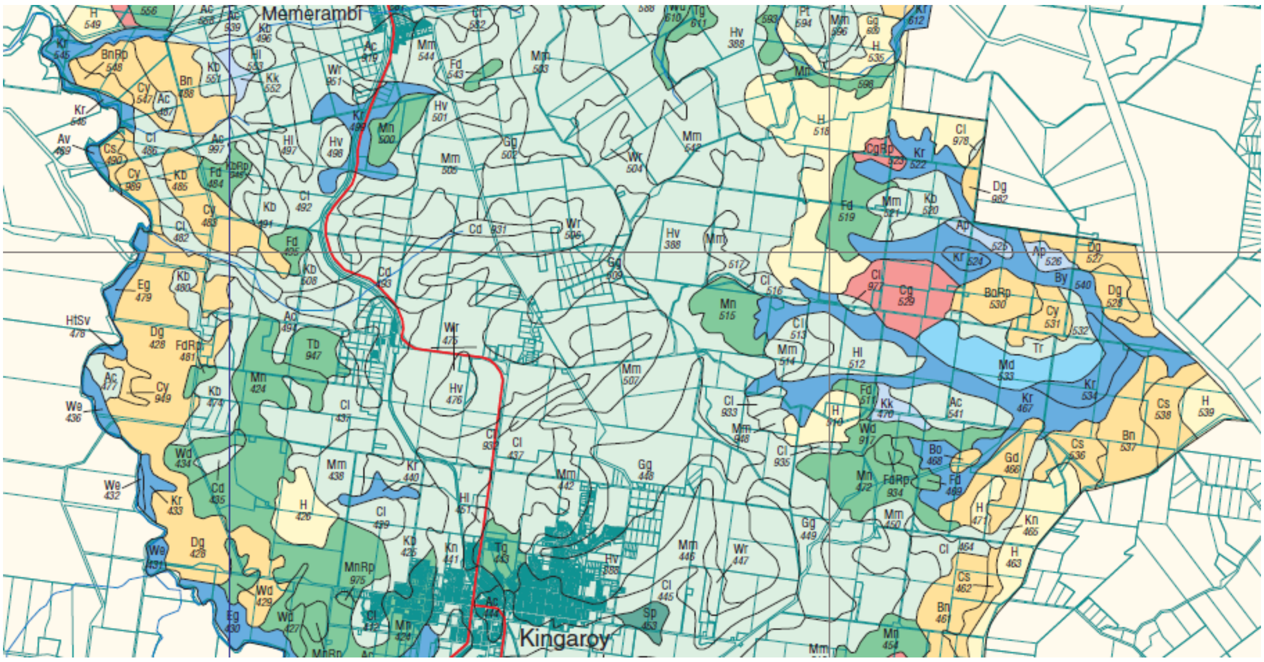
- Dermosol
- Chromosol
- Vertosol
- Sodosol
- Ferrosol
- Kandosol
- Tenosol
- Kurosol

These soil types are considered potentially suitable for crop production except for Sodosol soils, as they can have levels of sodium that make them unsuitable from a chemical or structural perspective. The remaining soil types listed above would broadly be considered suitable for crop production depending on specific attributes as follows:

- soil chemistry
- soil structural and physical characteristics
- depth of A horizon (upper profile and effective rooting depth)
- specific chemical and physical characteristics of the B horizon (subsoil layer and influence on root growth)

Image 4.2 is a small section from Appendix D showing the variability of soil types across the study area. The image shows the soil variability in an area from Kingaroy to 10km north to Memerambi, with each colour depicting a different soil type.

Image 4.2: Example of soil type variability across the study area



The level of soil type variability identified in Image 4.2 would suggest that a more detailed soil study would likely be required prior to any new irrigation project commenced. This would ensure that any specific area of land that was planned to be considered for irrigated crop production would have suitable chemical and physical characteristics and potential rooting depth.

The soil study also classified the soils across the area into a land use class range from class 1 to class 5 soil types. The use of soil class 1 – 5 descriptions, classifies land on the basis of '*A specified land use which allows for optimum production with minimal degradation to the land resource in the long term*' (Appendix C). The use of soil classes allows for a simplified approach to defining what the soil is suitable for, with the soil class explanation from Appendix C summarised in ***Table 4.1***.

Table 4.1: Soil class explanation

Class Type	Description
Class 1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
Class 2	Suitable land with minor limitations which either reduce production or require more than the simple management practices of Class 1 to maintain economic production.
Class 3	Suitable land with moderate limitations which either further lower production or require more than the management practices of class 2 land to maintain economic production.
Class 4	Marginal land with severe limitations which make it doubtful whether the inputs required to achieve and maintain production (and/or minimise land degradation) outweigh the long-term benefits.
Class 5	Unsuitable land with extreme limitations that preclude its use.

Image 4.3 presents a small section from Appendix C showing the variability of soil classes across the study area. The image shows the soil variability in an area from Kingaroy to 10km north to Memerambi, with each colour depicting a different soil class, using the following colour range:

a) Class 1: yellow

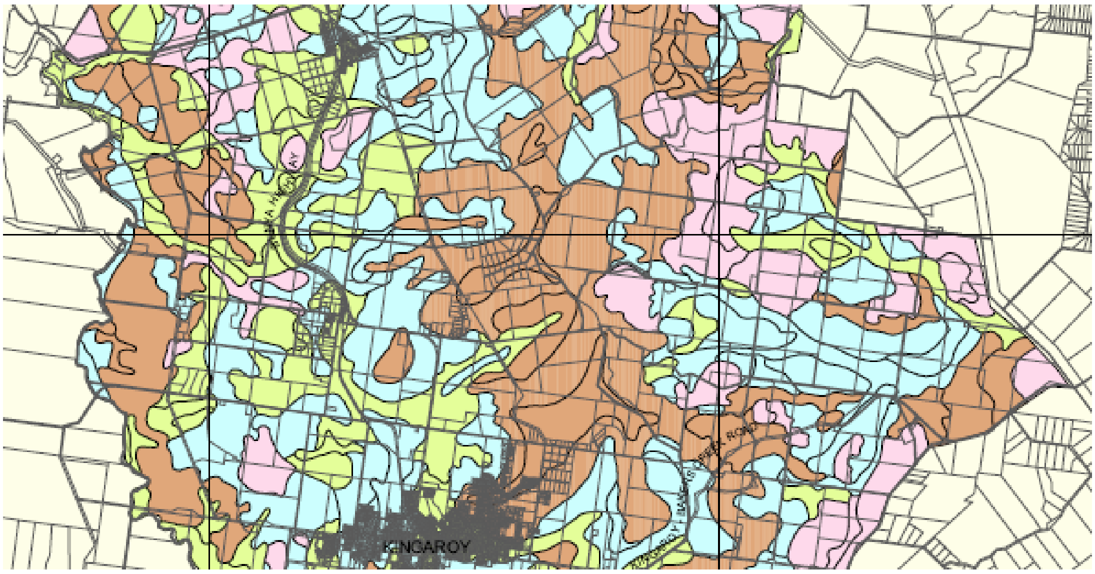
b) Class 2: green

c) Class 3: blue

d) Class 4: brown

e) Class 5 pink

Image 4.3: Example of soil class variability across the study area



In this section of the soil class variability map, the areas of class 2 and 3 soils that would likely be suitable for irrigated crop production are evident by the green and blue shaded zones. The class 4 and 5 soils, depicted by the brown and pink shaded areas, would not be considered suitable for irrigated crop production. In this image, there are no identified areas of class 1 soils.

Image 4.3 clearly shows the high variability of soil classes across this section of the map and supports our belief that further detailed soil survey studies would be required during the planning stage of any new irrigation crop production project.

The soil type study conducted across the region used the collected data to categorize the soils across the red soil plateau into their potential agricultural uses. The potential agricultural uses include:

- dryland cropping
- dryland pastures
- tree and vine crops

Table 4.2 summarises the total area for each soil class from this study (Appendix B).

Table 4.2: Summary of land suitability by soil class and proposed crop production

Suitability Class	Dryland Cropping (ha)	Dryland Pastures (ha)	Tree and Vine Crops (ha)
1	0	3748	3795
2	23912	53487	17516
3	42888	35567	40148
Sub Total	***66800***	***92802***	***61459***
4	28118	14727	34656
5	31690	19079	30493
Total	***126608***	***126608***	***126608***

The data in Table 4.2 indicates that there is potentially up to 61,459ha of land that could be suitable for tree and vine crops, which represents approximately 49% of the total land area in the study.

It is unlikely that all the entire 61,459ha would be found to be suitable for irrigated crop production following a more detailed soil survey on a site-by-site basis. Depending on the water allocation and level of security offered to irrigators, there may be some interest from traditional dryland cropping businesses who would consider applying irrigation to some dryland cropping land, this would potentially result in a larger area of land suitable for irrigated crops.

5 Review of Water Quality from Boondooma and Gordonbrook Dams

This section will review the suitability of the water from Boondooma Dam and Gordonbrook Dam.

The water quality data has been provided by South Burnett Regional Council and is attached as;

Appendix E: Boondooma and Gordonbrook Dam Raw Water Data

Appendix F: Gordonbrook Dam Raw Water Data 2016 May 2022

The South Burnett Regional Council has the water quality of the water storages sampled and analysed weekly for the following chemical parameters:

- Electrical conductivity (EC)
- pH
- Hardness
- Alkalinity
- Total dissolved ions
- Total dissolved solids
- Colour
- Turbidity
- Bicarbonate
- Carbonate
- Hydroxide
- Silica

- Sodium
- Potassium
- Calcium
- Magnesium
- Hydrogen
- Chloride
- Fluoride
- Nitrate nitrogen
- Sulphate sulphur
- Iron
- Manganese
- Zinc
- Aluminium
- Boron
- copper

Over time, the test results for the above parameters can increase or decrease thereby changing the quality of the water and its potential use.

The quality of the water in any large storage can fluctuate depending on several factors including:

a) depth of the water

b) rainfall

c) volume of inflows

d) lateral underground seepage into the dam

e) runoff from catchment area

The following review of the water quality from the two dams will be focussed on agricultural use, with the key focus on pH, EC, hardness, sodium, and chloride as these parameters are critical to water quality and crop suitability.

The EC classification system grades water into 5 classes according to EC concentration and the crops that are suitable to be grown with that water.

Table 5.1 presents the EC class and crop suitability correlation.

Table 5.1: EC water class and crop suitability

EC (uS/cm)	Class	Suitability
0 - 280	1	Low salinity water can be used with most crops on most soils, with little likelihood that a salinity problem with develop.
280 - 800	2	Medium salinity water can be used in well drained soils. Suitable for medium salt tolerant crops and use on salt sensitive crops may result in leaf scorch.
800 - 2300	3	High salinity water should not be used on poorly drained soils. Suitable for crops with a high salt tolerance with specific management to avoid problems.
2300 - 5500	4	Very high salinity water and not suitable for irrigation under most conditions. Use requires very well drained soils and specific soil, irrigation and plant management.
≥5500	5	Extremely high salinity water and should only be used on salt tolerant crops in an emergency water shortage situation only.

The above table shows that class 1 and 2 water sources are the most suitable for irrigated crop production. The use of class 3 – 5 water sources require careful management to avoid soil or crop performance issues and the careful consideration of the salt tolerance of proposed crops.

The water hardness scale represents the amount of dissolved calcium and magnesium in a water sample. The results are expressed as mg/L of calcium carbonate with the water hardness scale reproduced in ***Table 5.2***.

Table 5.2: Water hardness scale

Calcium Carbonate (mg/L)	Classification
0 - 50	Soft
50 -100	Moderately soft
100 - 150	Slightly hard
150 - 300	Hard
300 - 500	Very hard
>500	Extremely hard

The potential issues with regards to hardness of water in agriculture is related to its use in irrigation and the risk of system blockages and interaction with some fertiliser and chemical products.

Boondooma Dam

This section will review the water quality from the Boondooma Dam storage with data supplied from 12 May 2016 – 21 May 2019 which included 132 individual weekly test results.

From the supplied data we have summarised this dataset and provided the following figures:

- Highest test value
- Lowest test value
- Average test value
- Median test value

Table 5.3 presents the summarised water quality data for Boondooma Dam.

Table 5.3: Summary of the Range of Water Quality in Boondooma Dam

Test Result	pH	EC (uS/cm)	Hardness	Sodium (mg/L)	Chloride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Bicarbonate (mg/L)
Highest	7.94	1900	446	192	520	54	79	714
Lowest	6.71	500	108	50	110	16	17	72
Average	7.49	686	153	69	159	22	24	92
Median	7.49	679	150	68	150	21	23	92

The average EC value of 686uS/cm. This water is considered a class 2 water that is suitable for most crops except for some very salt sensitive crops, of if used on poorly drained soils.

There are three data spikes across the recorded data period where the water test result is showing as class 3 (EC in the range of 800 – 2300uS/cm). EC values in this range would potentially impose more restrictions on use depending on crop and soil type.

In general terms, the levels of sodium and chloride are considered acceptable if irrigation applications are managed well and used on moderately salt tolerant crops grown on well drained soils.

The water hardness value of typically less than 150mg/L means the water is slightly hard which would not impact its use for irrigation. The data spikes in EC also aligns with spikes in hardness. The major cations (Na, Ca and Mg) show data spikes in conjunction with the EC spike, resulting in the lift in hardness value to around 400^{+}mg/L. A very hard water is still suitable for irrigation use but does require some specific management around irrigation system maintenance and how/what fertilisers are incorporated into the irrigation water to avoid blockages.

There is a small level of bicarbonate in the water due to the pH. This may result in additional cleaning being required for micro irrigation systems (drip, micro sprinklers etc), but these values are not considered a major issue compared to other regions in Australia.

This water is suitable for a wide range of the crops that are either grown in the region or are considered suitable for irrigated crop production.

Gordonbrook Dam

This section will review the water quality from the Gordonbrook Dam storage with data supplied from 12 February 2016 – 18 May 2022 which included 195 individual test results.

From the supplied data we have summarised this dataset and provided the following figures:

- Highest test value
- Lowest test value
- Average test value
- Median test value

Table 5.4 presents the summarised water quality data for Gordonbrook Dam.

Table 5.4: Summary of the Range of Water Quality in Gordonbrook Dam

Test Result	pH	EC (uS/cm)	Hardness	Sodium (mg/L)	Chloride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Bicarbonate (mg/L)
Highest	8.85	2980	661	330	910	83	130	660
Lowest	6.43	200	52	16	30	4	0	55
Average	7.85	1825	425	185	495	53	71	144
Median	7.87	1760	425	172	470	56	67	146

The EC on average is 1825uS/cm which puts it in the mid Class 3 range, where it is recommended to be only used for irrigation on moderately salt tolerant crops. The minimum value of 200uS/cm occurred after significant inflows into the dam with the value rising to 800uS/cm within 8wks.

The EC has been greater than 2300uS/cm over the six-year period 21% of the time, which means it is not suitable for irrigation in most situations. EC results of this value put it in the class 4 range which increases the risk to plant performance and should only be used on well drained soils, on salt tolerant crops or for emergency water shortage periods. Some crops such as macadamias, grain sorghum and even peanuts can cope with EC values this high for a short period of time, but some crop impact is likely if used for an extended period.

The cause of the high EC appears to result from an increase in both sodium and chloride with some influence also likely from calcium and magnesium.

The level of sodium is mostly manageable in well drained soils so long as there is a focus on crop nutrient management and soil health. The raised level of sodium may impact soil structure over time with prolonged use.

The chloride level at 250mg/L is manageable but when it reaches or exceeds the average of 466mg/L, it will be an issue for most crops, with even salt tolerant crops showing some symptoms of leaf margin burn (leaf scorch).

The hardness is usually caused by increased levels of sodium, calcium, and magnesium in conjunction with a pH over 8. When the hardness levels peak at more than 500, the water would be considered too hard for use as irrigation water in most situations.

This water could be used for irrigating some crop types but there will be periods of time where the water may not be suitable for all these crops. During these unsuitable use periods, if practical, the water could be blended with better quality sources, so long as other water sources are available.

Based on the supplied data, the Gordonbrook Dam water quality will be a challenge to use in its raw form due to the fluctuations in water quality parameters and changing suitability for irrigation on some crops. With ongoing monitoring and a planned strategy for when the water quality declines, this water could be used for the emergency irrigation of salt tolerant crops on well drained soils.

6 Overview of Current Cropping in the Region

This section will review the current crop production across the red soil plateau region that was covered by the soil survey discussion in section 4.

Annual crop production

The region has been recognised for many years as being a significant annual row cropping area, which produces the following:

- peanuts
- corn/maize
- mung beans
- faba beans
- soybeans
- adzuki beans
- forage sorghum
- sorghum
- chickpeas
- wheat
- barley
- oats
- millet
- cotton
- pumpkins
- watermelons

Although it has traditionally been considered a dryland cropping region, there has also been some irrigated crop production. The sources of water used for irrigation in the region include the following:

- river allocation
- flood pump and on-farm ring tank storage allocation
- overland flow captured in on-farm dams
- bore
- off-take from the Tarong pipeline

The types of irrigation systems used include the following:

- centre pivots
- lateral move irrigators
- flood irrigation
- drip irrigation
- under-tree sprinklers and micro irrigation

Growers with a current irrigation water allocations are either supplementary or fully irrigating a range of annual crops that include the following:

- peanuts
- forage crops
- cotton
- beans
- corn
- chickpeas
- pumpkins
- watermelons

Perennial crop production

There has been perennial crop production in the region for many years with crops that are successfully grown including:

- bananas
- stone fruit
- wine grapes
- avocados
- macadamias
- lucerne
- citrus (limes, cumquats)
- Duboisia

Although perennial crops have been grown in the region for many years, the growth in production area of these crops has been limited for a range of reasons including:

a) limited reliable water allocations
b) generational farming practices
c) reduction in supporting businesses
d) recognition of the region being suitable for these crop types
e) lack of vision and desire to invest in on-farm irrigation infrastructure (on-farm storages, dams, delivery hardware etc)

As discussed in section 3, based on the BOM climate data, the risk of frosts in the region is high. Anecdotal evidence indicates that the incidence of frost can be managed in part by site selection. While gathering stakeholder input and utilising generational knowledge of the region, it became evident that frosts occurring in the region can be very patchy and site specific. For example, a grower has been producing bananas in the region for nearly 30 years. Bananas are a very frost sensitive plant. The farmer has got around this by planting in an elevated site with a low risk of frost. Anecdotally, crops planted in elevated positions will receive frosts in both regularity and severity like coastal farming locations, such as Bundaberg.

There is an opportunity for frost sensitive crops to be considered as expansion opportunities for the region, however, this will require careful selection of sites for development.

7 Irrigated Crop Opportunities

This section will review the potential crops that would likely be a focus for expansion if additional water allocation were to become available.

The region has a broad range of crops already being grown, with many of these crops also being irrigated where irrigation water is available. It is likely that the major opportunity for growth in irrigated crops is with the current crops being grown in the region. Currently, the crops are either supplementary irrigated annual crops or fully irrigated perennial crops.

We will divide our discussion on the potential growth of irrigated crops into annual or perennial crops. Annual crops are likely to only require medium priority water reliability, while perennial crops would require either high priority or high priority ag water reliability.

Annual crops

The cropping of the following annual crops would benefit from a reliable irrigation allocation from both a productivity and economic standpoint.

- cotton
- peanuts
- beans
- chickpeas
- corn/maize
- pumpkins
- watermelons

In conjunction with the above crops, there may also be vertically integrated farming operations, such as pig producers or dairy farmers, who would have a desire to increase the reliability of both forage and grain crop production. These inputs are essential for their primary business of producing pork or dairy products.

Perennial crops

The following perennial crops are likely to be opportunities for growth if additional water allocations were made available in the region.

- macadamias
- avocados
- citrus
- stone fruit
- wine grapes

Macadamias are not widely grown in the region currently, although there are currently a small number of non-commercial plantings in a limited number of locations in the region. One interviewed stakeholder had sufficient macadamia trees seedlings ordered to plant approximately 60ha on a site they identified as having a low risk of frost.

As previously discussed in section 3, the risk of frost could be considered a limitation for some crops. However, careful site selection could see perennial crops currently grown in the Bundaberg region, planted in this region.

Macadamias, avocados, and citrus are all frost sensitive crops that are grown successfully in the Bundaberg region, where some frosts occur. Growers in the Bundaberg region implement crop management practices that limit the impact of frosts on these perennial crops. Special attention is taken during the early crop development phase, when they are most sensitive to frosts. Growers in the Kingaroy region would need to consider these frost risk mitigation factors alongside careful site selection.

8 Crop Water Use and Potential Irrigated Land

This section will review the potential irrigation allocation demand for the annual and perennial crops. Using this information and the likely levels of additional water allocations to be made available from the Tarong pipeline, we will calculate the potential area that could be irrigated.

The calculations do not consider the following:

- reliability of water allocations
- capital cost of the water allocations
- annual costs of the water allocations
- distance to deliver or pump water to suitable areas/sites

Annual crop producers would likely only require medium priority water while perennial crop producers would require a higher level of water reliability. In most irrigation schemes, there is a difference in cost between the different water products based on reliability.

For these calculations, we have not made any assumptions as to the reliability of the water allocations that they receive. We also have not considered the cost of water and whether it is economically viable to irrigate the selected crops.

Annual crop water use

In discussions with stakeholders from the study region, growers who have irrigation for annual grain, cereal, or forage crops, will typically use 4-5ML/ha/yr of water to produce summer and winter crops in rotation.

Alternate crops such as Adzuki beans require 4-6ML/ha for a single crop, while crops such as cotton and corn, will use up to 10ML/ha for a single crop, depending on in-crop rainfall and timing of planting.

In order to calculate the potential area of land that could be irrigated with additional water allocations, we have assumed an annual demand figure of 4.5ML/ha for grain and cereal crop producers and 7ML/ha for adzuki bean, cotton, and corn producers. The projected water use requirements will require further investigation, including input from any demand assessment process implemented in future stages of the Tarong pipeline project.

Perennial crop water use

Perennial crops currently grown in the region, including avocados, citrus, and stone fruit, use 8-10ML/ha/yr.

For potential irrigated land area calculations, we will use a figure of 8ML/ha for irrigated perennial crop production. The projected water use requirements for these crops will need require further investigation, including input from any demand assessment process implemented in future stages of the Tarong pipeline project.

Potential irrigated land area

In consideration of the potential water allocation that might be available for agriculture, the following calculations have assumed a total annual water allocation range of 20,000ML to 30,000ML.

Table 8.1 summarises the potential irrigated land area if all water allocations were used for annual crop production. The calculations assume that all users are receiving high priority reliable water allocations, which is the current reliability level of the water used by Tarong Power Station.

Table 8.1: Summary of potential irrigated land area

Crop	Annual Water Demand (ML/ha)	Irrigated Area - 20GL (ha)	Irrigated Area - 30GL (ha)
Annual grain, cereal & forage crops	4.5	4444	6667
Adzuki beans, cotton, and corn crops	7.0	2857	4286
Perennial crops	8.0	2500	3750

The calculations in Table 7.1 indicate that the potential area of land that could be irrigated ranges from 2500 – 6667ha, depending on the water being only used on either annual or perennial crops.

Table 8.2 summarises the potential irrigated land area if there was a more balanced approach to the use of the water allocation across both annual and perennial crops. In these calculations, it is assumed that all annual crops use 50% of the total available water and perennial crops use 50% of the total available water.

Table 8.2: Summary of potential irrigated land area combining annual and perennial crop production

Crop	Total Water Allocation Use (%)	Irrigated Area - 20GL (ha)	Irrigated Area - 30GL (ha)
Annual grain, cereal & forage crops	25%	1111	1667
Adzuki beans, cotton, and corn crops	25%	714	1071
Perennial crops	50%	1250	1875
Total	***100%***	***3075***	***4613***

The calculations in Table 7.2 indicate that with a balance of annual and perennial crop being irrigated, the amount of land that can be converted into irrigated land ranges from 3075 – 4613ha.

9 Carbon Emissions and Soil Carbon Farming

Carbon emissions

The potential to produce more consistent and higher yields using irrigation, can have a positive impact on reducing net carbon emissions.

Some of the key factors that result in carbon emissions in agriculture, relate to the use of nitrogen fertiliser and the losses of applied nitrogen into the atmosphere as nitrous oxide (N2O). The crop management practices that influence nitrogen use efficiency and N2O losses are:

- rate of nitrogen application
- timing of nitrogen fertiliser application
- placement of nitrogen fertiliser

There are several factors where irrigated crops can act to reduce net carbon emissions including the following:

a) Irrigation enables a high level of confidence in yield potential. This means that nitrogen applications can be more accurately calculated to improve nitrogen use efficiency.

b) N2O losses can be reduced by applying nitrogen fertilisers more often throughout the crop growing cycle. Many irrigation systems, such as centre pivots or lateral move irrigators enable in-crop applications of fertiliser. With higher yield potential crops, growers are also more likely to change fertiliser application practices to maximise yield, which can involve more split applications of nitrogen fertiliser.

c) Incorporating fertiliser below the soil surface or applying fertiliser with irrigation water can reduce the potential losses of nitrogen as N2O, and increase nitrogen use efficiency.

d) The ability to produce consistently higher yielding crops with higher plant biomass each season can result in more carbon being stored in the soil. Irrigated crops with consistent biomass production each season can avoid the yield and biomass fluctuations that occur in dry-land cropping where soil carbon can accumulate during 'wet' years and previous years gains lost during a 'dry' year.

Soil carbon farming

Carbon sequestration is a subject that will be of increasing interest to growers and the industry in general in coming years. Apart from the environmental implications, it is likely that some growers will be able to develop an alternative income stream from carbon sequestration through the accumulation and sale of carbon credits. Alternatively, the growers may require the carbon credits internally within their business to offset carbon emissions, this would enable continued access to certain net carbon emission sensitive export markets.

There are several potential ways in which carbon sequestration could generate an income for landholders and more pathways are being created all the time.

It is reasonable to say however, that having an irrigation capability will expand the number of potential options and capacity for carbon sequestration available to a grower.

As the knowledge around crop management, fertiliser applications and soil carbon develop, the growers would also have the option to implement new concepts around crop types, cultivation practices or other crop management strategies that have the potential to increase crop yields and plant biomass, return organic matter to the soil, and increase stored carbon.

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Appendix A

Australian Government
Bureau of Meteorology

Climate statistics for Australian locations

Monthly climate statistics

All years of record

Note: Many statistics are updated quarterly and recent weather events may not be represented in the statistics below. For more current information on recent extreme values, please refer to the corresponding Daily rainfall, Maximum temperature and Minimum temperature data tables for this site, and our Australian Climate and Weather Extremes Monitoring System. Missing observations associated with the observer being unavailable (where observations are undertaken manually), a failure in the observing equipment, or when an event has produced suspect data may result in an extreme event not being recorded.

Site name: KINGAROY AIRPORT **Site number:** 040922 **Commenced:** 2001 Map
Latitude: 26.57° S **Longitude:** 151.84° E **Elevation:** 434 m **Operational status:** Open

View: ○ Main statistics ● All available | **Period:** 30 year period not available | **Text size:** ● Normal ○ Large

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
Temperature															
Maximum temperature															
Mean maximum temperature (°C)	30.9	29.8	28.3	25.8	22.5	19.8	19.8	21.7	25.1	27.5	29.2	30.3	25.9	21	2001 2022
Highest temperature (°C)	41.0	41.6	38.2	35.0	31.8	27.0	27.2	33.3	36.7	39.0	38.9	40.5	41.6	21	2001 2022
Date	04 Jan 2014	12 Feb 2017	13 Mar 2019	04 Apr 2006	04 May 2007	15 Jun 2002	22 Jul 2016	24 Aug 2009	28 Sep 2017	20 Oct 2002	16 Nov 2014	16 Dec 2019	12 Feb 2017		
Lowest maximum temperature (°C)	19.8	17.7	19.9	15.3	12.1	9.8	11.1	10.5	13.4	16.4	17.7	17.9	9.8	21	2001 2022
Date	08 Jan 2021	02 Feb 2018	09 Mar 2020	30 Apr 2015	23 May 2020	20 Jun 2007	23 Jul 2008	12 Aug 2005	05 Sep 2007	12 Oct 2018	06 Nov 2007	27 Dec 2006	20 Jun 2007		
Decile 1 maximum temperature (°C)	26.3	25.3	24.7	23.0	18.8	16.3	16.5	18.0	20.9	23.1	24.9	25.1		19	2001 2022
Decile 9 maximum temperature(°C)	35.0	33.7	31.9	29.0	26.0	22.9	22.9	25.5	29.6	32.1	33.5	34.6		19	2001 2022
Mean number of days ≥ 30 °C	18.4	13.7	8.7	1.3	0.1	0.0	0.0	0.2	2.6	7.1	12.4	16.7	81.2	21	2001 2022
Mean number of days ≥ 35 °C	3.4	2.3	0.5	0.0	0.0	0.0	0.0	0.0	0.2	0.8	1.8	3.6	12.6	21	2001 2022
Mean number of days ≥ 40 °C	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	21	2001 2022
Minimum temperature															
Mean minimum temperature (°C)	18.0	17.7	16.3	12.1	7.4	5.8	3.8	4.1	8.1	11.8	14.5	16.8	11.4	21	2001 2022
Lowest temperature (°C)	11.0	11.1	4.4	-0.6	-3.0	-5.0	-6.0	-4.9	-2.1	0.3	2.4	6.5	-6.0	21	2001 2022
Date	15 Jan 2009	09 Feb 2018	31 Mar 2008	30 Apr 2008	23 May 2002	12 Jun 2009	02 Jul 2002	07 Aug 2004	02 Sep 2012	09 Oct 2009	17 Nov 2006	29 Dec 2004	02 Jul 2002		
Highest minimum temperature (°C)	24.4	24.0	22.3	23.3	17.8	17.0	16.9	17.4	17.4	20.2	21.8	22.1	24.4	21	2001 2022
Date	15 Jan 2017	22 Feb 2004	21 Mar 2015	05 Apr 2006	04 May 2019	08 Jun 2002	13 Jul 2012	24 Aug 2016	05 Sep 2010	27 Oct 2004	23 Nov 2014	30 Dec 2014	15 Jan 2017		
Decile 1 minimum temperature (°C)	14.0	14.5	12.1	7.0	1.3	-0.5	-2.2	-1.2	3.0	6.6	10.1	12.5		19	2001 2022
Decile 9 minimum temperature (°C)	21.1	20.7	19.4	16.7	13.0	12.3	10.2	11.0	13.8	16.8	18.9	20.1		19	2001 2022
Mean number of days ≤ 2 °C	0.0	0.0	0.0	0.1	4.5	8.2	12.5	11.7	2.1	0.1	0.0	0.0	39.2	21	2001 2022
Mean number of days ≤ 0 °C	0.0	0.0	0.0	0.0	1.6	4.0	7.5	6.0	0.4	0.0	0.0	0.0	19.5	21	2001 2022
Ground surface temperature															
Mean daily ground minimum temperature (°C)															
Lowest ground temperature (°C)															
Date															
Mean number of days ground min. temp. ≤ -1 °C															

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
Rainfall															
Mean rainfall (mm)	87.4	92.1	71.2	21.6	32.9	41.9	23.7	26.9	25.2	62.3	63.6	96.2	648.1	19	2001 2022
Highest rainfall (mm)	345.8	213.2	210.4	57.8	88.4	163.0	83.4	105.6	139.4	130.8	243.8	359.6	1079.0	21	2001 2022
Date	2013	2001	2017	2014	2015	2005	2008	2010	2010	2017	2021	2010	2010		
Lowest rainfall (mm)	0.0	1.8	0.0	1.6	5.6	1.4	0.2	0.8	0.0	9.8	1.6	9.6	295.8	21	2001 2022
Date	2001	2014	2001	2018	2016	2004	2007	2009	2017	2014	2019	2017	2019		
Decile 1 rainfall (mm)	6.1	21.4	15.3	3.4	13.0	7.8	0.4	2.4	2.2	17.2	4.2	22.0	383.7	21	2001 2022
Decile 5 (median) rainfall (mm)	69.8	81.6	54.6	23.0	29.8	25.0	16.0	8.8	14.2	49.6	36.6	90.8	624.6	21	2001 2022
Decile 9 rainfall (mm)	165.1	182.9	122.7	42.1	70.8	87.2	52.8	77.2	49.6	109.4	156.2	136.0	949.2	21	2001 2022
Highest daily rainfall (mm)	234.0	89.2	87.4	50.4	60.0	56.4	37.8	57.0	54.6	58.2	87.0	75.8	234.0	21	2001 2022
Date	27 Jan 2013	26 Feb 2013	30 Mar 2017	14 Apr 2014	12 May 2021	20 Jun 2005	03 Jul 2021	11 Aug 2010	06 Sep 2010	07 Oct 2003	10 Nov 2001	28 Dec 2008	27 Jan 2013		
Mean number of days of rain	9.4	9.7	11.1	6.7	7.7	9.1	7.2	5.0	5.5	8.6	7.7	10.5	98.2	21	2001 2022
Mean number of days of rain ≥ 1 mm	6.2	6.7	6.0	3.5	4.4	4.0	3.1	3.0	3.1	6.0	5.1	7.4	58.5	21	2001 2022

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
Mean number of days of rain ≥ 10 mm	2.4	2.9	2.2	0.6	1.1	1.1	0.7	0.7	0.7	2.4	2.1	2.9	19.8	21	2001 2022
Mean number of days of rain ≥ 25 mm	0.8	1.1	0.7	0.0	0.4	0.4	0.2	0.2	0.1	0.5	0.6	1.0	6.0	21	2001 2022

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
Other daily elements															
Mean daily wind run (km)	247	235	224	187	174	179	184	197	214	225	231	230	211	16	2003 2022
Maximum wind gust speed (km/h)	89	76	68	61	55	61	85	70	87	93	78	115	115	18	2003 2022
Date	29 Jan 2004	19 Feb 2020	06 Mar 2022	04 Apr 2005	17 May 2008	05 Jun 2016	19 Jul 2004	12 Aug 2015	21 Sep 2012	31 Oct 2003	05 Nov 2015	17 Dec 2014	17 Dec 2014		
Mean daily sunshine (hours)															
Mean daily solar exposure (MJ/m^2)	23.8	21.4	19.5	17.0	13.8	12.2	13.4	16.5	19.9	22.2	24.0	24.3	19.0	32	1990 2022
Mean number of clear days															
Mean number of cloudy days															
Mean daily evaporation (mm)															

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
9 am conditions															
Mean 9am temperature (°C)	24.5	23.6	22.0	19.8	16.0	13.1	12.2	14.2	18.0	21.0	22.4	24.0	19.2	10	2001 2010
Mean 9am wet-bulb temperature (°C)														7	2001 2010
Mean 9am dew-point temperature (°C)	17.6	18.0	16.4	14.2	10.3	8.6	7.4	7.0	9.7	11.4	13.7	16.3	12.6	10	2001 2010
Mean 9am relative humidity (%)	67	72	71	71	70	76	74	64	61	57	60	64	67	10	2001 2010
Mean 9am cloud cover (oktas)															
Mean 9am wind speed (km/h)	15.3	13.9	14.8	13.2	10.5	10.3	9.0	11.8	15.0	15.3	14.9	14.7	13.2	10	2001 2010

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
3 pm conditions															
Mean 3pm temperature (°C)	29.3	28.1	26.8	24.8	21.4	18.7	18.5	20.4	23.8	26.5	27.3	28.9	24.5	10	2001 2010
Mean 3pm wet-bulb temperature (°C)														6	2001 2010
Mean 3pm dew-point temperature (°C)	15.6	16.4	14.2	11.3	6.9	6.5	4.8	3.4	5.7	7.5	11.3	13.8	9.8	10	2001 2010
Mean 3pm relative humidity (%)	47	52	48	45	43	49	44	36	35	33	41	43	43	10	2001 2010
Mean 3pm cloud cover (oktas)															
Mean 3pm wind speed (km/h)	16.0	15.0	16.0	14.7	14.7	15.1	15.3	16.3	16.2	16.1	15.5	16.2	15.6	10	2001 2010

red = highest value blue = lowest value

Product IDCJCM0036 Prepared at Thu 26 May 2022 00:35:00 AM EST

Monthly statistics are only included if there are more than 10 years of data. The number of years (provided in the 2nd last column of the table) may differ between elements if the observing program at the site changed. More detailed data for individual sites can be obtained by contacting the Bureau.

Related Links

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- About climate averages: http://www.bom.gov.au/climate/cdo/about/about-stats.shtml
- Data file (csv): http://www.bom.gov.au/clim_data/cdio/tables/text/IDCJCM0036_040922.csv
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Appendix B

QNRM01014

Land Resources Bulletin

Soils and Agricultural Suitability of the South Burnett Agricultural Lands, Queensland

P Sorby
formerly Department of Primary Industries

R E Reid
formerly Department of Natural Resources

Queensland Government
Natural Resources and Mines

Land Resources Bulletin

Soils and Agricultural Suitability of the South Burnett Agricultural Lands, Queensland

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Brisbane 2001

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This report is intended to provide information only on the subject under review. There are limitations inherent in land resource studies, such as accuracy in relation to map scale and assumptions regarding socio-economic factors for land evaluation. Readers are advised against relying solely on the information contained therein. Before acting on the information conveyed in this report, readers should be satisfied they have received adequate information and advice specific to their enquiry.

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NRM Ref No: SBT–I–A0 3286

Suitability for dryland crops: South Burnett Agricultural Lands; Scale 1: 100 000
NRM Ref No: SBT–B–A0 3287

Summary

The South Burnett Agricultral Soil Survey examines the red soil plateau area and adjacent areas that extend from the Barker–Barambah Creek Irrigation area in the north to the footslopes of the Bunya Mountains in the south.

The South Burnett is an important food producing area close to Brisbane markets and export terminals. Much of the area is intensively cropped for summer and winter grains with minor areas of vineyard and fruit orchards. The area is the centre of both the peanut and navybean industries with maize, wheat and barley following close in importance. Recent expansion has also occurred in the viticulture industry.

The study area of 126 607 hectares was mapped at a scale of 1:100 000. The area is covered mostly by both the Kingaroy and Murgon 1:100 000 sheets.

Forty-nine Soil Profile Classes were delineated from soil properties, landscape and geology, and their physical and chemical characteristics. A total of 985 Unique Mapping Areas (UMAs) were separated in terms of soil and topography to produce a UMA database. This database forms the basis of soil and crop suitability maps. The database includes UMA area, location, soil, geology, chemical and physical attributes, crop suitability and soil degradation.

Fifty three percent of the survey area is considered suitable for dryland cropping, 73% is suitable for dryland sown pastures, 48% is suitable for tree and vine crops. Approximately 80% of the study area has been cultivated at some stage. Very little of the original vegetation remains intact.

Salinity occurrs extensively in the study area. The UMA data will aid land management to avoid further degradation from salinity. Surface or sheet erosion has occurred on much of the study area since the time of European settlement. This has resulted in acidification and loss of organic matter in many areas. Major soil conservation programs since the mid 1950s have seen the implementation of conservation cropping practices reducing soil degradatiion.

The report and associated maps and databases will be an aid to all land managers to help improve or maintain rural productivity while avoiding degradation.

1. Introduction

Broadly defined by the resource survey of Vandersee and Kent (1983), the agricultural lands of the South Burnett are restricted to an area of deeply weathered basalt flows and adjacent areas situated around the town of Kingaroy (Figure 1). The survey covers part of the shires of Kingaroy, Nanango and Wondai.

The survey area abuts the irrigation suitability study of the Byee area carried out by Reid *et al.* (1979) to the north.

With approximately 126 600 hectares in area, the red soil plateau has historically been famous for cropping, dairying and timber products. The region is now an important summer grain producing area concentrating on peanuts, navy beans and maize. Numerous other intensive horticultural activities including stone fruit, vineyards, corkwood and flower production have been undertaken at various times. The intensity of farming practices in the district over the last 50 years has caused concern regarding land degradation.

The objectives of the survey are:

- To produce a soil map at 1:100 000 scale for use by all land managers including soil conservationists, land owners, planners, agronomists and soil scientists
- Develop a crop suitability map at 1:100 000 scale for a range of summer and winter crops in the South Burnett
- To define soils types which can be recognised by users for the development of property plans, management strategies and strategic plans
- Provide researchers and agronomists with a soil data base enabling research into sustaining or improving primary production with minimal degradation, and the development of management practices to rehabilitate degraded land.

The information on soils, their physical and chemical properties, and distribution will assist all land managers to develop sustainable management practices which will help kerb land degradation.

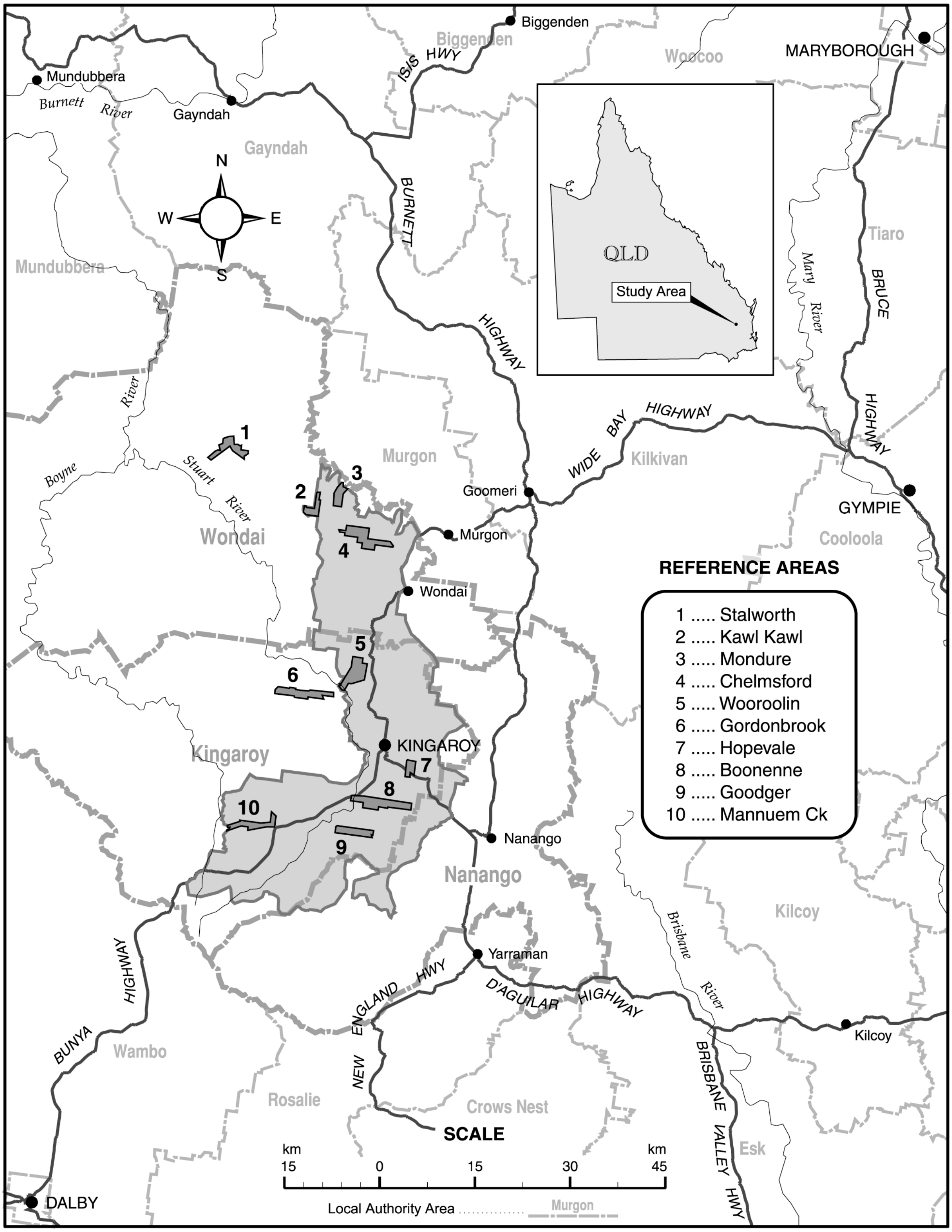

Figure 1. Locality map to show reference areas

2. The South Burnett Agricultural Area

2.1 Land Use History

European settlement commenced in the South Burnett area in 1846. Initially, the study area was part of a number of pastoral selections namely Tarong, Taabinga and Burrandowan in the south, and Barambah, Marshlands and Mondure in the north. Both sheep and cattle were run on these selections until the 1870s when the increasing incidence of grass seed (Black Spear) and predation by dingoes made sheep raising difficult, leading to beef and dairy cattle rearing becoming the predominant land use. Minor holdings still kept sheep for fat lamb production on selected pastures. It was often thought that the increased incidence of burning off of pastures may have contributed to the grass seed problem.

The occurrence of large quantities of useable timber, notably the Bunya pine (*Araucaria bidwillii*), hoop pine (*A. cunninghamii*), silky oak (*Grevillea robusta*), red cedar (*Toona australis*) and a host of other hardwoods, supported a large but short-lived timber industry. The resultant cleared lands gave rise to many mixed farming enterprises of which dairying was the major contributor.

Dairying was supported by a rail link to the coast at Maryborough where up to 8 tons of cream was transported in a single week. Numerous butter factories were built throughout the South Burnett which, together with the rail link facilitated the expansion of rural development in the area. The introduction of exotic pasture species, in particular Kikuyu in the early 1900s, increased livestock production in the red soil areas. However Kikuyu has become a problem in cropping and urban areas because of its prolific growth habits.

Another important introduction to the area from Africa in the 1920s was the groundnut (*Arachis hypogaea*) locally known as the peanut. The similarity of the red soils in the district to that of its origin allowed it to thrive. Given a weed free environment by the commonly used method of bare fallow or winter cereal rotation combined with inter-row weeding by chip hoe, tined implement and more recently herbicide application, then peanut production increased to some 23 500 tonnes from 20 340 hectares in 1979–80 (Vance 1981).

Enticed by good economic returns, many farmers reduced their dairy herds or got out of dairying completely to grow crops in the period 1950 to 1970. More country was opened up including the sandy forest soils on the outskirts of the red soil country.

This pattern of land use up to the present has resulted in a general perception by landholders that there has been a decline in soil structure and nutrient status, soil acidification; with increased salinity outbreaks and siltation of watercourses and impoundments.

The frequent occurrence of summer storms with intensities up to and including 75 millimetres per hour caused much run-off and erosion on the fallowed paddocks and led to the design and implementation of contour banks early in the district's cropping history. The very first contour bank built in Queensland was in the South Burnett in 1936. By 1989, approximately 90 percent of all cultivations in the South Burnett had been contoured.

In recent years the economic downturn has seen some diversification from the conventional crops of peanuts, maize, navy beans, sorghum and winter cereals to one of specialisation in horticultural crops and intensive specialty crops including native flowers, corkwood, hydroponically grown flowers, fruit, vegetables and vine crops such as grapes.

With the increasing environmental awareness shown by the community in the latter part of the 1980s, numerous Landcare groups have been formed which bring people together in the interests of improving environmental quality, inter-farmer co-operation and sustainable agricultural production on a catchment basis. Landcare groups have been an important target of government funding providing money for the purposes of rehabilitating degraded lands and research into the processes of degradation and possible remedies.

2.2 Climate

The study area is in the subtropical zone with hot summers and mild winters with intermittent to regular frosts (Bureau of Meterology 1990).

Rainfall is summer dominant with the majority of precipitation occurring during high intensity thunderstorm activity. Hail storms occasionally result in damage to crops particularly stone fruit orchards.

Climatic data for Kingaroy are presented in the accompanying tables. Median and mean rainfall figures are presented to show the comparison between rainfall averages, which are influenced by extreme events, and the median, which represent the **5th decile** or the midpoint of all registrations.

Table 1. Rainfall averages and medians, with minimum and maximum temperatures for Kingaroy

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Rainfall average	114.3	96.0	77.9	46.8	41.3	42.6	41.0	28.9	38.0	64.5	78.2	110.5	779.9
Rainfall median	96.7	84.2	59.0	32.6	30.0	30.1	29.2	23.1	32.7	57.7	67.2	98.1	763.7
Minimum Temp	17.4	17.5	15.8	12.1	8.6	5.4	4.0	4.8	7.9	11.7	14.4	16.5	
Maximum Temp	29.6	28.8	27.5	25.1	21.6	18.9	18.5	20.1	23.2	26.0	28.1	29.6	

Frosts occur frequently on low lying areas in the winter months, usually from May (average of 3) to September (average of 4). The greatest occurrences of frost occur in July with an average of 12 frosts in that month. The severity varies with landscape position, slope and temperature. Frost occurrences at the Kingaroy post office appear in Table 2.

Table 2. Frost days at Kingaroy

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Average	0	0	0	0	3	7	12	10	4	1	0	0
Highest	0	0	0	1	13	20	25	23	15	6	2	0
Lowest	0	0	0	0	0	0	0	0	0	0	0	0
Entries	35	35	35	35	35	35	35	35	35	35	34	35

Continual dry seasons with low rainfall totals have contributed to the district being drought declared on a few occasions. Table 3 lists drought declaration and revocation dates in three shires since 1965.

Table 3. Drought declarations and revocations since 1965

Shire	Declaration	Revocation	Duration*
Kingaroy	7 – 4 – 65	26 – 8 – 65	4
	2 – 2 – 69	22 – 1 – 70	11
	16 – 6 – 70	28 – 1 – 71	7
	5 – 9 – 77	3 – 5 – 78	8
	23 – 9 – 91	2 – 3 – 92	6
Nanango	2 – 2 – 69	22 – 1 – 70	11
	16 – 6 – 70	28 – 1 – 71	7
	17 – 8 – 77	3 – 5 – 78	9
	23 – 9 – 91	2 – 3 – 92	6
Wondai	25 – 3 – 65	23 – 12 – 65	6
	2 – 2 – 69	22 – 1 – 70	11
	28 – 5 – 70	28 – 1 – 71	8
	5 – 9 – 77	3 – 5 – 78	8

* months (approximately)

2.3 Geology and Landform

3.2.1 Geological units and landform

The study area is part of a high planation surface which is relatively undissected and forms a drainage subdivide between the Stuart River and Barambah Creek (Watkins 1967).

The age of this surface is late Miocone or approximately 22–26 million years and elevation is generally 440 to 540 metres above sea level but can reach 1000 metres in the Bunya Mountains a few kilometres south-west of the study area. The Bunya Mountains are the northern-most point of the Main Range volcanics where dating of a fresh basalt flow recorded a radiometric date of 22.1 million years (Webb *et al.* 1967) west of Nanango.

The Tertiary volcanics typified by this high erosional plane are considered by Macnish *et al*. (1987) to consist of a series of volcanic deposits under varying weathering regimes forming plateaux and terrace landscapes with moderate slopes and steep scarps. The occurrence of red soils in close association with basalt has long been considered to be due to weathering *in situ.* Analysis of the stratigraphy and minerology, indicates that although deposition of the red soils and basalt were of a similar age, the red compacted clayey material had already been weathered before it was covered by younger basalt flows. Fresh exposures of unweathered basalt may occur either above or below the red soil.

The elevation of the study area ranges between 260 metres above sea level on old alluvial terraces of Barambah Creek in the north, to approximately 600 meters above sea level on the north-easterly slopes of the Bunya Mountains near Halys Round Mountain. A majority of the red soils occur at an altitude of 440 to 540 meters above sea level which corresponds to the lower stratigraphic unit described by Macnish *et al.* (1987). However, landforms in the Kumbia-Kingaroy area also relate to that of the high stratigraphic level consisting of undulating plateau, moderate hillslopes and colluvial valley fills.

Minor areas of benches, saddles and spur ridges occur on the edge of the plateaux with only minor relief differences. Plateau remnants occur in the Kingaroy area at Mt Jones and Kingaroy Heights which may well be the upper stratigraphic unit referred to by Macnish *et al*. (1987).

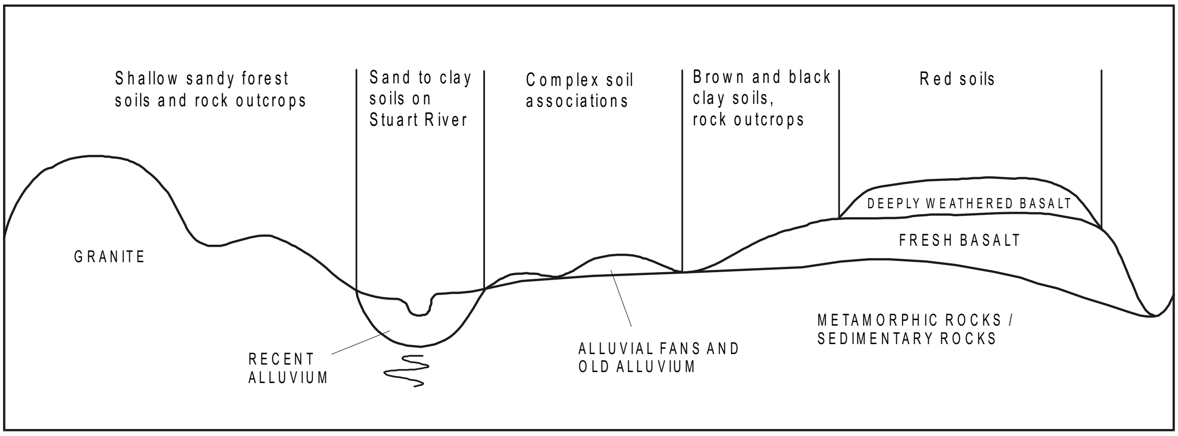

Figure 2. Schematic cross-section of the geological stratigraphy

Sheetwash and colluvium from higher elevations has been deposited in drainage depressions and on alluvial flats. Alluvial soils occur on minor valley flats along creeks and on the flood plains of major streams such as Barkers Creek, Flagstone Creek and the Stuart River. The major area of alluvial soils occurs north of the study area around Byee. These were mapped by Reid *et al.* (1979).

Granite of the Boondoomba Igneous Complex occurs on the western side of the study area. A large part of this complex is overlain by deeply weathered basalts and basalt of the Main Range Volcanics and minor areas of recent alluvia. The landforms in this geology unit range from undulating low hills to rolling hills with slopes ranging from moderate (6–7%) on crests and foothills to steep (15–35%) on mid and upper slopes.

A minor area of Devonian–Carboniferous beds which include gneiss, gneissic granodiorite or phyllite occur west of Memerambi giving rises and low hills.

On the eastern boundary of the study area, both the granites of the Boondoomba Igneous Complex and mudstones, slate, greywacke, chert and jasper of the Devonian–Carboniferous Maronghi Creek beds occur. The major portion of this country is under state forest or used for native pasture. Landforms are low hills and rises with gentle to moderate slopes.

Triassic Tarong beds of sandstone, conglomerate and coal seams appear as minor occurrences on the southern boundary of the study area. Landforms are predominately gently undulating rises to rolling rises of between 3% to 20% slope.

Sheetwash and the removal of soil downslope by illuviation into creeks and drainage depressions causes a mixing of materials originating from any number of substrate materials.

Tertiary sediments often occur at the break of slopes between the basaltic landscape and the alluvial plain. The tertiary sediments, which include sandstones, conglomerates, siltstones and mudstones occur as unconformable units often associated with volcanic flows. Small units occur in the study area north and west of Wondai and south of Kingaroy.

2.4 Vegetation

Vegetation in the study area has been described by White (1920), Ridley (1962), Reid *et al.* (1979) and Vandersee and Kent (1983). Very little of the original native vegetation remains in the study area. Most has been cleared on the red soils areas except a few isolated pockets of the original microphyll softwood scrub on scarps, road reserves and minor areas of a few hectares left on farming blocks. Many of the forest communities have been also cleared or thinned out. Clearing has caused saline outbreaks on the fringes of the red soil areas due to the changing hydrology and subsequent increases in watertable levels.

Generally, any area considered suitable for cropping was cleared by the 1930s. At the time of the peanut industry expansion in the 1970s, some granite and sandstone country was also cleared for cropping. However since the economic downturn in the industry and a series of low rainfall years these granite and sandstone areas have been returned to grazing with improved pastures or left fallow for native grass re-establishment. In some cases the areas left fallow have been subject to woody weed regrowth and undesirable grass species domination. The occurrence of regrowth such as wattle (*Acacia* spp.), dogwood (*Jacksonia scoparia*) and wild rosemary (*Cassinia leavis*) have caused problems by competing with pasture species for soil moisture, nutrients and sunlight. Regrowth of wattle, eucalypts and other shrubs have been in some instances so dense so as to make it impe+netrable to feeding cattle.

The original softwood scrub consists of crows ash (*Flindersia australis*), yellowwood (*Flindersia xanthoxyla*), Queensland cascarilla bark (*Crotin insularis*), red ash (*Alphitonia excelsa*), kurrajong (*Brachychiton populneum*), cumby cumby (*Pittosporum phylliraeoides*) and native olive (*Notelaea microcarpa*).

Forest species which are often associated with the scurb vegetation include narrow-leaved ironbark (*Eucalyptus crebra*), Yarraman ironbark (*E. melanoleuca*), gum-topped box (*E. molucanna*) and hoop pine (*Araucaria cunninghamii*). Lantana (*Lantana camara*) and wattle (*Acacia* spp.) occur as understorey species especially after disturbance. The softwood scrub vegetation type is closely associated with the red basaltic soils.

On the lower slope where soils trend towards a neutral pH, forest species start to dominate. The main species are narrow-leaved ironbark (*E. crebra*) and forest red gum (*E. tereticornis*) occurring in closed woodland to open forests, other tree species are sometimes present in this community but composition varies considerably. Species include silver-leaved ironbark (*E. melanophloia*), Moreton Bay ash (*Corymbia tessellaris*), pink bloodwood (*Corymbia intermedia*), broad-leaved apple (*Angophora subvelutina*) and gum-topped box (*E. molucanna*).

Understories in this community include the bull-oak (*Casuarina leuhmanii*), black she-oak (*C. littoralis*), forest she-oak (*C. torulosa*), quinine bush (*Petalostigma pubescens*), dogwood, wild rosemary and red ash.

On the shallow fresh basaltic soils, the silver-leaved ironbark (*E. melanophloia*) woodland community occurs. This community includes species such as the silver-leaved ironbark, narrow-leaved ironbark, Moreton Bay ash and forest red gum. Ironwood (*Acacia excelsa*), kurrajong and grass trees (*Xanthorrhoea* spp.) commonly occur in the understorey of this community.

On alluvial flats and drainage depressions, forest red gum, Moreton Bay ash, broad-leaved apple and rough-barked apple (*Angophora floribunda*) are the major species found. Gum-topped box may also occur. Weeping bottle brush (*Callistemon viminalis*) and river she-oak (*Casuarina cunninghamii*) occur on creek channels and benches. Occasionally cypress pine (*Callistris columellaris* and *C. endlicheri*), Yarraman ironbark (*E. melanoleuca*), corkwood (*Duboisia leichardtii*) and white bottle brush (*Callistemon salignos*) may occur.

Deep sandy soils formed from granite or sandstone wash tend to be the site for groves of rusty gum (*Angophora costata*) and spotted gum (*Corymbia maculata*). Spotted gum also occurs in association with narrow-leaved ironbark, small fruited grey gum (*E. propinqua*) and forest she-oak on steep upper slopes and stony ridges.

Black tea tree (*Melaleuca bracteata*) occurs on clay soils in drainage depressions and on relict terraces where drainage is restricted. It may also occur in association with gum-topped box. Only minor occurrences of brigalow (*Acacia harpophylla*) and belah (*Casuarina cristata*) appear in the study area and are usually in association with black tea tree.

In saline areas, most trees tend to die off if watertables are shallow. Rhodes grass (*Chloris gayana*) and eventually couch (*Cynodon dactylon*) invade saline areas as competition from less salt tolerant species is reduced. Eventually only high salt tolerant species such as sand spurry (*Spurgularia rubra*), epaltes (*Epaltes australis*) and salt bush (*Atriplex nummuleria*) survive as small clumps amongst bare areas of salt encrusted soils. Groundsel bush (*Baccharis halimifolia*), a declared noxious weed, is another shrub that occurs in saline affected areas along watercourses and drainage depressions.

Native grasses of the area include Queensland wire grass (*Aristida queenslandia*), kangaroo grass (*Themeda triandra*), black spear grass (*Heteropogon contortus*), rats tail grass (*Sporobolus crebra*), Queensland bluegrass (*Dicanthium sericeum*), forest bluegrass (*Bothriochloa bladhii*), pitted bluegrass (*B. decipiens*), cane grass (*Arundinella nepalensis*), native chloris (*Chloris* spp.) and lovegrass (*Eragrostis* spp.). Bladey grass (*Imperata cylindrica*), red natal grass (*Rhyndelytrum repens*) and grader grass (*Themeda quadrivalvis*) commonly occur on disturbed sites such as roadsides.

Rhodes grass (*Chloris gayana*), Kikuyu (*Pennisetum clandestinum*), paspalum (*Paspalum dilatatum*), green panic (*Panicum maximum*) and some legumes (siratro and vetch) have been introduced to most areas either intentionally or through natural spread.

3. Methodology

3.1 Soil mapping

Soils of the Kingaroy area were mapped at 1:100 000 scale and evaluated for agricultural suitability.

The initial stage of the survey involved a series of transects or traverses across the study area as part the reconnaissance stage. Soil observations were made in relation to the geology and position in the landscape and from these, the extent of the survey area was established.

The majority of soil observations were made using a 50 mm steel hydraulically driven push-tube which enabled the sampling of relatively undisturbed core. In stony areas or where vehicle access was too difficult, a 75 mm diameter jarret hand auger was used. The occasional road side cutting was used where available and were often useful in determining the type of parent material, soil formation and fluvial processes involved.

Ten reference areas ranging in size from approximately 150 hectares to 1200 hectares were selected using data gathered during the transect stage. Two of these reference areas, Gordonbrook and Stalworth, situated outside of the 1:100 000 mapping area, were selected to help gather additional data on granite soils and an outlying red soil area which has a markedly lower rainfall.

All reference areas were mapped at a scale of 1:25 000 or one soil observation per 6.25 hectares approximately. These were used to build up a soils database, from which a soils reference was formed, and to develop an understanding of the relationship between soils and geology. The locality of these reference areas is shown on the locality map (Figure 1).

Using soil information gathered during the reference making stage, major soil types were selected for sampling and subsequent chemical analysis. Forty sites were sampled using a Proline drill rig taking 150 mm diameter undisturbed soil cores down to a depth of 1.5 m or until parent material was reached.

Following the formulation of a draft soils reference, the mapping phase was commenced. Free survey techniques (Reid 1988) were used which incorporated a combination of aerial photograph interpretation and ground observations to determine soils types, map boundaries and distinguish Unique Mapping Areas (UMAs). Ground observations, including the sites from the transect and reference making stages, were carried out at a density of approximately one site per 70 hectares throughout the study area. Mapping units were delineated on 1:25 000 scale aerial photographs then transferred onto 1:100 000 scale topographic map sheets for digitising.

3.2 Soil analysis

A total of 53 soil profiles were sampled for detailed laboratory analysis. These represented the major soil profile classes of the survey area.

These profiles were sampled to a depth of 1.5 m where possible, and analysed at the standard depths as shown in Table 4. The sampling intervals were occasionally altered to allow for thin surface horizons and avoid sampling across horizon boundaries (Baker and Eldershaw 1993). At each of these sites, a bulk (0–0.1 m) surface sample (composed of 8–10 subsamples) was collected for surface fertility assessment. The specific analyses performed at each depth are shown in Table 4. Full site descriptions and laboratory analyses for these sites are included in Appendix 2. More information on the specific analytical methods together with general interpretations are contained in Baker and Eldershaw (1993). The general ratings listed in Bruce and Rayment (1982) were also used for interpretation of the chemical analyses.

Table 4. Laboratory analyses performed for each standard soil depth sample

Analysis	Sample type and depth (m)						
	Bulk	Profile					
	0–0.1	0–0.1	0.1–0.2	0.5–0.6	0.8–0.9	1.1–1.2	1.4–1.5
pH, EC, Chloride	x	x	x	x	x	x	x
Exch. cations, CEC or ECEC		x	x	x	x	x	
Total P, K, S		x	x	x	x	x	
Organic C, Total N	x						
Bicarb. extractable P	x						
Extractable K	x						
Nitrate nitrogen	x	x	x	x	x	x	
Sulfate sulfur*	x						
DTPA ext. Fe, Mn, Cu, Zn	x						
Particle size analysis		x	x	x	x	x	
Dispersion ratio		x	x	x	x		
Moisture measurements –							
% air dry		x	x	x	x	x	
1500 kPa content		x	x	x	x		

* not for all bulk samples

3.3 Resource inventory compilation

Each occurrence of a mapping unit, named a unique mapping area (UMA), was given a unique number and individually described in terms of area, land resources and degradation. The land resource information includes geology, dominant soil profile class, associated soil profile classes, landform, and disturbance (land use). The proportion of each soil profile class is estimated in a UMA. Information for each of the 985 delineated UMAs is stored in a UMA database.

The UMAs have generally been named after the dominant soil profile class present. Where adjacent UMAs have been given the same code, delineation has been made on the basis of modal slope category (which would affect management). Some UMAs were delineated according to *phases*, based on attributes that would have particular significance in the use of the land (eg. eroded, rocky, saline). The dominant soil profile class occupies at least 60% of a map unit area. The estimated proportions of the dominant soil profile class and associated soil profile classes for each UMA are shown in the UMA database. Some UMAs were recorded as consisting entirely of the dominant soil. It is unlikely these UMAs are pure, and at more intense mapping scales other soils may be delineated. In UMAs where two soils were regarded as being co-dominant, the UMAs were not split (for practical reasons at this scale of mapping). These UMAs were given a combined name from the two co-dominant soil profile classes.

3.4 Land suitability evaluation

The land in each unique map area (UMA) was assessed for its suitability for each of the following:

- dryland (rainfed) cropping
- dryland sown pastures
- tree and vine crops

This evaluation includes both current and potential land uses and may be used as a basis for property planning, catchment management and strategic planning (including planning dealing with Good Quality Agricultural Land).

3.4.1 Land use limitations

To determine the suitability of a UMA for a particular land use, it is necessary to consider the requirements for each land use. Soil and land attributes that cause less than optimum conditions for the particular use are known as limitations.

The specific land use limitations considered in this survey, together with their designated codes (Land Resources Branch Staff 1990) were:

- flooding (F)
- frost (Cf)
- microrelief – or gilgai (Tm)
- nutrient deficiency (Nd)
- rockiness (R)
- salinity (Sa)
- soil depth (Pd)
- soil water availability (M)
- surface condition (Ps)
- topography- slope (Ts)
- water erosion (E)
- wetness (W)
- workability (Pm)

Limitation values were assigned to each UMA on the basis of field observations, topographic position and/or local knowledge, and soil morphological and/or chemical properties.

3.4.2 Land suitability classification

The five class suitability classification (Land Resources Branch Staff 1990) used for dryland sown pastures, dryland cropping and tree/vine crops is as follows:

Class 1 Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
Class 2 Suitable land with minor limitations which either reduce production or require more than the simple management practices of Class 1 to maintain economic production.
Class 3 Suitable land with moderate limitations which either further lower production or require more than the management practices of Class 2 land to maintain economic production.
Class 4 Marginal land with severe limitations which make it doubtful whether the inputs required to achieve and maintain production (and/or minimise land degradation) outweigh the long term benefits.
Class 5 Unsuitable land with extreme limitations that preclude its use.

The first three classes are considered **suitable** for the specified land use. 'Suitable' is not the same as 'useable' and implies that the continued use of the land for the specified land use would be *sustainable* and *productive* in the long term. Land is classified as suitable on the assumption that appropriate soil conservation measures are implemented and maintained. If this is not the case, the specified land use may not be sustainable in the long term.

Class 4 land is considered to be **unsuitable** land, given that a higher level of inputs would be required to initiate and maintain production as well as contain land degradation. It is doubtful whether the cost of these inputs would outweigh the benefits in the long term, at least in the prevailing economic and technological conditions. Most Class 5 land would always remain unsuitable for that particular land use, as it has limitations that in aggregate are so severe that production would not be considered.

The types of land use considered in this study are shown below:

Dryland cropping	Cereals (grain sorghum, maize, wheat, barley, oats), grain legumes (chick peas, navy beans, soybeans, lupins), oilseeds (sunflower), forage legumes (lablab, cowpeas), peanuts and other forage crops (sorghums, millets).
Dryland sown pasture	Callide Rhodes grass, green panic, Gatton panic, Setaria, Pangola, Kikuyu, pasture legumes (Siratro, fine stem stylo, Glycine, Lotononis, Wynn cassia, Leucaena).
Tree and vine crops	Citrus, grapes, persimmon, low-chill stonefruit and low-chill apples.

As for crops, a five-class suitability system was used for dryland sown pastures.

While tree and vine crops are a minor current land use their suitability was assessed because of the considerable potential for further plantings of suitable species.

3.4.3 Land suitability assessment

Each mapping unit (UMA) was assessed as to how well it fulfils the requirements for the specified land uses. Land suitability assessment is a three stage process.

Firstly, the requirements of the specific land use are defined. Limitations to plant growth are considered as well as limitations for machinery usage and the management of land degradation.

The second stage in the process is to determine the effect of each limitation on the specific land use. This involves the derivation of *suitability subclasses*. Suitability subclasses are also rated on a scale of 1 to 5 (1 negligible, 2 minor, 3 moderate, 4 marginal, 5 severe). Suitability subclasses were defined following consultation with local extension staff, a literature review and field experience gained during the survey. The combination of suitability subclasses is then used to derive an overall *suitability class* (1–5) for each land use, for each UMA. The suitability class is usually determined by the most severe limitation identified (Land Resources Branch Staff 1990).

For each UMA, the suitability subclasses and the overall suitability class for each land use are recorded in the UMA database.

3.5 The databases

Two computer databases have been established to store data collected in the survey area: a site database and a UMA database. Data in this form is easily interrogated by user-defined queries.

Field data for the 1957 sites was recorded on field sheets. These were entered into a computer database (SALI site). Laboratory analytical data has been added to the same database for all relevant sample sites.

A comprehensive UMA database has been generated from the information on the site description sheets and interpreation of additional information relating to land suitability. For each UMA, the suitability subclasses, overall suitability classes (for sown pastures, dryland cropping and tree/vine crops) are recorded.

The complete UMA database has been integrated with the GIS spatial data so that maps pertaining to any category of UMA data can be produced.

Information in both the site database and the UMA database is available on request from the Data Coordinator, Natural Resource Sciences, 80 Meiers Road, Indooroopilly Q 4068.

4. Soils

4.1 Descriptions of the soil profile classes

The survey area has been mapped at broad regional scale by Vandersee and Kent (1983) at 1:250 000 scale and by Isbell *et al*. (1967) at 1:2 000 000 scale.

A total of 49 soil profile classes (SPCs) describe the profile attributes in detail together with soil classification, geology, landform and vegetation (Appendix I). The SPCs have been developed from 1957 site descriptions.

The SPCs have been grouped into six broad geomorphic/geological groups. These broad groups have been further subdivided on landscape (Table 5).

Table 5. The major attributes and classifications of the soil profile classes

Soil Profile Classes	Distinguishing attributes	Australian Classification*	Principle Profile Form*	Great Soil Group*
LEVEL TO GENTLY UNDULATING PLAINS ON ALLUVIUM OF CURRENT STREAMS				
Flood plains				
Hirst Ht	Brown or dark loamy sand to silty clay loam surface (0.1–0.3 m) over a red or brown structured sandy clay loam to sandy light clay B2 horizon (0.9–1.5 m) over a red or brown sand to sandy loam D horizon to 1.5m	Brown Dermosol Brown Chromosol	Gn3.22 Gn3.52 Db2.33 Db2.12 Dy3.43	No suitable group, affinities with soloth
Terrace Ta	Dark sandy light clay surface (0.1–0.2 m) over a dark medium clay B2 horizon (0.55–0.95 m) over a brown sandy light clay D horizon to 1.5m	Black Dermosol Black Vertosol	Uf6.32 Ug5.15	Prairie soil Black earth
Stagnant alluvial plains				
Avon Av	Brown sandy loam to clay loam surface (0.02–0.2 m) over a sporadically bleached A2 horizon (0.1–0.45 m) over a frequently mottled strongly alkaline, grey or brown medium clay B2 horizon to 1.5 m	Brown Sodosol Grey Sodosol	Db2.32 Db2.33 Dy2.33 Db1.33	Solodic soil
Byee By	Dark medium clay surface (0.1–0.2 m) over a dark medium clay B2 horizon (0.7–1.25 m) over a strongly alkaline, brown medium clay D horizon to 1.5m	Black Vertosol	Ug5.15	Black earth
Eastgate Eg	Dark medium clay surface (0.1–0.15 m) over a brown or black medium clay B21 horizon (0.45–0.95 m) over a strongly alkaline, brown medium clay B22 horizon to 1.5 m	Black Vertosol Brown Vertosol	Ug5.15 Ug5.34	Black earth Brown clay
Alluvial fans				
Kaber Kr	Brown light clay surface (0.2–0.3 m) over a brown medium clay B2 horizon to 1.5 m	Brown Vertosol	Ug5.34	Brown clay
Relict levees				
Weir We	Dark light clay surface (0.1–0.15 m) over a dark medium clay B2 horizon (0.6–1.05 m) over a strongly alkaline, brown light medium clay D horizon to 1.5 m	Black Vertosol	Ug5.15	Black earth

* Australian Classification - Isbell 1996
* Principle Profile Form – Northcote 1979
* Great Soil Group – Stace *et al.* 1968

Table 5 (continued)

Soil Profile Classes	Distinguishing attributes	Australian Classification*	Principle Profile Form*	Great Soil Group*
Drainage depressions				
Gueena Gn	Mottled dark medium clay surface (0.1–0.15 m) over a mottled, grey medium clay B2 horizon to 1.5 m	Grey Vertosol	Ug5.24 Ug5.28	Grey clay
GENTLY UNDULATING PLAINS TO UNDULATING RISES ON OLDER HIGHER LYING ALLUVIUM AND TERTIARY SEDIMENTS				
Hill crests and hillslopes				
Appaloosa Ap	Dark or brown light clay to medium clay surface (0.1–0.2 m) over a brown medium clay B2 horizon (0.6–1.2 m) over a mottled, brown, yellow or grey medium clay C horizon to 1.5 m	Brown Vertosol	Ug5.35 Ug5.34 Uf6.31 Ug3.3 Uf6.33 Ug5.2	Brown clay
Bushnell Bl	Gilgaied, brown or dark clay loam surface (0.05–0.2 m) over a bleached A2 horizon (0.07–0.25 m) over a frequently mottled, brown medium clay B2 horizon (0.9–1.5 m) frequently over a mottled, strongly alkaline, grey, brown or yellow light clay to medium clay C horizon to 1.5m	Brown Sodosol	Dy2.33 Dy3.33 Dy3.43 Db2.33 Db1.33	Solodic soil Solodized solonetz
Chelmsford Cf	Dark or red clay loam to light clay surface (0.05–0.25 m) over a red medium clay B2 horizon (0.85–1.3 m) over a strongly alkaline, mottled, red or grey light clay D horizon to 1.5m	Red Ferrosol	Uf6.31 Gn3.13 Gn3.12	Euchrozem
Kawl Kawl Kk	Gilgaied, dark or grey medium clay surface (0.1–0.15 m) over a grey medium clay B2 horizon to 1.5 m	Grey Vertosol	Ug5.24 Ug5.21	Grey clay
Lankowsky Lk	Red light sandy clay loam to clay loam surface (0.1–0.15 m) over a neutral, red clay loam to light clay B horizon to 1.5 m	Red Kandosol	Gn2.12 Gn2.15	Red earth
Long Peter Lp	Dark or brown clay loam surface (0.05–0.2 m) over a brown medium clay B2 horizon (1.3–1.5 m) occasionally over a mottled, grey, brown or yellow light clay to medium clay C horizon to 1.5 m	Brown Sodosol	Db1.13 Db2.13 Dy3.13 Dy2.13 Dy3.23	Solodic soil
Narrawong Nr	Red, dark or brown clay loam surface (0.05–0.15 m) over an occasionally mottled, red or brown medium clay B2 horizon (0.4–0.9 m) over a mottled, acid to alkaline, brown medium clay D horizon to 1.5 m	Red Ferrosol	Gn3.12 Gn3.52 Gn3.22 Gn3.33 Gn4.12	Euchrozem
Palouse Pl	Brown or grey sandy loam to light sandy clay loam surface (0.5–0.12 m) over a bleached A2 horizon (0.12–0.3 m) over a frequently mottled, brown medium clay B2 horizon (0.7–1.5 m) over a mottled, grey, brown or yellow light clay to medium clay C horizon to 1.5 m	Brown Sodosol	Dy3.43 Dy2.43 Db2.43 Dy3,33 Db2.33	Solodic soil Solodized solonetz

* Australian Classification - Isbell 1996
* Principle Profile Form – Northcote 1979
* Great Soil Group – Stace *et al.* 1968

Table 5 (continued)

Soil Profile Classes	Distinguishing attributes	Australian Classification*	Principle Profile Form*	Great Soil Group*
Wheatlands Wh	Brown sandy clay loam to clay loam surface (0.1–0.2 m) over a pale or occasionally sporadically bleached A2 horizon (0.1–0.3 m) over a frequently mottled, red or brown medium clay B2 horizon (1.05–1.5 m) over a frequently mottled, red or brown sandy clay loam to clay loam D horizon to 1.5 m	Red Dermosol Brown Dermosol	Gn3.16 Gn3.26 Dr2.22 Gn3.13 Dr3.33	No suitable group, affinities with red brown earth
PLAINS				
Marshlands Ml	Brown sandy clay loam to light clay surface (0.1–0.2 m) over a sporadically bleached A2 or B1 horizon (0.2–0.3 m) over a mottled, brown medium clay B2 horizon (0.4–1.5 m) over a mottled, brown medium clay to heavy clay D horizon to 1.5 m	Brown Sodosol	Db2.33 Uf6.41p Dy3.43 Dy3.31 Uf3	Solodic soil Soloth
Mondure Md	Brown or occasionally dark light clay or occasionally clay loam surface (0.05–0.15 m) over a brown medium clay B2 horizon to 1.5 m	Brown Dermosol	Uf6.31 Uf4.42 Uf6.4 Gn3.23 Db1.13	No suitable group
UNDULATING RISES TO ROLLING HILLS ON BASALT				
Hillcrests and upper hillslopes				
McEuen Mn	Dark or brown light clay to medium clay surface (0.05–0.1 m) over a dark or brown medium clay B2 horizon (0.3–0.55 m) over weathered rock	Black Vertosol Brown Vertoosl	Ug5.12 Ug5.32 Ug5.13	Black earth Brown clay
Taabinga Tb	Red clay loam to light clay surface (0.1–0.2 m) over a red light clay to medium clay B2 horizon (0.l5–1.2 m) over weathered rock	Red Ferrosol	Uf6.31 Gn3.12 Gn3.13	Euchrozem
Tureen Tn	Dark light clay or occasionally clay loam surface (0.1–0.15 m) over a dark or brown medium clay B2 horizon (0.25–0.55 m) over weathered rock	Black Dermosol Brown Dermosol	Uf6.32 Uf6.31 Db1.12	Prairie soil
Mid to lower hillslopes				
Fairdale Fd	Dark or brown medium clay surface (0.06–0.12 m) over a neutral to alkaline, dark or brown medium clay B2 horizon (0.6–0.9 m) over weathered rock	Black Vertosol Brown Vertosol	Ug5.12 Ug5.13 Ug5.32	Black earth Brown clay
Tingoora Tg	Dark or brown medium clay surface (0.05–0.2 m) over a neutral to alkaline, brown or dark B21 horizon (0.45–0.85 m) over a strongly alkaline, brown medium clay to heavy clay B22 horizon (1.2–1.5 m) over weathered rock	Brown Vertosol Black Vertosol	Ug5.32 Ug5.13 Ug5.12 Ug5.34	Brown clay Black earth
Pediments				
Iona In	Dark medium clay surface (0.1–0.25 m) over a neutral to alkaline, brown or dark medium clay B21 horizon (0.6–1.0 m) over a strongly alkaline, brown or red medium clay B22 horizon to 1.5 m occasionally over gravely D horizons	Brown Vertosol Black Vertosol	Ug5.34 Ug5.17 Ug5.15	Brown clay Black earth

* Australian Classification - Isbell 1996
* Principle Profile Form – Northcote 1979
* Great Soil Group – Stace *et al.* 1968

Table 5 (continued)

Soil Profile Classes	Distinguishing attributes	Australian Classification*	Principle Profile Form*	Great Soil Group*
Sadie Sd	Dark medium clay surface (0.05–0.1 m) over a neutral to alkaline, dark medium clay B21 and B22 horizons over a occasionally mottled, strongly alkaline, grey medium clay B23 horizon to 1.5 m	Black Vertosol	Ug5.16	Black earth
Wondai Wd	Gilgaied, dark or brown medium clay surface (0.05–0.15 m) over a brown or dark medium clay B21 horizon (0.5–1.1 m) over a frequently mottled, brown or red medium clay B22 or D horizon to 1.5 m frequently with gravel	Brown Vertosol Black Vertosol	Ug5.34 Ug5.15 Ug5.17 Ug5.35	Brown clay Black earth
UNDULATING RISES TO ROLLING HILLS ON DEEPLY WEATHERED BASALTIC MATERIAL				
Plateaus, hillcrests and upper hillslopes				
Goodger Gg	Loose, red clay loam to light clay surface (0.1–0.3 m) over an acid, red, massive to weakly structured B21 horizon (0.25–0.8 m) over an acid, red structured light clay B22 horizon to 1.5 m	Red Ferrosol	Gn3.11 Uf5.31	Krasnozem
Hopevale Hv	Loose, red loam surface (0.1–0.25 m) over an acid, red, weak to moderately structured clay loam B2 horizon (0.3–0.55 m) over deeply weathered basalt. Large amounts of ferruginous gravel throughout the profile	Red Ferrosol	Um4.21 Um5.21 Um6.24 Um6.31 Um6.33	Krasnozem Red earth
Proston Pt	Firm, red clay loam to light clay surface (0.1–0.25 m) over an acid, red, structured clay loam to light clay B2 horizon (0.9–1.5 m) with ferruginous gravel over deep weathered basalt	Red Ferrosol	Gn3.11 Uf6.31 Um6.31	Krasnozem
Mid to upper hillslopes				
Memerambi Mm	Firm, red clay loam to light clay surface (0.1–0.2 m) over an acid, red light clay B2 horizon to 1.5 m	Red Ferrosol	Uf6.31 Gn3.11	Krasnozem
Wooroolin Wr	Firm red clay loam to light clay surface (0.1–0.25 m) over an acid to neutral, red light clay B2 horizon (0.7–0.8 m) over deeply weathered basalt	Red Ferrosol	Gn3.11 Uf6.31	Krasnozem Euchrozem
Mid to lower hillslopes				
Coolabunia Cl	Firm, red clay loam to light clay surface (0.1–0.25 m) over a acid to neutral, red light clay to medium clay B21 horizon (0.45–1.0 m) over a acid to neutral, mottled, red light clay to medium clay B22 horizon (1.1–1.3 m) with large amounts of iron and manganiferous concretions over a red medium clay with weathered rock to 1.5 m	Red Ferrosol	Uf6.31 Uf6.4 Gn3.11 Gn3.12	Euchrozem Krasnozem

* Australian Classification - Isbell 1996
* Principle Profile Form – Northcote 1979
* Great Soil Group – Stace *et al.* 1968

Table 5 (continued)

Soil Profile Classes	Distinguishing attributes	Australian Classificatio*	Principle Profile Form*	Great Soil Group*
Crawford Cd	Firm, red clay loam to light clay surface (0.1–0.2 m) over an acid to neutral, mottled, red clay loam to light clay B21 horizon (0.5–0.8 m) over an acid to neutral, mottled, red or brown light clay to medium clay B22 horizon (1.0–1.3 m) with moderate amounts of manganiferous concretions over deeply weathered rock	Red Ferrosol	Uf6.31 Uf6.4 Gn3.11 Gn3.12	Euchrozem Krasnozem
Pediments				
Archookoora Ac	Red or brown light clay surface (0.1–0.25 m) over a red or brown light clay to medium clay B2 horizon (0.65–1.5 m) with manganiferous concretions over a brown medium clay D horizon to 1.5 m	Red Ferrosol Brown Ferrosol	Uf6.31 Uf6.4 Uf6.3	Euchrozem Krasnozem
Haly Hl	Red or brow light clay surface (0.15–0.2 m) over a mottled, brown medium clay B2 horizon to 1.5 m	Brown Ferrosol	Uf6.4	Xanthozem
Kumbia Kb	Brown or red clay loam to light clay surface (0.15–0.25 m) frequently with manganiferous segregations over a frequently mottled, brown or red light clay to medium clayB2 horizon (0.55–1.4 m) with manganiferous segregations over a mottled, brown or yellow medium clay to heavy clay D horizon to 1.5 m	Brown Ferrosol Red Ferrosol	Uf6.4 Gn3.12	Xanthozem
Kunioon Kn	Brown or red clay loam to light clay surface (0.1–0.25 m)with manganiferous nodules over a mottled, brown or red light clay to medium clay B2 horizon (to 1.5 m) with large amounts of manganiferous nodules	Brown Ferrosol Red Ferrosol	Uf6.4	Xanthozem
Tarong Tr	Brown sandy loam to clay loam sandy surface (0.5–0.2 m) over a bleached A2 horizon (0.15–0.3 m) over a mottled, brown or yellow light clay to medium clay B2 horizon (0.5–1.5 m) with manganiferous nodules frequently over a mottled, brown medium clay to heavy clay D horizon to 1.5 m	Brown Chromosol Brown Dermosol Yellow Chromosol Yellow Dermosol	Dy3.41 Dy3.32 Dy3.31 Db2.31	Yellow podzolic soil Brown podzolic soil No suitable group
GENTLY UNDULATING TO UNDULATING LOW HILLS ON GRANITES				
Hillcrests and upper hillslopes				
Booie Bo	Dark or brown sandy loam to sandy clay loam surface (0.1–0.2 m) over a bleached A2 horizon (0.3–0.45 m) over weathered rock	Bleached-Orthic Tenosol Orthic Tenosol	Uc2.12 Um3.12	Lithosol
Boonenne Bn	Brown sandy loam to sandy clay loam surface (0.1–0.2 m) over a conspicuously bleached A2 horizon (0.2–0.3 m) over an alkaline, mottled, brown medium clay B2 horizon (0.65–0.9 m) over weathered rock	Brown Sodosol	Dy3.43 Dy3.42 Dy2.43 Db2.42 Db2.43	Solodic soil
Dangore Dg	Dark sandy loam to sandy clay loam surface (0.08–0.2 m) over a bleached A2 horizon (0.2–0.4 m) over an acid, mottled, brown, grey or yellow fine gravely light clay to medium clay B2 horizon (0.5–1.0 m) over weathered rock	Brown Sodosol Brown Chromosol Grey Sodosol Yellow Sodosol	Dy3.41 Dy3.31 Db2.31 Db1.41	Soloth Podzolic soils

* Australian Classification - Isbell 1996
* Principle Profile Form – Northcote 1979
* Great Soil Group – Stace *et al.* 1968

Table 5 (continued)

Soil Profile Classes	Distinguishing attributes	Australian Classification*	Principle Profile Form*	Great Soil Group*
Mid to lower hillslopes				
Charlestown Ct	Dark or brown light sandy clay loam to clay loam sandy surface (0.1–0.2 m) over a bleached A2 horizon (0.15–0.2 m) over an acid to alkaline, red or brown medium clay B2 horizon (0.55–0.9 m) over weathered rock	Red Sodosol Brown Sodosol	Dr3.12 Dr2.32 Dr3.41 Db2.12 Dr1.12	Solodic soil Soloth
Gordonbrook Gd	Red or brown light sandy clay loam to sandy clay loam surface (0.1–0.15 m) over a pale A2 horizon (0.12–0.3 m) over an acid, red sandy light clay to medium clay B2 horizon (0.75–1.0 m) over deeply weathered rock	Red Chromosol Red Dermosol	Dr2.21 Uf6.4	Red podzolic soil No suitable group, affinities with soloth
Pediments				
Cooyar Cy	Dark brown or grey sandy loam to sandy clay loam surface (0.08–0.2 m) over a bleached A2 horizon (0.15–0.45 m) over an acid, mottled, brown or grey medium clay B2 horizon to 1.5 m	Brown Chromosol Brown Sodosol Brown Kurrosol Grey Sodosol	Dy3.41 Dy3.31	Yellow podzolic soil Soloth
Cushnie Cs	Dark or brown light sandy clay loam to clay loam fine sandy surface (0.08–0.15 m) over a conspicuously bleached A2 horizon (0.12–0.3 m) over a neutral to strongly alkaline, frequently mottled, brown or occasionally grey medium clay B2 horizon to 1.5 m	Brown Sodosol Grey Sodosol	Dy3.43 Dy2.42 Db2.13 Dy3.42	Solodic soil
GENTLY UNDULATING RISES TO UNDULATING LOW HILLS ON METAMORPHIC MATERIAL AND SEDIMENTARY ROCKS				
Hillcrests and upper hillslopes				
Cherbourg Cg	Brown or grey sandy loam to sandy clay loam surface (0.1–0.15 m) over a bleached A2 horizon (0.1–0.4 m) over an acid, brown medium clay B2 horizon (0.25–0.85 m) over weathered rock	Yellow Kurosol Brown Sodosol	Db2.41 Dy3.21 Dy3.41 Um1	Soloth, Lithosol No suitable group
Mid to lower hillslopes				
Hillsdale Hd	Dark or brown sandy clay loam surface (0.1–0.2 m) over a bleached A2 horizon (0.2–0.3 m) over a alkaline to strongly alkaline, mottled, brown or grey medium clay B2 horizon (0.9–1.3 m) over weathered sandstone	Brown Sodosol Grey Sodosol	Dy3.43 Db2.33 Db2.43	Solodic soil Solodized solonetz
Pediments and footslopes				
Hodgleigh Hg	Dark or brown fine sandy clay loam to clay loam sandy surface (0.1–0.2 m) over a conspicuously bleached A2 horizon (0.1–0.35 m) over a neutral, frequently mottled, brown or red medium clay B2 horizon (0.65–1.5 m) over weathered rock	Red Chromosol Brown Sodosol Brown Dermosol	Dr2.12p Dy3.42 Db2.32	Non calcic brown soil Solodic soil No suitable group

* Australian Classification - Isbell 1996
* Principle Profile Form – Northcote 1979
* Great Soil Group – Stace *et al.* 1968

4.1.1 Level to gently undulating plains on recent alluvium

Soils on low channel benches and levees associated with the flood plains of current streams (*Terrace, Hirst*) typically exhibit characteristics of soils formed in a sedimentary environment including depositional layering. The stagnant alluvial plains generally represent the slightly elevated rarely flooded plains. These plains have sodic texture contrast soils (*Avon*) and various cracking clays (*Byee, Eastgate, Weir*). Grey clays (*Gueena*) occur in drainage depressions on the alluvial plains.

Alluvial/colluvial deposits developed from small streams draining the surrounding landscapes have developed brown clays (*Kaber*) on alluvial fans and narrow alluvial plains.

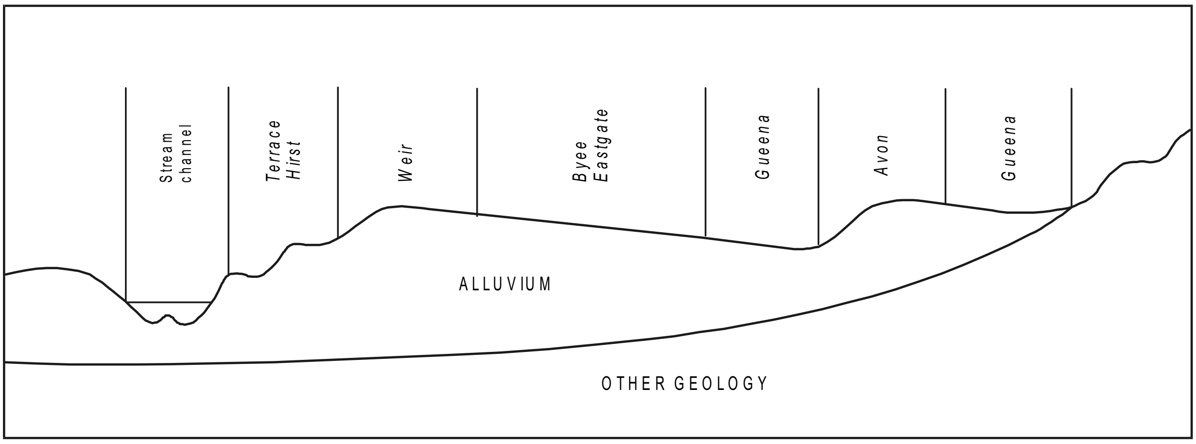

Figure 3. Typical cross-section of the recent alluvial landscapes

4.1.2. Gently undulating plains to undulating rises on older, higher lying alluvium and Tertiary sediments

The old alluvial and Tertiary sediment deposits occur high in the landscape and are not associated with current stream channels. Due to their elevations, landscapes are frequently undulating. Profile development corresponds to landscape position, degree of weathering and the occurrence of reworked alluvial/colluvial deposits over the old alluvium.

On the old alluvium and sediments, strongly sodic alkaline cracking clays (*Appaloosa, Kawl Kawl*) and sodic texture contrast soils (*Long Peter, Bushnell, Palouse*) predominate. In these soils brown colours occur on better drained positions higher in the landscape while yellow and grey colours are associated with lower landscape position. Soils are often gilgaied.

Isolated elevated remnants of alluvial/colluvial deposits overlie the older alluvial deposits in many areas. The alluvial/colluvial deposits probably originated in a wetter environment and have been eroded away in more recent times. Deep red massive soils (*Lankowsky*) and red structured soils overlying sodic old alluvial subsoils (*Chemsford*) occur on upper slopes. Mottled yellow and brown soils overlying sodic old alluvial subsoils (*Wheatlands, Mondure, Marshlands*) occur on lower slopes and plains. Soils become gilgaied where the old alluvium occurs close to the surface.

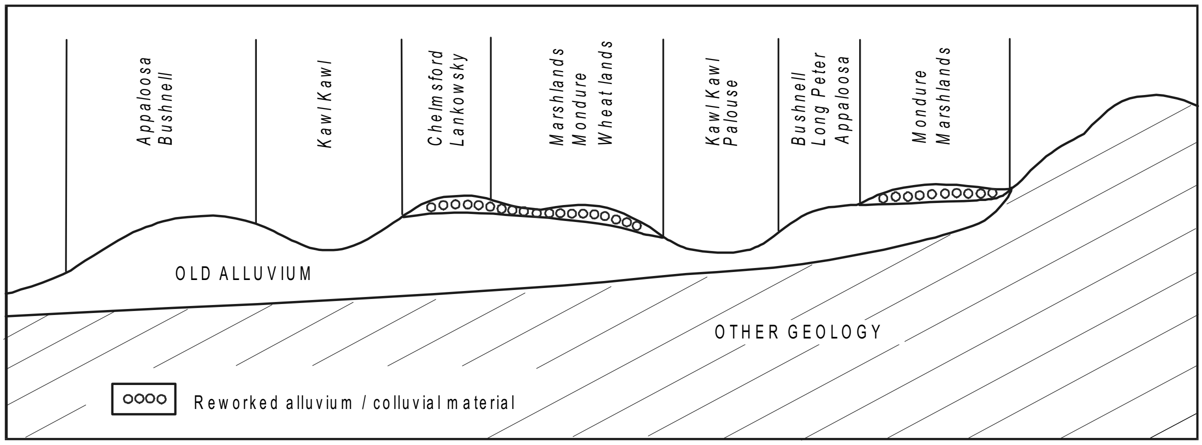

Figure 4. Typical cross-section of old alluvium and Tertiary sediments landform

4.1.3 Undulating rises to rolling hills on basalt

Soils developed from fresh exposures of Tertiary basalt occurring either above or below the red soil landscape tend to be shallow (<0.3 m) to moderately deep (>1.2 m) dark cracking clays. On crests and hillslopes with slopes of 2 to 12%, the soils can be as shallow as 0.3 m (*McEuen*), 0.6 m (*Fairdale*) or as deep as 1.2 m (*Tingoora*). These are frequently stony soils with frequent rock outcrops.

Below Haly's Round Mountain at the edge of the Bunya Mountains in the south western portion of the study area, the same parent material produces friable brown loams and clay-loams or prairie soils (*Tureen*). These are frequently stony and shallow and occur on crests and upper slopes in association with the dark clay soils *McEuen* and *Fairdale*.

Minor fluvial deposits or remnants of structured red soils (*Taabinga*) occur within this geomorphological unit on crests and flats. These overlie weathering basalt and can occur in association with the dark clay soils. They have a neutral pH and a hard setting surface.

Soils on the more gentle footslopes (slopes 1–4%) and pediments are usually very deep (>1.5 m) and vary in colour, pH and amount of coarse fragments of weathered basalt. Weak to moderate linear micro-relief occurs on long slopes. *Sadie* has a yellow to grey subsoil and an alkaline pH of 0.6 m and has a strongly self mulching surface. *Iona* has bands of carbonate in an alkaline grey-brown or brown subsoil by 0.9 and commonly has coarse fragments of weathering basalt from colluvial movement from higher lying materials. *Wondai* soil by comparison is a fairly uniform, deep, dark brown cracking clay soil becoming brown at depth, alkaline pH by 1.2 m and with minor concretions of carbonate. It occurs mainly on the pediments with little or negligible slope.

Coarse fractions of rounded basalt cobble and small boulders can occur in all soils in this unit in varying degrees of size and percentage with the greatest occurrence occurring on the crests and ridges. The remnant vegetation of this unit comprises of silver-leaved ironbark on the crests and slopes whilst forest red gum and Moreton Bay ash occur on drainage lines and along gullies.

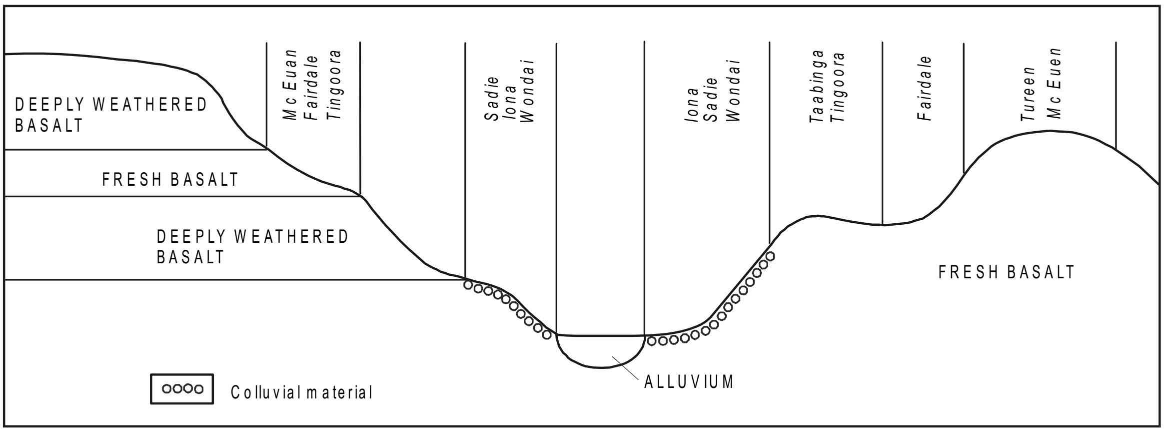

Figure 5. Typical cross-section of basalt landscapes

4.1.4 Undulating rises to rolling hills on deeply weathered basaltic material

Soil types in this landscape unit are very closely related to position in the landscape. The deeply weathered basalts may give rise to soils developed *in situ.* Others have developed from colluvial pediments derived from the basalt and/or mixed with other colluvial substrate.

Acid, red structured soils typically occur on upper slopes and plateaus of deeply weathered basalt. Soils have been subdivided into deep loose (or snuffy) surfaced (*Goodger*) or firm surfaced (*Memerambi*) soils. Shallower versions of these soils (*Proston, Hopevale, Wooroolin*) occur on steeper upper slopes crests and plateau margins.

Neutral, red structured soils (*Coolabunia, Crawford*) generally occur on mid to lower slopes (relative to the acid red soils) of the deeply weathered basalt.

Mottled brown structured soils occur on wetter lower slopes (*Haly*) and seepage areas (*Kunioon*). The amount of manganiferous segregations depends on the local landscape hydrology.

Mottled, yellow or brown structured soils (*Kumbia, Tarong, Archookoora*) occur where colluvial material from the deeply weathered basalts have been deposited over adjacent sodic old alluvial or Tertiary sediments. These soils generally occur adjacent to the basaltic rises and plateaus. The amount of manganiferous segregations also depends on local landscape hydrology.

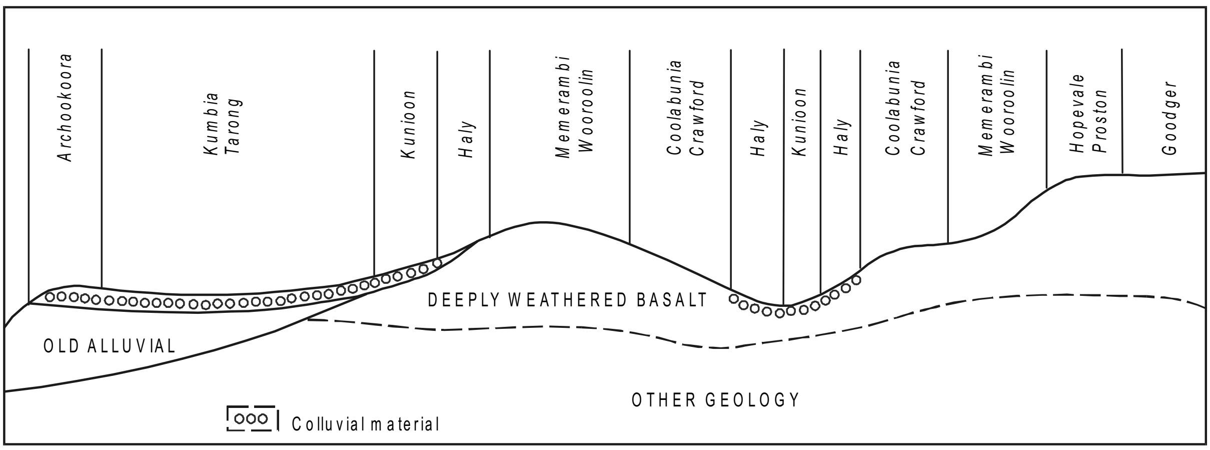

Figure 6. Typical cross-section of the deeply weathered basaltic landscape

4.1.5 Gently undulating to undulating low hills on granite

The geology comprises predominantly granite with minor granodiorites. Soils typically have light textured surfaces (sandy loams) on steeper slopes and crests while finer loams and clay loam surfaces predominate on gentle lower slopes.

Steep upper slopes and narrow crests typically have shallow sandy profiles (*Booie*) with rock outcrops. Moderately deep yellow and brown sodic texture contrast soils (*Dangore, Boonenne*) occur on upper slopes.

Broad gently sloping crests have moderately deep red texture contrast and gradational soils (*Gordonbrook*). Deeper red and brown texture contrast soils (*Charlestown*) occur on gentle mid slopes while mottled yellow and brown texture contrast soils (*Cooyar, Cushnie)* occur on lower slopes with colluvial deposition and drainage depressions.

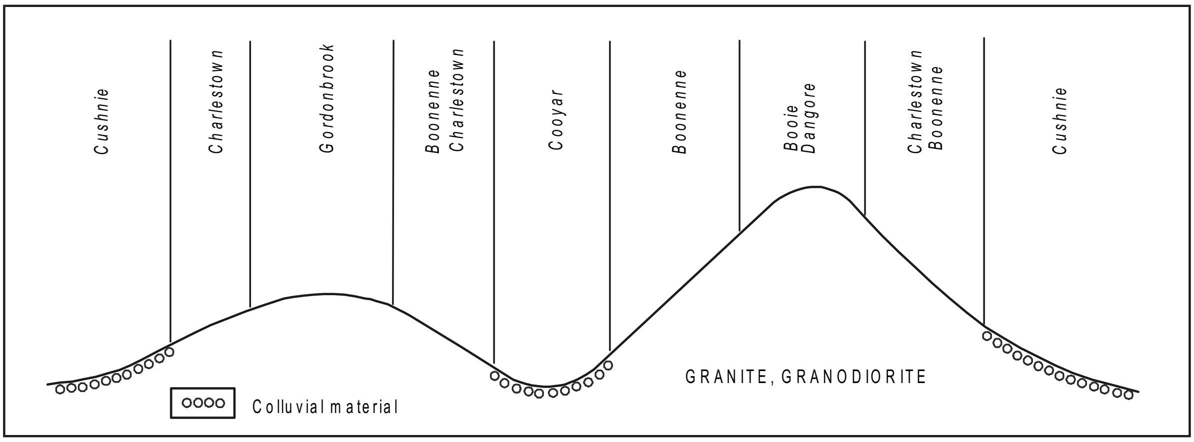

Figure 7. Typical cross-section of the granite landscape

4.1.6 Gently undulating rises to undulating low hills on metamorphic material and sedimentary rocks

Shallow sandy to loamy soils with rock outcrop (*Cherbourg*) occur on crests and upper slopes of the metamorphic rises and low hills.

Shallow texture contrast soils (*Hillsdale*) occur on mid slopes while deep sodic texture contrast soils (*Hodgleigh*) occur on lower slopes.

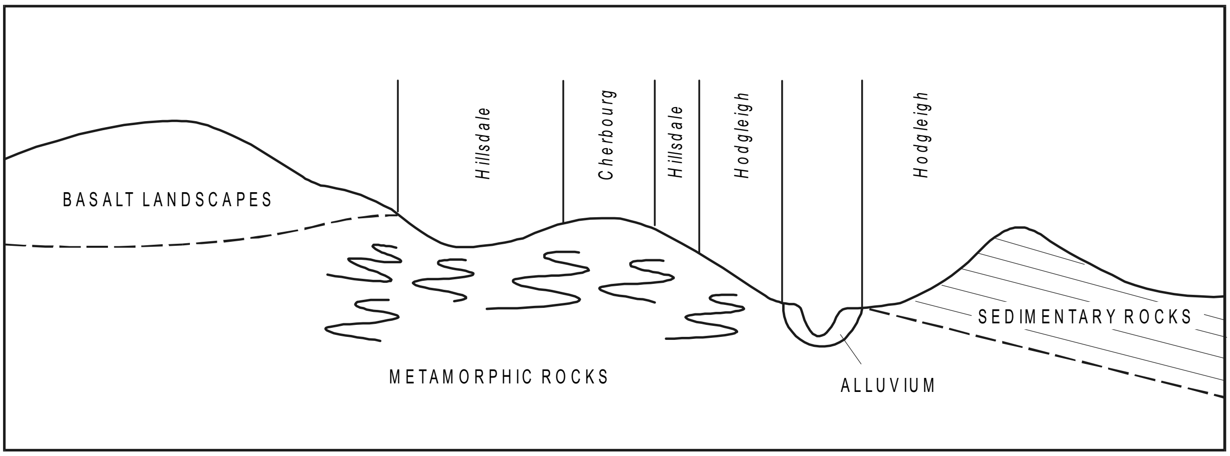

Figure 8. Typical cross-section of the metamorphic and sedimentary rocks landscapes

4.2 Soil chemical and physical properties

4.2.1 Soil Fertility

The soil chemical and physical properties are based on the soil groups for each of the six geomorphic/geological units. A total of 53 soil profiles were samples for detailed laboratory analysis. The fertility ratings in Table 6 are based on Baker and Eldershaw (1993) and Bruce and Rayment (1982).

Soil pH
Surface pH for all soils range from 4.6 to 8.4 while subsoil pH ranges from 4.0 to 9.2. The wide range of pH values reflects the diverse geology and geomorphic processes. The strongly acid pH values are usually associated with the deeply weathered landscapes. High pH (>8.5) is often associated with lime segregations.

The soils on young and old alluvium have slightly acid to neutral (pH 6.3–6.7) surfaces while subsoils are moderately alkaline to strongly alkaline (pH 8.1–9.1).

The surface pH of soils on the fresh basalts ranges from slightly acid to neutral (pH 6.1–7.0) and subsoils have neutral to moderately alkaline (pH 6.7–8.5).

On the deeply weathered basalts, pH is strongly related to landscape position. On upper slopes and plateaus, surface pH ranges from very strongly acid to slightly acid (pH 4.6–6.5) while subsoils range from extremely acid to medium acid (pH 4.0–6.0). On lower slopes and pediments, surface pH values are medium acid to slightly acid (pH 5.9–6.4) and subsoils are neutral to strongly alkaline (pH 6.7–8.5). On pediments, some buried horizons derived from old alluvial or Tertiary sediments are extremely acid (pH 4.3).

The granitic soils have medium acid to neutral (pH 5.8–6.7) surfaces and medium acid to moderately alkaline (pH 5.9–8.5) subsoils. Variations in pH are mainly related to the degree of weathering and lithology with the lower pH values on granites and higher values on granodiorites.

Soils on metamorphic and sedimentary rocks have slightly acid to mildly alkaline (pH 6.5–7.6) surfaces and slightly acid to strongly alkaline (pH 6.4–9.0) subsoils. The more acid pH values occur higher in the landscape.

Organic carbon and nitrogen
Organic carbon and nitrogen levels correspond to the amount of organic matter in the soil. Most samples were taken from undisturbed sites under native vegetation. Due to the long term agricultural development in the area, cultivated sites will have significantly lower carbon and nitrogen values.

Organic carbon ranges from low to very high (0.9–6.5%). The values generally correspond to type and density of vegetation. For example, the higher values occur under closed scrub forests while the lower values occur under open eucalypt woodlands with a sparse ground cover. The deeply weathered basaltic soils on upper slopes and plateaus with scrub vegetation have consistently high values (4.4–5.6%) while lower slopes with eucalypt vegetation have lower values (2.3–3.7%). Overall, the clay soils on all landscapes have higher values (1.7–2.9%) compared to the texture contrast soils (1.2–2.3%) which generally corresponds to a sparser ground cover.

Nitrogen values range from low to high (0.06–0.6%). Values show the same trends as organic carbon with lower nitrogen percentages corresponding to lower carbon levels.

The ratio of organic carbon to nitrogen (C/N) is often a useful indication of the ability of the soil to supply nitrogen. A high C/N ratio (>15) indicates a slow mineralisation process and reduced capacity to supply mineral nitrogen. C/N ratios vary from 8.2–29. The lower values generally correspond to the scrub soils and soils with dense grass cover. The higher values generally have eucalypt or *Acacia* vegetation.

Phosphorus

Phosphorus (P) is an important plant nutrient essential for cropping and good pasture growth.

Acid extractable P and bicarb. extractable P generally show corresponding values. Bicarb. P ranges from very low to very high (2–147 mg/kg). The lower values are characteristic of the soils on fresh basalt and old alluvium (4–12 mg/kg). The soils on young alluvium have medium to very high P levels (26–140 mg/kg). The wide range in values, but predominantly higher values, generally indicate young soils derived from mixed parent material.

The deeply weathered basaltic soils have very low (2–7 mg/kg) P levels in upper landscape positions and low to high (16–86 mg/kg) P levels in lower landscape positions. This corresponds to the relative ages and degree of weathering of the soils.

Granitic soils are very low to low (8–17 mg/kg) while the metamorphic soils have not been analysed.

Potassium

Exchangeable and replaceable potassium (K) show similar values. Exchangeable K ranges from low to very high (0.12–2.2 meq/100 g). Surface potassium levels are related to surface accumulation of organic matter and lithology of the parent material. In general, the level of organic matter is related to the density of vegetation which is related to the overall level of soil fertility. Granite rocks are high in K due to potassium feldspars and micas while granitic soils usually have low overall fertility which results in low organic matter due to sparse vegetation. As a result, the soils on granites have medium to high K values (0.27–0.67 meq/100 g). The higher values correspond to denser vegetation and higher organic C levels.

Basalt rocks typically have low K levels but basalt soils have high overall fertility and can have high organic matter levels from dense scrub or grass vegetation. As a result, the soils on fresh basalt have medium to high K values (0.37–0.65 meq/100 g) generally corresponding to medium to high organic carbon levels due to good grass cover. Deeply weathered basaltic soils have medium to very high (0.37–2.2 meq/100 g) values. Generally, the snuffy soils which originally had eucalypt vegetation have lower values.

The young alluvial soils have medium to high K values (0.26–0.99 meq/100 g). Old alluvium soils have low to very high (0.17–1.2 meq/100 g) values. The wide range in values reflects the diverse range in vegetation and parent material.

Micronutrients – Zn, Cu, Mn

Micronutrients levels are extremely variable with Zn ranging from low to high (0.2–12 mg/kg), Cu ranging from low to high (0.2–7.7 mg/kg) while Mn ranges from low to high (2–342 mg/kg). Generally, the sandy granitic soils are low to moderate in micronutrients (Zn 0.6–1.2, Cu 0.2–0.4, Mn 32–67 mg/kg). The deeply weathered basaltic soils high in the landscape (*Goodger, Hopevale*) are typically lower in Zn and Cu (Zn 0.3–0.6, Cu 0.2–0.7 mg/kg). All other soils generally have moderate to high Cu and Zn values (Zn 0.7–12, Cu 0.7–7.7 mg/kg).

Manganese levels in the old and young alluvial soils, and basaltic and deeply basaltic soils except the snuffy soils (*Goodger, Hopevale*) are predominantly high (57–342 mg/g) with some moderate values (16–33 mg/kg). The snuffy soils are lower (6–32 mg/kg) in manganese. The high manganese values on the strongly acid soils may result in manganese toxicity.

Table 6a. Soil chemical ratings for the soil profile classes

Soil profile class	Site No.	Org C %	Tot N %	Ratio C/N	Acid P mg/kg	BicarbP mg/kg	Tot P %	Extr K	Exch K meq/100g	Tot K %	Tot S %	Cu mg/kg	Zn mg/kg	Mn mg/kg
Appaloosa	RS27	1.9 (m)	.14 (l)	13.6	19 (l)	17 (l)	.066 (h)	1.0 (vh)	1.1 (vh)	.20 (l)	.030 (m)	1.6 (m)	1.6 (m)	123 (h)
Archookoora	S10	2.0 (m)	.14 (l)	14.3	3 (vl)	3 (vl)	.053 (h)	0.53 (h)	.03 (vl)	.13 (l)	.004 (vl)	2.1 (m)	1.2 (m)	226 (h)
Archookoora	S38	3.4 (h)	.23 (m)	14.8	3.4 (h)	11 (l)	0.12 (vh)	.42 (m)	.50 (m)	.101 (l)	.043 (m)	2.4 (m)	1.8 (m)	79 (h)
Avon	R527	1.4 (l)	.12 (l)	11.7	5 (vl)	8 (cvl)	.056 (h)	.57 (h)	.50 (h)	1.91 (h)	.017 (l)	0.7 (m)	0.3 (l)	33 (m)
Boonenne	S30	1.20 (l)	.07 (l)	17.1	4 (vl)	9 (v)l	.017 (l)	.27 (m)	.22 (m)	1.99 (h)	.010 (l)	0.2 (l)	0.6 (l)	32 (m)
Bushnell	S6	2.1 (m)	.19 (m)	11.1	33 (m)	22 (m)	.071 (h)	1.2 (vh)	.93 (h)	.24 (l)	.029 (m)	2.7 (m)	2.6 (m)	23 (m)
Bushnell/Palouse	S7	2.3 (m)	.16 (m)	14.4	25 (m)	11 (l)	.053 (h)	.76 (h)	.68 (h)	.16 (l)	.028 (m)	1.2 (m)	1.5 (m)	95 (h)
Bushnell/Palouse	R527	1.8 (m)	.14 (l)	12.9	18 (l)	16 (l)	.066 (h)	1.0 (h)	1.1 (vh)	.20 (l)	.03 (m)	1.5 (m)	1.5 (m)	119 (h)
Byee	RS27	1.6 (m)	.13 (l)	12.8	40 (m)	40 (m)	.056 (h)	.57 (h)	.35 (m)	.28 (l)	.022 (m)	2.9 (m)	0.7 (l)	26 (m)
Byee	BBR	2.2 (m)	.20 (m)	11	17 (l)	26 (m)	.063 (h)	.26 (m)	.18 (l)	.21 (ll	.034 (m)	3.8 (m)	1.6 (m)	58 (h)
Chelmsford	S19	3.1 (h)	.25 (m)	12.4	(svl)	11 (l)	.036 (m)	.24 (m)	.05 (vl)	.09 (vl)	.031 (m)	2.7 (m)	1.4 (m)	237 (h)
Coolabunia	S36	3.4 (h)	.24 (m)	14.2	27 (m)	16 (l)	.062 (h)	.68 (h)	.97 (h)	.15 (l)	.044 (m)	2.1 (m)	2.0 (m)	881 (h)
Eastgate	BBR S10	1.6 (m)	0.13 (l)	12.3	120 (vh)	100 (vh)	.115 (vh)	.61 (h)	.65 (h)	1.25 (h)	.019 (l0	3.0 (m)	1.0 (m)	63 (h)
Fairdale	S2	2.7 (h)	.24 (m)	11.3	8 (vl)	10 (vl)	.034 (m)	.41 (m)	.18 (l)	.38 (l)	.028 (m)	4.1 (m)	1.0 (m)	67 (h)
Fairdale	S28	2.8 (h)	.23 (m)	12.2	7 (vl)	12 (l)	.056 (h)	.37 (m)	.32 (m)	.44 (l)	.023 (m)	4.0 (m)	1.1 (m)	120 (h)
Goodger	S15	4.4 (h)	.24 (m)	18.3	8 (vl)	2 (vl)	.028 (m)	1.5 (vh)	2.2 (vh)	.23 (l)	.042 (m)	0.2 (l)	0.3 (l)	6 (m)
Goodger	S12	5.6 (vh)	.50 (h)	11.2	14 (l)	4 (vl)	.033 (m)	.78 (h)	.68 (h)	.11 (l)	.005 (l)	2.1 (m)	0.3 (l)	6 (m)
Goodger	S24	4.5 (h)	.35 (h)	12.9	7 (vl)	11 (l)	.004 (vl)	1.1 (vh)	.93 (h)	.12 (l)	.041 (m)	0.4 (n)	2.0 (m)	32 (m)
Gordonbrook	S25	3.2 (h)	.20 (m)	16	8 (vl)	17 (l)	.031 (m)	.67 (h)	.67 (h)	.16 (l)	.03 (m)	0.4 (m)	1.2 (m)	67 (h)
Gueena	BBR S5	1.7 (m)	.19 (m)	8.9	35 (m)	61 (h)	.088 (h)	.50 (h)	.80 (h)	.88 (m)	.033 (m)	3.2 (m)	1.0 (m)	57 (h)
Haly	S27	2.5 (h)	.16 (m)	15.6	12 (l)	27 (m)	.088 (h)	.33 (m)	.45 (m)	.14 (l)	.033 (m)	2.0 (m)	3.0 (m)	106 (h)
Hirst/Terrace	R527	1.3 (l0	.08 (l)	16.3	39 (m)	35 (m)	.043 (m)	.48 (m)	.44 (m)	2.54 (h)	.015 (l)	0.4 (m)	0.6 (m)	10 (m)
Hopevale	S14	2.9 (h)	.22 (m)	13.2	11 (l)	11 (l)	.068 (h)	1.8 (vh)	1.1 (vh)	.17 (l)	.051 (h)	1.3 (m)	3.2 (m)	15 (m)
Hopevale	R527	6.8 (vh)	.60v (h)	11.3	28 (m)	32 (m)	. 109(h)	1.9 (vh)	.33 (m)	.22 (l)	.103v (h)	0.7 (m)	1.7 (m)	10 (m)
Iona	S17	2.8 (h)	.21 (m)	13.3	22 (m)	18 (l)	.075 (h)	.65 (h)	1.2 (vh)	.59 (m)	.057 (h)	5.3 (h)	1.1 (m)	106 (h)
Kaber	S37	2.7 (h)	.19 (m)	20.8	-	12 (l)	.089 (h)	.78 (h)	1.0 (h)	.199 (l)	.045 (m)	3.0 (m)	0.7 (m)	4.2 (m)
Kawl Kawl	S32	2.3 (m)	.19 (m)	12.1	20 (m)	21 (m)	.055 (h)	.24 (m)	.25 (m)	.16 (l)	.04 (m)	2.0 (m)	0.8 (l)	33 (m)
Kawl Kawl	S33	1.9 (m)	.22 (m)	8.6	40 (m)	14 (l)	.033	.47 (m)	.656 (h)	.15 (l)	.073 (h)	0.6 (m)	0.5 (l)	13 (m)
Kawl Kawl	S3	2.6 (h)	.23 (m)	11.3	6 (vl)	7 (vl)	.043 (m)	.52 (h)	.51 (h)	.19 (l)	.056 (h)	1.4 (m)	0.6 (l)	25 (m)
Kumbia	S20	1.6 (m)	.13 (l)	12.3	2 (vl)	6 (vl)	.034 (m)	.32 (m)	.08 (vl)	.06 (vl)	.027 (m)	1.9 (m)	1.3 (m)	163 (h)
Lankowsky	S39	2.5 (h)	.13 (l)	19.2	-	6 (vl)	.073 (h)	.75 (h)	.78 (h)	.061 (vl)	.057 (h)	0.2 (l)	0.2 (l)	2 (l)
Long Peter	S40	1.9 (m)	.15 (l)	12.7	16 (l)	25 (m)	.093 (h)	.17 (l)	.03 (vl)	.22 (l)	.037 (m)	2.7 (m)	1.6 (m)	130 (h)

Table 6a (continued)

Soil profile class	Site No.	Org C %	Tot N %	Ratio C/N	Acid P mg/kg	BicarbP mg/kg	Tot P %	Extr K	Exch K meq/100g	Tot K %	Tot S %	Cu mg/kg	Zn mg/kg	Mn mg/kg
Marshlands	S9	2.4 (m)	.19 (m)	12.6	18 (l)	15 (l)	.063 (h)	.64 (h)	.45 (m)	.12 (l)	.027 (m)	2.0 (m)	1.6 (m)	147 (h)
McEuen	S16	2.8 (h)	.25 (m)	11.2	9 (vl)	8 (vl)	.038 (m)	.56 (h)	.35 (m)	.31 (l)	.028 (m)	5.0 (m)	1.7 (m)	107 (h)
Memerambi	S26	2.6 (h)	.32 (h)	8.1	70 (h)	86 (h)	.149 (vh)	2.2 (vh)	3.1 (vh)	.38 (l)	.04 (m)	3.8 (m)	7.3 (h)	179 (h)
Memerambi	S31	2.3 (m)	.22 (m)	10.5	46 (h)	36 (m)	.075 (h)	1.4 (vh)	.67 (h)	.54 (m)	.034 (m)	3.0 (m)	1.3 (m)	96 (h)
Memerambi	S35	2.9 (h)	.31 (h)	9.5	35 (m)	26 (m)	.022 (m)	1.4 (vh)	.65 (h)	.09 (vl)	.047 (m)	2.0 (m)	2.8 (m)	76 (h)
Memerambi	S21	2.5 (h)	.25 (m)	10	16 (l)	16 (l)	.05 (m)	1.9 (vh)	1.5 (vh)	.17 (l)	.038 (m)	1.9 (m)	2.7 (m)	142 (h)
Memerambi	S13	3.7 (h)	.32 (h)	11.6	6 (vl)	3 (vl)	.033 (m)	2.0 (vh)	.91 (h)	.13 (l)	.039 (m)	0.4 (m)	1.8 (m)	50 (h)
Memerambi	S1	4.9 (h)	.57v (h)	8.6	54 (h)	42 (h)	.13 (vh)	2.2 (vh)	2.0 (vh)	.27 (l)	.114v (h)	7.7 (h)	12 (h)	342 (h)
Memerambi	S34	2.9 (h)	.33 (h)	8.8	29 (m)	29 (m)	.073 (h)	1.9 (vh)	.67 (h)	.28 (l)	.053 (h)	4.0 (m)	4.0 (m)	211 (h)
Memerambi	S29	1.7 (m)	.12 (l)	14.2	4 (vl)	6 (vl)	.038 (m)	.37 (m)	.30 (m)	.10 (l)	.03 (m)	0.6 (m)	0.6 (m)(	24 (m)
Mondure	R527	0.9 (l)	.06 (l)	15	3 (vl)	6 (vl)	.023 (m)	.12 (l)	.14 (l)	.06 (vl)	.014 (l)	1.0 (m)	0.3 (l)	80 (h)
Mondure	S11	2.0 (m)	.13 (l)	15.5	5 (vl)	5 (vl)	.055 (h)	.35 (m)	.18 (l)	.09 (vl)	.026 (m)	2.6 (m)	1.5 (m)	320 (h)
Mondure	S8	2.1 (m)	.13 (l)	16.2	7 (vl)	6 (vl)	.062 (h)	.50 (h)	.31 (m)	.11 (l)	.028 (m)	2.0 (m)	1.2 (m)	280 (h)
Palouse	S5	1.7 (m)	.12 (l)	17	12 (l)	5 (vl)	.024 (m)	.47 (m)	.35 (m)	.18 (l)	.016 (l)	0.6 (m)	6.2 (h)	75 (h)
Palouse	S18	2.3 (m)	.17 (m)	13.5	6 (vl)	4 (vl)	.031 (m)	.59 (h)	.23 (m)	.20 (l)	.015 (l)	1.0 (m)	1.0 (m)	140 (h)
Tarong	S23	1.7 (m)	.10 (l)	17	6 (vl)	7 (vl)	.020 (l)	.13 (l)	.03 (vl)	.03 (vl)	.015 (l)	0.4 (m)	0.4 (l)	16 (m)
Tureen	S40	6.5 (vh)	.34 (j)	19.1	-	14.7 (vh)	.063 (vh)	.61 (h)	1.8 (vh)	1.93 (h)	.068 (h)	0.7 (m)	4.0 (m)	46 (m)
Weir	BBRS1	2.9 (h)	.10 (l)	29	120 (vh)	100 (vh)	.123 (vh)	.72 (h)	.66 (h)	1.39 (h)	.033 (m)	2.8 (m)	5.2 (h)	77 (h)
Weir	R527	1.6 (m)	.11 (l)	14.5	205 (vh)	140 (vh)	.104 (vh)	.99 (h)	.40 (m)	1.22 (h)	.02 (m)	2.0 (m)	1.8 (m)	48 (m)
Wooroolin	S22	3.1 (h)	.30 (h)	10.3	35 (m)	20 (m)	.042 (m)	1.0 (vh)	.82 (h)	.14 (l)	.048 (m)	0.7 (m)	3.4 (m)	70 (h)

vh – very high; h – high; m – medium; l – low; vl – very low

Table 6b. Soil chemical ratings for the soil profile classes

Soil Type	CL Depth (m)					pH Depth (m)					EC Depth (m)				
	0.05	.3	0.6	0.9	1.2	0.05	0.3	0.6	0.9	1.2	0.05	0.3	0.6	0.9	1.2
Appaloosa	vl	m	h	h	h	6.6	7.1	8.2	8.2	8.1	vl	l	m	m	m
Archookoora	vl	vl	vl	vl	vl	6.66	6.3	6.7	6.9	6.9	vl	vl	vl	vl	vl
Archookoora	vl	vl	m	h	h	6.5	6.4	6.6	8.2	8.8	vl	vl	l	m	h
Avon	vl	m	h	h	m	6.3	8.6	8.9	9.0	9.0	vl	l	m	m	m
Boonenne	vl	vl	m	l	l	5.8	6.7	7.9	8.4	8.5	vl	vl	l	l	vl
Bushnell	vl	vl	m	h	h	6.5	7.5	8.9	8.9	8.7	vl	vl	l	m	h
Bushnell/Palouse	vl	l	h	h	h	6.8	8.0	9.0	9.1	8.9	vl	l	m	m	h
Bushnell/Palouse	vl	m	h	h	m	6.6	7.1	8.3	8.2	8.1	vl	l	m	m	m
Byee	vl	vl	vl	l	l	6.7	7.5	7.9	7.9	8.4	vl	vl	vl	l	l
Byee	vl	vl	vl	l	l	6.6	7.1	7.0	7.4	8.3	vl	vl	vl	l	l
Chelmsford	vl	vl	vl	vl	vl	6.6	6.0	6.1	6.4	8.4	vl	vl	vl	vl	vl
Coolabunia	vl	vl	vl	vl	vl	5.9	6.3	6.6	6.7	6.7	vl	vl	vl	vl	vl
Eastgate	vl	l	m	m	m	6.4	6.7	7.3	7.9	8.1	vl	vl	l	l	l
Fairdale	vl	vl	vl	vl	l	6.1	6.8	7.9	8.5	8.4	vl	vl	l	vl	l
Fairdale	vl	vl	m	m	l	6.5	6.4	7.5	8.4	8.5	vl	vl	l	l	l
Goodger	vl	vl	vl	vl	vl	5.7	.59	6.2	5.8	6.1	vl	vl	vl	vl	vl
Goodger	vl	vl	vl	vl	vl	5.5	5.8	5.8	6.0	6.1	l	vl	vl	vl	vl
Goodger	vl	vl	vl	vl	l	5.4	5.8	5.6	5.9	5.9	vl	vl	vl	vl	vl
Gordonbrook	vl	vl	vl	vl	vl	6.7	6.4	5.9	6.0	5.9	vl	vl	vl	vl	vl
Gueena	vl	l	l	m	m	6.3	7.2	7.8	8.2	9.1	vl	vl	l	l	m
Haly	vl	vl	vl	vl	vl	5.9	5.6	6.4	6.7	6.7	vl	vl	vl	vl	vl
Hirst/Terrace	vl	vl	vl	vl	l	6.0	6.4	7.3	7.1	7.6	vl	vl	vl	vl	vl
Hopevale	vl	vl	vl	vl	vl	5.9	5.2	4.9	4.6	4.4	vl	vl	vl	vl	vl
Hopevale	vl	vl	vl	vl	vl	5.8	5.2	5.2	5.1	5.0	vl	vl	vl	vl	vl
Iona	vl	vl	h	m	m	7.0	7.1	8.1	7.9	8.3	l	vl	l	l	l
Kaber	vl	l	m	m	m	6.5	6.4	6.9	8.2	8.5	vl	vl	l	l	l
Kawl Kawl	l	h	vh	vh	vh	7.6	8.2	8.3	8.3	8.4	vl	m	h	vh	vh
Kawl Kawl	h	h	h	h	m	8.4	8.8	8.8	8.8	8.9	m	h	h	m	l

Table 6b (continued)

Soil Type	CL Depth (m)					PH Depth (m)					EC Depth (m)				
	0.05	.3	0.6	0.9	1.2	0.05	0.3	0.6	0.9	1.2	0.05	0.3	0.6	0.9	1.2
Kawl Kawl	vl	vl	vl	vl	vl	8.1	8.6	8.8	8.5	8.8	l	vl	vl	vl	vl
Kumbia	vl	vl	vl	vl	m	6.4	6.3	6.7	6.5	6.1	vl	vl	vl	vl	l
Lankowsky	vl	vl	vl	vl	vl	5.9	6.2	6.4	6.4	6.6	vl	vl	vl	vl	vl
Long Peter	vl	vl	h	h	vh	7.0	8.6	9.0	8.8	8.4	vl	l	m	h	h
Marshlands	vl	vl	m	h	h	7.5	7.0	6.6	6.4	7.5	vl	vl	l	m	m
McEuen	vl	vl	vl	vl	-	6.4	6.9	7.7	7.8	-	vl	vl	vl	vl	-
Memerambi	vl	vl	vl	vl	vl	5.4	5.5	4.6	4.3	4.0	vl	vl	vl	vl	vl
Memerambi	vl	vl	vl	vl	vl	6.4	5.7	4.7	4.5	4.5	vl	vl	vl	vl	vl
Memerambi	vl	vl	vl	vl	vl	4.9	4.4	4.5	4.2	4.6	vl	vl	vl	vl	vl
Memerambi	vl	vl	vl	vl	vl	4.6	4.7	4.5	4.4	4.7	vl	vl	vl	vl	vl
Memerambi	vl	vl	vl	vl	vl	5.6	5.8	5.5	5.3	5.3	vl	vl	vl	vl	vl
Memerambi	vl	vl	l	m	m	6.2	6.0	6.4	6.6	5.8	l	l	m	m	M
Memerambi	vl	vl	vl	vl	vl	6.5	6.7	6.4	6.2	6.0	vl	vl	vl	vl	vl
Memerambi	vl	vl	vl	vl	vl	6.0	6.5	6.3	6.3	6.4	vl	vl	vl	vl	vl
Mondure	vl	vl	m	m	-	6.0	6.1	7.9	9.2	-	vl	vl	l	l	-
Mondure	vl	vl	vl	l	m	6.0	6.3	6.7	6.6	7.8	vl	vl	vl	l	l
Mondure	vl	vl	m	h	h	7.1	6.9	6.4	6.6	8.1	vl	vl	l	m	m
Palouse	vl	m	h	h	h	7.2	8.1	6.8	6.7	7.3	vl	l	l	l	m
Palouse	vl	h	h	m	m	7.1	5.0	6.5	9.3	9.2	vl	m	m	l	l
Tarong	vl	vl	m	h	h	5.7	5.6	4.7	4.5	4.3	vl	vl	l	l	l
Tureen	vl	vl	vl	-	-	6.7	6.7	6.4	-	-	vl	vl	vl	-	-
Weir	vl	vl	m	m	m	6.4	6.7	8.2	8.8	8.7	vl	vl	l	l	l
Weir	vl	vl	vl	l	l	6.3	6.2	7.7	8.3	8.6	vl	vl	vl	vl	l
Wooroolin	vl	vl	vl	l	m	6.3	5.3	5.9	6.0	6.1	l	vl	vl	l	l

vh – very high; h – high; m – medium; l – low; vl – very low

Table 6c. Soil chemical ratings for the soil profile classes

Soil Type	Dispersion ratio					Ac/Mg					ESP					PAWC
	Depth (m)					Depth (m)					Depth (m)					
	0.05	0.3	0.6	0.9	1.2	0.05	0.3	0.6	0.9	1.2	0.05	0.3	0.6	0.9	1.2	mm
Appaloosa	0.49	.86	.99	.99	0	1.0	.62	.35	.24	.16	2.6	13.6	22.6	24.2	26.9	80
Archookoora	.3	.41	.36	.32	.42	1.6	1.6	2.1	2.0	1.8	1.5	1.4	1.5	1.7	1.9	180
Archookoora	.27	.50	.45	.97	0	1.02	.33	.22	.25	.26	2.6	7.5	14.4	24	30	120
Avon	.57	.99	.99	.99	0	.66	.38	.30	.29	.27	3	19	32	25	31	80
Boonenne	.43	.53	.95	.30	0	1.6	.52	.04	.01	.02	2.8	5.0	28	33	32	60
Tureen	.24	.26	.41	-	-	2.5	2.2	1.9	-	-	0.4	1.0	1.6	-	-	120
Bushnell	.36	.77	.85	.86	-	2.6	.77	.42	.29	.20	1.8	9.4	22.1	29.5	32	80
Bushnell/Palouse	.46	.65	.72	.82	.88	2.2	1.9	.45	.33	.19	1.3	12.1	21.0	28.9	31.8	70
Bushnell/Palouse	.49	.96	.99	.99	-	1.0	.48	.36	.25	.17	2.6	13	22	24	26	70
Byee	.48	.47	.66	.69	-	.91	.85	.77	.68	.50	1.4	3.5	6.0	6.1	7.2	150
Byee	.34	.36	.40	.42	-	0.63	0.61	.56	0.49	0.44	2.5	2.5	3.6	4.8	5.6	150
Chelmsford	.21	.15	.09	.15	-	2.3	2.2	2.5	3.2	2.9	0.6	0.5	0.6	0.4	0.6	200
Coolabunia	.32	.28	.28	.16	-	1.8	2.9	2.24	1.8	1.5	0.9	1.1	1.8	1.9	1.5	200+
Eastgate	.56	.62	.54	.63	-	.86	1.0	1.9	.95	.91	2.5	4.3	6.5	7.7	7.7	120
Fairdale	.49	.55	.57	.53	-	.64	.74	.78	.79	.78	1.8	3.2	4.0	5.1	5.4	200
Fairdale	.46	.47	-	.56	.53	.90	.68	.56	.55	.54	1.3	2.4	4.7	4.1	4.3	180
Goodger	.34	.57	.44	.18	.13	.63	.14	.06	.03	.02	0.5	1.1	3.5	5.6	8.7	150
Goodger	-	.2	.42	.30	.01	.96	.22	.03	.02	.02	0.8	1	2	6	7.5	150
Goodger	.40	.33	.34	.33	-	1.3	1.0	0.16	.03	.02	1.3	1.9	1.7	1.7	3.3	120
Gordonbrook	.28	.40	.16	.04	.08	2.9	3.1	2.0	1.7	1.5	0.6	2.0	1.5	1.7	2.8	150
Gueena	.43	.71	.85	.89	-	.76	.73	.67	.67	.61	1.8	4.9	9.8	13.0	15.6	150
Haly	.27	.21	.27	.38	.53	2.1	0.4	.04	.06	.11	0.5	1.5	5.0	6.7	7.1	180
Hirst/Terrace	.05	.94	.78	.78	-	1.3	3.3	1.4	1.4	1.6	1.25	1.67	1.25	3.0	4.3	150
Hopevale	.20	.20	.28	.36	.62	3.7	4.5	2.2	2.0	2.3	.42	.59	.63	1.1	2.0	120
Hopevale	-	-	.31	.32	-	1.7	4.0	7.0	1.4	-	.01	.10	.12	.52	-	120
Iona	.41	.43	.46	.51	.67	1.39	1.27	1.05	0.95	1.05	0.6	1.4	2.78	3.2	3.2	180
Kaber	.33	.51	.55	.63	-	.83	.58	.48	.54	.46	2.0	5.3	8.4	8.5	10.2	200

Table 6c (continued)

Soil Type	Dispersion ratio Depth (m)					Ca/Mg ratio Depth (m)					ESP Depth (m)					PAWC
	0.05	0.3	0.6	0.9	1.2	0.05	0.3	0.6	0.9	1.2	0.05	0.3	0.6	0.9	1.2	mm
Kawl Kawl	.35	.55	.64	.61	.78	.35	.20	.17	.12	.08	3.0	9.3	15.3	17.3	19.4	100
Kawl Kawl	.45	.61	.58	.67	.80	.28	.20	.25	.26	.33	7.0	9.0	7.0	7.0	7.0	120
Kawl Kawl	.30	.58	.56	.42	.45	3.0	2.2	1.4	.15	.88	0.2	0.5	0.5	0.9	0.7	150
Kumbia	.32	.31	.29	.02	.46	1.3	1.5	.84	.40	.31	0.6	0.9	0.8	1.3	3.4	200
Lankowsky	.42	.23	.38	.28	-	1.3	.81	1.2	1.0	1.0	2.6	.38	1.0	1.4	1.6	150
Long Peter	.35	.57	.76	.94	-	1.8	.93	.44	.20	.11	3.4	9.0	20.7	29.1	29.4	60
Marshlands	.45	.65	.51	.55	.91	1.2	.31	.09	.12	.16	2.8	6.8	15	19.1	28.8	100
McEuen	.33	.40	.68	.49	-	1.4	1.6	2.6	1.8		0.5	0.9	2.6	1.1		120
Memerambi	.22	.19	.17	.20	-	2.3	2.8	5.4	5.0	5.6	D.S	1.1	0.9	1.3	1.3	180
Memerambi	.22	.22	.01	.01	-	6.1	7.2	92	4	.98	.1	1	<1	<1	1.1	150
Memerambi	.18	.22	.20	.23	-	3.9	2.2	2.1	3.5	.28	0.3	0.4	0.4	1.5	2.2	100
Memerambi	.16	.19	.09	.04	.04	1.1	1.09	3.9	1.9	.21	0.5	0.6	0.7	0.9	0.9	120
Memerambi	.26	.21	.23	.02	.03	1.8	1.6	.05	.02	.02	0.3	0.4	0.5	0.8	1.9	150
Wooroolin	.22	.59	.18	.19	.05	2.6	1.6	.57	.55	.45	0.6	0.9	2.5	4.3	5.0	180
Memerambi	.17	.22	.27	.04	.03	4.4	3.6	3.1	2.2	0.6	0.3	0.9	1.3	1.5	1.5	
Memerambi	.25	.15	.23	.27	-	3.8	4.6	4.5	2.1	1.5	0.5	1.1	2.4	1.7	1.9	100
Memerambi	.35	.47	.34	.29	-	1.1	1.0	.13	.04	.09	1	1.2	3.5	4.7	7.0	100
Mondure	.49	.45	.90	.93	-	.35	.27	.46	.49		1.5	6.0	16.1	26.1		80
Mondure	.47	.53	.51	.60	.77	1.15	.64	.49	.41	.40	0.5	2	5	8.9	13.8	120
Mondure	.36	.62	.35	.64	.96	1.14	.57	.09	.09	.14	1.1	5.7	14.0	24.3	34.4	80
Palouse	.56	.89	.87	.88		3.3	.16	.04	.01	.02	2.6	14.5	20.7	30	32	60
Palouse	.46	.55	.82	.91	-	1.3	.15	.18	.25	.20	1.1	10.7	17.8	23.9	25.0	60
Tarong	.66	.36	.15	.54	.76	.71	.01	.01	.01	.01	.08	4.8	7.6	11.4	14.3	80
Weir	.39	.53	.55	.57	-	1.2	1.1	1.0	.9	.9	2.5	6.4	12.2	13.8	11.6	140
Weir	.81	.70	.78	.73	-	1.7	1.6	1.4	1.26	1.2	1.8	1.9	4.4	7.6	8.4	140

Salinity
Electrical conductivity (EC) is a measure of the total soluble salts in a soil while chloride (Cl) concentration indicates the contribution of chloride ions, usually as sodium chloride salt. For all soils in the Kingaroy area, chloride salts are the major contribution to salinity.

Surface EC and Cl levels are very low to low (EC <0.45 dS/m, Cl <0.03%) in the surface and very low to high (EC <0.15 to >2 dS/m, Cl <0.01 to >0.2%) in the subsoil.

Generally, higher salt levels correspond to higher pH values, particularly when pH >8.5. In the young alluvial soils, subsoil EC and Cl are low to moderate, while in old alluvium soils EC ranges from moderate to very high, and Cl from moderate to high corresponding to impermeable subsoils.

Salts in subsoils of the fresh basaltic soils are typically low except in the deep clays on lower slopes where a salt buldge with medium salt levels occurs at 0.6–0.9 m.

The highly permeable deeply weathered basaltic soils are typically very low to low in salts in the subsoils except where they overlie impermeable old alluvium or Tertiary sediments. The impermeable layers may have moderate to high salts levels. The highly permeable soils in upper landscape positions are typically recharge areas which contribute deep drainage and may result in discharge areas on adjacent lower slopes.

Granitic soils on mid to upper slopes are very low to low in subsoils salts. No profiles were analysed on lower slopes, however the presence of strongly alkaline pH (>8.5) would indicate impermeable subsoils and salt accumulation.

Sodicity and dispersion ratio
Sodicity is a measure of the exchangeable sodium percentage (ESP = exchangeable Na/CEC x 100) in the soil. Non sodic soils have an ESP <6%, sodic have an ESP 6–15%, and strongly sodic have an ESP >15% (Northcote and Skene 1972).

High sodicity influences physical properties of soils, causing clays to disperse which influences permeability and root growth. High ESP is usually associated with higher EC and Cl levels, a high dispersion ratio (>0.8), and high pH values. In low pH soils with high ESP, calcium is usually low.

ESP in the surface of all soils in the study area is predominately non sodic (ESP 0.01–3.4) with only one sample being sodic (ESP 7). Subsoil ESP ranges from non sodic to strongly sodic (ESP 0.4–34).

The subsoils of the young alluvial soils range from sodic to strongly sodic (ESP 7.2–26) corresponding to low to medium salt levels respectively. Dispersion ratios range from 0.69 to 0.99 corresponding to sodicity.

The older alluvium soils have strongly sodic subsoils (ESP 19–32) corresponding to a dispersion ratio of 0.78–0.99. These impermeable subsoils reflect moderate to very high salt levels and strongly alkaline pH (≥ 8.5).

Fresh basaltic soils are non sodic (ESP 1.6–5.4) and non dispersive (dispersion ratio 0.49–0.67) reflecting low salt levels. The deeply weathered basaltic soils are non sodic (ESP 0.18–3.3) except where soils overlie deeply weathered basalt rock or old alluvium and Tertiary sediments (ESP 7–14.3). The non sodic highly permeable soils are non dispersive (dispersion ratio 0.04–0.33) while the sodic deeply weathered clay and buried clays are also non dispersive (dispersion ratio 0.18–0.76). The non sodic soils have low salt levels and an acid to neutral pH while the sodic clays have salt accumulation.

The granitic soils have non sodic to strongly sodic subsoils (ESP 2.8–33) and non dispersive to dispersive subsoils (dispersion ratio 0.08–0.95). The non sodic soils have an acid pH while the strongly sodic subsoils are strongly alkaline.

Calcium/magnesium ratio

Calcium/magnesium ratio (Ca/Mg) is a measure of the relative abundance of the two exchangeable cations. On highly weathered soils the calcium tends to have been leached out of the profile while magnesium has accumulated. Calcium tends to accumulate in impermeable subsoils where the parent material is high in calcium, for example basalt. Also, pH is often related to relative abundance of calcium. For example, low calcium (<0.5 meq/100 g) and low Ca/Mg (<0.5) often corresponds to low pH, while high calcium (>2 meq/100 g) generally corresponds to a neutral to strongly alkaline pH. High Ca/Mg (>1) is usually associated with non dispersive soils, while low Ca/Mg (<0.5) is usually associated with dispersive soils.

Due to calcium accumulation at the surface from organic matter, all soils show a decrease in the Ca/Mg ratio with depth. The Ca/Mg ratio for all surface soils ranges from 0.28 to 6.1 while subsoils range from 0.01 to 5.6.

The young alluvial soils have a surface Ca/Mg of 0.63–1.7 decreasing slightly to 0.44–1.6 in the subsoil. These generally high Ca/Mg ratios correspond to neutral to alkaline pH.

Old alluvial soils have a surface Ca/Mg of 0.35–3.3 decreasing to 0.02–0.33 in the subsoil. These low subsoil Ca/Mg ratios indicate a relative decrease in calcium which correspond to strongly sodic and dispersive subsoils, high salt levels and high pH.

Soils on fresh basalt have a Ca/Mg ratio of 0.64–2.5 decreasing slightly to 0.54–1.9 in the subsoil. These calcium dominant or near co-dominant Ca/Mg ratio soils are generally non sodic, non saline, non dispersive and alkaline to moderately alkaline.

The surface of deeply weathered basaltic soils has a Ca/Mg ratio of 1.1–6.1 decreasing dramatically to 0.02–2.3 in the subsoil. The lower Ca/Mg ratio values correspond to the lower pH values. However, these soils are non sodic and non dispersive possibly indicating the influence of exchangeable aluminium. This results in a high soil stability where soils are strongly acid (pH <5.5).

Ca/Mg ratio of the granitic soils ranges from 1.6–2.9 in the surface decreasing to 0.01–1.5 in the subsoil. The higher Ca/Mg ratio values correspond to non sodic, non dispersive, slightly acid subsoils while the lower Ca/Mg ratio values are associated with strongly sodic, dispersive subsoils.

Plant available water capacity

Plant available water capacity (PAWC) is a measure of the amount of water stored in the soil available to plants over the rooting depth. PAWC has been determined for each 10 cm interval in the soil profile using the method of Shaw and Yule (1978). The effective rooting depth is determined as the depth of high salts (>0.6% Cl) or the depth to rock or other impermeable layers.

PAWC is also related to texture and clay types. Clay texture soils will hold greater amounts of water than sandy textured soils due to a higher proportion of fine pores. Structured soils will hold more water than similar textured non structured soils due to pore space between the structured peds.

The deep young alluvial and basaltic clays dominated by montmorillonite clays have high PAWC (120–150 mm to 1 m). The old alluvial clays have lower PAWC (80–120 mm) due mainly to shallow rooting depth (0.4–0.6 m). The sodic texture soils generally have slightly lower PAWC (60–100 mm) due to lighter surface textures and shallower rooting depth (dominantly 0.4–0.5 m).

PAWC on the deeply weathered basaltic soils ranges 120–200 mm. PAWC is high due mainly to a deep rooting depth (>1.2 m). Soils with very high organic matter in the surface have higher PAWC values.

Granitic soils have low to high PAWC (60–150 mm). The lower PAWC is associated with coarse sandy surfaced sodic texture contrast soil with a rooting depth of 0.4 m. The higher PAWC is associated with a deep, strongly structured non sodic soil.

Clay activity ratio

Clay activity ratio (CEC/Clay%) indicates the type of clay present. In general, a clay activity ratio <0.2 indicates kaolinitic clay, 0.3–0.5 indicates illite type clays, 0.5–0.7 indicates mixed clays and >0.8 indicates soils dominated by montmorillonite type clays. Due to surface organic matter influencing CEC, subsoil clay activity ratio is discussed only (≥ 0.6 m). Table 7 shows the clay activity ratio for the analysed soils.

The young alluvial soils have a CEC/clay ratio of 0.66–0.92 indicating soils are dominated by montmorillonite type clays. These montmorillonite clays usually have strong shrink swell properties and where associated with good Ca/Mg ratios (>0.5), soils are non dispersive. The lower CEC/clay ratio (0.21–0.56) in the soils on old alluvium indicates illite clays or mixed kaolinitic, illitic and montmorillinitic type clays. These lower values compared to the soils on young alluvium may indicate a longer period of weathering and/or a different source of parent material. The illite and mixed clay types in clay textured soils are frequently strongly sodic, saline and dispersive (Shaw *et al.* 1986).

The soils on fresh basalt have CEC/clay ratios of 0.72–4.4 indicating montmorillonite clays with strong shrink swell properties in clay textured soils. These soils are non sodic, non dispersive and generally fertile due to the high CEC.

Deeply weathered basaltic soils have a CEC/clay ratio of 0.1–0.4 but predominately <0.2 indicating kaolinitic clays. Where sodic buried alluvium or Tertiary sediments occur, these buried clays have a CEC/clay ratio of <0.2. These sodic buried clays are non dispersive indicating the influence of clay type on dispersion.

In the deeply weathered basaltic clays which are strongly acid (pH <5.5), the sum of cations is less than CEC indicating high levels of exchangeable aluminium (which was not assessed) and/or variable charged clays.

Granitic soils have a CEC/clay ratio of 0.19–0.78. The lower value of 0.19 is typical of the kaolinitic clays derived from potassium feldspars in granite while the higher value of 0.78 indicates montmorillonitic clays associated with granodiorite.

Table 7. Clay Activity Ratio* of soil profiles classes

SPC	Depth (m)				
	0.05	**0.3**	**0.6**	**0.9**	**1.2**
Appaloosa	0.89	0.64	0.53	0.56	0.53
Archookoora	0.57	0.52	0.29	0.25	0.28
Archookoora	0.69	0.38	0.31	0.39	0.41
Avon	0.95	0.6	0.56	0.55	0.55
Boonenne	0.67	0.22	0.3	0.43	0.78
Bushnell	0.63	0.36	0.3	0.32	0.32
Bushnell	0.82	0.41	0.34	0.3	0.28
Bushnell	0.85	0.61	0.51	0.55	0.51

Table 7 (continued)

SPC	Depth (m)				
	0.05	0.3	0.6	0.9	1.2
Byee	0.94	0.9	0.89	0.98	0.84
Byee	0.96	0.85	0.88	0.9	0.91
Chelmsford	0.46	0.29	0.21	0.27	0.4
Coolabunia	0.48	0.33	0.17	0.18	0.15
Eastgate	0.73	0.77	0.78	0.76	0.76
Fairdale	1.27	0.84	1.07	4.38	3.0
Fairdale	1.04	0.83	0.87	1.0	1.81
Goodger	5.56	6.5	0.96	0.38	0.25
Goodger	7.5	4.08	1.79	0.37	0.25
Goodger	1.09	0.87	0.59	0.29	0.16
Gordonbrook	0.71	0.17	0.19	0.2	0.2
Gueena	0.82	0.71	0.69	0.75	0.75
Haly	0.45	0.2	0.18	0.19	0.21
Hirst	1.33	1.5	0.6	0.48	0.56
Hopevale	0.57	0.47	0.37	0.26	0.21
Hopevale	8.86	8.83	4.33	1.27	-
Iona	1.26	0.86	1.03	0.99	1.14
Kaber	0.79	0.63	0.61	0.78	0.7
Kaber	0.56	0.56	0.34	0.23	0.21
Kawl Kawl	0.73	0.53	0.48	0.5	0.57
Kawl Kawl	0.87	0.42	0.36	0.39	0.42
Kawl Kawl	0.91	0.3	0.39	0.38	0.38
Kumbia	0.33	0.6	0.23	0.21	0.23
Lankowsky	1.39	1.17	0.5	0.24	0.16
Long Peter	0.74	0.46	0.43	0.48	0.49
Marshlands	0.83	0.45	0.3	0.29	0.34
McEuen	1.0	1.41	4.77	7.86	-
Memerambi	0.45	0.19	0.13	0.1	0.1
Memerambi	0.27	0.27	0.2	0.18	0.1
Memerambi	0.8	0.55	0.55	0.5	0.38
Memerambi	0.39	0.36	0.26	0.22	0.2

Table 7 (continued)

SPC	Depth (m)				
	0.05	0.3	0.6	0.9	1.2
Memerambi	1.03	1.06	0.4	0.17	0.16
Memerambi	0.92	0.43	0.22	0.18	0.17
Memerambi	0.53	0.36	0.21	0.24	0.22
Mondure	0.63	0.37	0.38	0.43	-
Mondure	0.78	0.32	0.24	0.32	0.34
Mondure	0.64	0.5	0.27	0.28	0.35
Palouse	0.67	0.24	0.29	0.34	0.43
Palouse	0.47	0.29	0.34	0.44	0.5
Tarong	0.4	0.26	0.28	0.31	0.35
Tureen	1.41	0.88	0.72	-	-
Weir	0.83	0.75	0.7	0.66	0.71
Weir	0.83	0.85	0.75	0.66	0.77
Wooroolin	0.89	0.52	0.26	0.28	0.2
Wooroolin	0.56	0.56	0.34	0.23	0.21

* The Clay Activity Ratio is calculated from the Cation Exchange Capacity (CEC) and Clay% i.e. CEC/Clay

5. Land Evaluation

5.1 Land use limitations by soil profile class

The agricultural potential of land in the survey area was assessed for:

- dryland (rainfed) cropping
- dryland sown pastures
- tree and vine crops

The five-class land suitability classification used in this study is outlined in Section 3.4. To quantify the limitations that apply in each UMA, particular limitation levels are recorded for each limitation. For example, in Table 8, there are four limitation levels for soil water availability coded M1 to M4, in order of increasing severity. On the basis of the limitation levels recorded, each UMA is then allocated to one of the pre-determined soil water suitability subclasses for each land use. All the limitations are considered in turn, and the combination of suitability subclasses in each UMA is then used to derive an overall suitability class (1 to 5) for each land use. The suitability class is usually determined by the most severe limitation identified (Land Resources Branch Staff 1990). The limitation level codes listed in each table in this section are the soil/land limitation level recorded in the UMA database.

5.1.1 Soil water availability (M)

One of the main functions of soil is to store moisture and supply it to plants between rainfall events. Plant yield is decreased by periods of water stress, particularly during critical growth periods.

The amount of water stored in the soil that is available for plant growth is called the PAWC (plant available water capacity). Soil morphological and analytical properties (texture, structure and soil depth) are used to derive estimates of PAWC for each soil profile class however, it is necessary for this to be modified depending on observations (or estimations) of soil depth. Maximum rooting depth is assumed to be 1 metre.

Soil water availability is a critical limiting factor for rainfed land use options. A limitation level of M3 (PAWC 60–90 mm) is considered inadequate for dryland cropping and is therefore given a suitability subclass of 4. A limitation level of M4 (PAWC <60 mm) is regarded as a prohibitive limitation for dryland sown pasture.

Table 8. Soil water availability limitation

Limitation level	Code	Suitability subclass for various land uses		
		Dryland sown pastures	Dryland crops	Tree and vine crops
PAWC >120 mm	M1	1	2	1
PAWC 90 – 120 mm	M2	2	3	2
PAWC 60 – 90 mm	M3	3	4	2
PAWC <60 mm	M4	4	5	3

5.1.2 Workability (Pm)

Soil workability refers to the suitability of the soil for cultivation based on strength and moisture range.

Strength of soil is its resistance to breaking or deformation (McDonald *et al.* 1990), it is a measure of how 'tough' the soil is. Moisture range refers to the appropriate range in soil moisture content over which a soil can be successfully cultivated (without compacting or pulverising the soil, both of which can lead to long-term soil damage). Some soils can be worked at any moisture content, while others have only a narrow suitability range.

Limitation levels are established from a knowledge of soil properties. Suitability subclasses are derived from local knowledge and extension advice. Extra management is required on soils with physical limitations.

Table 9. Workability limitation

Limitation level	Code	Suitability subclass for various land uses		
		Dryland sown pastures	Dryland crops	Tree and vine crops
Sands; loose to firm loams	Pm1	1	1	1
Strongly structured light clays and clay loams; coarse sandy clay loams	Pm2	1	2	1
Self-mulching clays; hard setting sandy loams to clay loams	Pm3	2	2	2
Coarse structured (hard) clays	Pm4	2	3	2
Eroded and very hard setting soils	Pm5	4	5	4

Workability is not a severe limitation for any of the land uses investigated except in the case of eroded and very hard setting soils (Pm5 attribute level).

5.1.3 Surface condition (Ps)

Seedling emergence and establishment are affected by adverse physical conditions of the surface soil including hard setting, crusting or coarse surface structure conditions. Surface condition is not a precluding limitation for any of the investigated land uses. However, soils with hard setting or crusting surfaces are given a moderate limitation for dryland cropping.

All soil profile classes were allocated an attribute level for soil condition that applied generally throughout the survey area. However, these were modified on the basis of field observations and two or three surface condition categories may apply in different situations. Site disturbance and management also have an effect.

Table 10. Surface condition limitation

Limitation level	Code	Suitability subclass for various land uses		
		Dryland sown pastures	Dryland crops	Tree and vine crops
Sands, fine self-mulching clays	Ps1	1	1	1
Coarse self-mulching clays, firm surface duplex soils	Ps2	2	2	1
Other soils – hard setting or crusting	Ps3	2	3	1

5.1.4 Nutrient deficiency (Nd)

Inadequate nutrient supply causes reduction in plant yield, especially during critical periods such as flowering and fruiting. Livestock production may be limited by either a reduction in pasture growth or pasture nutritive value caused by low soil nutrients.

Limitation levels and suitability subclasses are based on critical levels of key nutrients required for pasture production (Rayment and Bruce 1984; Ahern *et al.* 1994). Critical levels for nitrogen have not been included as nitrate-nitrogen varies according to the rate of mineralisation from soil organic matter and losses of nitrate by leaching and biological removal. Temperature, rainfall and other soil conditions also influence these processes (Rayment and Bruce 1984). Addition of nutrients is standard management practice for crops as well as tree and vine crops.

Table 11. Nutrient deficiency limitation

Limitation level	Code	Suitability subclass for various land uses		
P = bicarb. extr. P (mg/kg) S = extr. sulfate S (mg/kg) K = extr. K (m. equiv/100g)		**Dryland sown pastures**	**Dryland crops**	**Tree and vine crops**
>30 P, >5 S, >0.25 K	Nd1	1	1	1
>30 P, >5 S, <0.25 K >30 P, <5 S, >0.25 K >30 P, <5 S, <0.25 K 20 – 30 P, >5 S, >0.25 K 20 – 30 P, >5 S, <0.25 K 20 – 30 P, <5 S, >0.25 K	Nd2	2	2	1
20 – 30 P, <5 S, <0.25 K 10 – 20 P, >5 S, >0.25 K 10 – 20 P, >5 S, <0.25 K 10 – 20 P, <5 S, >0.25 K	Nd3	3	3	1
10 – 20 P, <5 S, <0.25 K <10 P, >5 S, >0.25 K <10 P, >5 S, <0.25 K <10 P, <5 S, >0.25 K <10 P, <5 S, <0.25 K	Nd4	4	4	2

On the basis of laboratory analyses, all soil profile classes were allocated an attribute level for nutrient deficiency that applied throughout the survey area.

5.1.5 Flooding (F)

Land periodically inundated by water from stream channel overflow has a flooding limitation. Flooding causes damage due to both fast flowing water and submersion by water. The severity of flooding as a limitation depends on the frequency, duration, depth and velocity of the floodwaters. The duration of inundation is perhaps the most critical factor of all and the most difficult to estimate.

Limitation levels and suitability subclasses are based on landform observations and local knowledge.

Table 12. Flooding limitation

Limitation level	Code	Suitability subclass for various land uses		
Flood frequency		**Dryland sown pastures**	**Dryland crops**	**Tree and vine crops**
Flood free	F1	1	1	1
>1:10 years	F2	1	2	2
1:2 to 1:10 years	F3	2	2	3
< 1:2 years	F4	2	4	4

Areas with an average flood frequency of more than one flood every two years (attribute level F4) were given a severe flooding limitation for dryland crops and tree and vine crops.

5.1.6 Frost (Cf)

Frosts may suppress growth, reduce yield or kill plants. Plant species vary in their tolerance to frost. Frost may damage the flowers or fruit of moderately sensitive crops.

Limitation levels and suitability subclasses are based on crop tolerance information, local knowledge, climate data and an assessment of local topography and landscape position. Low-lying areas may receive on average about 10–20 frosts in the period May to September (see Section 2.2)

Areas with frequent light and infrequent heavy frosts (Code Cf3) were given a moderate frost limitation for tree and vine crops.

Table 13. Frost limitation

Limitation level	Code	Suitability subclass for various land uses		
		Dryland sown pastures	**Dryland crops**	**Tree and vine crops**
Frost free	Cf1	1	1	1
Infrequent light frosts	Cf2	1	1	2
Frequent light frosts, or frequent light and infrequent heavy frosts	Cf3	2	2	3
frequent light and heavy frosts	Cf4	3	3	4

A limitation level of Cf4 was almost exclusively recorded for those soils occurring on low lying alluvium and lower slopes.

5.1.7 Rockiness (R)

Rock fragments in the plough zone, can damage and interfere with the effective use of farm machinery (including harvesting machinery).

Limitation levels are based on the size and abundance of coarse fragments (McDonald *et al.* 1990), as assessed in the field. Coarse gravel refers to fragments that are 20 to 60 mm in size (average maximum dimension), cobble/stone refers to fragments that are 60 to 600 mm in size, boulders are >600 m. Rock outcrop is defined as being continuous with bedrock.

Rockiness suitability subclasses are based on the added inputs required to cultivate and establish crops and pastures as well as harvest on stony soils, or the inputs required to remove the limitation.

Table 14. Rockiness limitation

Limitation level		Code	Suitability subclass for various land uses		
			Dryland sown pastures	Dryland crops	Tree and vine crops
Rock free		Ra1	1	1	1
Coarse gravel (20–60 mm)	<2%	Ra2	1	1	1
	2–10%	Ra3	2	3	2
	10–20%	Ra4	3	4	2
	20–50%	Ra5	4	5	3
	>50%	Ra6	5	5	4
Cobble/stone (60–600 mm)	<2%	Rb1	1	2	1
	2–10%	Rb2	2	3	2
	10–20%	Rb3	3	4	3
	20–50%	Rb4	4	5	4
	>50%	Rb5	5	5	5
Rock outcrop or boulders (>600 m)	<2%	Ro1	3	4	3
	2–10%	Ro2	4	5	4
	10–20%	Ro3	5	5	5
	20–50%	Ro4	5	5	5
	>50%	Ro5	5	5	5

For a particular soil profile class, where a significant number of UMAs (three or more) were observed to have surface rock (rocky outcrop, coarse gravel or cobble) in sufficient quantity[1] for it to be a severe limitation for land use, a rocky phase was defined.

5.1.8 Soil depth (Pd)

Shallow soils limit root growth and the ability of the plant to support itself. Requirements for anchorage are particularly important for tree crops with large canopies. Areas with a soil depth of <0.6 m (attribute level of Pd3) were given a severe soil depth limitation for tree and vine crops. Areas assessed as having a soil depth of 0.4 m or less were considered to have a severe or extreme soil depth limitation for cropping enterprises (see Table 15).

Shallow depth (<0.6 m) is a common characteristic[2] of the soil occurring on steep slopes, narrow ridges and sodic texture contrast soils.

[1] gravel >20% and cobble >10%
[2] occurring more than 50% of UMAs

Table 15. Soil depth limitation

Limitation level	Code	Suitability subclass for various land uses		
Soil depth		Dryland sown pastures	Dryland crops	Tree and vine crops
> 1 m	Pd1	1	1	1
0.6–1.0 m	Pd2	2	2	3
0.4–0.6 m	Pd3	2	3	4
0.3–0.4 m	Pd4	3	4	5
<0.3 m	Pd5	4	5	5

5.1.9 Microrelief (Tm)

Microrelief refers to the uneven land surface due to gilgai. Gilgai (or melonhole) is associated with soils containing shrink-swell clays. In the study area, gilgai was observed mainly in cracking clays and shallow colluvial deposits overlying shrink-swell clays. Gilgai microrelief results in water ponding and uneven crop production.

Limitation levels are based on the vertical interval (depth) of the depressions. In the study area, the vertical interval was rarely greater than 0.3 m. Suitability subclasses indicate the cost of works to level the land and/or the reductions in yield expected.

Table 16. Microrelief limitation

Limitation level	Code	Suitability subclass for various land uses		
Vertical interval		Dryland sown pastures	Dryland crops	Tree and vine crops
0.1 m	Tm1	1	1	1
0.1 m to 0.3 m	Tm2	1	2	1
0.3 m to 0.6 m	Tm3	2	3	3
>0.6 m	Tm4	3	3	4

5.1.10 Wetness (W)

Waterlogged soils reduce plant growth and delay effective machinery operation. Excess water in the soil impedes oxygen supply to plant roots and promotes plant diseases. Excess water can occur due to poor soil permeability, restricted surface drainage or a combination of both.

Attribute levels for wetness are based on field observations of site drainage (slope, topographic position) and soil morphological features such as mottling, colour, segregations, structure and impermeable layers. Suitability subclasses have been derived from knowledge of plant tolerance information and consultation with research and extension staff.

Table 17. Wetness limitation

Limitation level	Code	Suitability subclass for various land uses		
Drainage class (from McDonald *et al.* 1990)		Dryland sown pastures	Dryland crops	Tree and vine crops
Rapidly drained to well drained	W1	1	1	1
Moderately well drained	W2	1	2	2
Imperfectly drained	W3	2	3	4
Poorly drained	W4	3	4	5
Very poorly drained	W5	4	5	5

Wetness is a critical limitation for all land uses. Areas with imperfect drainage (limitation level W3) were given a severe limitation for tree and vine crops, while poorly drained sites (limitation level W4) were given a severe limitation for dryland crops.

5.1.11 Water erosion (E)

Soil erosion depends on rainfall intensity, land slope, soil erodibility, vegetative cover and management practices. For land uses involving regular cultivation to be sustainable, soil conservation measures are required on all sloping land. Soils in the survey area have been divided into two groups based on their erodibility and the stability of the subsoil. Texture contrast soils with sodic subsoils are more at risk than other soils and therefore have lower cultivation slope limits.

Table 18. Water erosion limitation

Limitation level	Code	Suitability subclass for various land uses		
		Dryland sown pastures	Dryland crops	Tree and vine crops
Stable soils (other than sodic texture soils)				
<1% slope	E1	1	1	1
1–5%	E2	1	2	1
5–8%	E3	2	3	2
8–15%	E4	3	4	3
>15%	E5	4	5	4
Sodic texture contrast soils				
<1–3% slope	E6	1	2	1
3–5%	E7	2	3	2
5–12%	E8	3	4	3
>12%	E9	4	5	4

Suitability subclasses for water erosion are based on the added management requirements required to control erosion. They have been determined by consultation with soil conservation extension staff.

5.1.12 Slope (Ts)

The topography limitation has a direct affect on the ease of machinery operations and land use efficiency in general. It covers the slope limits for the safe use of machinery.

The slope limit for the safe and efficient use of machinery is 15%. However, all land greater than 15% in the study area, except the deep red structured soils on deeply weathered basaltic material, is unsuitable or marginal for agricultural development due to other limitations.

Table 19. Slope limitation

Limitation level	Code	Suitability subclass for various land uses		
Slope		Dryland sown pastures	Dryland crops	Tree and vine crops
0–15%	Ts1	1	1	1
15–20%	Ts2	2	4	3
>20%	Ts3	4	5	4

5.1.13 Salinity (Sa)

Under stable climatic conditions, in a natural environment, a hydrological equilibrium occurs between water intake from rainfall and water loss through plant uptake, evaporation, runoff and leakage to groundwater (Shaw *et al.* 1986). Practices associated with agriculture, particularly clearing and irrigation are major ways in which this hydrological balance is disturbed. Increases in accession to groundwater may result in raised watertables which may be either non-saline or saline.

Intake or recharge areas are those areas in which there is a downward component to groundwater flow near the soil surface. These recharges areas tend to occur upslope and on convex topography often with shallow or permeable soils over fractured rock (Shaw *et al.* 1986).

In discharge (seepage) areas, there is an upward component to groundwater flow near the soil surface which may result in secondary salinisation due to evaporation concentration of soluble salts. Discharge areas occur at breaks of slope, in flat or incised areas or in regions of concave slope.

High soil salt levels are associated with fine grained sedimentary rocks and deeply weathered basalts while sandstones and granites usually have low salt levels.

Salinisation is consistently evident on the yellow, brown and grey soils on lower slopes of deeply weathered basalts and associated drainage lines, and on sodic clays and sodic duplex soils developed on fine grained sedimentary, metamorphic and basaltic rocks, and old alluvium and Tertiary sediments found on discharge areas.

Shaw *et al.* (1982) considered that effective drainage will be difficult to achieve, especially on the sodic soils of low hydraulic conductivity which are present in many of the potential discharge areas. Any area with existing natural salinisation is considered unsuitable for development.

Table 20. Salinity limitation

Limitation level	Code	Suitability subclass for various land uses		
		Dryland sown pastures	Dryland crops	Tree and vine crops
No salinity evident or profiles have low salt levels	S1	1	1	1
Soil profiles with low to moderate salt levels at 1 m	S2	2	2	2
Soil profiles with moderate salt levels at 0.5 m or high salt levels at 1 m	S3	3	3	3
Soil profiles with high salt levels at 0.5 m	S4	4	4	4
Surface salinity evident	S5	5	5	5

5.2 Land suitability assessment

The land suitability assessment of the survey area is summarised in Table 21. The land suitability for each soil group is summarised in Table 22. In each table, the land area in each category is shown as hectares (ha) and as a percentage (%) of the total survey area of 126 608 ha. There is no Class 1 land for any land use. Areas not assessed (dams, quarries, hills and mountains, rock) are 11 167 ha or 9.1% of the total area.

Table 21. Summary of the land suitability assessment for the survey area

Suitability Class	Dryland crops		Dryland sown pastures		Tree and vine crops	
	ha	%	ha	%	ha	%
1	0	0	3 748	3.0	3 795	3.0
2	23 912	18.9	53 487	42.2	17 516	13.8
3	42 888	33.9	35 567	28.1	40 148	31.7
4	28 118	22.2	14 727	11.6	34 656	27.4
5	31 690	25	19 079	15.1	30 493	20.5

Table 22. Summary of the land suitability assessment for soil geological groups

Soil Geological Group	Suitable for dryland crops		Suitable for dryland sown pastures		Suitable for tree and vine crops	
	ha	%	ha	%	ha	%
Soils on alluvium of current streams	11 681	9.2	11 881	9.4	8 023	6.3
Soils on older alluvium	6 044	4.8	8 452	6.7	2 078	1.6
Soils on basalt	8 891	7.0	15 209	12.0	11 749	9.3
Soils on deeply weathered basaltic material	39 021	30.8	51 433	40.6	38 098	30.1
Soils on granite	918	0.7	4 511	3.5	1 433	1.1
Soils on metamorphic and sedimentary rocks	244	0.2	1 316	1.0	78	0.1
TOTALS	**66 800**	**52.7**	**92 802**	**73.2**	**61 459**	**48.5**

Table 22 shows that the soils derived from the deeply weathered basaltic material, predominantly the red soils, account for about 50% of the land suitable for intensive development.

5.2.1 Land suitability for dryland cropping

The broadacre field crops considered in the land suitability assessment include cereals (grain sorghum, maize, wheat, barley and oats), grain legumes (chick peas, navy beans, soybeans, lupins), oilseeds (sunflower), peanuts, forage legumes (lablab, cowpeas) and other forage crops (sorghums, millets). Their agronomic and management requirements were considered similar enough not to warrant separate classification for each crop. For simplification, no attempt was made to separate winter and summer growing crops. Eight percent of the survey area is considered suitable for dryland cropping.

Ten limitations were identified as being potential severe limitations for dryland cropping in the Kingaroy area. The most important of these is soil water availability. Plant available water capacity (PAWC) of less than 90 mm in the root zone (maximum depth considered to be 1 m) was considered to be a prohibitive limitation for dryland cropping over 22 342 ha.

Land may also be considered unsuitable for dryland cropping because of the following limitations:
- Eroded and/or extremely hard setting soils (workability limitation) affect 209 ha.
- Nutrient availability. Only a total of 2858 ha has soils low in available phosphorus, sulfate sulfur and extractable potassium which are considered unsuitable; the cost of applying all nutrients would, in most situations be prohibitive.
- Wetness (poor drainage). A total of 3000 ha has poorly/very poorly drained sites which are considered unsuitable.
- Flooding. Only 86 ha has an average flood frequency of more than one flood every two years and were given a severe flooding limitation.
- Soil depth. For dryland cropping, this limitation is strongly linked to soil moisture availability. A total of 15 735 ha was assessed as having a soil depth of 0.4 m or less. These shallow soils were considered to have a severe or extreme soil depth limitation.
- Rockiness. Greater than 10–20% coarse gravel or cobble occupy 40 496 ha and is considered to be prohibitive.
- Water erosion. Sodic texture contrast soils of 5% slope or more and other soils of slope greater than 8% occupy 32 937 ha and are considered unsuitable for dryland crops.
- Salinity. Large areas (2953 ha) of existing salinity occur in the study area mainly occurring on lower slopes associated with the red soils of the deeply weathered basaltic material.
- Topography. Steep slopes prohibit the use of machinery on 38 638 ha.

5.2.2 Land suitability for dryland sown pastures

The dryland sown pastures considered in the land suitability assessment include Callide Rhodes grass, green panic, Gatton panic, setaria, pangola, kikuyu and pasture legumes (Siratro, fine stem stylo, Glycine, Lotononis, Wynn cassia, Leucaena). A total of 92 802 ha or 73.2% of the survey area is considered suitable for dryland sown pastures.

Nine limitations were identified as being potential severe limitations for dryland sown pastures in the Kingaroy area. The most important of these is soil water availability. A plant available water capacity (PAWC) of less than 60 mm in the root zone (maximum depth considered to be 1 m) was considered to be a prohibitive limitation for dryland sown pastures over 2002 ha.

Land may also be considered unsuitable for dryland sown pasture because of the following limitations:
- Eroded and/or extremely hard setting soils (workability limitation) affects 209 ha.
- Nutrient availability. Soils low in available phosphorus, sulfate sulfur and extractable potassium are considered unsuitable as the cost of applying all nutrients would, in most situations be prohibitive on 2858 ha.
- Wetness (poor drainage). Very poorly drained sites are considered unsuitable on 318 ha.
- Soil depth. A total of 21 ha was assessed as having a soil depth of 0.3 m or less and was considered to have a severe or extreme soil depth limitation.
- Rockiness. 20–50% coarse gravel or cobble is considered to be prohibitive on 24 188 ha.
- Water erosion. Sodic texture contrast soils of 8% slope or more and other soils of slope greater than 12% occupy 10 650 ha and are considered unsuitable for dryland sown pasture.
- Salinity. 2953 ha have existing salinity and are unsuitable for pastures.
- Topography. Steep slopes prohibit the use of machinery on 18 710 ha.

5.2.3 Land suitability for tree and vine crops

The tree and vine crops considered in the land suitability assessment include citrus, grapes, persimmon, low-chill stonefruit, low-chill apples.

For simplification, no attempt was made to provide information on suitability classes for each individual crop. The suitability information contained in this report is therefore general in nature. Details of specific land use and management requirements for the range of tree and vine crops suitable for south-east Queensland may be found in the *Agrilink* Series[3]. The choice of crop will depend on both a careful analysis of crop requirements (including irrigation requirements) and careful site selection. Site layout to account for variations in soil depth, site drainage, frost and wind is important.

Forty nine percent of the survey area is considered suitable for tree and vine crops. The availability of suitable irrigation water was not evaluated in this assessment but is assumed irrigation water is available from streams or on-farm storages.

Ten limitations were identified as having the potential to severely limit the production of tree and vine crops in the Kingaroy area. They are:

- Climate (frosts) severely affect 3697 ha.
- Eroded and/or extremely hard setting soils (workability limitation) affect 209 ha.
- Wetness (poor drainage). A total of 3375 ha has imperfectly drained, poorly drained and very poorly drained sites which are considered unsuitable. Clay soils on alluvial flats and most of the texture contrast soils (where there is inadequate site drainage) will generally have a severe drainage limitation.
- Flooding. Areas (84 ha) with an average flood frequency of more than one flood every two years were considered unsuitable.
- Soil depth. Areas assessed as having a soil depth of 0.6 m or less occupy 30 645 ha and were considered to have a severe or extreme soil depth limitation. Most tree crops prefer 0.6–1.5 m of well drained soil with no rock or clay layers to impede drainage. In some instances, it may be possible to achieve the minimum depth requirement by the use of mounds.
- Rockiness. >50% coarse gravel or 20–50% cobble occupy 24 068 ha and are considered to be prohibitive.
- Water erosion. Soils of 15% slope or more occupy 10 656 ha and are considered unsuitable for tree and vine crops.
- Salinity. Soils with existing salinity or high salt levels in the profile affect 2953 ha and are unsuitable.
- Microrelief. Large gilgai (>0.6 m) occupy 4040 ha. Gilgai makes leveling difficult and expensive and influences crop growth due to uneven water distribution.
- Topography. Steep slopes prohibit the use of machinery on 18 710 ha.

The incidence of severe frosts makes this a severe limitation for sensitive crops in low lying areas. It may be necessary for protective measures to be taken for some crops at certain times of the year and at certain stages in the growing cycle. For example, citrus are susceptible to frost when young, while mature plants have a degree of resistance.

[3] *Agrilink: your growing guide to better farming*. Series first published by the Department of Primary Industries (Queensland) 1997 (ISSN 13228-0457)

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References

Ahern, C.R., Shields, P.C., Enderlin, N.G. and Baker D.E. (1994). *Soil Fertility of Central and North-east Queensland Grazing Lands.* Queensland Department of Primary Industries, Information Series, QI94065

Baker, D.E. and Eldershaw, V.J. (1993). *Interpreting soil analyses for agricultural land use*. Queensland Department of Primary Industries, Queensland, Project Report Series Q093014.

Bruce, R.C. and Rayment, G.E. (1982). *Analytical methods and interpretations used by the Agricultural Chemistry Branch for soil and land use surveys.* Queensland Department of Primary Industries, Bulletin QV92004.

Bureau of Meteorology. Meteorological Information Services Section, Kingaroy Post Office 1957 to 1990.

Isbell, R.F. (1996). *The Australian Soil Classification,* CSIRO, Australia.

Isbell, R.F., Thompson, C.H., Hubble, G.D., Bechmann, G.G. and Paton, T.R. (1967). *Atlas of Australian Soils.* CSIRO/Melbourne University Press.

Land Resources Branch Staff (1990). *Guidelines for Agricultural Land Evaluation in Queensland.* Queensland Department of Primary Industries, Information Series QI90005, Brisbane.

McDonald, R.C., Isbell, R.D., Speight, J.G., Walker, J. and Hopkins, M.S. (1990). *Australian Soil and Land Survey Field Handbook*. Second Edition, Inkata Press, Melbourne.

Macnish, S.E., Koppi, A.J., Little, I.P. and Schafer, B.M. (1987) *The distribution, nature and origin of some red sesquoxidic materials in southeastern Queensland, Australia*. Geoderma 41, 1-27. (1987)

Northcote, K.H. (1979). *A Factual Key for the Recognition of Australian Soils* 4th Ed. Rellim Technical Pulications, Glenside, South Australia

Northcote, K.H. and Skene J.K.M. (1972). *Australian soils with saline and sodic properties*. Division of Soils, CSIRO, Soils Publication 27.

Rayment, G.E. and Bruce, R.C. (1984). *Soil testings and some soil test interpretations used by the Queensland Department of Primary Industries.* Queensland Department of Primary Industries, Information Series QI84029.

Reid, R.E. (1988). *Soil survey specifications.* In *Australian soil and land survey handbook: Guidelines for conducting surveys.* (Gunn, RH, Beattie, JA, Reid, RE, Vandergraff, RHM), Inkata Press, Melbourne.

Reid, R.E., Shaw, R.J. and Baker, D.E. (1979). *Soils and potential of the alluvial flats of the Byee area, Barambah Creek, Murgon, Queensland.* Agricultural Chemistry Branch, Technical Report No 14, Queensland Department of Primary Industries.

Ridley, W.F. (1962). Vegetal distribution relative to geology in a complex part of south east Queensland. *Proceedings of the Royal Society of Queensland* **72**, 45–59.

Shaw, R.J. and Yule, D.F. (1978). *The assessment of soils for irrigation, Emerald, Queensland*. Queensland Department of Primary Industries, Agricultural Chemistry Branch, Technical Report 13.

Shaw, R.J., Hughes, K.K., Dowling, A.J. and Thorburn, P.J. (1986). *Principles of landscape, soils and water salinity – processes and management options, Part A in Landscape Soil and Water Salinity.* Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986. Queensland Department of Primary Industries, Publication QC86003.

Shaw, R.J., Thorburn, PJ, McShane, T.J., Maltby, J.E. and Robson, C.K. (1982). *The effectiveness of drainage on a region of variable aquifer hydraulic conductivity in the lower Burdekin Region, north Queensland.* In RJ Smith and AJ Dixon (eds) Rural Drainge in Northern Australia, poceedings of Symposium, Darling Downs Instititute of Advanced Education, pp 192–42.

Stace, H.C.T., Hubble, G.O., Brewer, R., Northcote, K.H., Sleeman, J.R., Mulcahy, M.J. and Hallsworth, E.G. (1968). *A Handbook of Australian Soils.* Rellim Technical Publications, Glenside, South Australia.

Vance, P.N. (1981). Peanut growing in the South Burnett. *Queensland Agricultural Journal* July-August, **107**, No 4.

Vandersee, B.E. and Kent, D.J. (1983). *Land Resources of the Burnett Region, Part I: South Burnett.* Queensland Department of Primary ,

Watkins, J.R. (1967). The relatioship between climate and the development of landforms in the Cainozoic rocks of Queensland. *Journal of the Geological Society Australia* **14(**1), 153-158.

Webb, A.W., Stevens, N.C. and McDougal, I. (1968). Isotopic age determination on Tertiary volcanic rocks and intrusives of south east Queensland. *Proceedings of the Royal Society of Queensland* **79**, 79–92.

White, C.T. (1920). Flora of the Bunya Mountains. *Queensland Agricultural Journal* **13**, pp 25–31

APPENDIX I

Soil profile classes

Conventions used in the descriptions of the morphology, landscape and vegetation of the soil profile classes

A soil profile class is a three dimensional soil body of group or soil bodies, such that any profile within the body(s) has a similar number and arrangement of major horizons whose attributes, primarily morphological, are within a defined range. All profiles within the units have similar parent materials. The soil profile class may be at varying levels of generalisation depending primarily on the scale of the survey and density of ground observations.

A **soil variant** is a soil with profile attributes clearly outside the range of defined soil types but not extensive enough to warrant defining a new type.

A **soil phase** is a subdivision of a soil profile class based on attributes that have particular significance in the use of the soil, for example, rocky phase.

Australian Classification as described by Isbell (1996) are listed in order of frequency of occurrence.

Great Soil Group as described by Stace *et al.* (1968) are listed in order of frequency of occurrence.

Principle Profile Form (PPF) as defined by Northcote (1979) are listed in order of frequency of occurrence.

Geology as defined on the Maryborough 1:250 000 geology series map, 1992.

Surface characteristics as in McDonald *et al.* (1990).

Landform as in McDonald *et al.* (1990).

Vegetation structural formation as in McDonald *et al.* (1990)

Vegetation species listed in order of frequency of occurrence. "/" means with or without.

The **pH profiles** are based on field determination for each horizon.

Horizons as in McDonald *et al.* (1990).

Textures are field textures as in McDonald *et al.* (1990)

Structure as in McDonald *et al.* (1990).

Segregation as in McDonald *et al.* (1990).

Boundary type as in McDonald *et al.* (1990).
Frequency of occurrence
Frequently = >30% of occasions
Occasionally = <30% of occasions

Colour codes (moist) and nomenclature are those of Munsel soil colour charts (1994).

References

Isbell, R.F (1996). *The Australian Soil Classification*. CSIRO, Australia.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (1990), *Australian Soil and Land Survey Field Handbook,* Inkata Press, Melbourne.

Munsel soil colour charts (1994), McBeth Division of Koll Morgan Instruments Corporation, New York.

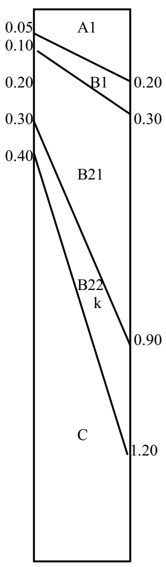
Northcote, K.H. (1979), *A Factual Key for the Recognition of Australian Soils,* 4th Ed. Rellim Technical Publications, Glenside, South Australia.

Stace, H.C.T., Hubble, G.O., Brewer, R., Northcote, K.H., Sleeman, J.R., Mulcahy, M.J. and Hallsworth, E.G. (1968), *A Handbook of Australian Soils,* Rellim Technical Publications, Glenside, South Australia.

APPALOOSA (Ap)

Concept:	Brown clays frequently with weak to moderate gilgai on old alluvium
Australian Classification:	Brown Vertosol
PPF:	Ug5.35, Ug5.34, Uf6.31, Ug3.3, Uf6.33, Ug5.2
Great soil group:	Brown clay
Landform:	Crests and slopes of undulating rises. Slopes 0.5-4%
Geology:	Quaternary alluvium (Qa), Tertiary sediments (Ts)
Vegetation:	Poplar box open forest. Regrowth of black tea tree can occur after clearing. Poorly to moderately developed grass layer of blue grasses and love grasses
Surface feature:	Cracking, gilgaied, hardsetting to weak self mulching

Depth (m)



A1: Dark or brown (7.5YR, 10YR, 3/2, 3/3, 4/4); light clay to medium clay, moderate medium to fine subangular blocky; dry hard to very hard; manganiferous concretions.

B1 Occasionally present. Brown (7.5YR, 10YR 3/3, 3/4, 4/3, 4/4); light medium clay to medium clay; moderate fine to medium angular blocky; dry very hard to extremely hard; manganiferous concretions.

B21: Occassionally yellow mottled; brown (7.5YR, 10YR 3/3, 3/4, 4/3, 4.4); medium clay to medium heavy clay; strong medium lenticular or occasionally moderate medium angular blocky; dry hard to very hard; manganiferous concretions and occasionally ferruginous segregations.

B22k: Grey, gley or yellow mottles; yellow brown, yellow or grey (10YR 5/4, 5/6, 6/2, 6/4, 6/6); medium clay to medium heavy clay; moderate fine to medium angular blocky; dry very hard, manganiferous veins and or concretions, occasionally ferruginous segregations and soft or concretionary lime.

C: Grey, gley or yellow mottled; yellow brown, yellow or grey (10YR 5/4, 5/6, 6/2, 6/4, 6/6); medium clay to medium heavy clay; moderate fine to medium angular blocky; dry very hard; manganiferous veins and or concretions, occasionally ferrugenous segregations and soft or concretionary lime.

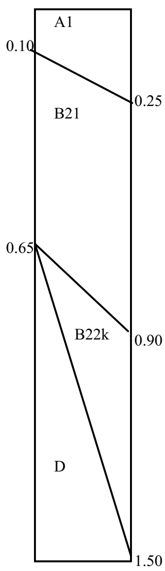
Note: Surface carried 2-10% gravel (3-50 mm), subangular to rounded, petrified wood, kaolinised basalt chert, chalcedony and ironstone with some silcrete.

Sites: 133, M214, 215, 222, 242, 243, 372, 373, 374, 405, 406, 407, 457, 461

ARCHOOKOORA (Ac)

Concept:	Red structured soil derived from deeply weathered basaltic material overlying old alluvium
Australian Classification:	Red Ferrosol, Brown Ferrosol
PPF:	Uf6.31, Uf6.4, Uf6.3
Great soil group:	Euchrozems, Krasnozem
Landform:	Crests and slopes on low hills and fans and/or higher alluvial material
Geology:	Deeply weathered basaltic colluvium over old alluvium or Tertiary sediments
Vegetation:	Narrow leaved ironbark and Moreton Bay ash open forest. Kangaroo and blue grass.
Surface features:	Firm to hardsetting. Occasionally surface angular silcrete, lateritised basalt and/or metamorphic gravels

Depth (m)



A1: Dark red dish brown or dark brown (5YR, 7.5YR 3/3, 3/5); light clay to light medium clay; strong fine granular structure; dry slightly hard consistence; 0-10% manganiferous and ferromanganiferous nodules. Clear change to

B21 Reddish brown or brown (5YR, 7.5YR 4/4, 4/6); light clay to light medium clay; strong fine polyhedral to subangular blocky structure; dry hard consistence; 10-20% manganiferous concretions and minor ferromanganiferous nodules. Diffuse change to

B22k: Dark reddish brown or brown or bright brown (5YR, 7.5YR, 10YR 3/4, 4/6, 5/6); light clay to medium heavy clay; strong fine subangular blocky to polyhedral structure; dry hard to very hard; 0-10% manganiferous segregations. Clear or gradual change

D: Brown or dull brown (7.5YR, 10YR 4/6, 5/4); medium clay to medium heavy clay; strong fine subangular blocky to medium angular blocky to lenticular structure; 0-10% manganiferous concretions

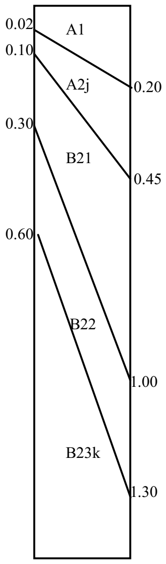
Variants: B horizons may be bright brown (7.5YR 5/6 moist) and may have a red and/or yellow mottle. B horizon may have angular blocky to fine lenticular structure. D horizons where present may be bright brown (2.5YR 5/6) and have a heavy clay texture

Sites: 99, 169, 254, 381, 382, 390, 402, 405, 410, 417, 419, 530, 538, 541, 573, 586, 598, 600, 635, 657, 658, 660, 678, 681, 682, 702, 718, 722, 724, 725, 770, 771

AVON (Av)

Concept: Sodic texture contrast soil on alluvial plains of current streams
Australian Classification: Brown Sodosols, Grey Sodosol
PPF: Db2.32, Db2.33, Dy2.33, Db1.33
Great soil group: Solodic soil
Landform type: Back plains and high terraces associated with major streams
Geology: Unconsolidated sediments from Quaternary alluvium (Qa)
Vegetation: Poplar box woodland, minor areas of forest red gum.
Surface feature: Hardsetting, occasionally crusting

Depth (m)



A1: Brownish black or dark brown (10YR 3/3, 3/3); sandy loam to clay loam; massive; dry hard consistence; trace amounts of manganiferous concretions. Gradual change to

A2j: Sporadically bleached. Brown black or dull yellowish brown (7.5YR, 10YR 3/2, 4/3, 5/4); loamy sand to clay loam, then as above. Abrupt change to

B21: Dark grey or yellow mottled; brown grey or brown (7.5YR, 10YR 4/1, 4/2, 4/3, 4/4, 4/6); medium clay to medium heavy clay; strong fine prismatic to subangular to angular blocky structure; dry extremely hard consistence; trace amounts of manganiferous and carbonate concretions and segregation. Gradual change to

B22: As above except greyish yellow brown or dully yellowish brown or brown or dark greyish yellow (10YR, 2.5Y 4/2, 4/3, 4/6). Clear change to

B23k: As above except brown or dull yellowish brown (10YR 4/4, 4/6, 5/3); light clay to medium heavy clay; moderate amounts of carbonate concretions and segregations, trace amount of manganiferous concretions.

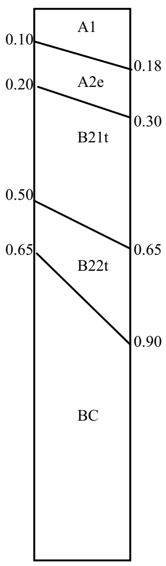
Variants: Deep surfaced sandy loam of around 0.6 occur. Moderately acid soil reaction trends in deeper surface variants. Reddish brown (5YR 4/4, 4/6) medium clay B horizons. Some variants have silty clay surface texture and moderate fine granular structure

Sites: 154. See also Gordonbrook reference area. Consult DNR study area for more detail.

BOONENNE (Bn)

Concept: Neutral to alkaline brown sodic texture contrast soil on mid to upper slopes on granite
Australian Classification: Hypernatric Brown Sodosol
PPF: Dy3.43, Dy3.42, Dy2.43, Db2.42, Db2.43
Great Soil Group: Solodic soil
Landform type: Hillslopes of undulating low hills to rolling hills. Slopes 2-10%
Geology: Granite, adamellite
Vegetation: Silver leaved ironbark, narrow leaved ironbark, bloodwood, open forest. Ground cover of wire grass
Surface feature: Firm to hardsetting

Depth (m)



A1: Brown (7.5YR, 10YR 4/3, 4/4); sandy loam to sandy clay loam; massive to weak 2-5 mm granular to subangular blocky structure; dry weak consistence; field pH 5.7-6.0. Clear change to

A2e: Conspicuously bleached; loamy sand to light sandy clay loam; massive; dry weak consistence; 2-10% manganiferous concretions; field pH 5.7-6.0. Abrupt change to

B21t: Brown mottled; yellowish brown (7.5YR 5/4, 10YR 5/6); light medium clay to medium clay; strong 20-30 mm angular blocky to prismatic structure; dry extremely hard consistence; 0-2% manganiferous segregations, field pH 6.0-8.5. Gradual change to

B22t: Grey mottled; dark yellowish brown (7.5YR, 10YR 4/4, 4/6); sandy light clay to medium clay; moderate 20-50 mm angular blocky structure; dry very hard consistence; field pH 8.5-8.9.

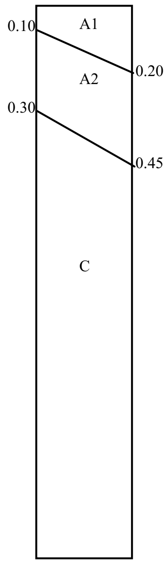
BC: Dark mottled; yellowish brown or brownish yellow (7.5YR, 10YR 5/6, 6/8); loamy sand to loamy coarse sand; massive; fragments of weathering parent material; field pH 8.6-8.8.

Sites: 146, 209, 339, 346, 464, 553, 566, 709, 710, 723, 778

BOOIE (Bo)

Concept: Shallow loams and sand with little or no horizon development formed on decomposing granite
Australian Classification: Bleached–orthic Tenosol, Orthic Tenosol
PPF: Uc2.12, Um3.12
Great soil group: Lithosol
Landform: Crests and upper slopes of undulating low hills. Slopes 2-15%
Geology: Granite
Vegetation: Rusty gum, spotted gum open forest
Surface feature: Loose to firm

Depth (m)



A1: Dark brown or brownish black (7.5YR 2/2, 10YR 3/3); sandy loam to sandy clay loam massive to weak granular; field pH 6-6.5. Clear change to

A2e,j: Conspicuously or sporadically bleached; sandy loam to sandy clay loam; massive; field pH 6-6.8. Gradual change to

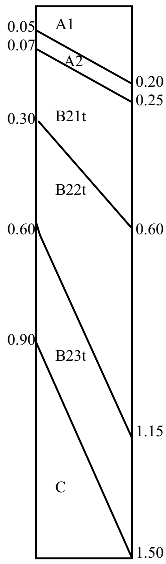
C: Weathered granite.

Sites: 141, 217, 220, 264, 280, 291, 333, 343

BUSHNELL (Bl)

Concept: Gilgaied clay loam surfaced brown sodic texture contrast soil on Tertiary sediments
Australian Classification: Brown Sodosol
PPF: Dy2.33, Dy3.33, Dy3.43, Db2.33, Db1.33
Great Soil Group: Solodic soil, solodized solonetz
Landform type: Crests and slopes of low hills. Slopes 1.5-6%
Geology: Tertiary sediments
Vegetation: Narrow leaved ironbark with gun topped box, Moreton Bay ash and belah (occasionally associated) open forest
Surface feature: Hardsetting, frequently gilgaied

Depth (m)



A1: Brown or dark (7.5YR, 10YR 2/2, 3/2, 3/3, 3/4, 4/3, 4/4); clay loam to fine sandy clay loam to silty clay loam to clay loam sandy; weak fine subangular blocky to granular; dry hard; manganiferous concretions.
A2e,j: Sporadically or conspicuously bleached. As above.
B21t: Frequently yellow, brown or dark mottled; yellow or yellow-brown or brown (7.5YR, 10YR 3/3, 3/4, 4/3, 4/4, 4/6, 5/3, 5/4, 5/6); medium clay to medium heavy clay; strong to moderate medium prismatic to columnar; dry very hard to extremely hard; manganiferous concretions and occasionally veins.
B22t: As above but frequently strong medium lenticular or moderate medium blocky; frequently soft or concretionary lime.
B23t: As above but frequently dark mottled.
C: Frequently present. Brown, grey, gley or yellow mottled; grey or yellow-brown or yellow or brown (10YR, 7.5YR, 2.5Y 4/4, 5/3, 5/4, 5/6, 6/2, 6/2, 6/6, 7/1, 7/2, 8/1, 8/2); sandy light clay to medium heavy clay; moderate medium blocky to massive; dry very hard to extremely hard; manganiferous concretions and veins, ferruginous segregations.
Notes: Surface carried 2-15% gravel (3-75 mm), angular (silcrete) to subangular to rounded – petrified wood, kaolinized basalt, chert, chalcedony, ironstone and silcrete. C horizons include mottled clay, weakly lithified argillaceous sandstone and kaolonite rich sandy material, apparently a laterite pallid zone. The later occurs low in the landscape

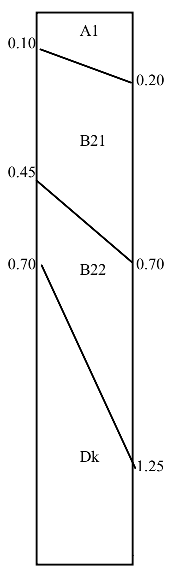
Variants: A horizons may be light clay giving Uf3 after alluviation. B21 horizon may be yellow mottled red (5YR 4/6) giving Dr3.33. This is frequently associated with sites just below basalt caps on ridges

Sites: 371, 375, 420, 427, 428, 430, 431, 432, 433, 437, 449, 452, 457, 458, 468, 488, 505, 513, 644

BYEE (By)

Concept: Moderately self mulching black cracking clay over brown calareous subsoils on alluvial plains
Australian Classification: Black Vertosol
PPF: Ug5.15
Great Soil Group: Black Earths
Landform type: Lower alluvia often associated with drainage lines form the surrounding hills. Slopes 0.5-1%
Geology: Quarternary alluvium (Qa)
Vegetation: Forest red gun open forest. Well developed grass layer of blue grasses
Surface feature: Cracking, self mulching

Depth (m)



A1: Dark (10YR 2/1, 2/2, 3/1, 3/2); medium clay to medium heavy clay; strong fine blocky; dry very hard.

B21: As above with strong medium blocky.

B22: As above with strong medium lenticular; frequently manganiferous concretions.

Dk: Brown (7.5YR, 10YR 2/3, 3/3, 4/3, 4/4); medium clay to medium heavy clay; strong medium blocky; dry very hard; manganiferous concretions, concretionary lime.

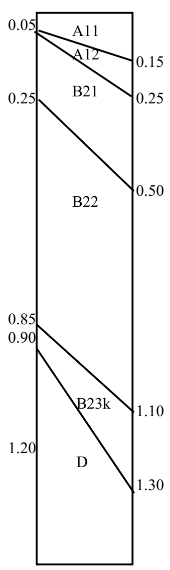
Variant: Dk horizon grey (10YR 4/2)

Sites: 28, 29, 69, 73, 82, 96, 287, 319, 326, 336, 337, 349, 351, 388, 411, 469, 608, 615, 645

CHELMSFORD (Cf)

Concept: Red structured soils derived from trasported deeply weathered basaltic material overlying old alluvium
Australian Classification: Red Ferrosol
PPF: Uf6.31, Gn3.13, Gn3.12
Great Soil Group: Euchrozems
Landform type: Crests of low hills
Geology: Deeply weathered basaltic colluvium/alluvium overlying old alluvium
Vegetation: Narrow leaved ironbark and Moreton Bay ash open forest. Strongly developed grass layer of kangaroo grass and blue grasses
Surface feature: Hardsetting

Depth (m)



A11: Dark or red (2.5YR, 5YR 3/2, 3/3, 3/4); clay loam to light clay; moderate to strong fine granular; dry slightly hard; manganiferous concretions.

A12: Frequently present in uncultivated situations. Red (2.5 YR, 5YR 3/2, 3/3); light clay; medium subangular blocky; dry slightly hard to hard; manganiferous concretions.

B21: Red (10R, 2.5 YR, 5YR 3/4); light medium clay to medium clay; strong fine to medium blocky to polyhedral; dry hard; manganiferous concretions and iron segregations.

B22: As above but red (10R, 2.5YR, 5YR 3/6) and occasionally with slickensides.

B23k: Frequently present. As above but occasionally brown (7/5YR 4/6) and with manganiferous veins and concretionary lime.

D: Red or grey mottled; red or grey (2.5YR 3.6, 10YR 7/2, 8/3); light clay to light medium clay; strong fine angular blocky to massive; manganiferous veins, ferruginous segregations and concretionary lime.

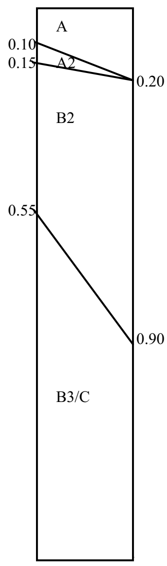
Notes: Surface carries 5-15% of gravel (3-75 mm) subangular kaolinised basalt

Sites: 374, 384, 409, 412, 415, 416, 423, 502, 503, 525, 534, 544, 549 84

CHARLESTOWN (Ct)

Concept: Hardsetting red or brown acid to neutral sodic texture contrast soil on granite
Australian Classification: Red Sodosol, Brown Sodosol
PPF: Dr3.12, Dr2.32, Dr3.41, Db2.12, Dr1.12
Great Soil Group: Solodic soil
Landform type: Mid to upper slopes on undulating hills. Slopes 3-15%
Geology: Granite
Vegetation: Narrow leaved ironbark open forest
Surface feature: Hardsetting

Depth (m)



A: Dark or dark brown (7.5YR 3/2, 3/3, 10YR 3/2, 2/3); light sandy clay loam to clay loam sandy; massive to weak granular; field pH 6.0-6.5. Clear to gradual change to

A2e,j: Frequently occur. Conspicuously or sporadically bleached; light sandy clay loam to clay loam sandy; massive. Abrupt change to

B2: Bright reddish brown or brown (2.5YR 3/6, 5YR 4/6, 7.5YR 4/4, 10YR 4/4, 5/6); medium clay to medium heavy clay; moderate to strong angular blocky; occasionally manganiferous segregations; field pH 5.3-6.5 in upper B horizon frequently increasing to 8.0-8.5 in lower B horizon. Clear change to

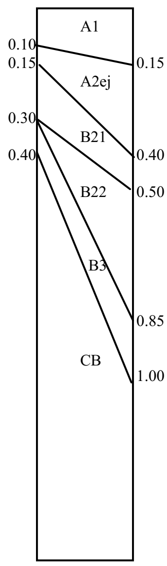
B3/C: Sandy clay loam to sandy medium clays with weathered rock.

Sites: 268, 270, 292, 335, 362

CHERBOURG (Cg)

Concept: Shallow, loose to firm, sandy loams to sandy clay loams overlying weak to moderate structured brown medium clays on sedimentary rocks, acid to neutral soil reaction trend
Australian Classification: Yellow Kurrosols, Brown Sodosols
PPF: Db2.41, Dy3.21, Dy3.41, Um1
Great Soil Group: Soloths, Lithosols, no suitable group
Landform type: Crests and upper slopes of undulating to rolling hills. Slopes 0-15%
Geology: Shales, sandstones of the Marburg Sandstones and Tarong Beds
Vegetation: *Angophora* spp., narrow leaved ironbark woodland, understory of *Acacia* spp.*, Aristida* spp.
Surface feature: Loose to firm

Depth (m)



A1: Brown or yellowish brown (0YR 4/4, 5/4, 4/2, 4/1); sandy loam to sandy clay loam; massive to weak 2-5 mm granular; field pH 6.0-7.0. Clear change to

A2e,j: Conspicuously bleached to sporadically bleached; greyish yellow brown or brownish grey (7.5YR, 10YR 6/2, 5/1); sandy loam to sandy clay loam; massive to weak granular structure 2-5 mm; field pH 5.5-7.0; few ferromanganiferous nodules. Abrupt change to

B21: Occasionally mottled; brown or yellowish brown (7.5YR, 10YR 4/4, 5/6); medium clay to sandy medium clay; moderate angular blocky structure; field pH 5.0-6.5; few to small amounts of ferromanganiferous nodules and segregations. Gradual change to

B22: Frequently mottled; brown or yellowish brown or bright brown (7.5YR 10YR 4/4, 5/4, 5/6); medium to medium heavy clay; moderate angular blocky structure; field pH 5.0-6.5; few to small amounts ferromanganiferous nodules and segregations. Gradual change to

B3: Mottled; yellowish brown or bright yellowish brown (7.5YR, 109YR 5/4, 5/6, 5/8, 6/6, 7/6); light clay to medium weak subangular blocky; field pH 5.0-6.5; few manganese segregations; 10% gravels and soft substrate material.

CB: Mottled; light yellowish brown (10YR 6/8); clay loam; weak subangular blocky structure; field pH 5.5. Large amounts (50%+) decomposing sandstone on shales and gravels.

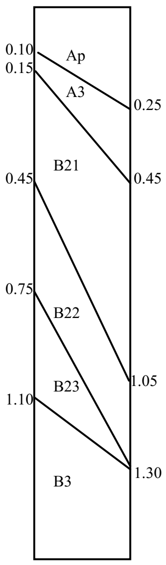
Variants: Gravelly phases may occur where parent material comes close to surface. Shallow sandy lithosols overlying parent rock occur in this landform type.

Sites: 166, 204, 308, 313, 315, 318, 350a&b, 607, 659, 800, 802

COOLABUNIA (Cl)

Concept: Neutral to slightly alkaline strongly structured red clay soils on deeply weathered basaltic material
Australian Classification: Red Ferrosol
PPF: Uf6.31, Uf6.4, Gn3.11, Gn3.12
Great Soil Group: Euchrozems
Landform type: Mid to lower hillslopes of undulating rises to rolling hills
Geology: Deeply weathered basaltic material (Tm)
Vegetation: Cleared
Surface feature: Firm, hardsetting

Depth (m)



Ap: Dark or very dark reddish brown (10R, 2.5YR, 5YR, 2/3, 2/3, 3/3, 3/4); clay loam to light medium clay; moderate to strong fine granular; dry hard; trace amounts ironstone and manganiferous concretions. Gradual change to

A3: Dark reddish brown or dark red (10R, 2.5YR, 3/3, 3/4); light clay to light medium clay; moderate fine polyhedral to fine subangular blocky; dry hard; small amounts of ironstone and manganiferous concretions. Gradual change to

B21: Dark reddish brown (10R, 2.5YR, 3/4, 3/6, 4/6); light medium clay; moderate fine to strong medium polyhedral; dry very hard, small amounts of ironstone and manganiferous concretions. Gradual change to

B22: Dark mottled; reddish brown or red (10R, 2.5YR, 3/4, 3/6, 4/4, 4/6); light clay to medium clay; strong fine to medium polyhedral; dry very hard; large amounts of ironstone and manganiferous concretions; small amounts of decomposed basalt. Gradual change to

B23: Dark and grey mottled; reddish brown (10R, 2.5YR, 3/4, 3/6, 4/6); light medium to medium clay; strong medium polyhedral; dry very hard; large amounts of ironstone and manganiferous concretions; moderate amounts of decomposed basalt. Gradual change to

B3: Reddish brown (2.5YR, 5YR, 4/6, 4/8); light medium to medium clay; strong medium polyhedral to strong medium blocky; dry extremely hard; large amounts of ironstone and manganiferous concretions; moderate amounts of decomposed basalt.

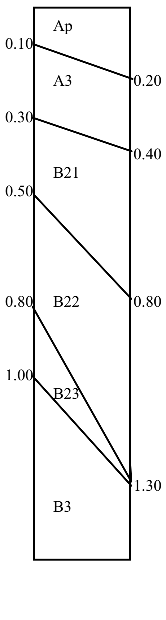
Variant: Occasionally alkaline soil reaction trends occur in lower slopes

Sites: 63, 104, 114, 119, 121, 122, 123, 128, 153, 185, 189, 190, 193, 196, 197, 203, 215, 225, 238, 239, 242, 263, 271,302, 463, 494, 495, 522, 552, 557, 562, 575, 578, 623, 634, 638, 648, 650, 655, 670, 718, 734, 744, 765, 790, 786

CRAWFORD (Cd)

Concept: Acid to slightly alkaline mottled strongly structured red clay soils on deeply weathered basaltic material
Australian Classification: Red Ferrosol
PPF: Uf6.31, Uf6.4, Gn3.11, Gn3.12
Great Soil Group: Krasnzems, Euchrozems (mottled)
Landform type: Mid to lower slopes of undulating rises to rolling hills
Geology: Deeply weathered basltic material (Tm)
Vegetation: Mostly cleared
Surface feature: Firm

Depth (m)



Ap: Dark red or reddish brown (10R, 2.5YR, 5YR, 3/3, 3/4, 4/2); clay loam to light clay; weak to strong fine granular; dry soft; moderate amounts of ironstone and manganiferous concretions; moderate amount of tuff (laterite) present in surface. Gradual change to

A3: Faint dark mottled; dark reddish brown (2.5YR, 5YR, 3/3, 3/4, 3/6); clay loam to light medium clay; weak fine granular to strong fine polyhedral; dry hard; moderate amounts of ironstone and manganiferous concretions. Gradual change to

B21: Dark mottled; reddish brown (10R, 2.5YR, 3/4, 3/6, 4/6, 4/8); clay loam to light medium clay; strong fine polyhedral to strong subangular fine blocky; dry very hard; small amounts of ironstone and manganiferous concretions; small amounts of kaolinised basalt. Gradual change to

B22: Dark red, yellow or grey mottled; reddish brown or brown (10R, 2.5YR, 5YR, 7.5YR, 3/4, 3/6, 4/4, 4/8, 5/6); light clay to medium clay; strong medium polyhedral; dry very hard; moderate amounts manganiferous concretions; small amount of ironstone and kaolinised basalt. Gradual change to

B23: As above except moderate amounts of ironstone and manganiferous concretions.

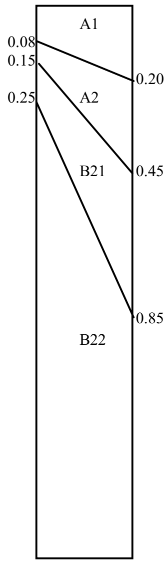
B3: As above except strong medium polyhedral to medium prismatic; dry extremely hard, large amounts of kaolinised basalt.

Sites: 213, 216, 231, 249, 275, 461, 579, 636, 639, 665, 675, 698, 715, 721, 762, 779, 785, 805

COOYAR (Cy)

Concept: Hardsetting acid yellow texture contrast soils on pediments derived from granite
Australian Classification: Brown Chromosol, Brown Sodosols, Brown Kurosol, Grey Sodosol
PPF: Dy3.41, Dy3.31
Great Soil Group: Yellow podzolic soil, soloth
Landform type: Lower slopes of pediments. Slopes 0-4%
Geology: Granite
Vegetation: Poplar box open forest
Surface feature: Hardsetting

Depth (m)



A1: Dark, dark brown or dull yellowish brown (7.5YR 3/3, 10YR 3/2, 3/4, 4/2); sandy loam to sandy clay loam; massive to weak granular; field pH 5.5-6.5. Clear change to

A2e,j: Conspicuously or sporadically bleached; sandy loam to sandy clay loam; massive to weak granular. Clear change to

B21: Mottled; bright brown or yellowish brown (7.5YR 5/2, 5/6, 10YR 4/3, 5/6); light medium clay to medium heavy clay; moderate to strong angular blocky or polyhedral; frequently ferromanganiferous or manganiferous segregations; field pH 5.0-6.5. Gradual change to

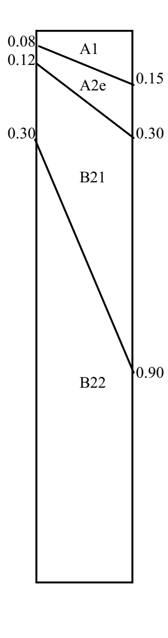
B22: Mottled; bright brown or greyish brown (7.5YR 6/2, 10YR 5/2, 5/4, 5/6); light clay to medium heavy clay; angular blocky; field pH 5.5-6.5.

Sites: 305, 328, 368, 574, 596, 617, 716, 747, 780

CUSHNIE (Cs)

Concept: Hardsetting neutral to alkaline, sodic texture contrast soils on pediments derived from granite
Australian Classification: Brown Sodosol, occasionally Grey Sodosol
PPF: Dy3.43, Dy2.42, Db2.13, Dy3.42
Great Soil Group: Solodic soil
Landform type: Lower slopes of pediments. Slopes 1-6%
Geology: Granite
Vegetation: Narrow leaved ironbark, Moreton Bay ash open forest. *Aristida* species ground cover
Surface feature: Hardsetting

Depth (m)



A1: Dark or dark brown (7.5YR 3/1, 3/2, 3/4); light sandy clay loam to clay loam and clay loam fine sandy; massive to moderate granular; field pH 6 to 6.3. Clear change to

A2e: Conspicuously bleached; sandy clay loam to clay loam fine sandy; massive. Abrupt to clear change to

B21: Frequently mottled; brown or bright brown or occasionally grey (7.5YR 4/4, 4/6, 10YR 3/3, 5/6, 2.5Y 5/2); light medium clay to medium heavy clay; strong angular blocky or occasionally columnar; frequently ferromanganiferous segregations; field pH 7-8. Clear change to

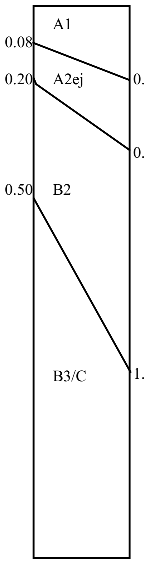
B22: Brown or dull brown (7.5YR 5/4, 4/6, 10YR 5/3, 5/5); light medium clay to medium heavy clay; strong angular blocky; 2-20% manganiferous and/or calcareous segregations; field pH 8-9.5.

Sites: 284, 322, 344, 369, 378, 540, 622, 624

DANGORE (Dg)

Concept: Hardsetting acid texture contrast soils on upper slopes and crests on granite
Australian Classification: Brown Sodosols, Brown Chromsols, Grey Sodosol, Yellow Chromosol
PPF: Dy3.41, Dy3.31, Db2.31, Db1.41
Great Soil Group: Soloth, podzolic soil
Landform type: Upper slopes and crests of undulating low hills. Slopes 0-10%
Geology: Granite
Vegetation: Narrow leaved ironbark, rough barked apple open forest
Surface feature: Hardsetting

Depth (m)



A1: Dark or brownish black (7.5YR 2/2, 3/2, 10YR 2/2, 2/3, 3/2); sandy loam to sandy clay loam; massive to weak granular; field pH 5.5-6.0. Clear change to

A2e,j: Conspicuously or sporadically bleached; sandy loam to sandy clay loam; massive. Abrupt change to

B2: Mottled; brownish black, brown or bright brown (7.5YR 5/6, 6/6, 10YR 3/3, 4/2, 4/3, 5/3, 5/4, 5/6); fine gravelly light clay to medium clay; moderate to strong angular blocky, occasionally polyhedral; frequently manganiferous nodules; field pH 5.5-6.0. Gradual change to

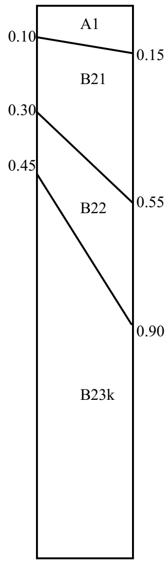
B3/C: Fine gravelly sandy clay loam to light clay or weathered rock.

Sites: 144, 210, 261, 262, 279, 288, 296, 312, 340, 550, 551, 572, 613, 776

EASTGATE (Eg)

Concept: Weak self mulching to hardsetting black or brown cracking clay on alluvial plains
Australian Classification: Black Vertosol, Brown Vertosol
PPF: Ug5.15, Ug5.34
Great Soil Group: Black earths, brown clays
Landform type: Alluvial plains and levee backslopes. Slopes 0-1.5%
Geology: Qurternary alluvium (Qa)
Vegetation: Gum topped box, poplar box with occasional forest red gum open forest woodland
Surface feature: Cracking, weak self mulching to hardsetting, occasionally weak gilgai

Depth (m)



A1: Dark (7.5YR, 10YR 2/1, 2/2, 3/1, 3/2); light medium clay to medium clay; strong fine to medium blocky; dry very hard; manganiferous concretions.

B21: Brown (10YR 3/3, 4/3) or dark (7.5YR, 10YR 2/1, 2/2, 3/1, 3/2); medium clay to medium heavy clay; strong medium blocky; dry very hard to extremely hard; manganiferous concretions.

B22: As above but frequently strong fine to medium lenticular.

B23k: Brown (7.5YR 3/3, 3/4, 4/3, 4/4, 4/6); light medium clay to medium clay; moderate to strong fine to medium blocky; dry hard to very hard; manganiferous concretions, concretionary lime.

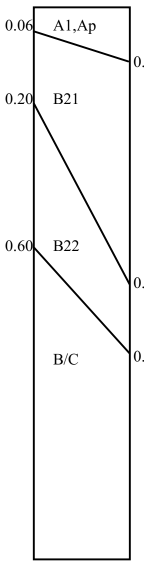
Variant: A sporadic bleach occasionally occurs towards the base of the A horizon in uncultivated situations.

Sites: 9, 14, 20, 93, 94, 113, 159, 165, 182, 211, 212, 218, 219, 228, 230, 267, 269, 286, 297, 306, 309, 311, 323, 324, 330, 334, 348, 354, 356, 357, 359, 360, 393, 403, 408, 414, 422, 434, 467, 473, 480, 567, 595, 653, 656, 719, 756, 774, 775, 782

FAIRDALE (Fd)

Concept: Moderately deep dark or brown cracking clays on basalt
Australian Classification: Black Vertosol, Brown Vertosol
PPF: Ug5.12, Ug5.13, Ug5.32
Great Soil Group: Black earth, brown clay
Landform type: Mid slopes of undulating rises to rolling hills. Slopes 2-7%
Geology: Tertiary Main Range basalt (Tm)
Vegetation: Silver leaved ironbark open forest
Surface feature: Self mulching, cracking

Depth (m)



A1,Ap: Dark or dark brown (7.5YR 3/2, 3/3, 10YR 2/2, 2/3, 3/2); light medium clay to medium clays; strong granular to subangular blocky; field pH 6.5-7.0. Clear change to

B21: Dark or brown (7.5YR 3/2, 4/4, 10YR 2/2, 3/2); medium clay to medium heavy clay; strong subangular block becoming lenticular in lower horizon; field pH 7.0-8.0. Diffuse or gradual change to

B22: Frequently occurs. Dark brown or brown (7.5YR 3/3, 4/4, 10YR 3/3, 3/4); medium clay to medium heavy clay; lenticular; frequently calcareous segregations; field pH 8.0-8.5. Gradual change to

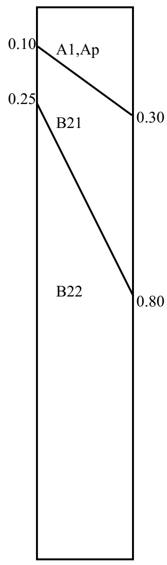
B/C: Gravelly clay loam to light clay with calcareous segregations.

Sites: 10, 25, 30, 31, 36, 58, 70, 71, 86, 87, 100, 108, 150, 180, 187, 246, 299, 483, 493, 501, 514, 515, 524, 593, 626, 641, 643, 647, 749, 795

GOODGER (Gg)

Concept: Deep loose surfaced (snuffy) red structured soil developed on deeply weathered basalt
Australian Classification: Red Ferrosol
PPF: Gn3.11, Uf5.31
Great Soil Group: Krasnozem
Landform type: Plateaus, hill crests and upper slopes. Slopes 0-12%
Geology: Deeply weathered Tertiary Main Range basalt (Tm)
Vegetation: Narrow leaved ironbark, broad leaved ironbark woodland. Mostly cleared.
Surface feature: Loose

Depth (m)



A1, Ap: Dark reddish brown (2.5YR 3/4, 4/6, 5YR 2/3, 3/6); clay loam to light clay; massive to weak granular; field pH 5.5-6.5. Clear to gradual change to

B21: Dark red or dark reddish brown (10R 3/4, 4/4, 2.5YR 3/4, 3/6, 5YR 3/6); clay loam to light clay; massive to weak polyhedral in upper horizon with increasing structure at depth; field pH 5.0-5.5. Diffuse change to

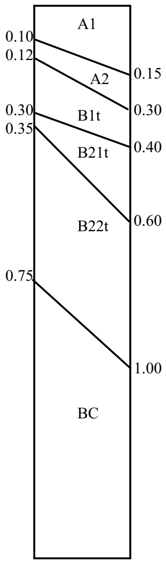
B22: Dark red, red or dark reddish brown (10R3/6, 4/6, 2.5YR 3/6, 4/6); light clay; moderate to strong polyhedral; field pH 5.0-5.5.

Sites: 244, 255, 256, 257, 258, 259, 272, 293, 535, 603, 604, 628, 666, 674, 736, 750, 757, 768, 787, 788, 798

GORDONBROOK (Gd)

Concept: Hardsetting sandy clay loam surface over a red structured clay subsoil on deeply weathered granite
Australian Classification: Dystrophic Red Chromosol, Red Dermosol
PPF: Dr2.21, Uf6.4p
Great Soil Group: Red podzolic soil; no suitable group, affinities with soloths
Landform type: Hillslopes and crests on undulating low hills. Slopes 2-6%
Geology: Granite (deeply weathered)
Vegetation: Moreton Bay ash, Apple gum, narrow leaved ironbark, silver leaved ironbark. Ground cover of wire grass and Queensland blue grass
Surface feature: Loose to firm

Depth (m)



A1: Dark reddish brown or brown (5YR, 7.5YR 2/4, 3/4); light sandy clay loam to sandy clay loam; weak fine granular structure to massive; dry weak consistence; 2-15% angular siliceous coarse fraction; field pH 6.0 to 6.3. Clear boundary to

A2: Dark yellowish red or reddish brown (5YR 3/6, 4/6); light sandy clay loam; massive; dry weak consistence; 2-15% angular siliceous coarse fraction; pH 6.0. Clear change to

B1t: Dark reddish brown or dark red (2.5YR, 5YR 3/4, 3/6); sandy light clay; weak to moderate subangular blocky to polyhedral structure; dry firm consistence; 2-15% angular quartz grains; field pH 6.0. Gradual change to

B21t: Dark red or yellowish red (2.5YR, 5YR 3/4, 3/6); sandy light clay to medium clay; moderate subangular blocky to polyhedral structure; dry firm to hard consistence; 2-15% angular quartz grains occasionally present; field pH 6.0. Gradual change to

B22t: Occasionally yellow mottled; dark red or dark yellowish brown (2.5YR, 5YR, 7.5YR, 10YR 3/4, 3/6, 4/6); sandy light clay to medium clay; moderate 10-20 mm angular blocky to strong polyhedral structure; dry hard consistence; 10-20% coarse fractions of weathered granite; field pH 6.0-5.8. Gradual change to

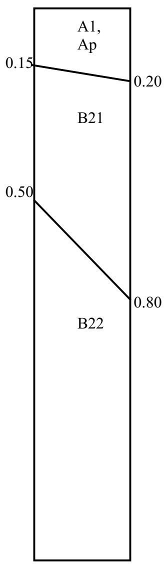
BC: Frequently mottled; reddish brown or yellowish brown (2.5YR, 5YR, 7.5YR, 10YR 3/6, 4/6); sandy clay to sandy clay loam; moderate to weak subangular blocky to polyhedral structure; dry slightly hard consistence; 30-50% coarse fraction of weathered granite; field pH 6.0-5.6.

Sites: 199, 240, 241, 245, 294, 295, 301, 539, 547, 554, 555, 620, 629, 677, 711, 712, 717, 720, 727, 745, 748,

HALY (Hl)

Concept: Mottled yellow or brown structured soils on lower slopes of basaltic pediments
Australian Classification: Brown Ferrosol
PPF: Uf6.4
Great Soil Group: Zanthozem
Landform type: Lower slopes of gently undulating pediments. Slopes 0-2%
Geology: Deeply weathered Tertiary Main Range basalt (Tm)
Vegetation: Mostly cleared. Rough barked apple, forest red gum, Moreton Bay ash and gum topped box open forest
Surface feature: Firm to hardsetting

Depth (m)



A1,Ap: Dark reddish brown or dark brown (5YR 3/3, 3/4, 7.5YR 3/4, 10YR 3/3, 3/4); light clay; strong granular; field pH 5.8-6.5. Clear to gradual change to

B21: Mottled; bright brown, yellowish brown or brown (7.5YR 5.5, 10YR 4/6, 5/6); light medium clay to medium clay; polyhedral; manganiferous nodules; field pH 6.5-7.0. Diffuse change to

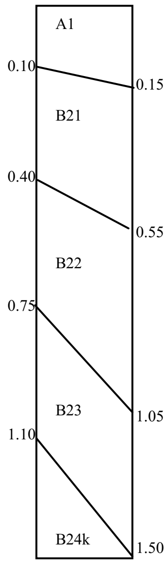
B22: Mottled; dark reddish brown, bright brown or yellowish brown (5YR 3/4, 3/6, 7.5YR 5/6, 10YR 5/6, 5/8); light medium clay to medium clay; strong polyhedral or subangular blocky; 2-20% manganiferous nodules; field pH 6.7-8.0.

Sites: 24, 55, 126, 170, 175, 178, 188, 195, 224, 227, 233, 234, 247, 276, 481, 559, 606, 691, 730, 767, 803

GUEENA (Gn)

Concept: Grey clays in drainage depressions on alluvium
Australian Classification: Grey Vertosol
PPF: Ug5.24, Ug5.28
Great Soil Group: Grey clays
Landform type: Levee backswamps and broad drainage lines. Slopes 0-1%
Geology: Quaternary alluvium (Qa)
Vegetation: Forest red gum open forest. Moderately developed grass layer of blue grasses
Surface feature: Cracking, self mulching, weak gilgai in uncultivated situation

Depth (m)



A1: Mottled; dark (10YR 2/1, 2/2, 3/1, 3/2); medium clay; strong medium blocky; dry very hard; manganiferous concretions.

B21: Brown mottled; grey (10YR, 2.5Y 4/1, 4/2, 5/2); medium clay to medium heavy clay; strong fine to medium blocky; dry very hard; manganiferous concretions.

B22 As above but strong medium lenticular.

B23: As above but only occasionally mottled.

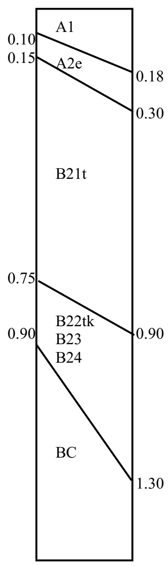
B24k: Grey (10YR, 2.5Y 4/1, 4/2) or occaionally brown (10YR 4/3); medium clay to medium heavy clay; strong fine blocky; dry very hard; manganiferous concretions, concretionary lime.

Sites: 142, 331, 342, 345, 354, 445

HILLSDALE (Hd)

Concept: Brown sodic texture contrast soil on lower slopes derived form sandstone
Australian Classification: Mesonatric Brown Sodosol, Grey Sodosol
PPF: Dy3.43, Db2.33, Db2.43
Great Soil Group: Solodic soil, solodized solonetz
Landform type: Hillslopes of undulating low hills to rolling hills. Slopes 3-12%
Geology: Sandstone
Vegetation: Narrow leaved ironbark, Moreton Bay ash. Ground cover of speargrass and kangaroo grass
Surface feature: Hardsetting

Depth (m)

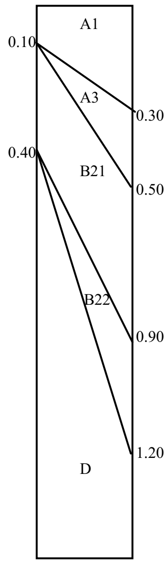


A1: Dark brown or brown (7.5YR, 10YR 2/2, 3/2, 5/3); sandy clay loam; massive to weak <2 mm granular structure; dry moderately weak consistence; field pH 5.8-6.8. Clear change to
A2e: Conspicuous or occasionally sporadically bleached; sandy clay loam; massive to weak <2mm granular structure; dry moderately weak consistence; field pH 5.3-6. Clear or abrupt change to
B21t: Grey to yellow mottled; brown or dark greyish brown (7.5YR, 10YR 4/2, 4/4); light medium clay to medium clay to sandy clay; occasionally strong 100-200 mm columnar structure breaking to strong 10-20 m prismatic or subangular blocky; dry very firm to hard consistence; 0-10% manganiferous segregations and concretions; field pH 6.8-9.1. Gradual change to
B22tk: Grey to yellow mottled; yellowish brown or light olive brown (7.5YR, 10YR, 2.5Y, 5/4, 5/6); light medium clay to medium clay; strong 20-60 mm subangular blocky to 60-200 mm prismatic structure; dry very firm consistence; 0-2% manganiferous concretions, 2-10% carbonate concretions; field pH 8.3 to 9.1. Gradual change to
B23: As above except brown (10YR 4/4); light medium clay, strong 20-60 mm angular blocky structure
B24 As above except light yellowish brown (2.5Y 6/4); light clay, then as above. Gradual change to
BC: Olive yellow (10YR 6/6); sandy clay to light clay; moderate 6-20 mm subangular blocky to massive structure; 10-50% fragments of weathered sandstone; field pH 9.1.
Sites: 111, 160, 198, 300, 358, 470, 478, 532, 543, 545, 546, 590, 800, 804

HIRST (Ht)

Concept: Massive hardsetting surface over brown structured subsoils on levels and channel benches
Australian Classification: Brown Dermosol, Brown Chromosol
Gn3.22, Gn3.52, Db2.33, Db2.12, Dy3.43
Great Soil Group: No suitable group, affinities with soloth
Landform type: Levees and terraces and backplains of minor creeks
Geology: Quaternary alluvium (Qa)
Vegetaton: Forest red gum and Moreton Bay ash open forest. Some broad leaved ironbark. Occasional stands of Belah
Surface feature: Firm to hardsetting

Depth (m)



A1: Dark brown or brownish black (7.5YR, 10YR 2/2, 2/3, 3/3, 3/2); loamy sand to sandy loam to silty clay loam; massive to moderate fine granular structure; dry slightly hard consistence. Clear change to

A3: Brown or yellow brown (7.5YR, 10YR 3/4, 4/4, 6/4); sandy loam to clay loam; weak to moderate fine granular structure. Clear change to

B21: Reddish brown or dark brown or yellowish brown (5YR, 7.5YR, 10YR 3/4, 4/6, 6/4); sandy clay loam to sandy light clay; moderate fine subangular blocky to angular blocky structure; trace amount manganese concretions. Gradual change to

B22: As above except grey to yellow mottled, and strong angular blocky structure.

D: Occasionlly grey mottled; reddish brown or brown or yellow (5YR, 7.5YR, 10YR 4/4, 4/6, 5/6); coarse sand to sandy loam; massive to weak fine granular to subangular blocky; traces of managanese concretions.

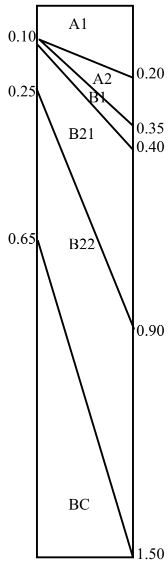
Variants: Some surface textures are sandy in alluvial fan deposits. In backplain areas, bleached variants occur. B horizons may have a sandy clay loam texture under sandy A horizons which can be massive. Some variants include deep sandy soils PPF Uc3.32.

Sites: 442. Also refer to Gordonbrook Reference area – west of study area.

HODGLEIGH (Hg)

Concept: Deep hardsetting fine sandy clay loam to clay loam sandy surface over strongly structured brown neutral clayey B horizon on lower slopes of sedimentary rocks
Australian Classification: Red Chromosol, Brown Sodosol, Brown Dermosol
PPF: Dr2.12, Dy3.42, Db2.32
Great Soil Group: Non-calcic brown, solodic soils, no suitable group
Landform type: Pediments and foot slopes of undulating low hills. Slopes 1-6%
Geology: Colluvium off Marburg sandstone and Tarong sediments
Vegetation: Narrow leaved ironbark open woodland
Surface feature: Firm to hardsetting

Depth (m)



A1: Dark brown or brown black (7.5YR, 10YR 3/2, 3/3); fine sandy clay loam to clay loam sandy; massive to moderate fine granular structure; field pH 5.8-7.0. Clear or gradual change to

A2, e,j: Occasionally sporadically on conspicuously bleached; dull orange or brown (7.5YR 3/4); sandy clay loam to clay loam sandy; massive to weak granular structure; field pH5.8–7.5; frequently moderate amounts manganese concretions. Clear change to

B1: Dark brown (7.5YR 3/4); light clay; moderate 10-50 mm angular blocky to subangular blocky; field pH 72. Gradual change to

B21: Occasionally mottled; dull yellow orange or reddish brown or brown (5YR, 7.5YR, 10YR 4/4, 4/6, 6/4); light medium to medium clay; strong fine angular blocky to coarse prismatic structure; small amounts ferruginous concretions and ferromanganiferous nodules. Gradual change to

B22: Frequently mottled; reddish brown or bright yellowish brown or brown (5YR, 7.5YR, 4/4, 6/4, 10YR 4/6); light medium clay to medium clay; strong 20-50 mm angular blocky; 0-10% manganese segregations. Gradual change to

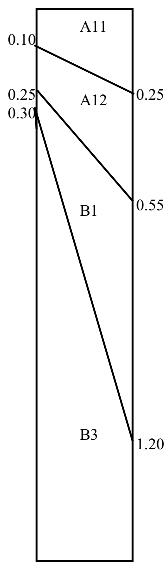
BC: Dull yellowish brown (10YR 5/4); sandy clay loam to fine sandy light medium clay; weak subangular blocky: manganese segregations.

Sites: 200, 317, 361, 801

HOPEVALE (Hv)

Concept: Shallow to moderately deep loose surface (snuffy) red structured soil developed on deeply weathered basalt
Australian Classification: Red Ferrosol
PPF: Um4.21, Um5.21, Um6.24, Um6.31, Um6.33
Great Soil Group: Red earth
Landform type: Margins of plateaus, hill crests and upper slopes of undulating rises and rolling hills. Slopes 1-3%
Geology: Deeply weathered basaltic material
Vegetation: Mostly cleared. Minor softwood scrub
Surface feature: Loose

Depth (m)



A11: Reddish brown (2.5YR, 10R 2/2, 2/3, 2/4, 3/2, 3/3, 3/4); loam; massive to weak very fine granular, large amounts ironstone; trace amounts manganiferous concretions. Clear change to

A12: As above but loam to light clay loam with extremely large amounts ferruginous gravel; weak to medium very fine granular; dry hard; trace amounts manganiferous concretions. Gradual change to

B1: As above (but not always present) clay loam with increasingly large amounts ferruginous gravel; medium fine granular; dry very hard. Gradual change to

B3: Reddish brown (2.5YR, 10R 3/3, 3/4, 3/6, 4/4); loam to light clay with very large amounts ferruginous material; massive to weak fine polyhedral; dry hard; large amounts of ironstone and trace amounts manganiferous concretions.

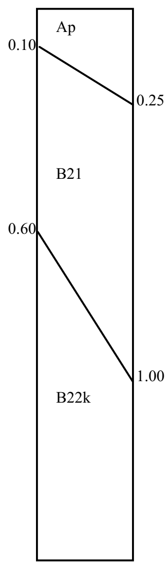
C: Lateritic, kaolinized basalt (ferruginous material).

Sites: 274, 466, 529, 591, 605, 633, 637, 738, 753

IONA (In)

Concept: Brown or black cracking clays over brown subsoils on lower slopes of pediments derived from fresh basalt
Australian Classification: Brown Vertosol, Black Vertosol
PPF: Ug5.34, Ug5.17, Ug5.15
Great Soil Group: Brown clays, black earth
Landform type: Lower slopes of gently undulating pediments. Slopes 0-5%
Geology: Tertiary Main Range basalt (Tm)
Vegetation: Silver leaved ironbark, Moreton Bay ash open forest
Surface feature: Self mulching, cracking

Depth (m)



Ap: Dark (7.5YR 3/2, 10YR 2/3); light medium clay to medium clay; strong subangular blocky; field pH 6.0-6.5. Clear change to

B21: Dark, dark brown or brown (7.5YR 2/2, 3/3, 3/4, 4/4, 10YR 3/2); medium clay to medium heavy clay; subangular blocky in upper horizon becoming lenticular in lower horizon; field pH 7.0-8.5. Diffuse change to

B22k: Dark brown or reddish brown (5YR 3/4, 4/6, 7.5YR 3/4); medium clay to medium heavy clay; strong lenticular; calcareous segregations; field pH 8.5-9.5.

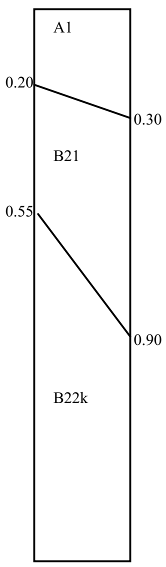
D: Gravelly horizons occasionally occur.

Sites: 118, 133, 145, 155, 161, 232, 303, 407

KABER (Kr)

Concept: Brown cracking clays on alluvial fans
Australian Classification: Brown Vertosol
PPF: Ug5.34
Great Soil Group: Brown clays
Landform type: Alluvial fans receiving wash from adjacent hills. Slopes 0.5-1.5%
Geology: Quaternary alluvium (Qa)
Vegetation: Forest red gum and broad leaved ironbark open forest
Surface feature: Cracking, weak self mulching

Depth (m)



A1: Brown (7.5YR, 10YR 3/3, 5/3); light clay to light medium clay; moderate fine blocky; dry hard to very hard; iron manganese concretions.

B21: Brown (7.5YR, 10YR 3/3, 4/3, 4/4); medium clay to medium heavy clay; strong medium blocky; dry very hard; manganiferous concretions.

B22k: As above but frequently mottled and with concretionary lime.

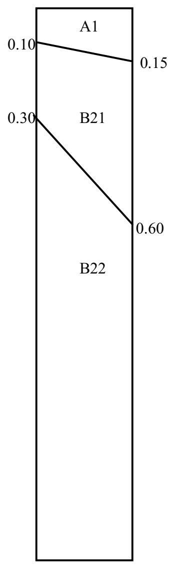
Variant: A dark (10YR 3/1, 3/2) medium clay D horizon may occur below 0.9 m.

Sites: 5, 23, 266, 283, 290, 477, 486, 528, 531, 560, 565, 583, 611, 612, 619, 627, 673, 733, 746, 755, 760, 777

KAWL KAWL (Kk)

Concept: Gilgaied grey clay on old alluvium
Australian Classification: Grey Vertosol
PPF: Ug5.24, Ug5.21
Great Soil Group: Grey clay
Landform type: Gently undulating plains. Slopes 0-5%
Geology: Quaternary alluvium (Qa), Tertiary sediments (Ts)
Vegetation: Brigalow, belah, gum topped box open forest with softwood scrub understorey. Extensively cleared.
Surface feature: Gilgaied, hardsetting, cracking

Depth (m)



A1: Dark, grey yellow brown or dark greyish yellow (7.5YR 2/2, 3/2, 10YR 2/2, 3/1, 3/3, 4/2, 2.5Y 5/2); light medium clay to medium clay; strong subangular blocky or occasionally granular; field pH 6.5-9. Clear to gradual change to

B21: Brownish grey or dark greyish yellow (10YR 4/1, 4/2, 2.5Y 5/2); light medium clay to medium heavy clay; angular blocky or lenticular; field pH 7-9. Clear change to

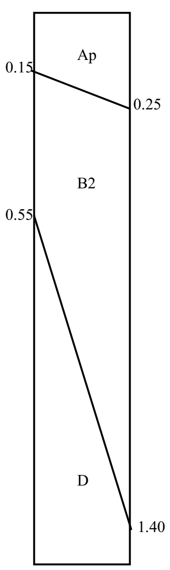
B22: Frequently mottled; brownish grey, greyish yellow brown or dark greyish yellow (7.5YR 4/2, 10YR 4/1, 10YR 5/1, 10YR 5/2, 2.5Y 5/2); light medium clay to medium heavy clay; lenticular; calcareous segregations; field pH 8-9.5.

Sites: 556, 588, 592, 610

KUMBIA (Kb)

Concept: Mottled, yellow or brown structured soils derived from tertiary deeply weathered pediments over buried tertiary clays
Australian Classification: Brown Ferrosol, Red Ferrosol
PPF: Uf6.4, Gn3.12
Great Soil Group: Xanthozem
Landform type: Lower slopes of very gently undulating pediments. Slopes 0-3%
Geology: Deeply weathered Tertiary Main Range basalts (Tm)
Vegetation: Mostly cleared. Rough barked apple, forest red gum Moreton Bay ash and gum topped box open forest
Surface feature: Hardsetting

Depth (m)



Ap: Dark brown or dull reddish brown (5YR 4/4, 7.5YR 3/3, 3/4, 10YR 3/4); clay loam to light medium clay; moderate to strong granular; frequently manganiferous segregations; field pH 5.8-6.3. Clear change to

B2: Frequently mottled; brown, yellowish brown or reddish brown (5YR 4/6, 7.5YR 4/4, 4/6, 5/6, 10YR 4/6, 5/6); light clay to medium clay; strong polyhedral; manganiferous segregations; field pH 6-8. Clear change to

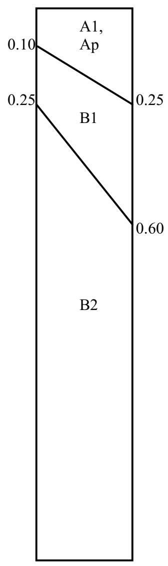
D: Mottled; brown, dull brown, bright brown or yellowish brown (7.5YR 4/4, 5/4, 5/6, 10YR 4/6, 5/6, 6/6); medium clay to heavy clay; strong angular blocky, field pH 7-9.

Sites: 2, 3, 85, 90, 97, 101, 125, 127, 131, 164, 167, 168, 173, 184, 191, 194, 204, 237, 248, 404, 406, 471, 498, 589, 594, 597, 640, 652, 758, 783

KUNIOON (Kn)

Concept: Mottled, yellow or brown structured soil with large amounts (>20%) of manganiferous nodules on pediments derived from deeply weathered basalt
Australian Classification: Brown Ferrosol, Red Ferrosol
PPF: Uf6.4
Great Soil Group: Xanthozem
Landform type: Lower slopes of gently undulating pediments. Slopes 0-3%
Geology: Deeply weathered Tertiary Main Range basalt (Tm)
Vegetation: Rough barked apple, forest red gum, Moreton Bay ash open forest
Surface feature: Hardsetting

Depth (m)



A1,Ap: Dark brown or dark reddish brown (5YR 3/4, 4/4, 7.5YR 3/3, 3/4); clay loam to light clay; moderate to strong granular; 2-20% manganiferous nodules; field pH 6.0-6.5. Clear to gradual change to

B1: Mottled; brown, reddish brown or yellowish brown (5YR 4/4, 4/6, 7.5YR 4/3, 4/4, 4/6, 5/6, 10YR 5/6); light clay to light medium clay; strong granular or polyhedral; 2-50% manganiferous nodules; field pH 5.5-7.0. Gradual change to

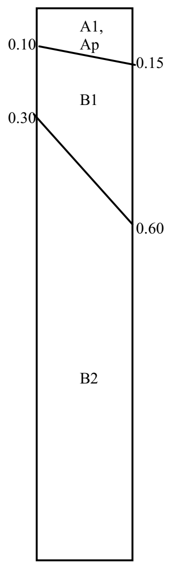
B2: Mottled; bright brown, reddish brown or dull yellow orange (5YR 4/6, 5/6, 7.5YR 5/6, 10YR 4/6); light clay to medium clay; strong polyhedral; 10-50% manganiferous nodules; field pH 5.0-7.0.

Sites: 6, 120, 129, 135, 176, 177, 202, 206, 221, 536, 569, 642, 697, 706, 713, 714, 793

LANKOWSKY (Lk)

Concept: Deep red massive soils on deeply weathered Tertiary sediments
Australian Classification: Red Kandosol
PPF: Gn2.12, Gn2.15
Great Soil Group: Red earth
Landform type: Upper slopes and crests of gently undulating low hills. Slopes 1-4%
Geology: Tertiary sediments (Ts)
Vegetation: Cleared
Surface feature: Firm

Depth (m)



A1, Ap: Dark reddish brown (5YR 2/4, 3/3); light sandy clay loam to clay loam; massive to weak granular; field pH 5.8-6.0. Gradual change to

B1: Dark reddish brown (2.5YR 3/4, 5YR 3/3); sandy clay loam to clay loam; massive; field pH 6.0-7.0. Diffuse change to

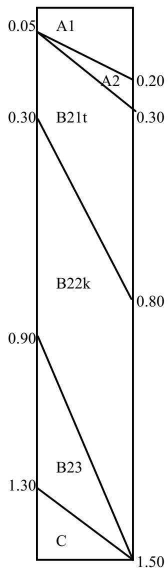
B2: Dark reddish brown (2.5YR 3/6); clay loam to light clay; massive to weak polyhedral; field pH 6.7-7.0.

Sites: 757, S39

LONG PETER (Lp)

Concept: Hardsetting clay loam surfaced, brown sodic texture contrast soil on Tertiary sediments hillcrests
Australian Classification: Brown Sodosol
PPF: Db1.13, Db2.13, Dy3.13, Dy2.13, Dy3.23
Great Soil Group: Solodic soil
Landform type: Broad crest of low hills. Slopes 0-1.5%
Geology: Tertiary sediments (Ts)
Vegetation: Gum topped box and narrow leaved ironbark open forest. Regrowth of black tea tree can occur after clearing. Moderately developed grass layer of blue grass and love grass
Surface feature: Hardsetting

Depth (m)



A1: Dark or brown (7.5YR, 10YR 2/2, 2/3, 3/2, 3/3, 3/4); clay loam, clay loam sandy to fine sandy clay loam; weak to moderate medium blocky; dry hard; manganiferous concretions.
A2: Occasionally present. As above but brown (10YR, 7.5YR 4/4).
B21t: Occasionally red, yellow or brown mottled; brown or yellow brown or yellow (7.5YR, 10YR 3/4, 4/3, 4/4, 3/5, 5/4, 5/6, 5/8); light medium clay to medium heavy clay; strong medium blocky to prismatic; dry hard to extremely hard; manganiferous concretions.
B22 k: Brown or yellow brown or yellow (7.5YR 10YR 3/4, 4/3, 4/4, 4/6, 5/4, 5/6, 5/8, 6/8); medium clay to medium heavy clay; moderate medium blocky to strong medium lenticular; dry very hard to extremely hard; manganiferous concretions, soft or concretionary lime; occasionally ferruginous segregations.
B23: As above but without lime, discontinuous mangans occasionally occur.
C: Occasionally present. Moderately grey, gley, brown or yellow mottled; grey or yellow brown or yellow or brown (10YR, 7.5YR 4/4, 4/6, 5/4, 5/6, 6/2, 6/4, 7/2); sandy light clay to medium heavy clay; moderate medium blocky; dry very hard to extremely hard; manganiferous concretions and vein; ferruginous segregations.
Notes: 2-15% surface gravel (3-75 mm), angular (silcrete) to subangular to rounded petrified wood, kaolinised basalt, chert, chalcedony, ironstone and silcrete.

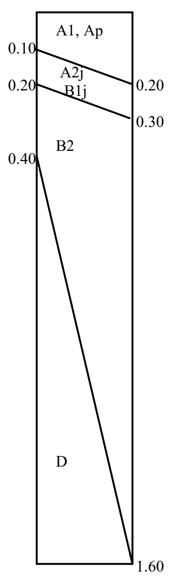
Variants: Loam A11 horizons 2.5 to 8 cm thick occasionally occur in uncultivated situations

Sites: 440, 462, 465, 497, 517

MARSHLANDS (Ml)

Concept: Gilgaied, hardsetting, texture contrast and uniform soils over sodic D horizons on old alluvial plains
Australian Classification: Brown Sodosol
PPF: Db2.33, Uf6.41p, Dy3.32, Dy3.31, Uf3
Great Soil Group: Solodic soil, soloth
Landform type: Plains. Slopes 0-3%
Geology: Quaternary alluvium (Qa), Tertiary sediments (Ts
Vegetation: Poplar box open forest
Surface feature: Hardsetting

Depth (m)



A1, Ap: Dark brown or dull yellowish brown (7.5YR 3/3, 3/4, 10YR 3/4, 4/3); sandy clay loam to light clay; strong granular; 2-10% manganiferous concretions; field pH 6-6.5. Clear change to

A2j, B1j: Sporadically bleached in undistributed soils; dark brown, dull yellowish brown or brown (7.5YR 3/4, 4/3, 4/4, 10YR 3/4, 4/4); sandy clay loam to light clay; strong granular to subangular blocky; 2-20% manganiferous concretions; field pH 6.5-7.5. Clear to abrupt change to

B2: Mottled; yellowish brown or brown (7.5YR 4/6, 10YR 4/4, 4/6, 5/6, 5/8); light medium clay to medium heavy clay; polyhedral or subangular blocky; 2-20% manganiferous concretions; field pH 5.8-8.5. Clear change to

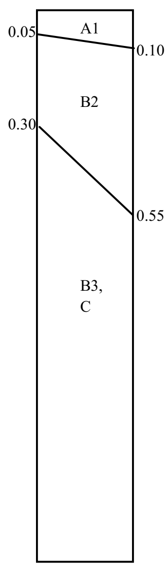
D: Mottled; brown or yellowish brown (7.5YR 4/6, 5/6, 10YR 4/4, 4/6, 5/6); medium heavy to heavy clay; angular blocky, prismatic or lenticular; 2-20% manganiferous concretions and occasionally calcareous segregations; field pH 7.0-9.0.

Sites: 364, 383, 389, 397, 418, 439

McEUEN (Mn)

Concept: Shallow dark clays on basalt
Australian Classification: Black Vertosol, Brown Vertosol
PPF: Ug5.12, Ug5.32, Ug5.13
Great Soil Group: Black earths, brown clay
Landform type: Upper slopes and crests of undulating rises and low hills. Slopes 0-10%
Geology: Tertiary Main Range basalt (Tm)
Vegetation: Silver leaved ironbark open forest
Surface feature: Self mulching, cracking, surface coarse fragments

Depth (m)



A1: Dark, brownish black or dark brown (7.5YR 3/2, 3/3, 10YR 2/2, 2/3); light clay to medium clay; strong subangular blocky; field pH 6.0-7.0. Clear change to

B2: Dark, brownish black or dark brown (7.5YR 2/3, 3/2, 3/3, 10YR 2/2, 3/2, 3/3); medium clay to medium heavy clay; strong subangular blocky or lenticular; field pH 7.8-8.5. Clear change to

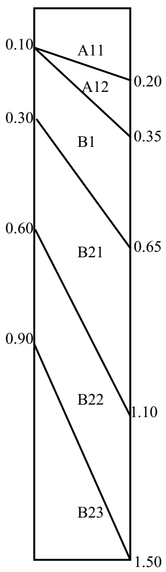
B3, C: Dark, brownish black or dark brown (10YR 2/3, 3/3); light clay to medium heavy clay with rock fragments or weathered rock; field pH 8.5-8.8.

Sites: 4, 16, 19, 21, 34, 54, 77, 78, 81, 83, 84, 92, 98, 109, 110, 127, 134, 137, 152, 156, 172, 175, 281, 285, 289, 426, 485, 489, 492, 516, 519, 527, 568, 631, 649, 667, 701, 742, 773, 763

MEMERAMBI (Mm)

Concept: Deep acid red structured uniform and gradational soils on deeply weathered basalt
Australian Classification: Red Ferrosol
PPF: Uf6.31, Gn3.11
Great Soil Group: Krasnozem
Landform type: Mid to upper slopes of undulating rises to rolling hills
Geology: Deeply weathered Tertiary Main Range basalt (Tm)
Vegetation: Mostly cleared
Surface feature: Firm

Depth (m)



A11: Dark reddish brown (2.5YR, 10R, 3/3, 3/4); clay loam to light clay; weak very fine granular to moderate fine granular; dry slightly hard; small amounts ferruginous material included; ironstone and manganiferous concretions.

A12: As above except strong fine granular to strong fine polyhedral; dry hard; moderate amounts ferruginous ironstone; small amounts manganiferous concretions.

B1: As above but light to light clay; ferruginous material increasing with depth.

B21: Reddish brown (2.5YR, 10R, 3/4, 3/6); light clay to light medium clay with 15-50% rounded ferruginous coarse material; strong medium subangular blocky to strong fine polyhedral; dry very hard; moderate amounts ironstone and' manganiferous concretions.

B22: As above with >50% rounded ferruginous coarse material and subangular lateritic material.

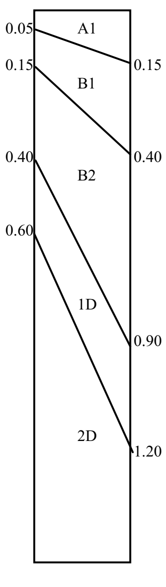
B23: As above but clay loam to light clay, large amounts ferruginous gravel, strong fine polyhedral; dry very hard.

Sites: 107, 148, 149, 169, 236, 251, 252, 260, 265, 273, 277, 523, 563, 570, 571, 581, 602, 625, 630, 632, 668, 669, 671, 679, 680, 683, 684, 685, 687, 688, 694, 739, 741, 751, 754, 759, 764, 766, 792, 796, 799, 807

NARRAWONG (Nr)

Concept: Mottled red structured soil derived from transport deeply weathered basaltic material overlying old alluvium
Australian Classification: Red Ferrosol
PPF: Gn3.12, Gn3.52, Gn3.22, Gn3.33, Gn4.12
Great Soil Group: Euchrozems
Landform type: Sloping area or crests of rises. Slopes 1-5%
Geology: Transported material of basaltic origin overlying Tertiary sediments
Vegetation: Cleared
Surface feature: Hardsetting

Depth (m)



A1: Red brown or dark (5YR, 7.5YR 2/2, 3/2, 3/3, 3/4); clay loam to clay loam sandy; moderate fine subangular blocky; dry slightly hard; manganiferous concretions.

B1: Red or red-brown (2.5YR, 5YR 3/4, 4/4, 4/6) or occasionally brown (7.5 YR 4/4); light clay; strong fine blocky to moderate fine subangular blocky; dry hard to slightly hard; manganiferous concretions.

B2: Occasionally yellow mottled; red or brown (2.5YR, 5YR, 7.5YR 4/6, 4/8); light medium clay; strong fine to medium blocky to polyhedral; dry very hard to hard; manganiferous concretions.

1D: Frequently red or yellow mottled; brown or yellow (10YR 4/4, 4/6, 5/6); light medium clay to medium heavy clay; moderate fine to medium angular blocky or occasionally strong medium lenticular; dry hard to very hard; manganiferous concretions.

2D: Frequently grey or yellow mottled; brown or yellow (7.5YR, 10YR 4/6, 5/8, 6/6); medium to medium heavy clay; moderate fine to medium blocky; dry very hard, manganiferous concretions and veins, frequently concretionary lime.

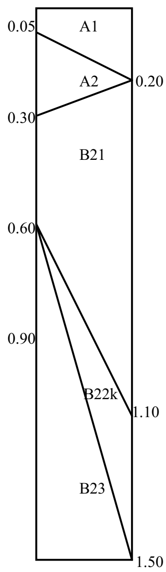
Notes: Surface 1-5% subangular to rounded ironstone, kaolinized basalt chert chalcedony and silcrete gravel 3-50 mm

Sites: 131, 213, M216, 217, 234, 268

MONDURE (Md)

Concept: Non cracking brown clays on elevated old alluvial plains
Australian Classification: Brown Dermosol
PPF: Uf6.31, Uf4.42, Uf6.4, Gn3.23, Db1.13
Great Soil Group: No suitable group
Landform type: Elevated plains. Slopes 1-3%
Geology: Quaternary alluvia (Qa)
Vegetation: Narrow leaved ironbark and gun topped box with occasional forest red gum open forest, moderately developed grass layer of kangaroo grass and glue grass
Surface feature: Firm to hardsetting, occasionally gilgaied

Depth (m)



A1: Brown or red brown (7.5YR, 5YR 3/3, 3/4, 4/4) or occasionally dark (7.5YR 3/2); light clay or occasionally clay loam; weak fine granular; dry slightly hard to hard; manganiferous concretions, occasionally ironstone segregations.

A2: Occasionally present. As above dark mottled; brown (7.5YR 4/4); light clay.

B21: Occasionally red mottled; brown or yellow brown or yellow (7.5YR, 10YR 3/4, 4/3, 4/4, 4/6, 5/4, 5/6); light medium clay to medium clay; moderate medium blocky; dry hard to extremely hard; manganiferous concretions.

B22k: Frequently present. Brown or yellow brown or yellow (7.5YR, 10YR 3/4, 4/3, 4/4, 4/6, 5/4, 5/6); medium clay to medium heavy clay; moderate medium blocky to strong medium lenticular; dry very hard to extremely hard; manganiferous concretions, concretionary lime.

B23: As above but occasionally yellow or grey mottled; manganiferous concretions and/or veins, with or without lime.

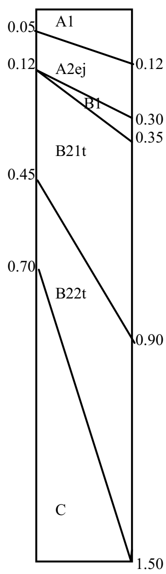
Notes: Surface carries 0-10% subangular to rounded kaolinised, ironstone, laterite, basalt and silcrete gravel
5-100 mm.

Sites: 126, 127, 182, 189, 190, 191, 194, 196, 203, 204, 205, 206, 207, 208, 507

PALOUSE (Pl)

Concept: Hardsetting sandy loam to light sandy clay loam surfaced mottled brown sodic texture contrast soil on Tertiary sediments
Australian Classification: Brown Sodosol
PPF: Dy3.43, Dy2.43, Db2.43, Dy3.33, Db2.33
Great Soil Group: Solodic soil, solodized solonetz
Landform type: Crest and slopes of low hills. Slopes 1-7%
Geology: Tertiary sediments (Ts)
Vegetation: Narrow leaved ironbark, gum topped box and belah open forest
Surface feature: Hardsetting

Depth (m)



A1: Brown or grey (7.5YR, 10YR 3/3, 3/4, 4/2, 4/3, 4/4); sandy loam to light sandy clay loam to fine sandy loam; massive to weak fine granular or subangular blocky; very slightly hard to very hard; manganiferous concretions.

A2j,e: As above but sporadically or conspicuously bleached and occasionally loamy sand.

B1: Occasionally present. Dark mottled; yellow brown (10YR 5/4); sandy clay; strong coarse columnar; dry extremely hard; manganiferous concretions.

B21t: Frequently brown, red or yellow mottled; yellow or yellow brown or brown (7.5YR, 10YR 4/3, 4/4, 4/6, 5/3, 5/4, 5/6, 6/3); light medium clay to medium heavy clay; strong coarse columnar to strong medium prismatic; dry extremely hard; manganiferous concretions.

B22t: As above but whole coloured, occasionally strong coarse lenticular and frequently with soft or concretionary lime.

C: Brown, grey, gley or yellow mottled; grey or yellow brown or yellow (10YR 5/6, 6/2, 6/4, 6/6, 7/1, 7/2, 8/1, 8/2); sandy clay loam to sandy light clay to medium clay; moderate medium angular blocky to massive; dry hard to extremely hard; manganiferous veins and ferruginous segregations.

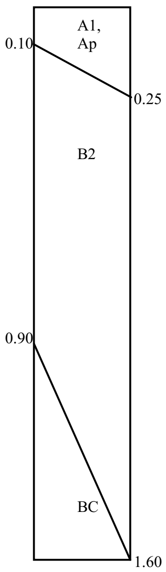
Notes: Surface carries 2-15% angular (silcrete) to subangular to rounded, petrified wood, kaolonized basalt, chert, chalcedony, ironstone and silcrete gravel 3-75mm. Up to 15% stone cover of weakly lithified argillaceous sandstone also occurs in some areas. This apparently turns from grey to yellow-brown on exposure and is the massive, extremely hard material mentioned in the C horizon

Sites: 150, 151, 169, 518, S5. M219, 220, 221, 228, 233, 271, 280, 281, 290, 330, 343, 365, 423, 452

PROSTON (Pt)

Concept: Red structured soil with large amounts of ferruginous gravel on deeply weathered basalt
Australian Classification: Red Ferrosol
PPF: Gn3.11, Uf6.31, Um6.31
Great Soil Group: Krasnozem
Landform type: Upper slopes and hill crests of undulating rises and rolling hills, and plateau margins. Slopes 5-20%
Geology: Deeply weathered Tertiary Main Range basalt (Tm)
Vegetation: Soft wood scrub. Mostly cleared
Surface feature: Firm

Depth (m)



A1,Ap: Dark reddish brown (2.5YR 3/3, 3/5, 3/6); clay loam to light clay; weak to moderate granular; 2-20% ferruginous gravel, field pH 5.5-6.0. Clear to gradual change to

B2: Dark reddish brown or dark red (2.5YR 3/4, 3/6, 4/6, 10R 3/4); clay loam to light clay; moderate to strong polyhedral; 10-50% ferruginous gravel; field pH 4.5-6.0. Gradual to diffuse change to

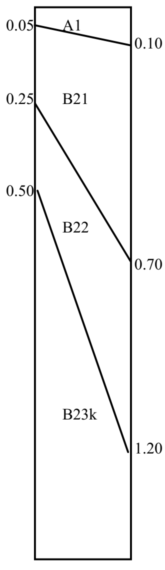
B/C: As above with weathered rock.

Sites: 115, 201, 253, 580, 663, 784

SADIE (Sd)

Concept: Deep black cracking clays on lower slopes of pediments derived from fresh basalt
Australian Classification: Black Vertosol
PPF: Ug5.16
Great Soil Group: Black earth
Landform type: Lower slopes of pediments. Slopes 0-1%
Geology: Quaternary alluvium (Qa)
Vegetation: Forest red gum open forest with occasional broad leaved apple. Well developed grass layer of blue grasses
Surface feature: Cracking, self mulching

Depth (m)



A1: Dark (7.5YR, 10YR, 2/2/, 3/2) or occasionally brown (10YR 2/3, 3/3); light medium clay to medium heavy clay; strong fine granular, dry very hard.

B21: Dark (7.5YR, 10YR 2/1, 2/2, 3/1, 3/2); medium clay to medium heavy clay; moderate medium to fine subangular blocky; dry very hard; occasionally manganiferous concretions, iron segregations and concretionary lime.

B22: As above but strong medium to coarse lenticular; manganiferous concretions, iron segregations and occasionally concretionary lime.

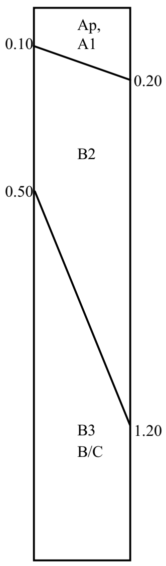
B23k: Occasionally yellow or grey mottled; grey or yellow brown (10YR, 2.5Y 4/2, 4/2, 5/3) or occasionally dark (10YR 2/1, 3/1); medium clay to medium heavy clay; moderate fine to medium subangular blocky; dry very hard; manganiferous concretions and moderate amounts concretionary lime.

Sites: 152, 166, 167, M206, 207, 433, 450, 451, 454

TAABINGA (Tb)

Concept: Neutral structured red soil on weathered basalt
Australian Classification: Red Ferrosol
PPF: Uf6.31, Gn3.12, Gn3.13
Great Soil Group: Euchrozem
Landform type: Upper slopes and crests of undulating rises to rolling hills. Slopes 2-5%
Geology: Tertiary Main Range basalt (Tm)
Vegetation: Cleared
Surface feature: Hardsetting

Depth (m)



Ap,A1: Dark reddish brown (2.5YR 3/4, 5YR 2/3, 3/3, 3/4, 3/6); clay loam to light clay; moderate to strong granular; frequently ferruginous concretions; field pH 5.5-6.8. Gradual change to

B2: Reddish brown or dark reddish brown (2.5YR 3/6, 4/6. 5YR 3/4, 3/6, 4/6); light clay to medium clay; moderate to strong polyhedral; frequently ferruginous concretions; field pH 7.0-8.5. Gradual change to

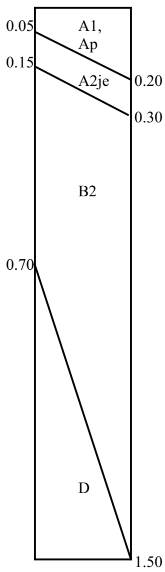
B3, B/C: Mottled; bright brown, reddish brown or dull brown (2.5YR 4/6, 5/8, 5YR 4/6, 4/8, 5/6, 5/9, 7.5YR 5/4); clay loam to medium clay with rock fragments or weathered rock; field pH 7.0-9.0.

Sites: 7, 8, 11, 89, 102, 103, 327, 526

TARONG (Tr)

Concept: Hardsetting, bleached, brown or yellow texture contrast soils on pediments derived from mixed basaltic material and sediments
Australian Classification: Brown Chromosol, Brown Dermosol, Yellow Chromosol, Yellow Dermosol
PPF: Dy3.41, Dy3.32, Dy3.31, Db2.31
Great Soil Group: Yellow podzolic soil, brown podzolic soil, no suitable group
Landform type: Lower slopes of gently undulating pediments. Slopes 0-4%
Geology: Mixed basaltic material and unconsolidated sediments
Vegetation: Narrow leaved ironbark open forest with scattered forest red gum
Surface feature: Hardsetting

Depth (m)



A1,Ap: Dark brown or greyish brown (5YR 3/4, 7.5YR 3/4, 4/2, 10YR 3/3, 3/4); sandy loam to clay loam sandy; granular or massive; field pH 6.0-7.0. Clear change to

A2j,e: Sporadically or conspicuously bleached; sandy loam to clay loam sandy; massive to weak granular; frequently manganiferous nodules; field pH 6.0-7.0. Clear to abrupt change to

B2: Mottled; yellowsh brown, bright brown or greyish brown (7.5YR 5/6, 5/8, 10YR 4/4, 4/6, 5/4, 5/6, 6/8); light clay to medium clay; polyhedral or subangular blocky; 2-20% manganiferous nodules; field pH 6.0-7.5. Clear change to

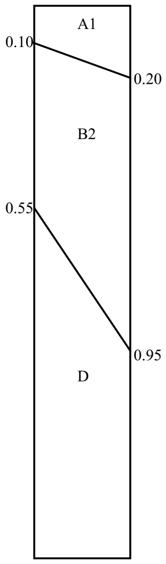
D: Frequently occurs. Mottled; bright brown or yellowish brown (7.5YR 5/6, 10YR 4/4, 5/6, 5/8); medium clay to heavy clay; lenticular or angular blocky; field pH 5.5-9.0.

Sites: 106, 186, 214, 222, 223, 226, 229, 438, 537, 618, 690, 707, 708, 726, 731, 781, 789, 808

TERRACE (Ta)

Concept: Dark clay over buried deposition layers on flood plains
Australian Classification: Black Dermosol, Black Vertosol
PPF: Uf6.32, Ug5.15
Great Soil Group: Prairie soil, minor black earth
Landform type: Flood plain below main levee level. Slopes 1-10%
Geology: Quaternary alluvium (Qa)
Vegetation: Forest red rum, rough barked apple and broad leaved ironbark open forest. Some red bottlebrush occurs. Moderately developed grass layer of blue grasses
Surface feature: Firm

Depth (m)



A1: Dark (10YR, 2.5Y 3/1, 3/2); sandy light clay; strong fine subangular blocky; dry very hard.

B2: Dark (10YR 2/3, 3/2); light medium clay to medium clay; strong fine subangular blocky; dry very hard.

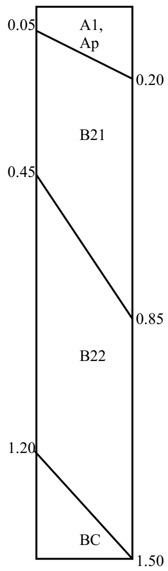
D: Brown (7.5YR, 10YR 3/3, 4/3, 4/4); sandy light clay; moderate medium subangular blocky; dry hard.

Sites: 314, 321, 444, 599. See also Gordonbrook Reference Area sites - west of study area. DNR, Indooroopilly.

TINGOORA (Tg)

Concept: Deep black and brown clays on fresh basalt
Australian Classification: Brown Vertosol, Black Vertosol
PPF: Ug5.32, Ug5.13, Ug5.12, Ug5.34
Great Soil Group: Brown clay, black earth
Landform type: Mid to lower slopes on undulating rises and low hills. Slopes 3-8%
Geology: Tertiary Main Range basalt (Tm)
Vegetation: Silver leaved ironbark open forest. Extensively cleared
Surface feature: Self mulching, cracking

Depth (m)



A1,Ap: Dark or dark brown (7.5YR 2/1, 3/2, 3/4, 10YR 3/3); light medium clay to medium clay; strong subangular blocky; field pH 6.0-8.5. Clear change to

B21: Dark or dark brown (7.5YR 3/2, 3/3, 4/3, 10YR 2/3, 3/3); medium clay to medium heavy clay; strong lenticular; field pH 7.0-8.5. Gradual change to

B22k: Dark brown, brown or dull yellowish brown (7.5YR 3/4, 4/3, 4/4, 10YR 4/3); medium clay to heavy clay; strong lenticular; 10-20% calcareous segregations; field pH 8.5-9.3. Clear to gradual change to

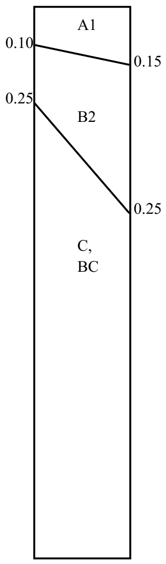
BC: Brown (7.5YR 3/4, 10YR 3/6); clay loam to medium clay with rock fragments; field pH 8.5-9.5.

Sites: 26, 171, 282, 425, 476, 500, 651, 740, 809

TUREEN (Tn)

Concept: Stony, shallow, black to brown soils on fresh basalt
Australian Classification: Uf6.32, Uf6.31, Db1.12
PPF: Black Dermosol, Brown Dermosol
Great Soil Group: Praire soil
Landform type: Upper slopes and crests of undulating rises and low hills. Slopes 0-15%
Geology: Tertiary main range basalt (Tm)
Vegetation: Silver leaved ironbark, narrow leaved ironbark open forest
Surface feature: Firm

Depth (m)



A1: Dark (7.5 YR 2/1, 2/2, 2/3, 3/2, YR 2/1, 2/2); light clay or occasionally clay loam; strong granular; field pH 6.0-7.0. Clear change to

B2: Dark brown or dark (7.5YR 3/2, 3/3, 3/4, 10YR 2/3, 3/2, 3/3,3/4); light medium clay to medium clay; strong subangular blocky; field pH 6.0-8.0. Clear to gradual change to

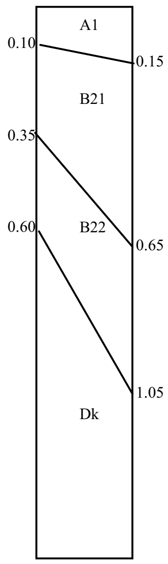
C, BC: Weathered rock or clay with weathered rock

Sites: 15, 22, 33, 35, 37, 42, 53, 65, 72, 75, 80, 91, 124, 130, 136, 138. 143. 151. 307, 389

WEIR (We)

Concept: Black cracking clays on levees
Australian Classification: Black Vertosol
PPF: Ug5.15
Great Soil Group: Black earths
Landform type: Relect levees of present and former stream channels. Slopes 0.5-2%
Geology: Quaternary alluvium (Qa)
Vegetation: Forest red gum, rough-barked apple and broad leaved ironbark open forest
Surface feature: Hardsetting to weak self mulching

Depth (m)



A1: Dark (10YR 3/1, 2/2, 3/1, 3/2); light clay to light medium clay; strong fine subangular blocky; dry hard.

B21: Dark (10YR 2/1, 2/2, 3/1, 3/2); medium clay; strong medium subangular blocky; dry very hard.

B22: As above with strong medium lenticular structure and occasionally manganiferous concretions.

Dk: Brown (7.5YR, 10YR 3/3, 3/5, 4/3, 4/4); light medium clay; strong fine to medium subangular; dry very hard; manganiferous concretions, concretionary lime.

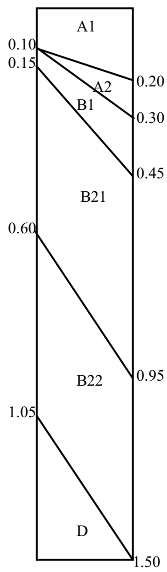
Variant: A sporadic bleach occasionally occurs towards the base of the A horizon in uncultivated situations.

Sites: 304, 310, 312, 316, 320, 329, 332, 338, 341, 347, 352, 355, 646

WHEATLANDS (Wh)

Concept: Alkaline and neutral, red gradational and texture contrast soils on old alluvium
Australian Classification: Red Dermosol, Brown Dermosol
PPF: Gn3.16, Gn3.26, Dr2.22, Gn3.13, Dr3.33
Great Soil Group: No suitable group, affinities with red brown earth
Landform type: Hillcrests and hillslopes of gently undulating plains to undulating rises. Slopes 1-4%
Geology: Elevated Quaternary alluvium (Qa)
Vegetation: Forest red gum and broad leaved ironbark open forest. Moderately developed grass layer of blue grasses
Surface feature: Hardsetting

Depth (m)



A1: Brown (7.5YR 3/4, 4/3); sandy clay loam to clay loam sandy; massive; dry slightly hard to hard; occasionally manganiferous concretions and veins.

A2: Occasionally sporadically bleached. As above, but brown or yellow brown (7.5YR 4/4, 5/6).

B1: Red brown or brown (5YR, 7.5YR 3/6, 4/4, 4/6); sandy light clay to light clay; moderate medium angular blocky; dry hard; frequently manganiferous concretions and veins.

B21: Frequently mottled; red brown or brown (5YR, 7.5YR 3/6, 4/4, 4/6); medium clay; strong medium angular blocky; dry hard; frequently manganiferous concretions and veins.

B22: As above but always has manganiferous concretions and veins.

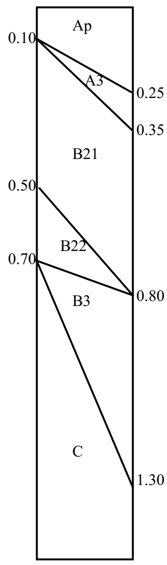
D: As above but sandy clay loam to clay loam sandy frequently with subangular gravel.

Sites: 365, 543. Also described in Barker-Barambah Irrigation Suitability Study, Reid *et al*. 1979.

WOOROOLIN (Wr)

Concept: Shallow, moderate to well structured, red clay soil over kaolinized basalt
Australian Classification: Red Ferrosol
PPF: Gn3.11, Uf6.31
Great Soil Group: Krasnozem, Euchrozem
Landform type: Upper slopes of gently undaulting to rolling hills
Geology: Deeply weathered Main Range basalt (Tm)
Vegetation: Most cleared. Minor softwood scrub
Surface feature: Firm

Depth (m)



Ap: Very dark reddish brown (10R, 2.5 YR, 2/3, 2/4, 3/3, 3/4); clay loam to light clay; weak to moderate fine granular; dry hard; moderate amounts of ironstone and manganiferous concretions. Clear or gradual change to

A3: Very dark reddish brown (10R, 2.5YR, 2/3, 3/3, 3/4, 3/6); light clay; strong fine granular to strong fine blocky; dry hard; moderate amounts of ironstone and manganiferous concretions. Gradual change to

B21: Reddish brown (10R, 2.5YR, 3/3, 3/4, 3/6, 4/3, 4/6); light clay to light medium clay; strong fine to medium polyhedral; dry very hard; moderate amounts of ironstone and manganiferous concretions; moderate amount of kaolinized basalt. Gradual change to

B22: Reddish brown (10R, 2.5 YR, 3/4, 3/6, 4/3, 4/4, 4/6); light clay to light medium clay; strong fine to medium polyhedral; dry very hard; moderate amounts of ironstone and manganiferous concretions; moderate amounts of kaolinized basalt. Gradual change to

B3: Reddish brown (10R, 2.5 YR, 3/4, 3/6); light clay to medium clay; strong fine to strong medium polyhedral; dry very hard; large amounts of ironstone and manganiferous concretions, moderate to large amounts of kaolinized and decomposing basalt. Gradual change to

C: Kaolinized basalt

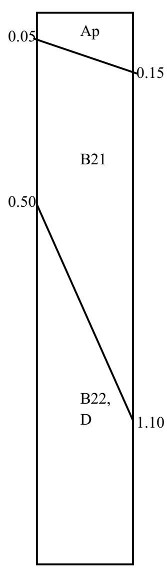
Variant: Occasionally alkaline soil reaction trends occur in lower solum

Sites: 132, 139, 147, 157, 163, 233, 243, 250, 558, 561, 577, 576, 582, 587, 601, 603, 661, 672, 676,

WONDAI (Wd)

Concept: Gilgaied brown or black cracking clays on lower slopes of pediments derived from fresh basalt
Australian Classification: Brown Vertosol, Black Vertosol
PPF: Ug5.34, Ug5.15, Ug5.17, Ug 5.35
Great Soil Group: Brown clays, black earth
Landform type: Lower slopes of gently undulating pediments. Slopes 2-6%
Geology: Tertiary Main Range basalt (Tm)
Vegetation: Gum topped box, narrow leaved ironbark open forest. Mostly cleared
Surface feature: Gilgaied, cracking, weak self mulching

Depth (m)



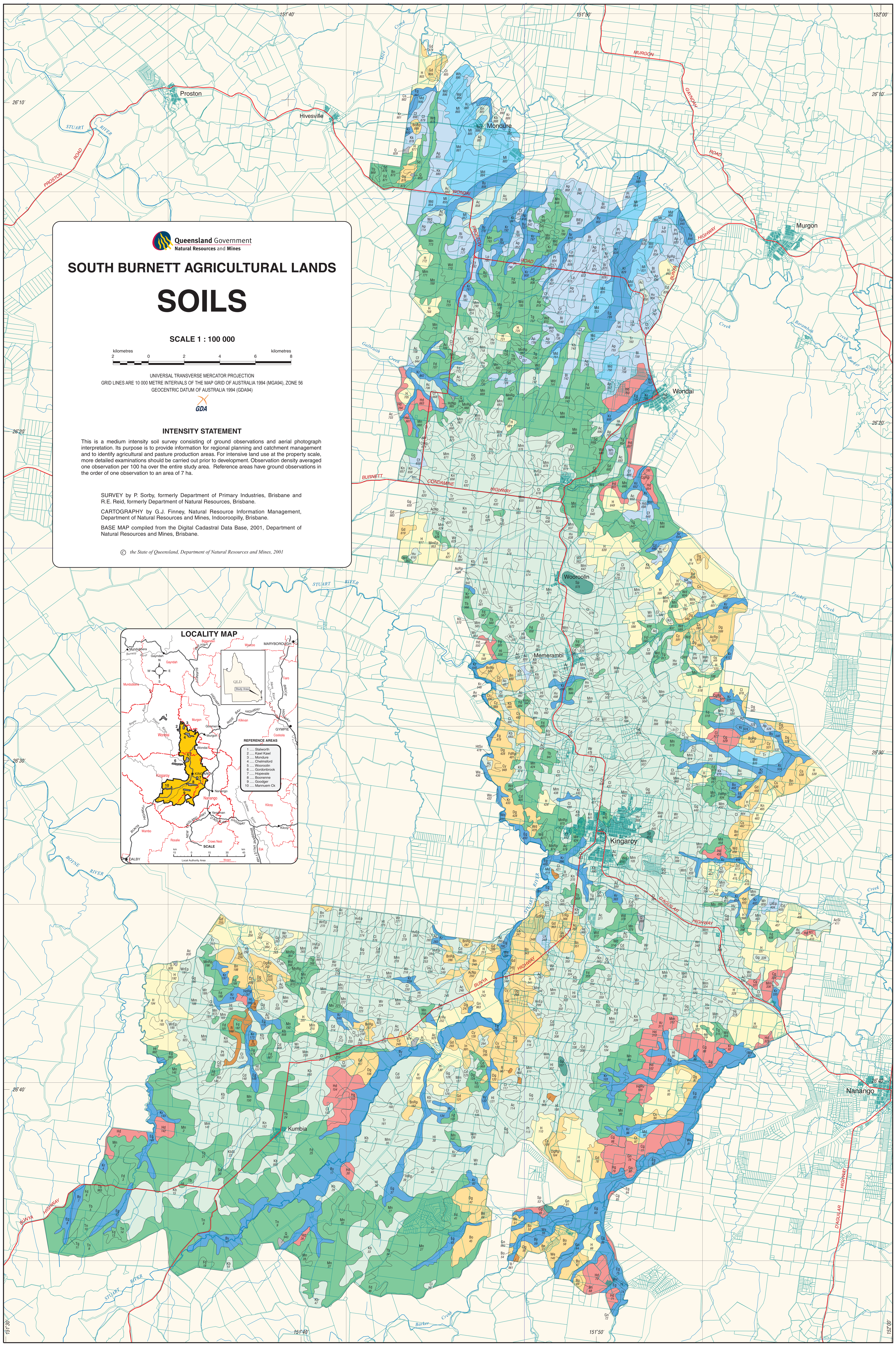
Ap: Dark or dark brown (7.5YR 3/2, 3/3, 3/4, 10YR 2/2); light medium clay to medium heavy clay; subangular blocky; field pH 6.0-7.0. Clear change to

B21: Dark brown, brown or dark (7.5YR 3/2, 3/3, 3/4, 4/4, 4/6, 10YR 2/2); medium clay to medium heavy clay; subangular blocky or lenticular; occasionally managaniferous nodules; field pH 6.0-8.0. Diffuse change to

B22,D: Frequently mottled; dark brown or brown (5YR 3/4, 4/4, 7.5YR 3/4, 4/4, 4/6, 5/6, 10YR 3/4, 5/4); medium clay to medium heavy clay; lenticular B22 or polyhedral to subangular blocky D horizons frequently with gravel; frequently with calcareous segregations; field pH 7.5-8.5.

Sites: 79, 370, 372, 385, 456, 482, 490, 491, 499, 518, 521, 548, 564, 696, 700, 704, 761

Appendix C



Queensland Government
Natural Resources and Mines

SOUTH BURNETT AGRICULTURAL LANDS

SOILS

SCALE 1 : 100 000

kilometres 2 0 2 4 6 8 kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
GRID LINES ARE 10 000 METRE INTERVALS OF THE MAP GRID OF AUSTRALIA 1994 (MGA94), ZONE 56
GEOCENTRIC DATUM OF AUSTRALIA 1994 (GDA94)

GDA

INTENSITY STATEMENT

This is a medium intensity soil survey consisting of ground observations and aerial photograph interpretation. Its purpose is to provide information for regional planning and catchment management and to identify agricultural and pasture production areas. For intensive land use at the property scale, more detailed examinations should be carried out prior to development. Observation density averaged one observation per 100 ha over the entire study area. Reference areas have ground observations in the order of one observation to an area of 7 ha.

SURVEY by P. Sorby, formerly Department of Primary Industries, Brisbane and R.E. Reid, formerly Department of Natural Resources, Brisbane.

CARTOGRAPHY by G.J. Finney, Natural Resource Information Management, Department of Natural Resources and Mines, Indooroopilly, Brisbane.

BASE MAP compiled from the Digital Cadastral Data Base, 2001, Department of Natural Resources and Mines, Brisbane.

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REFERENCE

Mapping Unit		Distinguishing Attributes	Australian Classification	Principal Profile Form	Great Soil Group	Area (ha)
LEVEL TO GENTLY UNDULATING PLAINS ON ALLUVIUM OF CURRENT STREAMS						
Flood plains						
Ht	Hirst	Brown or dark loamy sand to silty clay loam surface (0.1-0.3 m) over a red or brown structured sandy clay loam to sandy light clay B2 horizon (0.9-1.5 m) over a red or brown sand to sandy loam D horizon to 1.5m	Brown Dermosol Brown Chromosol	Gn3.22 Gn3.52 Db2.33 Db2.12 Dy3.43	No suitable group, affinities with soloth	18
Ta	Terrace	Dark sandy light clay surface (0.1-0.2 m) over a dark medium clay B2 horizon (0.55-0.95 m) over a brown sandy light clay D horizon to 1.5m	Black Dermosol Black Vertosol	Uf6.32 Ug5.15	Prairie soil Black earth	124
Stagnant alluvial plains						
Av	Avon	Brown sandy loam to clay loam surface (0.02-0.2 m) over a sporadically bleached A2 horizon (0.1-0.45 m) over a frequently mottled strongly alkaline, grey or brown medium clay B2 horizon to 1.5 m	Brown Sodosol Grey Sodosol	Db2.32 Db2.33 Dy2.33 Db1.33	Solodic soil	12
By	Byee	Dark medium clay surface (0.1-0.2 m) over a dark medium clay B2 horizon (0.7-1.25 m) over a strongly alkaline, brown medium clay D horizon to 1.5m	Black Vertosol	Ug5.15	Black earth	3207
Eg	Eastgate	Dark medium clay surface (0.1-0.15 m) over a brown or black medium clay B21 horizon (0.45-0.95 m) over a strongly alkaline, brown medium clay B22 horizon to 1.5 m	Black Vertosol Brown Vertosol	Ug5.15 Ug5.34	Black earth Brown clay	3930
Alluvial fans						
Kr	Kaber	Brown light clay surface (0.2-0.3 m) over a brown medium clay B2 horizon to 1.5 m	Brown Vertosol	Ug5.34	Brown clay	3936
Relict levees						
We	Weir	Dark light clay surface (0.1-0.15 m) over a dark medium clay B2 horizon (0.6-1.05 m) over a strongly alkaline, brown light medium clay D horizon to 1.5 m	Black Vertosol	Ug5.15	Black earth	779
Drainage depressions						
Gn	Gueena	Mottled dark medium clay surface (0.1-0.15 m) over a mottled, grey medium clay B2 horizon to 1.5 m	Grey Vertosol	Ug5.24 Ug5.28	Grey clay	308
GENTLY UNDULATING PLAINS TO UNDULATING RISES ON OLDER HIGHER LYING ALLUVIUM AND TERTIARY SEDIMENTS						
Hillcrests and hill slopes						
Ap	Appaloosa	Dark or brown light clay to medium clay surface (0.1-0.2 m) over a brown medium clay B2 horizon (0.6-1.2 m) over a mottled, brown, yellow or grey medium clay C horizon to 1.5 m	Brown Vertosol	Ug5.35 Ug5.34 Uf6.31 Ug3.3 Uf6.33 Ug5.2	Brown clay	1443
Bl	Bushnell	Gilgaied, brown or dark clay loam surface (0.05-0.2 m) over a bleached A2 horizon (0.07-0.25 m) over a frequently mottled, brown medium clay B2 horizon (0.9-1.5 m) frequently over a mottled, strongly alkaline, grey, brown or yellow light clay to medium clay C horizon to 1.5m	Brown Sodosol	Dy2.33 Dy3.33 Dy3.43 Db2.33 Db1.33	Solodic soil Solodized solonetz	1992
Cf	Chelmsford	Dark or red clay loam to light clay surface (0.05-0.25 m) over a red medium clay B2 horizon (0.85-1.3 m) over a strongly alkaline, mottled, red or grey light clay D horizon to 1.5m	Red Ferrosol	Uf6.31 Gn3.13 Gn3.12	Euchrozem	808
Kk	Kawl Kawl	Gilgaied, dark or grey medium clay surface (0.1-0.15 m) over a grey medium clay B2 horizon to 1.5 m	Grey Vertosol	Ug5.24 Ug5.21	Grey clay	187
Lk	Lankowsky	Red light sandy clay loam to clay loam surface (0.1-0.15 m) over a neutral, red clay loam to light clay B horizon to 1.5 m	Red Kandosol	Gn2.12 Gn2.15	Red earth	203
Lp	Long Peter	Dark or brown clay loam surface (0.05-0.2 m) over a brown medium clay B2 horizon (1.3-1.5 m) occasionally over a mottled, grey, brown or yellow light clay to medium clay C horizon to 1.5 m	Brown Sodosol	Db1.13 Db2.13 Dy3.13 Dy2.13 Dy3.23	Solodic soil	674
Nr	Narrawong	Red, dark or brown clay loam surface (0.05-0.15 m) over an occasionally mottled, red or brown medium clay B2 horizon (0.4-0.9 m) over a mottled, brown medium clay D horizon to 1.5 m	Red Ferrosol	Gn3.12 Gn3.52 Gn3.22 Gn3.33 Gn4.12	Euchrozem	34
Pl	Palouse	Brown or grey sandy loam to light sandy clay loam surface (0.5-0.12 m) over a bleached A2 horizon (0.12-0.3 m) over a frequently mottled, brown medium clay B2 horizon (0.7-1.5 m) over a mottled, grey, brown or yellow light clay to medium clay C horizon to 1.5 m	Brown Sodosol	Dy3.43 Dy2.43 Db2.43 Dy3.33 Db2.33	Solodic soil Solodized solonetz	1137
Wh	Wheatlands	Brown sandy clay loam to clay loam surface (0.1-0.2 m) over a pale or occasionally sporadically bleached A2 horizon (0.1-0.3 m) over a frequently mottled, red or brown medium clay B2 horizon (1.05-1.5 m) over a frequently mottled, red or brown sandy clay loam to clay loam D horizon to 1.5 m	Red Dermosol Brown Dermosol	Gn3.16 Gn3.26 Dr2.22 Gn3.13 Dr3.33	No suitable group, affinities with red brown earth	46
Plains						
Ml	Marshlands	Brown sandy clay loam to light clay surface (0.1-0.2 m) over a sporadically bleached A2 or B1 horizon (0.2-0.3 m) over a mottled, brown medium clay B2 horizon (0.4-1.5 m) over a mottled, brown medium clay to heavy clay D horizon to 1.5 m	Brown Sodosol	Db2.33 Uf6.41p Dy3.43 Dy3.31 Uf3	Solodic soil Soloth	1442
Md	Mondure	Brown or occasionally dark light clay or occasionally clay loam surface (0.05-0.15 m) over a brown medium clay B2 horizon to 1.5 m	Brown Dermosol	Uf6.31 Uf4.42 Uf6.4 Gn3.23 Db1.13	No suitable group	1647
UNDULATING RISES TO ROLLING HILLS ON BASALT						
Hillcrests and upper hill slopes						
Mn	McEuen	Dark or brown light clay to medium clay surface (0.05-0.1 m) over a dark or brown medium clay B2 horizon (0.3-0.55 m) over weathered rock	Black Vertosol Brown Vertosol	Ug5.12 Ug5.32 Ug5.13	Black earth Brown clay	12539
Tb	Taabinga	Red clay loam to light clay surface (0.1-0.2 m) over a red light clay to medium clay B2 horizon (0.l5-1.2 m) over weathered rock	Red Ferrosol	Uf6.31 Gn3.12 Gn3.13	Euchrozem	1938
Tn	Tureen	Dark light clay or occasionally clay loam surface (0.1-0.15 m) over a dark or brown medium clay B2 horizon (0.25-0.55 m) over weathered rock	Black Dermosol Brown Dermosol	Uf6.32 Uf6.31 Db1.12	Prairie soil	3367
Mid to lower hill slopes						
Fd	Fairdale	Dark or brown medium clay surface (0.06-0.12 m) over a neutral to alkaline, dark or brown medium clay B2 horizon (0.6-0.9 m) over weathered rock	Black Vertosol Brown Vertosol	Ug5.12 Ug5.13 Ug5.32	Black earth Brown clay	4269
Tg	Tingoora	Dark or brown medium clay surface (0.05-0.2 m) over a neutral to alkaline, brown or dark B21 horizon (0.45-0.85 m) over a strongly alkaline, brown medium clay to heavy clay B22 horizon (1.2-1.5 m) over weathered rock	Brown Vertosol Black Vertosol	Ug5.32 Ug5.13 Ug5.12 Ug5.34	Brown clay Black earth	782
Pediments						
In	Iona	Dark medium clay surface (0.1-0.25 m) over a neutral to alkaline, brown or dark medium clay B21 horizon (0.6-1.0 m) over a strongly alkaline, brown or red medium clay B22 horizon to 1.5 m occasionally over gravelly D horizons	Brown Vertosol Black Vertosol	Ug5.34 Ug5.17 Ug5.15	Brown clay Black earth	77
Sd	Sadie	Dark medium clay surface (0.05-0.1 m) over a neutral to alkaline, dark medium clay B21 and B22 horizons over a occasionally mottled, strongly alkaline, grey medium clay B23 horizon to 1.5 m	Black Vertosol	Ug5.16	Black earth	381
Wd	Wondai	Gilgaied, dark or brown medium clay surface (0.05-0.15 m) over a brown or dark medium clay B21 horizon (0.5-1.1 m) over a frequently mottled, brown or red medium clay B22 or D horizon to 1.5 m frequently with gravel	Brown Vertosol Black Vertosol	Ug5.34 Ug5.15 Ug5.17 Ug5.35	Brown clay Black earth	3147
UNDULATING RISES TO ROLLING HILLS ON DEEPLY WEATHERED BASALTIC MATERIAL						
Plateaus, hillcrests and upper hill slopes						
Gg	Goodger	Loose, red clay loam to light clay surface (0.1-0.3 m) over an acid, red, massive to weakly structured B21 horizon (0.25-0.8 m) over an acid, red structured light clay B22 horizon to 1.5 m	Red Ferrosol	Gn3.11 Uf5.31	Krasnozem	3172
Hv	Hopevale	Loose, red loam surface (0.1-0.25 m) over an acid, red, weak to moderately structured clay loam B2 horizon (0.3-0.55 m) over deeply weathered basalt. Large amounts of ferruginous gravel throughout the profile	Red Ferrosol	Um4.21 Um5.21 Um6.24 Um6.31 Um6.33	Krasnozem Red earth	7912
Pt	Proston	Firm, red clay loam to light clay surface (0.1-0.25 m) over an acid, red, structured clay loam to light clay B2 horizon (0.9-1.5 m) with ferruginous gravel over deep weathered basalt	Red Ferrosol	Gn3.11 Uf6.31 Um6.31	Krasnozem	231
Mid to upper hill slopes						
Mm	Memerambi	Firm, red clay loam to light clay surface (0.1-0.2 m) over an acid, red light clay B2 horizon to 1.5 m	Red Ferrosol	Uf6.31 Gn3.11	Krasnozem	11487
Wr	Wooroolin	Firm red clay loam to light clay surface (0.1-0.25 m) over an acid to neutral, red light clay B2 horizon (0.7-0.8 m) over deeply weathered basalt	Red Ferrosol	Gn3.11 Uf6.31	Krasnozem Euchrozem	3876
Mid to lower hill slopes						
Cl	Coolabunia	Firm, red clay loam to light clay surface (0.1-0.25 m) over a acid to neutral, red light clay to medium clay B21 horizon (0.45-1.0 m) over a acid to neutral, mottled, red light clay to medium clay B22 horizon (1.1-1.3 m) with large amounts of iron and manganiferous concretions over a red medium clay with weathered rock to 1.5 m	Red Ferrosol	Uf6.31 Uf6.4 Gn3.11 Gn3.12	Euchrozem Krasnozem	8672
Cd	Crawford	Firm, red clay loam to light clay surface (0.1-0.2 m) over an acid to neutral, mottled, red clay loam to light clay B21 horizon (0.5-0.8 m) over an acid to neutral, mottled, red or brown light clay to medium clay B22 horizon (1.0-1.3 m) with moderate amounts of manganiferous concretions over deeply weathered rock	Red Ferrosol	Uf6.31 Uf6.4 Gn3.11 Gn3.12	Euchrozem Krasnozem	1559
Pediments						
Ac	Archookoora	Red or brown light clay surface (0.1-0.25 m) over a red or brown light clay to medium clay B2 horizon (0.65-1.5 m) with manganiferous concretions over a brown medium clay D horizon to 1.5 m	Red Ferrosol Brown Ferrosol	Uf6.31 Uf6.4 Uf6.3	Euchrozem Krasnozem	3541
Hl	Haly	Red or brow light clay surface (0.15-0.2 m) over a mottled, brown medium clay B2 horizon to 1.5 m	Brown Ferrosol	Uf6.4	Xanthozem	3355
Kb	Kumbia	Brown or red clay loam to light clay surface (0.15-0.25 m) frequently with manganiferous segregations over a frequently mottled, brown or red light clay to medium clayB2 horizon (0.55-1.4 m) with manganiferous segregations over a mottled, brown or yellow medium clay to heavy clay D horizon to 1.5 m	Brown Ferrosol Red Ferrosol	Uf6.4 Gn3.12	Xanthozem	6380
Kn	Kunioon	Brown or red clay loam to light clay surface (0.1-0.25 m) with manganiferous nodules over a mottled, brown or red light clay to medium clay B2 horizon (to 1.5 m) with large amounts of manganiferous modules	Brown Ferrosol Red Ferrosol	Uf6.4	Xanthozem	1539
Tr	Tarong	Brown sandy loam to clay loam sandy surface (0.5-0.2 m) over a bleached A2 horizon (0.15-0.3 m) over a mottled, brown or yellow light clay to medium clay B2 horizon (0.5-1.5 m) with manganiferous nodules frequently over a mottled, brown medium clay to heavy clay D horizon to 1.5 m	Brown Chromosol Brown Dermosol Yellow Chromosol Yellow Dermosol	Dy3.41 Dy3.32 Dy3.31 Db2.31	Yellow Podzolic soil Brown Podzolic soil No suitable group	2120
GENTLY UNDULATING TO UNDULATING LOW HILLS ON GRANITES						
Hillcrests and upper hill slopes						
Bo	Booie	Dark or brown sandy loam to sandy clay loam surface (0.1-0.2 m) over a bleached A2 horizon (0.3-0.45 m) over weathered rock	Bleached-Orthic Tenosol Orthic Tenosol	Uc2.12 Um3.12	Lithosol	965
Bn	Boonenne	Brown sandy loam to sandy clay loam surface (0.1-0.2 m) over a conspicuously bleached A2 horizon (0.2-0.3 m) over an alkaline, mottled, brown medium clay B2 horizon (0.65-0.9 m) over weathered rock	Brown Sodosol	Dy3.43 Dy3.42 Dy2.43 Db2.42 Db2.43	Solodic soil	2264
Dg	Dangore	Dark sandy loam to sandy clay loam surface (0.08-0.2 m) over a bleached A2 horizon (0.2-0.4 m) over an acid, mottled, brown, grey or yellow fine gravelly light clay to medium clay B2 horizon (0.5-1.0 m) over weathered rock	Brown Sodosol Brown Chromosol Grey Sodosol Yellow Sodosol	Dy3.41 Dy3.31 Db2.31 Db1.41	Soloth Podzolic soils	3147
Mid to lower hill slopes						
Ct	Charlestown	Dark or brown light sandy clay loam to clay loam sandy surface (0.1-0.2 m) over a bleached A2 horizon (0.15-0.2 m) over an acid to alkaline, red or brown medium clay B2 horizon (0.55-0.9 m) over weathered rock	Red Sodosol Brown Sodosol	Dr3.12 Dr2.32 Dr3.41 Db2.12 Dr1.12	Solodic soil Soloth	64
Gd	Gordonbrook	Red or brown light sandy clay loam to sandy clay loam surface (0.1-0.15 m) over a pale A2 horizon (0.12-0.3 m) over an acid, red sandy light clay to medium clay B2 horizon (0.75-1.0 m) over deeply weathered rock	Red Chromosol Red Dermosol	Dr2.21 Uf6.4	Red podzolic soil No suitable group, affinities with soloth	1120
Pediments						
Cy	Cooyar	Dark brown or grey sandy loam to sandy clay loam surface (0.08-0.2 m) over a bleached A2 horizon (0.15-0.45 m) over an acid, mottled, brown or grey medium clay B2 horizon to 1.5 m	Brown Chromosol Brown Sodosol Brown Kurrosol Grey Sodosol	Dy3.41 Dy3.31	Yellow podzolic soil Soloth	917
Cs	Cushnie	Dark or brown light sandy clay loam to clay loam fine sandy surface (0.08-0.15 m) over a conspicuously bleached A2 horizon (0.12-0.3 m) over a neutral to strongly alkaline, frequently mottled, brown or occasionally grey medium clay B2 horizon to 1.5 m	Brown Sodosol Grey Sodosol	Dy3.43 Dy2.42 Db2.13 Dy3.42	Solodic soil	535
GENTLY UNDULATING RISES TO UNDULATING LOW HILLS ON METAMORPHIC MATERIAL AND SEDIMENTARY ROCKS						
Hillcrests and upper hillslopes						
Cg	Cherbourg	Brown or grey sandy loam to sandy clay loam surface (0.1-0.15 m) over a bleached A2 horizon (0.1-0.4 m) over an acid, brown medium clay B2 horizon (0.25-0.85 m) over weathered rock	Yellow Kurosol Brown Sodosol	Db2.41 Dy3.21 Dy3.41 Um1	Soloth, Lithosol No suitable group	1472
Mid to lower hill slopes						
Hd	Hillsdale	Dark or brown sandy clay loam surface (0.1-0.2 m) over a bleached A2 horizon (0.2-0.3 m) over a alkaline to strongly alkaline, mottled, brown or grey medium clay B2 horizon (0.9-1.3 m) over weathered sandstone	Brown Sodosol Grey Sodosol	Dy3.43 Db2.33 Db2.43	Solodic soil Solodized solonetz	2529
Pediments and footslopes						
Hg	Hodgleigh	Dark or brown fine sandy clay loam to clay loam sandy surface (0.1-0.2 m) over a conspicuously bleached A2 horizon (0.1-0.35 m) over a neutral, frequently mottled, brown or red medium clay B2 horizon (0.65-1.5 m) over weathered rock	Red Chromosol Brown Sodosol Brown Dermosol	Dr2.12p Dy3.42 Db2.32	Non calcic brown soil Solodic soil No suitable group	154
MISCELLANEOUS UNITS						
D	Dam					10
H	Hills					10645
Q	Quarry					78
R	Rock					218
Sp	Swamp					216

PHASES AND VARIANTS

ep	Eroded phase
np	Nodular phase
rp	Rocky phase
sl	Saline phase
rv	Red variant
sv	Sandy variant

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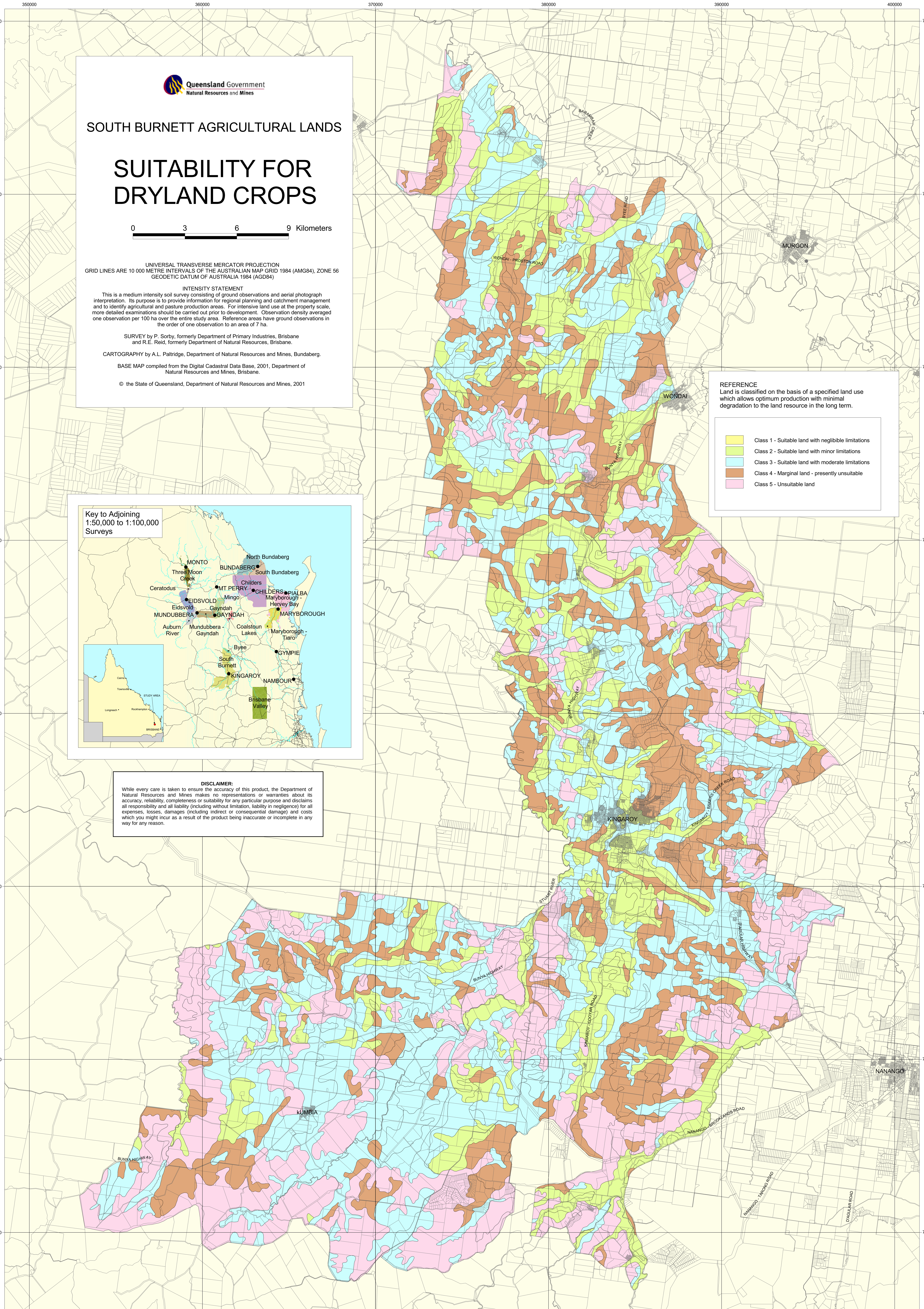
SOUTH BURNETT AGRICULTURAL LANDS
SOILS
NR&M Ref. No. SBT-I-A0 3286

Appendix D

Queensland Government
Natural Resources and Mines

SOUTH BURNETT AGRICULTURAL LANDS

SUITABILITY FOR DRYLAND CROPS



UNIVERSAL TRANSVERSE MERCATOR PROJECTION
GRID LINES ARE 10 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID 1984 (AMG84), ZONE 56
GEODETIC DATUM OF AUSTRALIA 1984 (AGD84)

INTENSITY STATEMENT

This is a medium intensity soil survey consisting of ground observations and aerial photograph interpretation. Its purpose is to provide information for regional planning and catchment management and to identify agricultural and pasture production areas. For intensive land use at the property scale, more detailed examinations should be carried out prior to development. Observation density averaged one observation per 100 ha over the entire study area. Reference areas have ground observations in the order of one observation to an area of 7 ha.

SURVEY by P. Sorby, formerly Department of Primary Industries, Brisbane and R.E. Reid, formerly Department of Natural Resources, Brisbane.

CARTOGRAPHY by A.L. Paltridge, Department of Natural Resources and Mines, Bundaberg.

BASE MAP compiled from the Digital Cadastral Data Base, 2001, Department of Natural Resources and Mines, Brisbane.

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NRM Ref No SBT-B-A0 3287

Appendix E

	Source	Date	Conductivi	pH	Total Harn	Tempoary	Alkalinity	Residual Al	Silica	Total disso	Total disso	Colour	Turbidity	pH Sat	Satuartion	Mole Ratio	Sodium Ab	Figure of n	Na Sodium	K Potassiur	Ca Calcium	Mg Magne	Hydrogen	HCO3 Bica
BOON R	Raw Water	21/05/2019	710	7.31	157	73	73	0	11	385	351	10	3	8.3	-1	3.3	2.5	1	73	6.4	22	25	0	88
BOON R	Raw Water	14/05/2019	713	7.19	157	75	75	0	11	386	351	10	3	8.3	-1.1	3.4	2.5	1	72	6.4	22	25	0	91
BOON R	Raw Water	8/05/2019	700	7.21	155	74	74	0	11	385	351	10	2	8.3	-1.1	3.4	2.5	1	72	6.4	22	24	0	89
BOON R	Raw Water	30/04/2019	713	7.41	151	72	72	0	11	383	349	9	2	8.3	-0.9	3.2	2.6	1	72	6.3	21	24	0	88
BOON R	Raw Water	16/04/2019	701	7.24	152	72	72	0	11	382	348	9	1	8.3	-1.1	3.4	2.5	1	72	6.4	21	24	0	87
BOON R	Raw Water	2/04/2019	685	7.37	148	73	73	0	10	374	339	12	2	8.3	-0.9	3.2	2.5	1	70	6.1	21	23	0	89
BOON R	Raw Water	19/03/2019	698	7.66	151	72	72	0	11	380	346	13	3	8.3	-0.6	3	2.5	1	70	6.2	22	24	0	87
BOON R	Raw Water	12/03/2019	700	7.27	153	73	73	0	11	382	347	11	<1	8.3	-1	3.4	2.5	1	72	6.3	22	24	0	89
BOON R	Raw Water	5/03/2019	704	7.86	153	72	72	0	11	379	346	15	3	8.3	-0.4	2.8	2.5	1	71	6.2	22	24	0	87
BOON R	Raw Water	26/02/2019	705	7.94	156	71	71	0	10	391	358	14	1	8.3	-0.3	2.7	2.5	1	72	6.4	23	24	0	86
BOON R	Raw Water	19/02/2019	693	7.72	151	71	71	0	11	383	350	12	<1	8.3	-0.6	2.9	2.6	0.9	73	6.3	22	23	0	86
BOON R	Raw Water	12/02/2019	694	7.66	152	73	73	0	11	377	343	15	1	8.3	-0.6	3	2.5	1	71	6.2	22	24	0	88
BOON R	Raw Water	5/02/2019	697	7.65	153	73	73	0	11	378	344	15	4	8.3	-0.6	3	2.5	1	71	6.3	22	24	0	89
BOON R	Raw Water	30/01/2019	688	7.56	156	73	73	0	11	383	349	17	<1	8.3	-0.7	3.1	2.5	1	71	6.6	23	24	0	88
BOON R	Raw Water	22/01/2019	684	7.86	150	72	72	0	11	371	338	15	2	8.3	-0.4	2.8	2.5	1	69	6.2	22	23	0	87
BOON R	Raw Water	15/01/2019	684	7.7	149	72	72	0	11	373	340	12	<1	8.3	-0.6	2.9	2.5	1	69	6.2	22	23	0	88
BOON R	Raw Water	8/01/2019	687	7.74	153	73	73	0	11	374	340	15	1	8.3	-0.5	2.9	2.4	1	69	6.2	22	24	0	89
BOON R	Raw Water	18/12/2018	712	7.79	157	75	75	0	11	384	349	13	<1	8.2	-0.4	2.8	2.5	1	71	6.2	23	24	0	91
BOON R	Raw Water	11/12/2018	713	7.3	158	76	76	0	11	388	352	14	<1	8.2	-0.9	3.3	2.5	1	72	6.3	23	24	0	93
BOON R	Raw Water	4/12/2018	705	7.6	157	76	76	0	11	384	348	13	2	8.2	-0.6	3	2.4	1	69	6.1	23	24	0	92
BOON R	Raw Water	27/11/2018	711	7.49	154	77	77	0	12	382	346	12	6	8.2	-0.7	3.1	2.4	1	69	6.2	23	24	0	94
BOON R	Raw Water	6/11/2018	685	6.87	153	77	77	0	11	373	337	13	10	8.2	-1.4	3.7	2.4	1	67	6.1	23	23	0	94
BOON R	Raw Water	31/10/2018	704	6.71	156	80	80	0	11	384	346	6	6	8.2	-1.5	3.9	2.4	1	69	6.2	23	24	0	97
BOON R	Raw Water	23/10/2018	700	7.22	158	79	79	0	11	388	350	10	1	8.2	-1	3.4	2.4	1	70	6.2	23	24	0	97
BOON R	Raw Water	16/10/2018	715	7.16	160	80	80	0	11	389	351	8	<1	8.2	-1.1	3.4	2.4	1	71	6.3	24	25	0	97
BOON R	Raw Water	9/10/2018	729	7.23	165	82	82	0	11	399	360	8	1	8.2	-0.8	3.4	2.4	1.1	72	6.4	24	26	0	100
BOON R	Raw Water	2/10/2018	723	7.14	162	81	81	0	12	396	358	9	<1	8.2	-1.1	3.5	2.5	1	72	6.4	24	25	0	98
BOON R	Raw Water	18/09/2018	720	7.38	159	80	80	0	12	393	355	10	<1	8.2	-0.8	3.2	2.5	1	71	6.3	23	24	0	97
BOON R	Raw Water	11/09/2018	724	7.3	160	80	80	0	12	392	354	9	2	8.2	-0.9	3.3	2.5	1	71	6.3	23	25	0	98
BOON R	Raw Water	28/08/2018	712	7.16	158	78	78	0	12	387	350	11	<1	8.2	-1	3.4	2.4	1	71	6.2	23	24	0	95
BOON R	Raw Water	21/08/2018	714	7.21	159	80	80	0	12	393	356	9	<1	8.2	-1	3.4	2.4	1	71	6.2	23	25	0	97
BOON R	Raw Water	15/08/2018	712	7.12	157	79	79	0	12	389	351	13	2	8.2	-1.1	3.5	2.4	1	70	6.2	23	24	0	96
BOON R	Raw Water	31/07/2018	712	7.39	159	76	76	0	12	386	351	11	<1	8.2	-0.8	3.2	2.4	1	70	6.3	23	25	0	92
BOON R	Raw Water	24/07/2018	702	7.41	157	74	74	0	12	382	349	11	<1	8.2	-0.8	3.2	2.4	1	70	6.2	23	24	0	90
BOON R	Raw Water	19/07/2018	698	7.11	153	78	78	0	12	376	340	11	<1	8.2	-1.1	3.5	2.4	1	69	6.1	22	24	0	94
BOON R	Raw Water	17/07/2018	710	7.37	156	77	77	0	12	381	345	10	2	8.2	-0.8	3.2	2.4	1	70	6.1	23	24	0	94
BOON R	Raw Water	10/07/2018	708	7.36	156	77	77	0	12	386	350	8	2	8.2	-0.9	3.3	2.4	1	69	6.2	23	24	0	94
BOON R	Raw Water	3/07/2018	700	6.91	157	77	77	0	12	385	349	11	<1	8.3	-1.3	3.7	2.4	1	69	6.3	23	24	0	94
BOON R	Raw Water	26/06/2018	701	7.09	157	79	79	0	12	393	356	12	<1	8.2	-1.1	3.5	2.4	1	70	6.3	23	24	0	96
BOON R	Raw Water	12/06/2018	690	7.04	152	76	76	0	12	384	349	13	<1	8.3	-1.2	3.6	2.4	1	69	6.1	22	24	0	93
BOON R	Raw Water	5/06/2018	693	7.13	155	77	77	0	12	386	351	12	1	8.2	-1.1	3.5	2.5	1	71	6.3	22	24	0	94
BOON R	Raw Water	29/05/2018	698	7.29	156	76	76	0	12	383	348	12	<1	8.2	-0.9	3.3	2.5	1	71	6.2	22	24	0	92
BOON R	Raw Water	22/05/2018	714	7.18	159	78	78	0	11	385	348	1	<1	8.2	-1	3.4	2.4	1	71	6.2	23	25	0	95
BOON R	Raw Water	15/05/2018	710	7.2	158	75	75	0	11	389	351	12	1	8.3	-1.1	3.4	2.5	1	71	6.2	22	25	0	92
BOON R	Raw Water	8/05/2018	713	7.43	156	76	76	0	11	389	353	10	<1	8.2	-0.8	3.2	2.5	1	72	6.1	22	25	0	92
BOON R	Raw Water	2/05/2018	713	7.39	157	72	72	0	11	384	351	10	1	8.2	-0.9	3.3	2.5	1	71	6.2	22	25	0	88
BOON R	Raw Water	23/04/2018	718	7.36	161	77	77	0	11	391	354	8	<1	8.2	-0.8	3.3	2.4	1	71	6.2	24	25	0	93
BOON R	Raw Water	17/04/2018	706	7.48	152	74	74	0	11	384	349	11	1	8.3	-0.8	3.2	2.5	1	71	6.1	21	24	0	90
BOON R	Raw Water	10/04/2018	702	7.81	150	72	72	0	10	380	345	13	2	8.3	-0.5	2.8	2.5	1	71	6	21	24	0	88
BOON R	Raw Water	4/04/2018	693	7.61	151	71	71	0	11	375	342	11	2	8.3	-0.7	3	2.5	1	71	6.2	21	24	0	86
BOON R	Raw Water	26/03/2018	691	7.7	151	73	73	0	11	374	340	10	<1	8.2	-0.5	2.9	2.5	1	69	6.1	21	24	0	89
BOON R	Raw Water	20/03/2018	679	7.74	150	72	72	0	11	370	335	12	1	8.2	-0.5	2.9	2.4	1	69	6.2	21	24	0	87
BOON R	Raw Water	13/03/2018	679	7.67	149	71	71	0	11	369	336	13	2	8.3	-0.6	3	2.4	1	68	6.1	21	24	0	86
BOON R	Raw Water	6/03/2018	688	7.45	151	72	72	0	11	374	340	11	1	8.3	-0.8	3.2	2.4	1	69	6.2	21	24	0	88
BOON R	Raw Water	26/02/2018	694	7.41	153	73	73	0	11	388	354	10	1	8.3	-0.9	3.2	2.5	1	70	6.2	22	24	0	88
BOON R	Raw Water	20/02/2018	682	7.51	151	73	73	0	7	380	342	10	1	8.3	-0.7	3.1	2.5	1	70	6.2	24	21	0	88
BOON R	Raw Water	13/02/2018	686	7.72	150	73	73	0	8	373	337	15	1	8.2	-0.5	2.9	2.4	1	69	6.2	22	23	0	88
BOON R	Raw Water	7/02/2018	683	7.49	149	74	74	0	9	375	337	11	1	8.2	-0.7	3.1	2.4	1	68	6.2	21	24	0	90
BOON R	Raw Water	31/01/2018	682	7.39	153	72	72	0	9	374	338	11	1	8.3	0.9	3.3	2.5	1	70	6.3	22	24	0	88
BOON R	Raw Water	17/01/2018	663	7.69	146	73	73	0	1.1	365	331	12	2	8.3	0.6	3	2.4	1	68	6.1	21	23	0	89
BOON R	Raw Water	10/01/2018	648	7.73	143	72	72	0	11	357	323	11	1	8.3	0.06	3.1	2.4	1	65	6	20	22	0	88
BOON R	Raw Water	2/01/2018	647	7.84	141	73	73	0	12	354	321	13	1	8.3	0.4	2.9	2.4	1	65	6	21	22	0	83
BOON R	Raw Water	20/12/2017	635	7.75	141	72	72	0	12	349	316	12	1	8.3	0.5	2.9	2.3	1	64	6	20	22	0	87
BOON R	Raw Water	7/12/2017	630	7.82	139	72	72	0	12	346	313	13	1	8.3	0.04	2.7	2.3	1	63	6.1	20	22	0	88
BOON R	Raw Water	30/11/2017	632	7.62	142	75	75	0	12	351	317	14	1	8.2	0.6	2.9	2.3	1	63	6.1	21	22	0	91
BOON R	Raw Water	14/11/2017	630	7.45	138	72	72	0	12	344	311	13	1	8.3	0.8	3.1	2.3	1	62	6.1	20	21	0	88

BOON R	Raw Water	8/11/2017	619	7.53	136	72	72	0	12	338	306	12	2	8.3	0.8	3	2.3	1	62	5.9	20	21	0	87
BOON R	Raw Water	1/11/2017	619	7.67	136	71	71	0	12	338	306	16	1	8.3	-0.6	2.9	2.3	1	61	0	20	21	0	86
BOON R	Raw Water	24/10/2017	613	7.78	135	71	71	0	12	339	307	14	1	8.3	0.5	2.9	2.3	1	62	5.9	20	21	0	86
BOON R	Raw Water	17/10/2017	616	7.88	137	71	71	0	12	340	309	14	1	8.3	0.4	2.7	2.3	1	62	6	20	21	0	86
BOON R	Raw Water	3/10/2017	622	7.42	140	72	72	0	12	344	312	22	1	8.3	0.8	3.1	2.3	1	62	6	21	21	0	88
BOON R	Raw Water	27/09/2017	619	7.5	142	72	72	0	12	348	316	18	1	8.3	0.8	3.3	2.3	1	62	6.2	21	22	0	87
BOON R	Raw Water	19/09/2017	621	7.7	137	71	71	0	13	341	310	17	1	8.3	-0.6	2.9	2.3	1	62	6	20	21	0	86
BOON R	Raw Water	12/09/2017	617	7.55	137	72	72	0	13	341	309	20	1	8.3	-0.7	3	2.3	1	62	6	20	21	0	87
BOON R	Raw Water	5/09/2017	611	7.18	136	70	70	0	13	337	307	19	1	8.3	1.1	3.4	2.3	1	62	5.9	20	21	0	85
BOON R	Raw Water	29/08/2017	613	7.43	136	71	71	0	13	339	308	23	1	8.3	0.9	3.3	2.3	1	61	6	20	21	0	87
BOON R	Raw Water	23/08/2017	612	7.45	134	71	71	0	13	338	307	18	<1	8.3	-0.9	3.2	2.3	1	61	5.8	20	21	0	86
BOON R	Raw Water	16/08/2017	627	7.58	143	79	79	0	12	352	315	19	1	8.2	-0.6	3	2.3	1	62	6	24	20	2	96
BOON R	Raw Water	27/07/2017	606	7.28	133	69	69	0	13	334	304	22	3	8.4	-1.1	3.4	2.3	1	61	5.8	20	20	0	84
BOON R	Raw Water	18/07/2017	602	7.32	134	68	68	0	13	332	303	23	3	8.4	-1	3.3	2.3	1	60	5.9	20	21	0	83
BOON R	Raw Water	12/07/2017	604	7.29	134	70	70	0	13	333	303	21	4	8.3	-1	3.3	2.2	1	60	5.7	20	21	0	85
BOON R	Raw Water	5/07/2017	606	7.27	134	69	69	0	13	334	304	19	7	8.3	-1.1	3.4	2.3	1	61	5.8	19	21	0	84
BOON R	Raw Water	29/06/2017	603	7	134	69	69	0	13	332	303	23	4	8.4	-1.4	3.6	2.3	1	60	5.8	20	21	0	84
BOON R	Raw Water	20/06/2017	597	7.28	131	67	67	0	1.3	328	299	24	8	8.4	-1.1	3.3	2.3	1	61	5.8	19	20	0	82
BOON R	Raw Water	13/06/2017	599	7.14	131	68	68	0	13	328	299	28	8	8.4	-1.2	3.5	2.3	1	60	5.9	19	20	0	82
BOON R	Raw Water	7/06/2017	597	7.24	130	67	67	0	13	329	301	30	8	8.4	-1.1	3.4	2.3	1	61	5.9	19	20	0	81
BOON R	Raw Water	29/05/2017	590	7.24	129	64	64	0	13	323	297	34	9	8.4	-1.2	3.4	2.3	1	60	5.9	18	20	0	78
BOON R	Raw Water	24/05/2017	586	7.26	129	64	64	0	13	323	296	34	10	8.4	-1.1	3.3	2.2	1	58	5.9	18	20	0	78
BOON R	Raw Water	17/05/2017	593	7.27	132	68	68	0	13	327	298	35	13	8.3	-1.1	3.4	2.2	1	59	5.9	20	20	0	82
BOON R	Raw Water	11/05/2017	577	7.25	126	62	62	0	13	317	292	40	15	8.4	-1.2	3.4	2.3	1	59	5.8	18	20	0	75
BOON R	Raw Water	2/05/2017	570	7.26	125	61	61	0	13	309	284	40	17	8	-1.2	3.4	2.2	1	58	5.7	18	20	0	714
BOON R	Raw Water	27/04/2017	560	7.37	122	60	60	0	13	304	279	45	16	8.4	-1.1	3.3	2.2	1	57	5.7	17	19	0	73
BOON R	Raw Water	19/04/2017	547	7.13	117	59	59	0	12	295	271	52	32	8.5	-1.3	3.5	2.2	1	55	5.6	17	18	0	72
BOON R	Raw Water	10/04/2017	503	6.87	108		63		12		251	42	51		-1.6				50	5.5	16	17		77
BOON R	Raw Water	27/03/2017	678	7.28	148		84		11		340	8	2		-0.09				70	6	21	24		103
BOON R	Raw Water	23/03/2017	674	7.44	148		84		11		332	6	2		-0.8				68	6.1	20	24		103
BOON R	Raw Water	14/03/2017	688	7.83	153		0		12		346	7	1		8.2				71	6.1	21	24		104
BOON R	Raw Water	7/03/2017	683	7.89	154		88		12		346	5	<1		-0.3				70	6.1	22	24		105
BOON R		28/02/2017	694	7.69	153		87		11		342	7	3		-0.5				70	6.2	21	24		105
BOON R	Raw Water	15/02/2017	686	7.6	154		91		91		342	8	3		-0.5				70	6.1	22	24		110
BOON R		8/02/2017	667	7.62	153		93		11		336	8	<1		8.1				68	6.1	22	24		113
BOON R	Raw Water	25/01/2017	680	7.81	149		92		11		335	8	1		-0.3				66	6.2	21	23		110
BOON R	Raw Water	18/01/2017	679	7.76	151		96		11		390	7	1		8.1				68	6.1	22	24		116
BOON R	Raw Water	11/01/2017	675	7.88	152		100		11		345	7	<1		-0.2				69	6.2	22	24		120
BOON R	Raw Water	21/12/2016	666	7.61	154		96		12		345	6	1		-0.5				68	6.2	22	24		117
BOON R	Raw Water	24/11/2016	655	7.83	150		94		12		331	7	1		-0.3				66	5.9	22	23		113
BOON R	Raw Water	11/11/2016	652	7.73	148		91		12		324	7	1		-0.4				64	5.9	22	23		110
BOON R	Raw Water	3/11/2016	648	7.79	142		94		12		319	7	1		-0.4				62	5.7	21	22		113
BOON R	Raw Water	26/10/2016	639	7.75	147		94		12		322	5	2		-0.4				62	5.8	22	22		114
BOON R	Raw Water	21/10/2016	1790	7.82	436		118		6		893	9	8		7.7				180	7.4	54	73		142
BOON R	Raw Water	12/10/2016	639	7.67	143		93		12		315	6	3		-0.5				63	5.9	21	22		113
BOON R	Raw Water	6/10/2016	616	7.9	141		89		12		311	7	1		8.2				62	5.8	21	21		108
BOON R	Raw Water	27/09/2016	640	7.91	141		90		12		311	6	2		-0.3				61	5.7	21	22		109
BOON R	Raw Water	22/09/2016	638	7.85	142		91		12		313	10	2		-0.3				61	5.8	21	22		110
	Raw Water	14/09/2016	627	7.9	140		88		12		314	7	1		-0.3				62	5.7	21	21		107
BOON R	Raw Water	1/09/2016	635	7.78	140		84		12		310	6	2		-0.4				62	5.8	21	21		101
BOON R	Raw Water	25/08/2016	620	7.91	139		84		12		311	5	1		-0.3				62	5.8	21	21		101
BOON R	Raw Water	17/08/2016	616	7.91	139		84		12		311	6	<1		-0.3				62	5.7	21	21		102
BOON R	Raw Water	11/08/2016	1600	7.75	384		114		8		816	10	4		0				163	7.3	49	64		138
BOON R	Raw Water	4/08/2016	623	7.82	137		83		12		309	7	<1		-0.4				61	5.7	20	21		100
BOON R	Raw Water	25/07/2016	621	7.89	138		83		13		314	8	1		-0.4				62	5.8	21	21		101
BOON R	Raw Water	19/07/2016	615	7.5	136		88		13		310	8	<1		-0.7				62	5.8	20	21		107
BOON R	Raw Water	14/07/2016	630	7.5	139		85		13		310	6	1		-0.7				62	5.8	20	21		103
BOON R	Raw Water	7/07/2016	613	7.5	136		86		13		309	9	<1		-0.7				61	5.8	20	21		104
BOON R	Raw Water	29/07/2016	609	7.44	136		85		13		307	9	2		-0.8				61	5.8	20	21		103
BOON R	Raw Water	23/06/2016	617	7.48	138		83		13		312	9	2		-0.8				62	5.8	20	21		101
BOON R	Raw Water	15/06/2016	621	7.61	140		83		13		313	8	3		-0.6				62	5.8	21	21		101
BOON R	Raw Water	9/06/2016	633	7.57	139		83		12		318	6	2		-0.7				64	5.9	20	22		101
BOON R	Raw Water	1/06/2016	647	7.63	143		82		12		322	8	1		-0.6				65	5.9	20	22		100
BOON R	Raw Water	26/05/2016	653	7.6	144		81		12		323	8	1		-0.6				66	5.9	20	23		98
BOON R	Raw Water	12/05/2016	1900	7.49	446		106		7		934	9	154		-0.3				192	7.9	54	76		129
		max	1900	8	446	82	118	0	91	399	934	52	154	9	8	4	3	1	192	8	54	76	2	714
		min	503	7	108	59	0	0	1	295	251	1	1	8	-2	3	2	1	50	0	16	17	0	72

CO3 Carbo	Hydroxide	Cl Chloride	F Fluoride	NO3 Nitrat	SO4 Sulpha	Fe Iron	Mn Manga	Zn Zinc	Al Aluminiu	B Boron	Cu Copper
0.1	0	170	0.17	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.18	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
0.1	0	170	0.18	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.18	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.18	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	160	0.17	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	170	0.18	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.18	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
0.5	0	160	0.18	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.6	0	180	0.18	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	170	0.18	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	160	0.18	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	160	0.17	0.6	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.17	<0.5	4	0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.5	0	160	0.18	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	160	0.17	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4	0	160	0.17	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4	0	160	0.16	0.6	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	160	0.17	0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	160	0.17	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	160	0.17	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0	0	160	0.17	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0	0	160	0.17	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	160	0.17	0.6	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	160	0.17	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.18	0.7	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.17	0.9	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.18	0.9	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.17	0.9	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	160	0.17	1	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.17	1	3	<0.01	<0.01	0.01	<0.05	0.04	<0.03
0.1	0	170	0.18	0.7	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.17	0.9	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	160	0.48	1.5	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	160	0.16	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	160	0.21	1.3	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.19	1.3	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.19	0.6	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.23	1.2	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	170	0.2	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	160	0.2	0.9	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	160	0.18	0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	160	0.22	0.7	3	<0.01	<0.01	<0.01	<0.05	0.03	<0.03
0.1	0	170	0.19	<0.6	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.19	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.2	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.19	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	170	0.2	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4	0	170	0.19	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	160	0.19	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	160	0.2	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4	0	160	0.17	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3	0	160	0.2	<0.5	3	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2	0	160	0.18	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.03	<0.03
0.2	0	160	0.18	9.6	4	<0.01	<0.01	<0.01	<0.05	0.03	<0.03
0.2	0	170	0.21	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.03	<0.03
0.3	0	160	0.2	<0.5	4	<0.01	<0.01	0.01	<0.05	0.04	<0.03
0.2	0	160	0.19	<0.5	4	<0.01	<0.01	<0.01	<0.05	0.03	0.03
0.1	0	160	0.19	0.5	4	0.01	0.01	0.01	0.05	0.04	0.03
0.3	0	150	0.19	0.5	4	0.01	0.01	0.26	0.05	0.04	0.03
0.2	0	150	0.22	0.5	4	0.01	0.01	0.01	0.05	0.04	0.03
0.3	0	150	0.16	0.6	4	0.01	0.01	0.01	0.05	0.04	0.03
0.3	0	150	0.15	0.5	4	0.01	0.01	0.01	0.05	0.04	0.03
0.4	0	140	0.16	0.05	4	0.01	0.01	0.01	0.05	0.04	0.03
0.3	0	140	0.15	0.7	4	0.01	0.01	0.01	0.05	0.03	0.03
0.2	0	140	0.15	0.5	4	0.01	0.01	0.01	0.05	0.03	0.03

0.2	0	140	0.18	0.5	4	0.01	0.01	0.01	0.05	0.03	0.03
0.3	0	140	0.15	0.5	4	0.01	0.01	0.01	0.05	0.04	0.03
0.3	0	140	0.18	0.5	4	0.01	0.01	0.01	0.05	0.04	0.03
0.5	0	140	0.18	0.6	4	0.01	0.01	0.01	0.05	0.04	0.03
0.2	0	140	0.16	1.1	4	0.01	0.01	0.01	0.05	0.04	0.03
0.1	0	140	0.17	0.9	4	0.01	0.01	0.01	0.05	0.04	0.03
0.3	0	140	0.16	1	4	0.01	0.01	0.01	0.05	0.04	0.03
0.2	0	140	0.15	1.1	4	0.01	0.01	0.01	0.05	0.04	0.03
0.1	0	140	0.2	1.2	4	0.01	0.01	0.01	0.05	0.04	0.03
0.1	0	140	0.18	1.2	4	0.01	0.01	0.01	0.05	0.04	0.03
0.2	0	140	0.17	1.4	4	<0.01	<0.01	<0.01	<0.05	0.03	<0.03
0.3	0	140	0.19	0.5	4	0.03	0.18	<0.01	<0.05	0.03	<0.03
0.1	0	140	0.13	1.7	4	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	140	0.14	1.5	4	0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	140	0.15	1.6	4	<0.01	<0.01	0.01	<0.05	0.03	<0.03
0.1	0	140	0.14	1.8	4	<0.01	<0.01	0.01	<0.05	0.04	<0.03
0.1	0	140	0.18	1.5	4	0.01	<0.01	0.01	<0.05	0.03	<0.03
0.1	0	130	0.13	1.3	4	0.02	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	140	0.11	1.3	3	<0.04	<0.01	0.01	<0.05	0.03	<0.03
0.1	0	140	0.13	1.2	4	<0.05	<0.01	0.01	<0.05	0.04	<0.03
0.1	0	140	0.13	1.2	3	0.06	<0.01	0.01	<0.05	0.04	<0.03
0.1	0	140	0.13	1.2	4	0.06	<0.01	<0.01	0.06	0.04	<0.03
0.1	0	140	0.12	1	3	0.06	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	140	0.07	1.1	3	0.09	<0.01	0.01	0.07	0.04	<0.03
0.1	0	130	0.14	0.7	4	0.07	<0.01	<0.01	<0.05	0.04	<0.03
0.1	0	130	0.13	0.7	4	0.1	<0.01	0.02	0.08	0.04	0.03
0.1	0	120	0.13	0.6	4	12	<0.01	0.04	<0.05	0.04	<0.03
0		110	0.11			0.09	<0.01	0.01	0.08	0.04	<0.03
0.2		160	0.16			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2		150	0.18			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4		160	0.19			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.7		160	0.19			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3		150	0.19			<0.01	<0.01	0.01	<0.05	0.05	<0.03
0.4		150	0.2			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4		150	0.18			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.6		150	0.18			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.6		150	0.19			0.19	<0.01	<0.01	<0.05	0.04	<0.03
0.8		150	0.2			<0.01	<0.01	0.15	<0.05	0.04	<0.03
0.4		150	0.19			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.6		140	0.16			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
0.5		140	0.16			<0.01	<0.01	0.38	<0.05	0.04	<0.03
0.5		140	0.16			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
0.3		140	0.16			<0.01	<0.01	<0.01	<0.05	0.04	0.05
0.5		490	<0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
0.3		130	0.16			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4		130	0.17			<0.01	<0.01	<0.01	<0.05	0.03	<0.03
0.6		130	0.15			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4		130	0.13			<0.01	<0.01	<0.01	<0.05	0.03	0.05
0.4		140	0.15			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4		130	0.16			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.5		140	0.16			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.5		140	0.16			<0.01	<0.01	0.01	<0.05	0.04	<0.03
0.4		450	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.4		140	0.15			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.5		140	0.16			<0.01	<0.01	0.01	<0.05	0.03	<0.03
0.2		130	0.14			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2		130	0.15			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2		130	0.16			<0.01	<0.01	<0.01	<0.05	0.03	<0.03
0.2		130	0.14			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.1		140	0.14			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3		140	0.16			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.2		140	0.17			<0.01	<0.01	<0.01	<0.05	0.03	<0.03
0.3		140	0.16			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
0.3		140	0.16			<0.01	<0.01	<0.01	>0.05	0.04	<0.03
0.2		520	<0.35			0.02	0.03	<0.01	<0.05	0.04	<0.03
1	0	520	0	10	4	12	0	0	0	0	0
0	0	110	0	0	3	0	0	0	0	0	0

	Source	Date	Cond	pH	Total Hardı	Temp Hard	Alkalinity	Residual Al	Silica	Total Disol	Total Disso	Colour	Turbidity	pH Sat	Satuartion	Mole ratio	Sodium Ab	Figure of M	Na Sodium	K Potassiur	Ca Calcium	Mg Magne	H Hydroger	HCO3 Bicar	CO3 Carbo	OH Hydrox
GORD R	Raw Water	21/05/2019	1930	8.5	474	147	147	0	6	1050	966	16	13	7.6	0.9	0.4	3.9	1.1	190	11	63	77	0	172	3.4	0
GORD R	Raw Water	14/05/2019	1940	8.39		149	149	0	6	1060	972	15	12	7.5	0.8	2.6	4	1.1	200	11	62	76	0	177	2.3	0
GORD R	Raw Water	8/05/2019	1890	8.21	462	148	148	0	6	1040	953	15	10	7.5	0.7	2.7	3.9	1.1	190	10	62	75	0	177	1.6	0
GORD R	Raw Water	30/04/2019	1920	8.49	452	145	145	0	6	1030	953	16	14	7.6	0.9	2.5	3.9	1.1	190	10	60	74	0	170	3	0
GORD R	Raw Water	16/04/2019	1880	7.49	447	137	137	0	7	1020	940	14	6	7.6	-0.1	3.5	3.8	1.1	190	10	59	73	0	167	0.2	0
GORD R	Raw Water	2/04/2019	1830	7.9	427	135	135	0	8	981	906	14	13	7.6	0.3	3.1	3.8	1.1	180	9.9	56	70	0	163	0.7	0
GORD R	Raw Water	26/03/2019	1820	7.9	433	134	134	0	8	972	898	19	4	7.6	0.3	3.1	3.8	1.1	180	10	57	71	0	162	0.6	0
GORD R	Raw Water	19/03/2019	1820	7.92	430	139	139	0	8	966	889	17	7	7.6	0.3	3	3.8	1.1	180	10	58	69	0	168	0.8	0
GORD R	Raw Water	12/03/2019	1830	7.88	440	145	145	0	9	998	918	20	4	7.6	0.3	3.1	3.8	1.1	180	10	59	71	0	175	0.6	0
GORD R	Raw Water	5/03/2019	1820	8.43	437	144	144	0	9	970	892	19	15	7.6	0.8	2.5	3.7	1.1	180	10	59	70	0	171	2.3	0
GORD R	Raw Water	26/02/2019	1800	8.38	438	141	141	0	9	967	891	21	10	7.6	0.8	2.5	3.7	1.1	180	10	60	70	0	166	2.6	0
GORD R	Raw Water	19/02/2019	1750	8.4	415	137	137	0	8	944	870	19	10	7.6	0.8	2.5	3.8	1.1	180	9.4	60	65	0	163	2.4	0
GORD R	Raw Water	12/02/2019	1710	8.42	414	135	135	0	9	943	870	17	9	7.6	0.8	2.6	3.7	1.1	170	9.6	56	66	0	161	2	0
GORD R	Raw Water	5/02/2019	1700	8.14	412	136	136	0	9	918	844	17	7	7.6	0.5	2.8	3.5	1.1	170	9.6	56	66	0	163	1.2	0
GORD R	Raw Water	30/01/2019	1660	8.05	410	133	133	0	8	921	850	19	5	7.6	0.4	2.4	3.5	1.2	160	9.7	57	65	0	156	3.1	0
GORD R	Raw Water	22/01/2019	1630	8.49	395	131	131	0	7	888	817	19	9	7.6	0.9	2.4	3.5	1.1	160	9.2	55	63	0	154	2.7	0
GORD R	Raw Water	15/01/2019	1590	8.11	383	130	130	0	7	857	784	18	3	7.7	0.5	2.8	3.4	1.1	150	9	54	61	0	156	1.1	0
GORD R	Raw Water	8/01/2019	1560	8.37	378	127	127	0	6	838	768	20	10	7.7	0.7	2.6	3.4	1.1	150	8.8	52	60	0	151	1.9	0
GORD R	Raw Water	18/12/2018	1460	7.94	349	118	118	0	6	772	705	17	4	7.7	0.2	2.9	3.2	1.2	140	8.2	49	55	0	143	0.8	0
GORD R	Raw Water	11/12/2018	1500	7.86	361	126	126	0	6	807	735	22	5	7.7	0.2	3	3.3	1.1	150	8.6	51	57	0	153	0.6	0
GORD R	Raw Water	4/12/2018	1470	8.32	354	123	123	0	6	786	718	19	8	7.7	0.6	2.6	3.2	1.2	140	8.2	50	56	0	147	1.7	0
GORD R	Raw Water	27/11/2018	1460	7.94	346	122	122	0	6	775	706	19	10	7.7	0.2	3	3.2	1.2	140	8.2	49	54	0	148	0.6	0
GORD R	Raw Water	20/11/2018	1420	7.9	346	117	117	0	7	791	727	19	9	7.7	0.2	2.5	3.3	1.1	140	8	49	55	0	139	2.2	0
GORD R	Raw Water	13/11/2018	1410	7.34	339	117	117	0	8	755	691	24	8	7.8	-0.4	3.6	3.2	1.2	140	8.1	48	54	0	143	0.1	0
GORD R	Raw Water	6/11/2018	1390	7.25	331	113	113	0	9	736	675	22	6	7.8	-0.5	3.6	3.2	1.2	130	7.8	47	52	0	138	0.2	0
GORD R	Raw Water	31/10/2018	1420	7.01	338	116	116	0	9	757	694	27	7	7.7	-0.7	3.9	3.3	1.1	140	7.7	48	53	0	141	0.1	0
GORD R	Raw Water	23/10/2018	1490	7.67	362	120	120	0	8	802	737	25	17	7.7	0	3.2	3.3	1.2	140	7.8	50	58	0	145	0.4	0
GORD R	Raw Water	16/10/2018	1710	7.83	418	141	141	0	8	927	848	19	18	7.6	0.2	3.1	3.5	1.2	170	8.6	59	66	0	171	0.6	0
GORD R	Raw Water	9/10/2018	1760	8.32	432	153	153	0	8	951	866	14	13	7.5	0.6	2.6	3.6	1.2	170	8.9	61	68	0	183	2.1	0
GORD R	Raw Water	2/10/2018	1740	7.66	423	152	152	0	8	944	858	12	9	7.5	0.1	3.2	3.6	1.1	170	8	60	66	0	184	0.5	0
GORD R	Raw Water	18/09/2018	1710	7.85	410	153	153	0	8	928	843	16	13	7.5	0.3	2.9	3.6	1.1	170	8.7	59	64	0	185	0.8	0
GORD R	Raw Water	11/09/2018	1680	7.79	405	150	150	0	8	938	824	13	8	7.6	0.2	3	3.5	1.2	160	8.5	58	63	0	181	0.7	0
GORD R	Raw Water	4/09/2018	1650	7.62	404	146	146	0	8	908	826	13	8	7.6	0.1	3.2	3.5	1.1	160	8.5	58	63	0	177	0.5	0
GORD R	Raw Water	28/08/2018	1630	7.8	396	147	147	0	8	882	800	16	8	7.6	0.2	3	3.5	1.2	160	8.4	57	62	0	177	0.7	0
GORD R	Raw Water	21/08/2018	1620	7.64	389	140	140	0	8	877	799	13	10	7.6	0	3.3	3.4	1.1	160	8.2	56	61	0	170	0.4	0
GORD R	Raw Water	15/08/2018	1600	7.52	385	144	144	0	8	864	784	14	11	7.6	-0.1	3.3	3.4	1.1	160	8.2	55	60	0	175	0.3	0
GORD R	Raw Water	31/07/2018	1560	7.66	381	138	138	0	8	844	767	15	6	7.6	0.1	3.3	3.4	1.2	150	8.2	54	60	0	167	0.4	0
GORD R	Raw Water	26/07/2018	1480	7.57	364	131	131	0	8	818	745	17	2	7.6	-0.1	3.3	3.3	1.2	140	7.7	52	57	0	157	0.5	0
GORD R	Raw Water	24/07/2018	1540	7.82	373	132	132	0	8	839	766	14	6	7.6	0.2	3	3.4	1.1	150	8	54	58	0	160	0.7	0
GORD R	Raw Water	17/07/2018	1520	7.95	365	138	138	0	8	819	742	15	7	7.6	0.3	3	3.3	1.2	150	7.8	52	57	0	166	0.7	0
GORD R	Raw Water	10/07/2018	1500	7.74	361	135	135	0	8	813	738	12	6	7.7	0.1	3.1	3.3	1.1	150	7.9	52	56	0	163	0.5	0
GORD R	Raw Water	3/07/2018	1480	7.21	358	132	132	0	8	811	737	15	1	7.7	-0.5	3.7	3.3	1.1	140	7.9	51	56	0	161	0.1	0
GORD R	Raw Water	12/06/2018	1450	7.77	348	129	129	0	8	788	716	16	7	7.7	0.1	3.1	3.3	1.1	140	7.7	49	55	0	157	0.5	0
GORD R	Raw Water	5/06/2018	1450	7.55	347	125	125	0	8	793	724	15	5	7.7	-0.2	3.2	3.3	1.1	140	7.8	49	55	0	152	0.4	0
GORD R	Raw Water	29/05/2018	1430	7.92	346	126	126	0	8	786	717	16	3	7.7	0.2	2.9	3.3	1.1	140	7.9	49	57	0	160	0.3	0
GORD R	Raw Water	22/05/2018	1420	8.23	333	125	125	0	7	755	687	16	6	7.7	0.5	2.5	3.3	1.1	140	7.5	46	53	0	149	1.7	0
GORD R	Raw Water	15/05/2018	1460	7.61	346	153	153	0	10	804	720	14	6	7.6	0	3.1	3.2	1.2	140	8.8	49	55	0	185	0.5	0
GORD R	Raw Water	8/05/2018	1400	7.87	333	119	119	0	8	755	690	16	5	7.7	0.1	2.9	3.3	1.1	140	7.5	46	53	0	144	0.7	0
GORD R	Raw Water	23/04/2018	1360	7.56	317	114	114	0	8	731	668	17	6	7.8	-0.2	3.3	3.2	1.1	130	7.4	43	51	0	138	0.3	0
GORD R	Raw Water	17/04/2018	1370	7.61	327	116	116	0	8	740	676	16	4	7.8	-0.2	3.2	3.2	1.1	130	7.6	45	52	0	141	0.3	0
GORD R	Raw Water	10/04/2018	1360	8.08	312	114	114	0	7	723	661	21	9	7.8	0.3	2.7	3.3	1.1	130	7.4	42	51	0	136	1.1	0
GORD R	Raw Water	4/04/2018	1330	7.82	316	108	108	0	8	725	666	18	6	7.8	0	3.2	3.3	1.1	130	7.6	42	51	0	131	0.4	0
GORD R	Raw Water	26/03/2018	1330	7.69	312	107	107	0	8	709	651	18	5	7.8	-0.1	3.2	3.2	1.1	130	7.5	42	50	0	129	0.4	0
GORD R	Raw Water	20/03/2018	1320	7.97	311	105	105	0	8	750	649	22	5	7.9	0.2	2.9	3.2	1.1	130	7.4	41	50	0	126	0.8	0
GORD R	Raw Water	13/03/2018	1350	7.74	317	106	106	0	8	723	666	23	5	7.8	-0.1	3.1	3.3	1.1	130	7.6	42	52	0	128	0.5	0
GORD R	Raw Water	6/03/2018	1430	7.6	333	110	110	0	8	760	701	21	4	7.8	-0.2	3.3	3.4	1.1	140	7.8	44	55	0	133	0.3	0
GORD R	Raw Water	26/02/2018	1620	7.54	382	120	120	0	7	874	807	16	4	7.7	-0.2	3.5	3.6	1.1	160	8.9	50	63	0	146	0.2	0
GORD R	Raw Water	20/02/2018	1610	7.48	379	119	119	0	4	862	792	16	4	7.7	-2	3.5	3.6	1.1	160	8.9	49	62	0	145	0.2	0
GORD R	Raw Water	13/02/2018	1660	7.96	386	124	124	0	4	877	806	20	4	7.7	0.3	3	3.6	1.1	160	9	51	63	0	149	0.8	0
GORD R	Raw Water	7/02/2018	1660	7.57	386	122	122	0	4	883	812	17	3	7.7	-0.1	3.3	3.6	1.1	160	9	50	63	0	149	0.3	0
GORD R	Raw Water	30/01/2018	1650	7.64	396	124	124	0	5	894	822	18	6	7.7	0	3.3	3.7	1.1	170	9.4	51	65	0	151	0.4	0
GORD R	Raw Water	16/01/2018	1600	8.1	374	120	120	0	6	864	796	18	8	7.7	0.4	2.8	3.6	1.1	160	8.6	49	61	0	144	1.1	0
GORD R	Raw Water	10/01/2018	1600	8.01	378	120	120	0	4	847	778	17	10	7.7	0.3	2.9	3.6	1.1	160	8.4	49	62	0	145	0.9	0
GORD R	Raw Water	3/01/2018	1570	7.93	367	118	118	0	4	838	770	19	7	7.7	0.2	3	3.5	1.1	150	8.2	48	60	0	142	0.8	0
GORD R	Raw Water	20/12/2017	1580	7.9	375	120	120	0	3	851	782	17	4	7.7	0.2	3	3.5	1.1	160	8.4	50	61	0	144	0.7	0
GORD R	Raw Water	7/12/2017	1550	7.97	363	120	120	0	2	835	763	16	4	7.7	0.3	3	3.4	1.1	150	8.4	48	59	0	146	0.7	0
GORD R	Raw Water	1/12/2017	1530	8	365	117	117	0	1	816	745	18	2	7.7	0.3	2.8	3.4	1.1	150	8.4	49	59	0	140	1	0
GORD R	Raw Water	14/11/2017	1500	7.6	352	118	118	0	3	797	727	17	3	7.7	0.1	3.3	3.4	1.1	150	8.3	48	57	0	143	0.4	0
GORD R	Raw Water	8/11/2017	1460	7.95	341	114	114	0	4	767	700	14	7	7.7	0.2	3	3.3	1.1	140	7.9	46	55	0	138	0.6	0
GORD R	Raw Water	1/11/2017	1450	7.83	341	118	118	0	4	774	705	17	3	7.7	0.1	3.1	3.3	1.1	140	8.4	46	55	0	143	0.5	0
GORD R	Raw Water	24/10/2017	1400	8.42	331	113	113	0	3	751	686	20	6	7.8	0.6	2.5	3.3	1.1	140	7.9	45	53	0	133	2.2	0

GORD R	Raw Water	17/10/2017	1400	8.36	331	114	114	0	4	748	684	17	10	7.7	0.6	2.5	3.3	1.1	140	8	46	53	0	135	2.1	0
GORD R	Raw Water	3/10/2017	1380	7.79	330	113	113	0	3	743	676	20	6	7.7	0.1	3.1	3.3	1.1	140	7.8	46	52	0	137	0.5	0
GORD R	Raw Water	27/09/2017	1370	8.12	331	112	112	0	3	739	673	16	8	7.7	0.4	2.7	3.2	1.1	140	7.8	46	53	0	135	1.1	0
GORD R	Raw Water	19/09/2017	1350	8.11	318	110	110	0	2	718	654	14	5	7.8	0.3	2.7	3.2	1.1	130	7.6	44	51	0	131	1	0
GORD R	Raw Water	12/09/2017	1310	8.07	313	109	109	0	2	703	639	17	4	7.8	0.3	2.7	3.1	1.1	130	7.5	4	50	0	130	1.3	0
GORD R	Raw Water	5/09/2017	1300	8.08	310	106	106	0	2	702	640	15	3	7.8	0.3	2.9	3.2	1.1	130	7.3	44	49	0	127	0.7	0
GORD R	Raw Water	30/08/2017	1270	8.27	302	105	105	0	2	684	622	20	3	7.9	0.4	2.6	3.1	1.1	120	7.3	42	48	0	126	1.4	0
GORD R	Raw Water	23/08/2017	1250	8.13	294	102	102	0	2	682	622	16	1	7.9	0.2	2.7	3.1	1.1	120	7.2	41	47	0	122	1.1	0
GORD R	Raw Water	16/08/2017	1230	7.86	288	100	100	0	2	660	600	18	3	7.9	0	3.1	3	1.1	120	7.1	40	46	0	122	0.4	0
GORD R	Raw Water	27/07/2017	1160	7.77	270	93	93	0	2	617	532	22	2	8	0.2	3.1	3	1.1	110	7	37	43	0	113	0.4	0
GORD R	Raw Water	19/07/2017	1120	7.6	261	89	89	0	2	594	541	22	2	8	-0.4	3.3	2.9	1.1	110	7.1	36	42	0	108	0.2	0
GORD R	Raw Water	13/07/2017	1110	7.8	258	84	84	0	2	592	543	20	2	8	-0.2	3.1	2.9	1.1	110	6.8	34	42	0	102	0.4	0
GORD R		5/07/2017	1100	7.54	255	84	84	0	2	580	530	23	5	8	-0.5	3.3	2.9	1.1	110	6.9	34	42	0	102	0.2	0
GORD R		29/06/2017	1070	7.3	248	80	80	0	2	563	515	23	2	8.1	-0.8	3.6	2.9	1.1	110	6.9	32	40	0	98	0.1	0
GORD R		21/06/2017	1060	7.7	242	78	78	0	2	549	503	25	3	8.1	-0.4	3.2	2.9	1.1	100	6.7	31	40	0	95	0.3	0
GORD R		14/06/2017	1050	7.6	236	76	76	0	3	545	501	28	2	8.1	-0.5	3.4	2.9	1.1	100	6.8	31	39	0	92	0.2	0
GORD R		8/06/2017	1040	7.8	233	74	74	0	4	541	499	28	3	8.1	-0.3	3.1	2.9	1.1	100	6.8	30	39	0	90	0.4	0
GORD R		29/05/2017	1010	7.59	228	70	70	0	5	525	487	32	4	8.2	-0.6	3.4	2.8	1.1	99	6.8	29	38	0	85	0.2	0
GORD R		24/05/2017	993	7.98	225	69	69	0	5	520	843	35	4	8.2	-0.2	3	2.8	1.1	98	6.8	28	38	0	83	0.5	0
GORD R		17/05/2017	991	7.76	225	66	66	0	7	513	479	38	5	8.2	-0.4	3.3	2.8	1.1	97	6.8	28	38	0	81	0.2	0
GORD R		11/05/2017	987	7.55	222	65	65	0	8	513	481	40	4	8.2	-0.7	3.5	2.9	1	99	6.9	27	38	0	79	0.1	0
GORD R		2/05/2017	976	7.72	219	63	63	0	10	500	472	46	2	8.2	-0.5	3.2	2.8	1.1	96	6.9	27	37	0	76	0.3	0
GORD R		28/04/2017	974	7.56	217	60	60	0	11	503	477	52	7	8.3	-0.7	3.4	2.9	1	97	6.9	26	37	0	73	0.2	0
GORD R		19/04/2017	977	7.11	214	57	57	0	1.4	494	473	63	11	8.3	-1.2	3.9	2.8	1	95	6.8	26	36	0	70	0.1	0
GORD R		11/04/2017	981	6.77	215		53		15		479	17	69		-1.6				96	6.8	26	37		65	0	
GORD R		28/03/2017	2910	6.95	631		67		1420		1420	9	2		-1				310	8.8	53	120		82	0	
GORD R		23/03/2017	2900	7.58	635		68		2		1420	7	4		-0.3				310	8.9	53	120		82	0.2	
GORD R		14/03/2017	2980	7.77	661		72		3		1470	7	2		-0.1				330	9.2	56	130		87	0.2	
GORD R		7/03/2017	2930	8.15	656		74		3		1480	6	2		0.3				320	9.2	55	130		88	1	
GORD R		28/02/2017	2960	8.01	649		76		3		1450	8	1		0.2				320	9.2	56	120		91	0.6	
GORD R	Raw Water	14/02/2017	2910	8.05	648		83		3		1450	2	8		7.8				320	9.2	57	120		99	0.9	
GORD R		8/02/2017	2760	7.8	636		89		4		1420	8	2		0				310	9.1	57			108	0.4	
GORD R	Raw Water	2/02/2017	2800	7.66	629		93		3		1410	2	7		-0.1				300	9.1	58	120		113	0.3	
GORD R		25/01/2017	2780	7.67	615		93		3		1370	1	10		7.7				290	9.1	58	110		113	0.3	
GORD R	Raw Water	18/01/2017	2730	8.02	620		0		3		1430	8	2		0.3				300	8.7	59	120		121	0.9	
GORD R	Raw Water	11/01/2017	2650	7.94	625		105		3		1370	10	1		0.3				300	8.8	61	120		127	0.6	
GORD R	Raw Water	21/12/2016	2590	7.51	628		115		3		1350	7	2		-0.1				280	8.7	66	110		139	0.3	
GORD R	Raw Water	24/11/2016	2510	8.05	584		126		3		1250	9	3		0.5				260	8.3	68	100		152	1	
GORD R	Raw Water	11/11/2016	2450	7.61	584		127		3		1230	9	6		0.1				260	8.2	69	100		154	0.4	
GORD R	Raw Water	3/11/2016	2420	7.67	567		131		3		1200	9	5		0.1				250	7.9	68	96		159	0.5	
GORD R	Raw Water	26/10/2016	2320	8.17	568		129		3		1170	9	6		0.6				240	7.9	68	97		154	1.4	
GORD R	Raw Water	21/10/2016	2350	8	573		130		3		1200	10	4		0.5				240	8.1	70	97		156	1.2	
GORD R	Raw Water	12/10/2016	2330	7.68	566		136		3		1160	10	10		0.2				240	8.2	69	96		165	0.5	
GORD R	Raw Water	7/10/2016	2240	8.01	558		0		4		1150	10	5		0.5				235	8.2	69	94		162	1	
GORD R	Raw Water	27/09/2016	2290	8.08	540		133		4		1130	10	9		0.5				226	8.1	67	91		160	1.2	
GORD R	Raw Water	22/09/2016	2270	8.02	536		136		4		1100	12	8		0.5				225	8.2	67	90		164	1.1	
GORD R	Raw Water	14/09/2016	2220	8.09	533		134		4		1110	12	9		0.6				227	8	66	89		161	1.2	
	Raw Water	14/09/2016	627	7.9	140		88		12		314	7	1		-0.3				62	5.7	21	21		107	0.4	
GORD R	Raw Water	9/09/2016	2280	8	528		134		4		1110	11	9		0.5				224	8.2	66	88		162	0.9	
GORD R	Raw Water	31/08/2016	2210	8.13	533		132		4		1100	10	9		0.6				223	8.1	67	89		158	1	
GORD R	Raw Water	25/08/2016	2180	8.25	528		126		4		1090	10	11		0.7				221	8.1	66	88		150	1.6	
GORD R	Raw Water	17/08/2016	2150	8.29	519		128		4		1080	10	8		0.7				220	8	65	87		153	1.8	
GORD R	Raw Water	11/08/2016	2180	7.82	524		130		4		1080	12	7		0.2				221	8.2	65	88		157	0.8	
GORD R	Raw Water	4/08/2016	2130	7.91	500		126		5		1050	12	7		0.3				231	8.1	62	84		152	0.8	
GORD R	Raw Water	25/07/2016	2100	8.19	495		122		5		1050	15	7		0.5				212	8.2	62	83		146	1.3	
GORD R	Raw Water	19/07/2016	2070	7.91	489		125		5		1030	12	6		0.3				210	8.2	60	82		151	0.7	
GORD R	Raw Water	14/07/2016	2130	7.93	496		122		5		1030	10	7		0.3				212	8.3	61	84		147	0.8	
GORD R	Raw Water	7/07/2016	2060	7.97	486		125		5		1030	14	6		0.3				208	8.2	60	82		150	0.8	
GORD R	Raw Water	29/07/2016	2060	8	486		122		6		1020	13	9		0.4				209	8.2	60	82		147	0.9	
GORD R	Raw Water	23/06/2016	2040	8.21	485		119		6		1020	13	16		0.5				208	8.1	59	82		142	1.4	
GORD R	Raw Water	15/06/2016	2050	7.9	487		117		6		1020	12	8		0.2				209	8.2	59	82		141	0.7	
GORD R	Raw Water	9/06/2016	2040	8.1	479		115		6		1030	12	8		0.4				210	8.2	58	82		138	1.1	
GORD R	Raw Water	1/06/2016	2040	8.31	477		114		6		1000	13	6		0.6				208	8.1	58	81		136	1.6	
GORD R	Raw Water	26/05/2016	2010	7.89	471		112		6		989	13	10		0.2				205	8.1	57	80		135	0.7	
GORD R	Raw Water	12/05/2016	1970	7.77	465		112		6		982	13	7		0.1				202	8	55	80		136	0.6	
GORD R	Raw Water	5/05/2016	2000	7.7	459		110		6		989	13	5		0				202	8	54	79		134	0.5	
		max	2980	8.5	661	153	153	0	1420	1060	1480	63	69	8.3	7.8	3.9	4	1.2	330	11	70	130	0	185	3.4	0
		min	627	6.77	140	57	0	0	1	494	314	1	1	7.5	-2	0.4	2.8	1	62	5.7	4	21	0	65	0	0

Cl Chloride	F Fluoride	NO3 Nitrat	SO4 Sulpha	Fe Iron	Mn Manga	Zn Zinc	Al Aluminiu	B Boron	Cu Copper
510	0.22	<1	15	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
520	0.23	<1.5	14	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
510	0.24	<1.5	14	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
510	0.23	<1.5	14	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
510	0.24	<1.5	14	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
490	0.24	<1.5	13	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
480	0.22	<1.5	12	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
470	0.2	<1.5	13	0.01	<0.01	<0.01	<0.05	0.05	<0.03
490	0.31	<2.5	14	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
470	<0.25	<2.5	13	0.01	<0.01	<0.01	<0.05	0.06	<0.03
470	<0.25	<2.5	13	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
460	<0.25	<2.5	12	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
460	0.21	<1.5	12	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
440	0.21	>1.5	12	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
450	<0.25	<2.5	13	<0.01	<0.01	<0.01	<0.05	0.06	<0.03
430	0.2	<1.5	12	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
410	0.2	<1	12	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
400	0.19	<1	12	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
360	0.19	1.7	13	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
380	0.18	<1	14	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
370	0.18	<1	13	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
360	0.17	<1	14	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
380	0.17	<1	14	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
360	0.17	<1	13	0.02	<0.01	<0.01	<0.05	0.04	<0.03
350	0.13	<1.0	13	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
360	0.16	<1.0	13	0.02	<0.01	<0.01	<0.05	0.04	<0.03
380	0.19	<1.0	15	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
440	<0.25	<2.5	16	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
440	0.18	<1.5	15	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
440	<0.25	<2.5	15	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
430	<0.25	<2.5	15	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
420	0.19	<1.5	15	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
420	<0.25	<2.5	14	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
400	<0.25	<2.5	14	0.02	<0.01	0.01	<0.05	0.05	<0.03
410	<0.25	<2.5	14	0.01	<0.01	<0.01	<0.05	0.04	<0.03
400	0.18	1.1	14	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
400	<0.1	1.1	5	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
360	0.26	2	13	<0.01	<0.01	<0.01	<0.05	1.04	<0.04
390	0.19	<0.5	15	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
380	0.19	<1	13	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
370	0.22	<1	13	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
380	0.28	<1	13	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
360	0.26	<1	13	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
370	0.26	2.1	13	<0.01	<0.01	<0.01	<0.05	0.03	<0.03
380	0.18	<1	13	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
350	0.24	<1	11	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
360	0.2	<0.5	10	1	6.1	<0.01	<0.05	0.05	<0.03
350	0.22	<1	11	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
350	0.2	<1	11	0.01	<0.01	<0.01	<0.05	0.05	<0.03
350	0.2	<1	11	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
340	0.2	<1	10	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
350	0.2	<1	10	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
340	0.22	1.6	10	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
340	0.16	<1	9	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
350	0.2	<1	9	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
370	0.2	<1	9	<0.01	<0.01	<0.01	<0.05	0.03	<0.03
430	0.29	<2.5	10	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
430	<0.25	<2.5	9	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
430	0.25	<2.5	9	<0.01	<0.01	<0.01	<0.05	0.05	<0.03
440	<0.25	<2.5	9	<0.01	<0.01	0.02	<0.05	0.04	0.07
440	0.25	2.5	8	0.01	0.01	0.01	0.05	0.05	0.03
430	0.25	2.5	8	0.01	0.01	0.31	0.06	0.05	0.04
410	0.25	2.5	9	0.01	0.01	0.001	0.05	0.04	0.03
420	0.18	1	7	0.01	0.01	0.01	0.05	0.05	0.03
420	0.18	2	8	0.01	0.01	0.01	0.05	0.04	0.03
410	0.2	<1	9	0.01	0.01	0.01	0.05	0.04	0.03
400	0.18	1.5	9	0.01	0.01	0.01	0.05	0.04	0.03
390	0.18	1	9	0.01	0.01	0.01	0.05	0.04	0.03
370	0.2	1	8	0.01	0.01	0.01	0.05	0.04	0.03
370	0.18	1	9	0.02	0.01	0.01	0.05	0.04	0.03
360	0.2	1	8	0.01	0.01	0.01	0.05	0.04	0.03

360	0.22	1	8	0.01	0.01	0.01	0.05	0.05	0.03
360	0.22	1	8	0.01	0.01	0.01	0.05	0.04	0.03
360	0.1	0.5	4	0.01	0.01	0.01	0.05	0.04	0.03
340	0.2	1	9	0.01	0.01	0.01	0.05	0.04	0.03
330	0.18	1	9	0.01	0.01	0.01	0.05	0.04	0.03
340	0.2	1	9	0.01	0.01	0.01	0.05	0.04	0.03
330	0.22	1	9	0.01	0.01	0.01	0.05	0.04	0.03
330	0.2	<1	10	<0.01	<0.01	<0.01	<0.05	0.03	<0.03
320	0.2	<1	9	<0.01	<0.01	<0.01	<0.05	0.03	0.04
300	0.16	1	9	0.01	0.01	0.01	0.05	0.04	0.06
280	0.16	1	9	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
290	0.16	1.1	9	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
280	0.18	1.6	9	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
270	0.2	1.8	8	<0.01	<0.01	0.01	<0.05	0.03	<0.03
260	0.18	<1	8	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
270	0.12	<1	8	<0.01	<0.01	0.01	<0.05	0.04	<0.03
270	0.14	<1	9	<0.01	<0.01	0.01	<0.05	0.04	<0.03
260	0.14	<1	7	0.01	<0.01	<0.01	<0.05	0.04	<0.03
260	0.16	<1	9	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
260	0.16	<1	7	0.01	<0.01	<0.01	<0.05	0.04	<0.03
260	<0.1	<1	7	<0.01	<0.01	<0.01	<0.05	0.04	<0.03
250	0.2	<1	9	0.01	<0.01	<0.01	<0.05	0.04	<0.03
250	0.14	<1	9	0.02	<0.01	0.01	<0.05	0.04	<0.03
250	0.14	2.4	9	0.05	<0.01	0.01	<0.05	0.04	0.04
250	0.1			0.12	<0.01	0.01	0.07	0.04	<0.03
870	<0.25			<0.01	<0.01	0.02	<0.05	0.06	<0.03
870	0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
890	<0.25			<0.01	<0.01	<0.01	<0.05	0.06	<0.03
910	<0.25			<0.01	<0.01	<0.01	<0.05	0.06	<0.03
880	<0.25			<0.01	<0.01	<0.01	<0.05	0.06	<0.03
880	<0.25			<0.01	<0.01	<0.01	<0.05	0.06	<0.03
850	<0.25			<0.01	<0.01	<0.01	<0.05	0.06	<0.03
850	<0.25			<0.01	<0.01	<0.01	<0.05	0.06	<0.03
820	<0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
820	<0.25			<0.01	<0.01	0.61	<0.05	0.06	<0.03
810	<0.25			<0.01	<0.01	0.09	<0.05	0.06	<0.03
790	<0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
720	<0.25			<0.01	<0.01	<0.01	<0.05	0.06	<0.03
710	<0.25			<0.01	<0.01	0.41	<0.05	0.05	<0.03
680	<0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
660	<0.25			0.01	<0.01	<0.01	<0.05	0.04	<0.03
690	<0.25			<0.01	<0.01	<0.01	<0.05	0.06	<0.03
650	<0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
650	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
640	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
610	<0.25			0.01	<0.01	<0.01	<0.05	0.04	<0.03
620	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
140	0.15			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
620	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
610	<0.25			<0.01	<0.01	0.02	<0.05	0.04	<0.03
610	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
600	<0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
610	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
590	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
590	<0.25			<0.01	<0.01	<0.01	<0.05	0.03	<0.03
580	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
570	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
580	0.3			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
570	0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
580	0.25			<0.01	<0.01	0.03	<0.05	0.06	<0.03
580	<0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
580	0.25			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
560	0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
560	<0.25			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
550	0.55			<0.01	<0.01	<0.01	<0.05	0.04	<0.03
560	<0.025			<0.01	<0.01	<0.01	<0.05	0.05	<0.03
910	0.55	2.5	16	1	6.1	0.61	0.07	1.04	0.07
140	0.1	0.5	4	0.01	0.01	0.001	0.05	0.03	0.03

Appendix F

		Source		Cond	pH	Total Hardness	Temp Hardness	Alkalinity	Residual Alkalinity	Silica	Total Disolved Ions	Total Dissolve d Solids	Colour	Turbidity	pH Sat	Satuartio n Index	Mole ratio
Average		GORD R	Average	1825.62	7.85	425.19	119.81	116.02	0.00	13.35	894.82	904.56	17.87	8.81	7.73	0.58	3.06
Median		GORD R	Median	1760.00	7.87	425.00	122.00	120.00	0.00	6.00	845.50	870.00	16.00	7.00	7.70	0.30	3.05
Max		GORD R	Max	2980.00	8.85	661.00	156.00	156.00	0.00	1420.00	1550.00	1500.00	170.00	100.00	8.80	8.10	4.40
Min		GORD R	Min	200.00	6.43	52.00	45.00	0.00	0.00	1.00	127.00	120.00	1.00	1.00	7.40	-0.10	2.30
95%ile		GORD R	95%ile	2900.00	8.44	633.70	153.00	153.00	0.00	11.00	1470.00	1423.50	35.90	22.50	8.20	1.10	3.90
Count		GORD R	Count	195.00	195.00	194.00	142.00	195.00	142.00	194.00	142.00	194.00	195.00	195.00	142.00	194.00	142.00
SSP0079125	GORD R		18/05/2022	800	7.03	190	89	89	0	18	445	410	56	26	8.1	1	3.6
SSP0078611	GORD R		5/04/2022	800	7.02	191	89	89	0	17	443	400	27	6	8.1	1	3.6
SSP0078295	GORD R		16/03/2022	550	7.32	131	67	67	0	17	305	280	49	5	8.3	1	3.3
SSP0077917	GORD R		15/02/2022	550	7.09	149	97	97	0	11	331	280	28	5	8.1	1	3.3
SSP0077544	GORD R		18/01/2022	450	7.37	118	80	80	0	12	266	230	40	8	8.3	0.9	3
			7/12/2021	200	7.04	52	45	45	0	23	127	120	170	100	8.8	1.8	3.2
SSP0076836	GORD R		16/11/2021	1600	7.68	359	94	94	0	6.1	828	780	41	26	7.9	0.2	3.3
SSP0076381	GORD R		12/10/2021	2600	8.45	617	150	150	0	2.9	1390	1300	14	18	7.5	1	2.6
SSP0076062	GORD R		15/09/2021	2600	7.62	593	143	140	0	3.9	1360	1300	14	11	7.5	0.1	3.6
SSP0075692	GORD R		17/08/2021	2500	7.04	560	134	130	0	4.4	1310	1200	8	26	7.5	0.5	4.1
SSP0075024	GORD R		16/06/2021	2600	7.07	573	125	130	0	4.8	1340	1300	15	7	7.6	0.5	4
SSP0074613	GORD R		18/05/2021	2800	7.19	621	125	130	0	5.5	1490	1400	13	8	7.5	0.3	4
SSP0074158	GORD R		13/04/2021	2900	6.86	646	115	120	0	6.2	1520	1500	18	13	7.6	0.7	4.4
SSP0073813	GORD R		16/03/2021	2980	8.85	652	103	103	0	6.7	1550	1500	23	27	7.7	1.2	2.5
SSP0073385	GORD R		16/02/2021	2920	8.75	633	102	102	0	6.2	1510	1460	22	26	7.7	1.1	2.6
SSP0072803	GORD R		13/01/2021	2840	8.25	653	130	130	0	6.7	1520	1450	17	15	7.5	0.8	3
SSP0072476	GORD R		9/12/2020	2800	7.26	623	116	116	0	7	1470	1410	14	10	7.6	0.3	3.9
SSP0072173	GORD R		18/11/2020	2660	7.84	581	107	107	0	5.2	1380	1320	29	8	7.7	0.2	3.4
SSP0071732	GORD R		14/10/2020	2780	7.87	636	133	133	0	4.9	1470	1400	17	29	7.5	0.4	3.2
SSP0071372	GORD R		16/09/2020	2650	8.34	622	156	156	0	5.1	1420	1330	14	19	7.4	0.9	2.7
SSP0071067	GORD R		19/08/2020	2500	8.44	594	144	144	0	6.3	1350	1270	18	18	7.5	1	2.6
SSP0070615	GORD R		8/07/2020	2450	8.05	574	138	138	0	7.5	1330	1250	16	10	7.5	0.6	2.9
SSP0070308	GORD R		10/06/2020	2400	7.68	546	130	130	0	7.7	1290	1220	14	6	7.5	0.1	3.3
SSP0069982	GORD R		13/05/2020	2340	7.56	538	122	122	0	8.2	1250	1190	15	5	7.6	0	3.5
SSP0069706	GORD R		22/04/2020	2260	7.27	518	112	112	0.0	8.2	1220	1160	15	6	7.6	0.4	3.8
SSP0069004	GORD R		4/03/2020	2650	6.94	584	104	104	0	8.8	1400	1350	19	4	7.7	0.7	4.2
SSP0068642	GORD R		11/02/2020	2840	7.61	617	93	93	0	6.8	1470	1420	31	21	7.7	0.1	3.7
SSP0068228	GORD R		14/01/2020	2910	8.8			97					31	29			
SSP0068228	GORD R		14/01/2020	2910	8.8	618	97	97	0	6.1	1510	1460	31	29	7.7	1.1	2.4
SSP0067913	GORD R		10/12/2019	2590	8.27	559	101	101	0	4.9	1330	1270	18	21	7.8	0.5	2.8
SSP0067472	GORD R		11/11/2019	2380	8.11	540	123	123	0	2.8	1250	1180	19	13	7.7	0.4	3.1
SSP0067090	GORD R		16/10/2019	2240	7.79	521	135	135	0	3	1200	1120	20	8	7.6	0.2	3.3
SSP0066765	GORD R		17/09/2019	2180	8.16	519	153	153	0	4	1170	1080	15	18	7.5	0.7	2.8
SSP0066274	GORD R		6/08/2019	2040	8.35	494	152	152	0	4	1110	1020	18	8	7.5	0.8	2.4
SSP0066171	GORD R		30/07/2019	2020	8.36	482	152	152	0	4	1100	1010	12	8	7.5	0.9	2.6
SSP0066087	GORD R		23/07/2019	2000	8.66	484	154	154	0	4	1090	1000	13	10	7.5	1.2	2.3
SSP0066031	GORD R		17/07/2019	2010	8.38	488	156	156	0	5	1090	999	13	9	7.5	0.9	2.6
SSP0065927	GORD R		9/07/2019	1970	8.16	482	154	154	0	5	1080	990	12	9	7.5	0.7	2.8
SSP0065818	GORD R		2/07/2019	1970	8.25	479	153	153	0	5	1070	983	15	10	7.5	0.7	2.7
SSP0065721	GORD R		25/06/2019	1970	8.46	477	153	153	0	5	1070	983	15	13	7.5	0.9	2.5
SSP0065625	GORD R		18/06/2019	1940	8.38	468	150	150	0	5	1050	964	17	7	7.5	0.8	2.4
SSP0065523	GORD R		11/06/2019	1970	7.94	476	154	154	0	6	1070	980	16	4	7.5	0.5	2.9
SSP0065432	GORD R		4/06/2019	1980	7.95	475	153	153	0	6	1070	981	13	9	7.5	0.4	3
SSP0065329	GORD R		28/05/2019	1970	7.96	472	151	151	0	6	1070	983	17	7	7.5	0.4	3
SSP0065189	GORD R		21/05/2019	1930	8.5	474	147	147	0	6	1050	966	16	13	7.6	0.9	2.4
SSP0065082	GORD R		14/05/2019	1940	8.37	468	149	149	0	6	1060	972	15	12	7.5	0.8	2.6
SSP0064960	GORD R		8/05/2019	1890	8.21	462	148	148	0	6	1040	953	15	10	7.5	0.7	2.7
SSP0064813	GORD R		30/04/2019	1920	8.49	452	145	145	0	6	1030	953	16	14	7.6	0.9	2.5

SSP0064683	GORD R	16/04/2019	1880	7.49	447	137	137	0	7	1020	940	14	6	7.6	0.1	3.5
SSP0064561	GORD R	9/04/2019	1850	8.18	438	138	138	0	7	1000	926	19	9	7.6	0.6	2.8
SSP0064447	GORD R	2/04/2019	1830	7.9	427	135	135	0	8	981	906	14	13	7.6	0.3	3.1
SSP0064329	GORD R	26/03/2019	1820	7.9	433	134	134	0	8	972	898	19	4	7.6	0.3	3.1
SSP0064196	GORD R	19/03/2019	1820	7.92	430	139	139	0	8	966	889	17	7	7.6	0.3	3
SSP0064087	GORD R	12/03/2019	1830	7.88	440	145	145	0	9	998	918	20	4	7.6	0.3	3.1
SSP0063947	GORD R	5/03/2019	1820	8.43	437	144	144	0	9	970	892	19	15	7.6	0.8	2.5
SSP0063848	GORD R	26/02/2019	1800	8.38	438	141	141	0	9	967	891	21	10	7.6	0.8	2.5
SSP0063745	GORD R	19/02/2019	1750	8.4	415	137	137	0	8	944	870	19	10	7.6	0.8	2.5
SSP0063647	GORD R	12/02/2019	1710	8.42	414	135	135	0	9	943	870	17	9	7.6	0.8	2.6
SSP0063539	GORD R	5/02/2019	1700	8.14	412	136	136	0	9	918	844	17	7	7.6	0.5	2.8
SSP0063433	GORD R	30/01/2019	1660	8.05	410	133	133	0	8	921	850	19	5	7.6	0.4	2.4
SSP0063332	GORD R	22/01/2019	1630	8.49	395	131	131	0	7	888	817	19	9	7.6	0.9	2.4
SSP0063237	GORD R	15/01/2019	1590	8.11	383	130	130	0	7	857	784	18	3	7.7	0.5	2.8
SSP0063132	GORD R	8/01/2019	1560	8.37	378	127	127	0	6	838	768	20	10	7.7	0.7	2.6
SSP0062968	GORD R	19/12/2018	1460	7.94	349	118	118	0	6	772	705	17	4	7.7	0.2	2.9
SSP0062846	GORD R	11/12/2018	1500	7.86	361	126	126	0	6	807	735	22	5	7.7	0.2	3
SSP0062740	GORD R	4/12/2018	1470	8.32	354	123	123	0	6	786	718	19	8	7.7	0.6	2.6
SSP0062632	GORD R	27/11/2018	1460	7.94	346	122	122	0	6	775	706	19	10	7.7	0.2	3
SSP0062552	GORD R	20/11/2018	1420	7.9	346	117	117	0	7	791	727	19	9	7.7	0.2	2.5
SSP0062443	GORD R	13/11/2018	1410	7.34	339	117	117	0	8	755	691	24	8	7.8	0.4	3.6
SSP0062323	GORD R	6/11/2018	1390	7.25	331	113	113	0	9	736	675	22	6	7.8	0.5	3.6
SSP0062248	GORD R	31/10/2018	1420	7.01	338	116	116	0	9	757	694	27	7	7.7	0.7	3.9
SSP0062124	GORD R	23/10/2018	1490	7.67	362	120	120	0	8	802	737	25	17	7.7	0	3.2
SSP0062035	GORD R	17/10/2048	1710	7.83	418	141	141	0	8	927	848	19	18	7.6	0.2	3.1
SSP0061939	GORD R	10/10/2018	1760	8.32	432	153	153	0	8	951	866	14	13	7.5	0.8	2.6
SSP0061832	GORD R	3/10/2018	1740	7.66	423	152	152	0	8	944	858	12	9	7.5	0.1	3.2
SSP0061657	GORD R	19/08/2018	1710	7.85	410	153	153	0	8	929	843	16	13	7.5	0.3	2.9
SSP0061587	GORD R	12/09/2018	1680	7.79	405	150	150	0	8	908	824	13	8	7.6	0.2	3
SSP0061484	GORD R	5/09/2018	1650	7.62	404	146	146	0	8	908	826	13	8	7.6	0.1	3.2
SSP0061368	GORD R	29/08/2018	1630	7.8	396	147	147	0	8	882	800	16	8	7.6	0.2	3
SSP0061279	GORD R	21/08/2018	1620	7.64	389	140	140	0	8	877	799	13	10	7.6	0	3.3
SSP0061213	GORD R	15/08/2018	1600	7.52	385	144	144	0	8	864	784	14	11	7.6	0.1	3.3
SSP0060983	GORD R	31/07/2018	1560	7.66	381	138	138	0	8	844	767	15	6	7.6	0.1	3.3
SSP0060890	GORD R	24/07/2018	1540	7.82	373	132	132	0	8	839	766	14	6	7.6	0.2	3
SSP0060794	GORD R	11/07/2018	1520	7.95	365	138	138	0	8	819	742	15	7	7.6	0.3	3
SSP0060704	GORD R	10/07/2018	1500	7.74	361	135	135	0	8	813	738	12	6	7.7	0.1	3.1
SSP0060635	GORD R	3/07/2018	1480	7.21	358	132	132	0	8	811	737	15	1	7.7	0.5	3.7
SSP0060533	GORD R	26/06/2018	1480	7.57	364	131	131	0	8	818	745	17	2	7.6	0.1	3.3
SSP0060338	GORD R	12/06/2018	1450	7.77	348	129	129	0	8	788	716	16	7	7.7	0.1	3.1
SSP0060447	GORD R	19/06/2018	1480	7.52	350	131	131	0	8	798	725	12	8	7.7	0.2	3.4
SSP0060249	GORD R	6/06/2018	1450	7.55	347	125	125	0	8	793	724	15	5	7.7	0.2	3.2
SSP0060172	GORD R	30/06/2018	1430	7.92	346	126	126	0	8	786	717	16	3	7.7	0.2	2.9
SSP0060084	GORD R	23/05/2018	1420	8.23	333	125	125	0	7	755	687	16	6	7.7	0.5	2.5
SSP0059977	GORD R	16/05/2018	1460	7.61	346	153	153	0	10	804	720	14	6	7.6	0	3.1
SSP059862	GORD R	8/05/2018	1400	7.87	333	119	119	0	8	755	690	16	5	7.7	0.1	2.9
SSP0059817	GORD R	2/05/2018	1390	7.66	332	117	117	0	8	745	681	17	5	7.7	0.1	3.2
SSP0059668	GORD R	23/04/2018	1370	7.61	327	116	116	0	8	740	676	16	4	7.8	0.2	3.2
SSP0059585	GORD R	18/04/2018	1360	7.56	317	114	114	0	8	731	668	17	6	7.8	0.2	3.3
SSP0059490	GORD R	11/04/2018	1360	8.08	312	114	114	0	7	723	661	21	9	7.8	0.3	2.7
SSP0059392	GORD R	5/04/2018	1330	7.82	316	108	108	0	8	725	666	18	6	7.8	0	3.2
SSP0059260	GORD R	26/03/2018	1330	7.71	151	73	73	0	11	374	340	10	1	8.2	0.5	2.9
SSP0059260	GORD R	27/03/2018	1330	7.69	312	107	107	0	8	709	651	18	5	7.8	0.1	3.2
SSP0059172	GORD R	21/03/2018	1320	7.97	311	105	105	0	8	705	649	22	5	7.8	0.2	2.9
SSP0059069	GORD R	14/03/2018	1350	7.74	317	106	106	0	8	723	666	23	5	7.8	0.1	3.1
SSP0058952	GORD R	7/03/2018	1430	7.6	333	110	110	0	8	760	701	21	4	7.8	0.2	3.3
SSP0058834	GORD R	27/02/2018	1620	7.54	382	120	120	0	7	874	807	16	4	7.7	0.2	3.5
SSP0058776	GORD R	21/02/2018	1610	7.48	379	119	119	0	4	862	792	16	4	7.7	0.2	3.5
SSP0058649	GORD R	13/02/2018	1660	7.96	386	124	124	0	4	877	806	20	4	7.7	0.3	3

SSP0058567	GORD R		7/02/2018	1660	7.57	386	122	122	0	4	883	812	17	3	7.7	0.1	3.3
SSP0058463	GORD R		30/01/2018	1650	7.64	396	124	124	0	5	894	822	18	6	7.7	0	3.3
SSP0058318	GORD R		16/01/2018	1600	8.1	374	120	120	0	6	864	796	18	8	7.7	0.4	2.8
SSP0058222	GORD R		10/01/2018	1600	8.01	378	120	120	0	4	847	778	17	10	7.7	0.3	2.9
SSP0058135	GORD R		3/01/2018	1570	7.93	367	118	118	0	4	838	770	19	7	7.7	0.2	3
SSP0058058	GORD R		20/12/2018	1580	7.9	375	120	120	0	3	851	782	17	4	7.7	0.2	3
SSP0057893	GORD R		7/12/2017	1550	7.97	363	120	120	0	2	835	763	16	4	7.7	0.3	3
SSP0057800	GORD R		1/12/2017	1530	8	365	117	117	0	1	816	745	18	2	7.7	0.3	2.8
SSP0057565	GORD R		14/11/2017	1500	7.6	352	118	118	0	3	797	727	17	3	7.7	0.1	3.3
SSP0057493	GORD R		8/11/2017	1460	7.95	341	114	114	0	4	767	700	14	7	7.7	0.2	3
SSP0057386	GORD R		1/11/2017	1450	7.83	341	118	118	0	4	774	705	17	3	7.7	0.1	3.1
SSP0057283	GORD R		24/10/2017	1400	8.42	331	113	113	0	3	751	686	20	6	7.8	0.6	2.5
SSP0057202	GORD R		17/10/2017	1400	8.36	331	114	114	0	4	748	684	17	10	7.7	0.6	2.5
SSP0056997	GORD R		3/10/2017	1380	7.79	330	113	113	0	3	743	676	20	6	7.7	0.1	3.1
SSP0056933	GORD R		27/09/2017	1370	8.12	331	112	112	0	3	739	673	16	8	7.7	0.4	2.7
SSP0056848	GORD R		19/09/2017	1350	8.11	318	110	110	0	2	718	654	14	5	7.8	0.3	2.7
SSP0056732	GORD R		12/09/2017	1310	8.07	313	109	109	0	2	703	639	17	4	7.8	0.3	2.7
SSP0056659	GORD R		5/09/2017	1300	8.08	310	106	106	0	2	702	640	15	3	7.8	0.3	2.9
SSP0056582	GORD R		30/08/2017	1270	8.27	302	105	105	0	2	684	622	20	3	7.9	0.4	2.6
SSP0056510	GORD R		23/08/2017	1250	8.13	294	102	102	0	2	682	622	16	1	7.9	0.2	2.7
SSP0056417	GORD R		16/08/2017	1230	7.86	288	100	100	0	2	660	600	18	3	7.9	0	3.1
SSP0056154	GORD R		27/07/2017	1160	7.77	270	93	93	0	2	617	532	22	2	8	0.2	3.1
SSP0056037	GORD R		19/07/2017	1120	7.6	261	89	89	0	2	594	541	22	2	8	0.4	3.3
SSP0055973	GORD R		13/07/2017	1110	7.8	258	84	84	0	2	592	543	20	2	8	0.2	3.1
SSP0055883	GORD R		5/07/2017	1100	7.54	255	84	84	0	2	580	530	23	5	8	0.5	3.3
SSP0055799	GORD R		29/06/2017	1070	7.3	248	80	80	0	2	563	515	23	2	8.1	0.8	3.6
SSP0055686	GORD R		21/06/2017	1060	7.7	242	78	78	0	2	549	503	25	3	8.1	0.4	3.2
SSP005569	GORD R		14/06/2017	1050	7.6	236	76	76	0	3	545	501	28	2	8.1	0.5	3.4
SSP0055516	GORD R		8/06/2017	1040	7.8	233	74	74	0	4	541	499	28	3	8.1	0.3	3.1
SSP0055364	GORD R		29/05/2017	1010	7.59	228	70	70	0	5	525	487	32	4	8.2	0.6	3.4
SSP0055315	GORD R		24/05/2017	993	7.98	225	69	69	0	5	520	843	35	4	8.2	0.2	3
SSP0055164	GORD R		17/05/2017	991	7.76	225	66	66	0	7	513	479	38	5	8.2	0.4	3.3
SSP0055074	GORD R		11/05/2017	987	7.55	222	65	65	0	8	513	481	40	4	8.2	0.7	3.5
SSP0054963	GORD R		2/05/2017	976	7.72	219	63	63	0	10	500	472	46	2	8.2	0.5	3.2
SSP0054913	GORD R		28/04/2017	974	7.56	217	60	60	0	11	503	477	52	7	8.3	0.7	3.4
SSP0054802	GORD R		19/04/2017	977	7.11	214	57	57	0	1.4	494	473	63	11	8.3	1.2	3.9
SSP0054719	GORD R		11/04/2017	981	6.77	215		53		15		479	17	69		1.6	
SSP0054574	GORD R		28/03/2017	2910	6.95	631		67		1420		1420	9	2		1	
SSP0054511	GORD R		23/03/2017	2900	7.58	635		68		2		1420	7	4		0.3	
SSP0054342	GORD R		14/03/2017	2980	7.77	661		72		3		1470	7	2		0.1	
SSP0054242	GORD R		7/03/2017	2930	8.15	656		74		3		1480	6	2		0.3	
SSP0054145	GORD R		28/02/2017	2960	8.01	649		76		3		1450	8	1		0.2	
SSP0053867	GORD R	Raw Water	14/02/2017	2910	8.05	648		83		3		1450	2	8		7.8	
SSP0053756	GORD R		8/02/2017	2760	7.8	636		89		4		1420	8	2		0	
SSP0053686	GORD R	Raw Water	2/02/2017	2800	7.66	629		93		3		1410	2	7		0.1	
	GORD R		25/01/2017	2780	7.67	615		93		3		1370	1	10		7.7	
SSP0053457	GORD R	Raw Water	18/01/2017	2730	8.02	620		0		3		1430	8	2		0.3	
SSP0053361	GORD R	Raw Water	11/01/2017	2650	7.94	625		105		3		1370	10	1		0.3	
SSP0053210	GORD R	Raw Water	21/12/2016	2590	7.51	628		115		3		1350	7	2		-0.1	
SSP0052837	GORD R	Raw Water	24/11/2016	2510	8.05	584		126		3		1250	9	3		0.5	
	GORD R	Raw Water	11/11/2016	2450	7.61	584		127		3		1230	9	6		0.1	
SSP0052535	GORD R	Raw Water	3/11/2016	2420	7.67	567		131		3		1200	9	5		0.1	
SSP0052449	GORD R	Raw Water	26/10/2016	2320	8.17	568		129		3		1170	9	6		0.6	
	GORD R	Raw Water	21/10/2016	2350	8	573		130		3		1200	10	4		0.5	
SSP0052270	GORD R	Raw Water	12/10/2016	2330	7.68	566		136		3		1160	10	10		0.2	
SSP0052194	GORD R	Raw Water	7/10/2016	2240	8.01	558		0		4		1150	10	5		0.5	
SSP0052046	GORD R	Raw Water	27/09/2016	2290	8.08	540		133		4		1130	10	9		0.5	
SSP0052014	GORD R	Raw Water	22/09/2016	2270	8.02	536		136		4		1100	12	8		0.5	
SSP0051906	GORD R	Raw Water	14/09/2016	2220	8.09	533		134		4		1110	12	9		0.6	

		Raw Water	14/09/2016	627	7.9	140		88		12		314	7	1		0.3	
SSP0051850	GORD R	Raw Water	9/09/2016	2280	8	528		134		4		1110	11	9		0.5	
	GORD R	Raw Water	31/08/2016	2210	8.13	533		132		4		1100	10	9		0.6	
	GORD R	Raw Water	25/08/2016	2180	8.25	528		126		4		1090	10	11		0.7	
	GORD R	Raw Water	17/08/2016	2150	8.29	519		128		4		1080	10	8		0.7	
	GORD R	Raw Water	11/08/2016	2180	7.82	524		130		4		1080	12	7		0.2	
	GORD R	Raw Water	4/08/2016	2130	7.91	500		126		5		1050	12	7		0.3	
	GORD R	Raw Water	25/07/2016	2100	8.19	495		122		5		1050	15	7		0.5	
	GORD R	Raw Water	19/07/2016	2070	7.91	489		125		5		1030	12	6		0.3	
	GORD R	Raw Water	14/07/2016	2130	7.93	496		122		5		1030	10	7		0.3	
	GORD R	Raw Water	7/07/2016	2060	7.97	486		125		5		1030	14	6		0.3	
	GORD R	Raw Water	29/07/2016	2060	8	486		122		6		1020	13	9		0.4	
	GORD R	Raw Water	23/06/2016	2040	8.21	485		119		6		1020	13	16		0.5	
	GORD R	Raw Water	15/06/2016	2050	7.9	487		117		6		1020	12	8		0.2	
	GORD R	Raw Water	9/06/2016	2040	8.1	479		115		6		1030	12	8		0.4	
	GORD R	Raw Water	1/06/2016	2040	8.31	477		114		6		1000	13	6		0.6	
	GORD R	Raw Water	26/05/2016	2010	7.89	471		112		6		989	13	10		0.2	
	GORD R	Raw Water	12/05/2016	1970	7.77	465		112		6		982	13	7		0.1	
	GORD R	Raw Water	5/05/2016	2000	7.7	459		110		6		989	13	5		0	
SSP0050112		Raw Water	4/05/2016	1720	7.44	391		0		8		846	13	3		0.3	
SSP0050112		Raw Water	4/05/2016	2120	7.48	459		117		6		1090	1	1		7.7	
SSP0050112		Raw Water	4/05/2016	2060	6.43	461		46		6		1050	1	3		8.1	
	GORD R	Raw Water	28/04/2016	1970	7.54	457		110		7		996	13	6		0.2	
	GORD R	Raw Water	21/04/2016	1900	7.47	441		111		7		931	7	6		0.3	
	GORD R	Raw Water	30/03/2016	1920	7.8	434		105		7		941	13	6		0.1	
		Raw Water	Jan-14	1970	7.71	480		156		5		986	4	21		0.3	
		Raw Water	Dec13	1930	7.45	475		147		7		962	3	15		0	
		Raw Water	Nov-13	1800	8.16	443		153		8		891	8	15		0.7	
		Raw Water	Feb-12	1220	7.72	277		112		6		572	8	7		0.1	
			max	2980	8.85	661	156	156	0	1420	1550	1500	170	100	8.8	8.1	4.4
			min	200	6.43	52	45	0	0	1	127	120	1	1	7.4	-0.1	2.3
			average	1826	8	425	120	116	0	13	895	905	18	9	8	1	3
			median	1760	7.87	425	122	120	0	6	845.5	870	16	7	7.7	0.3	3.05

Average	1834.10	7.60	425.32		104.44		94.96		914.41	18.87	13.24		1.67	
Max	2980.00	8.85	661.00		156.00		1420.00		1500.00	170.00	100.00		8.10	
Min	200.00	6.43	52.00		0.00		1.00		120.00	1.00	1.00		-0.10	

Sodium Absorbtion Ratio	Figure of Merit Ratio	Na Sodium	K Potassium	Ca Calcium	Mg Magnesium	H Hydrogen	HCO3 Bicarbonate	CO3 Carbonate	OH Hydroxide	Cl Chloride	F Fluoride	NO3 Nitrate	SO4 Sulphate	Fe Iron	Mn Manganese	Zn Zinc	Al Aluminium	B Boron	Cu Copper
3.61	1.09	185.31	9.05	53.42	70.39	0.00	144.44	0.94	0.00	495.25	0.21	1.31	13.32	0.02	0.05	0.03	0.05	0.05	0.03
3.40	1.10	172.00	8.20	56.00	66.00	0.00	146.00	0.60	0.00	470.00	0.22	1.00	13.00	0.01	0.01	0.01	0.05	0.05	0.03
5.70	1.50	330.00	16.00	83.00	130.00	0.00	660.00	5.30	0.10	910.00	0.55	13.00	30.00	1.00	6.10	0.61	0.67	0.09	0.07
1.00	0.90	16.00	5.50	4.00	0.00	0.00	55.00	0.00	0.00	30.00	0.03	0.20	1.00	0.01	0.00	0.00	0.03	0.03	0.00
5.30	1.20	310.00	14.30	72.00	113.00	0.00	183.35	2.94	0.00	850.00	0.25	2.50	27.00	0.02	0.01	0.06	0.05	0.08	0.03
142.00	142.00	195.00	195.00	195.00	195.00	142.00	194.00	194.00	142.00	195.00	195.00	143.00	143.00	194.00	194.00	194.00	194.00	194.00	194.00
2.4	1.1	76	6.4	29	29	0	108	0.1	0	190	0.12	2.4	9.3	0.15	0.002	0.06	0.08	0.04	0.003
2.4	1.2	76	6.5	30	28	0	108	0.1	0	180	0.13	1.4	8	0.01	0.001	0.06	0.03	0.04	0.003
1.9	1.2	50	6	21	19	0	82	0.1	0	120	0.12	1.4	5.5	0.11	0.002	0.06	0.08	0.04	0.004
1.7	1.4	48	6.8	26	20	0	118	0.1	0	110	0.12	1.1	4	0.01	0.001	0.06	0.03	0.04	0.003
1.5	1.4	38	6.2	20	16	0	97	0.1	0	84	0.11	0.34	3.3	0.06	0.002	0.06	0.03	0.03	0.004
1	1.5	16	5.5	9.6	6.8	0	55	0	0	30	0.11	0.36	3.3	0.64	0.006	0.06	0.67	0.03	0.007
3.7	1	160	9.1	43	61	0	114	0.3	0	430	0.14	0.4	15	0.04	0.004	0.06	0.03	0.05	0.004
4.8	1	270	14	76	100	0	177	3.1	0	720	0.17	0.25	25	0.01	0.002	0.06	0.03	0.06	0.003
4.7	1	270	13	73	100	0	174	0.3	0	700	0.16	0.46	25	0.01	0.003	0.06	0.03	0.07	0.003
4.6	1	250	13	69	94	0	163	0.1	0	690	0.17	0.25	26	0.01	0.001	0.06	0.03	0.06	0.003
4.9	1	270	14	68	98	0	152	0.1	0	710	0.17	0.25	24	0.01	0.002	0.06	0.03	0.07	0.003
5.5	0.9	310	15	72	110	0	152	0.1	0	810	0.22	0.6	26	0.01	0.003	0.06	0.03	0.08	0.007
5.5	0.9	320	16	73	110	0	140	0.1	0	840	0.2	0.5	25	0.01	0.016	0.06	0.03	0.09	0.003
5.6	0.9	330	16	72	120	0	116	4.6	0.1	870	0.23	0.5	23	0.02	0.002	0.06	0.03	0.09	0.003
5.5	0.9	320	16	68	110	0	117	3.7	0.1	850	0.2	0.25	26	0.01	0.002	0.06	0.03	0.08	0.003
5.3	1	310	16	79	110	0	155	1.5	0	820	0.21	0.2	28	0.01	0.002	0.06	0.03	0.08	0.003
5.3	0.9	310	15	72	110	0	141	0.2	0	800	0.21	5.6	27	0.01	0.002	0.06	0.03	0.08	0.004
5.1	0.9	290	14	65	100	0	129	0.5	0	750	0.18	0.25	27	0.01	0.005	0.06	0.03	0.07	0.003
5.1	1	300	15	77	110	0	160	0.8	0	780	0.21	0.25	30	0.01	0.004	0.06	0.03	0.08	0.003
4.8	1	280	14	83	100	0	185	2.5	0	730	0.21	0.25	30	0.01	0.01	0.06	0.03	0.07	0.003
4.5	1.1	250	13	80	96	0	170	2.7	0	700	0.21	0.25	29	0.01	0.002	0.06	0.03	0.07	0.003
4.6	1	250	13	77	93	0	166	1.3	0	700	0.2	0.25	29	0.01	0.003	0.06	0.03	0.07	0.003
4.7	1	250	13	74	88	0	158	0.6	0	680	0.2	0.64	28	0.01	0.001	0.06	0.03	0.07	0.003
4.5	1	240	13	71	88	0	660	0.3	0	660	0.2	1.8	27	0.01	0.001	0.06	0.03	0.07	0.003
4.6	1.0	240	12	68	85	0.0	137	0.2	0.0	650	0.21	2.2	27	0.01	0.001	0.06	0.03	0.07	0.003
5.1	0.9	290	14	71	99	0	127	0.1	0	780	0.25	1.5	25	0.01	0.007	0.06	0.03	0.08	0.003
5.4	0.9	310	15	69	110	0	113	0.3	0	840	0.25	0.25	17	0.01	0.005	0.06	0.03	0.08	0.003
		320	16	66	110					860	0.27	0.5	13						
5.7	0.9	320	16	66	110	0	108	5.3	0.1	860	0.27	0.5	13	0.02	0.002	0.06	0.03	0.08	0.003
5.2	0.9	280	14	56	100	0	120	1.9	0	740	0.22	0.25	15	0.01	0.005	0.06	0.03	0.08	0.003
4.6	1	250	13	59	96	0	149	0.8	0	670	0.22	0.25	16	0.03	0.009	0.06	0.03	0.07	0.003
4.5	1	240	12	61	90	0	164	0.6	0	620	0.22	0.25	16	0.01	0.01	0.01	0.05	0.07	0.03
4.2	1.1	220	11	67	85	0	183	1.7	0	580	0.21	0.25	18	0.01	0.01	0.01	0.05	0.06	0.03
4.1	1.1	210	11	66	80	0	177	3.7	0	550	0.18	0.25	16	0.01	0.01	0.01	0.05	0.06	0.03
4	1.1	200	10	64	78	0	180	2.3	0	540	0.24	0.5	18	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	200	11	66	78	0	179	4.6	0.1	540	0.21	0.2	16	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	200	11	66	79	0	186	2.1	0	530	0.21	2	17	0.01	0.01	0.03	0.05	0.06	0.03
3.9	1.1	200	10	65	78	0	185	1.5	0	530	0.24	1.5	16	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	200	10	65	77	0	182	1.8	0	520	0.21	1	16	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	200	11	64	77	0	181	2.9	0	520	0.25	1	16	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	190	10	63	76	0	175	3.7	0	510	0.21	1	16	0.01	0.01	0.1	0.05	0.06	0.03
3.9	1.1	200	11	64	77	0	185	1.1	0	520	0.22	1	15	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	190	11	64	77	0	185	0.9	0	520	0.19	1.5	15	0.01	0.01	0.01	0.05	0.06	0.03
4	1.1	200	11	64	76	0	182	1	0	520	0.23	1	15	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	190	11	63	77	0	172	3.4	0	510	0.22	1	15	0.01	0.01	0.01	0.05	0.06	0.03
4	1.1	200	11	62	76	0	177	2.3	0	520	0.23	1.5	14	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	190	10	62	75	0	177	1.6	0	510	0.24	1.5	14	0.01	0.01	0.01	0.05	0.06	0.03
3.9	1.1	190	10	60	74	0	170	3	0	510	0.23	1.5	14	0.01	0.01	0.01	0.05	0.06	0.03

3.8	1.1	190	10	59	73	0	167	0.2	0	510	0.24	1.5	14	0.01	0.01	0.01	0.05	0.06	0.03
3.8	1.1	180	10	58	72	0	165	1.3	0	500	0.23	1.5	13	0.01	0.01	0.01	0.05	0.06	0.03
3.8	1.1	180	9.9	56	70	0	163	0.7	0	490	0.24	1.5	13	0.01	0.01	0.01	0.05	0.06	0.03
3.8	1.1	180	10	57	71	0	162	0.6	0	480	0.22	1.5	12	0.01	0.01	0.01	0.05	0.05	0.03
3.8	1.1	180	10	58	69	0	168	0.8	0	470	0.2	1.5	13	0.01	0.01	0.01	0.05	0.05	0.03
3.8	1.1	180	10	59	71	0	175	0.6	0	490	0.31	2.5	14	0.01	0.01	0.01	0.05	0.06	0.03
3.7	1.1	180	10	59	70	0	171	2.3	0	470	0.25	2.5	13	0.01	0.01	0.01	0.05	0.06	0.03
3.7	1.1	180	10	60	70	0	166	2.6	0	470	0.25	2.5	13	0.01	0.01	0.01	0.05	0.06	0.03
3.8	1.1	180	9.4	60	65	0	163	2.4	0	460	0.25	2.5	12	0.01	0.01	0.01	0.05	0.05	0.03
3.7	1.1	170	9.6	56	66	0	161	2	0	460	0.21	1.5	12	0.01	0.01	0.01	0.05	0.06	0.03
3.5	1.1	170	9.6	56	66	0	163	1.2	0	440	0.21	1.5	12	0.01	0.01	0.01	0.05	0.05	0.03
3.5	1.2	160	9.7	57	65	0	156	3.1	0	450	0.25	2.5	13	0.01	0.01	0.01	0.05	0.06	0.03
3.5	1.1	160	9.2	55	63	0	154	2.7	0	430	0.2	1.5	12	0.01	0.01	0.01	0.05	0.05	0.03
3.4	1.1	150	9	54	61	0	156	1.1	0	410	0.2	1	12	0.01	0.01	0.01	0.05	0.05	0.03
3.4	1.1	150	8.8	52	60	0	151	1.9	0	400	0.19	1	12	0.01	0.01	0.01	0.05	0.05	0.03
3.2	1.2	140	8.2	49	55	0	143	0.8	0	360	0.19	1.7	13	0.01	0.01	0.01	0.05	0.05	0.03
3.3	1.1	150	8.6	51	57	0	153	0.6	0	380	0.18	1	14	0.01	0.01	0.01	0.05	0.05	0.03
3.2	1.2	140	8.2	50	56	0	147	1.7	0	370	0.18	1	13	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.2	140	8.2	49	54	0	148	0.6	0	360	0.17	1	14	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	140	8	49	55	0	139	2.2	0	380	0.17	1	14	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.2	140	8.1	48	54	0	143	0.1	0	360	0.17	1	13	0.02	0.01	0.01	0.05	0.04	0.03
3.2	1.2	130	7.8	47	52	0	138	0.2	0	350	0.13	1	13	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	140	7.7	48	53	0	141	0.1	0	360	0.16	13	1	0.02	0.01	0.01	0.05	0.04	0.03
3.3	1.2	140	7.8	50	58	0	145	0.4	0	380	0.15	1	15	0.02	0.01	0.01	0.05	0.04	0.03
3.6	1.2	170	8.6	59	66	0	171	0.6	0	440	0.25	2.5	16	0.02	0.01	0.01	0.05	0.04	0.03
3.6	1.2	170	8.9	61	68	0	183	2.1	0	440	0.18	1.5	15	0.01	0.01	0.01	0.05	0.05	0.03
3.6	1.1	170	8.9	60	66	0	184	0.5	0	440	0.25	2.5	15	0.01	0.01	0.02	0.05	0.05	0.03
3.6	1.1	170	8.7	59	64	0	185	0.8	0	430	0.25	2.5	15	0.02	0.01	0.01	0.05	0.05	0.03
3.5	1.2	160	8.5	58	63	0	181	0.7	0	420	0.19	1.5	15	0.01	0.01	0.01	0.05	0.05	0.03
3.5	1.1	160	8.5	58	63	0	177	0.5	0	420	0.25	2.5	14	0.01	0.01	0.01	0.05	0.05	0.03
3.5	1.2	160	8.4	57	62	0	177	0.7	0	400	0.25	2.5	14	0.02	0.01	0.01	0.05	0.05	0.03
3.4	1.1	160	8.2	56	61	0	170	0.4	0	410	0.25	2.5	14	0.01	0.01	0.01	0.05	0.04	0.03
3.4	1.1	160	8.2	55	60	0	175	0.3	0	400	0.18	1.1	14	0.01	0.01	0.01	0.05	0.04	0.03
3.4	1.2	150	8.2	54	60	0	167	0.4	0	400	0.1	1.1	5	0.01	0.01	0.01	0.05	0.05	0.03
3.4	1.11	150	8	54	58	0	160	0.7	0	390	0.19	0.5	15	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.2	150	7.8	52	57	0	166	0.7	0	380	0.19	1	13	0.03	0.01	0.01	0.05	0.04	0.03
3.3	1.1	150	7.9	52	56	0	163	0.5	0	370	0.22	1	13	0.01	0.01	0.01	0.05	0.05	0.03
3.3	1.1	140	7.9	51	56	0	161	0.1	0	380	0.28	1	13	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.2	140	7.9	52	57	0	160	0.3	0	380	0.18	2	13	0.01	0.01	0.01	0.05	0.05	0.03
3.3	1.1	140	7.7	49	55	0	157	0.5	0	360	0.26	1	13	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	140	7.7	50	55	0	159	0.3	0	370	0.2	1	12	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	140	7.8	49	55	0	152	0.4	0	370	0.26	2.1	13	0.01	0.01	0.01	0.05	0.05	0.03
3.3	1.1	140	7.7	49	54	0	151	0.8	0	370	0.2	1	12	0.01	0.01	0.01	0.05	0.05	0.03
3.3	1.1	140	7.5	46	53	0	149	1.7	0	350	0.24	1	11	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.2	140	8.8	49	55	0	185	0.5	0	360	0.2	0.5	10	1	6.1	0.01	0.05	0.05	0.03
3.3	1.1	140	7.5	46	53	0	144	0.7	0	350	0.22	1	11	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.1	140	7.6	46	53	0	142	0.4	0	350	0.2	1	11	0.01	0.01	0.01	0.05	0.05	0.03
3.2	1.1	130	7.6	45	52	0	141	0.3	0	350	0.2	1	11	0.01	0.01	0.01	0.05	0.05	0.03
3.2	1.1	130	7.4	43	51	0	138	0.3	0	350	0.2	1	11	0.01	0.01	0.01	0.05	0.05	0.03
3.3	1.1	130	7.4	42	50	0	136	1.1	0	340	0.2	1	10	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	130	7.6	42	51	0	131	0.4	0	350	0.2	1	10	0.01	0.01	0.01	0.05	0.04	0.03
2.5	1	69	6.1	21	24	0	89	0.3	0	160	0.2	0.5	3	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.1	130	7.5	43	50	0	129	0.4	0	340	0.22	1.6	10	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.1	130	7.4	41	50	0	126	0.8	0	340	0.16	1	9	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	130	7.6	42	52	0	128	0.5	0	350	0.2	1	9	0.01	0.01	0.01	0.05	0.04	0.03
3.4	1.1	140	7.8	44	55	0	133	0.3	0	370	0.2	1	9	0.01	0.01	0.01	0.05	0.03	0.03
3.6	1.1	160	8.9	50	63	0	146	0.2	0	430	0.29	2.5	10	0.01	0.01	0.01	0.05	0.04	0.03
3.6	1.1	160	8.9	49	62	0	145	0.2	0	430	0.25	2.5	9	0.01	0.01	0.01	0.05	0.04	0.03
3.6	1.1	160	9	51	63	0	149	0.8	0	430	0.25	2.5	9	0.01	0.01	0.01	0.05	0.05	0.03

3.6	1.1	160	9	5	63	0	149	0.3	0	440	0.25	2.5	9	0.01	0.01	0.02	0.05	0.04	0.07
3.7	1.1	170	9.4	51	65	0	151	0.4	0	440	0.25	2.5	8	0.01	0.01	0.01	0.05	0.05	0.03
3.6	1.1	160	8.6	49	61	0	144	1.1	0	430	0.25	2.5	8	0.01	0.01	0.31	0.06	0.05	0.04
3.6	1.1	160	8.4	49	62	0	145	0.9	0	410	0.25	2.5	9	0.01	0.01	0.001	0.05	0.04	0.03
3.5	1.1	150	8.2	48	60	0	142	0.8	0	420	0.18	1	7	0.01	0.01	0.01	0.05	0.05	0.03
3.5	1.1	160	8.4	50	61	0	144	0.7	0	420	0.18	2	8	0.01	0.01	0.01	0.05	0.04	0.03
3.4	1.1	150	8.4	48	59	0	146	0.7	0	410	0.2	1	9	0.01	0.01	0.01	0.05	0.04	0.03
3.4	1.1	150	8.4	49	59	0	140	1	0	400	0.18	1.5	9	0.01	0.01	0.01	0.05	0.04	0.03
3.4	1.1	150	8.3	48	57	0	143	0.4	0	390	0.18	1	9	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	140	7.9	46	55	0	138	0.6	0	370	0.2	1	8	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	140	8.4	46	55	0	143	0.5	0	370	0.18	1	9	0.02	0.01	0.01	0.05	0.04	0.03
3.3	1.1	140	7.9	45	53	0	133	2.2	0	360	0.2	1	8	0.01	0.01	0.01	0.05	0.04	0.03
3.3	1.1	140	8	46	53	0	135	2.1	0	360	0.22	1	8	0.01	0.01	0.01	0.05	0.05	0.03
3.3	1.1	140	7.8	46	52	0	137	0.5	0	360	0.22	1	8	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.1	140	7.8	46	53	0	135	1.1	0	360	0.1	0.5	4	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.1	130	7.6	44	51	0	131	1	0	340	0.2	1	9	0.01	0.01	0.01	0.05	0.04	0.03
3.1	1.1	130	7.5	4	50	0	130	1.3	0	330	0.18	1	9	0.01	0.01	0.01	0.05	0.04	0.03
3.2	1.1	130	7.3	44	49	0	127	0.7	0	340	0.2	1	9	0.01	0.01	0.01	0.05	0.04	0.03
3.1	1.1	120	7.3	42	48	0	126	1.4	0	330	0.22	1	9	0.01	0.01	0.01	0.05	0.04	0.03
3.1	1.1	120	7.2	41	47	0	122	1.1	0	330	0.2	1	10	0.01	0.01	0.01	0.05	0.03	0.03
3	1.1	120	7.1	40	46	0	122	0.4	0	320	0.2	1	9	0.01	0.01	0.01	0.05	0.03	0.04
3	1.1	110	7	37	43	0	113	0.4	0	300	0.16	1	9	0.01	0.01	0.01	0.05	0.04	0.06
2.9	1.1	110	7.1	36	42	0	108	0.2	0	280	0.16	1	9	0.01	0.01	0.01	0.05	0.04	0.03
2.9	1.1	110	6.8	34	42	0	102	0.4	0	290	0.16	1.1	9	0.01	0.01	0.01	0.05	0.04	0.03
2.9	1.1	110	6.9	34	42	0	102	0.2	0	280	0.18	1.6	9	0.01	0.01	0.01	0.05	0.04	0.03
2.9	1.1	110	6.9	32	40	0	98	0.1	0	270	0.2	1.8	8	0.01	0.01	0.01	0.05	0.03	0.03
2.9	1.1	100	6.7	31	40	0	95	0.3	0	260	0.18	1	8	0.01	0.01	0.01	0.05	0.04	0.03
2.9	1.1	100	6.8	31	39	0	92	0.2	0	270	0.12	1	8	0.01	0.01	0.01	0.05	0.04	0.03
2.9	1.1	100	6.8	30	39	0	90	0.4	0	270	0.14	1	9	0.01	0.01	0.01	0.05	0.04	0.03
2.8	1.1	99	6.8	29	38	0	85	0.2	0	260	0.14	1	7	0.01	0.01	0.01	0.05	0.04	0.03
2.8	1.1	98	6.8	28	38	0	83	0.5	0	260	0.16	1	9	0.01	0.01	0.01	0.05	0.04	0.03
2.8	1.1	97	6.8	28	38	0	81	0.2	0	260	0.16	1	7	0.01	0.01	0.01	0.05	0.04	0.03
2.9	1	99	6.9	27	38	0	79	0.1	0	260	0.1	1	7	0.01	0.01	0.01	0.05	0.04	0.03
2.8	1.1	96	6.9	27	37	0	76	0.3	0	250	0.2	1	9	0.01	0.01	0.01	0.05	0.04	0.03
2.9	1	97	6.9	26	37	0	73	0.2	0	250	0.14	1	9	0.02	0.01	0.01	0.05	0.04	0.03
2.8	1	95	6.8	26	36	0	70	0.1	0	250	0.14	2.4	9	0.05	0.01	0.01	0.05	0.04	0.04
		96	6.8	26	37		65	0		250	0.1			0.12	0.01	0.01	0.07	0.04	0.03
		310	8.8	53	120		82	0		870	0.25			0.01	0.01	0.02	0.05	0.06	0.03
		310	8.9	53	120		82	0.2		870	0.25			0.01	0.01	0.01	0.05	0.05	0.03
		330	9.2	56	130		87	0.2		890	0.25			0.01	0.01	0.01	0.05	0.06	0.03
		320	9.2	55	130		88	1		910	0.25			0.01	0.01	0.01	0.05	0.06	0.03
		320	9.2	56	120		91	0.6		880	0.25			0.01	0.01	0.01	0.05	0.06	0.03
		320	9.2	57	120		99	0.9		880	0.25			0.01	0.01	0.01	0.05	0.06	0.03
		310	9.1	57	0		108	0.4		850	0.25			0.01	0.01	0.01	0.05	0.06	0.03
		300	9.1	58	120		113	0.3		850	0.25			0.01	0.01	0.01	0.05	0.06	0.03
		290	9.1	58	110		113	0.3		820	0.25			0.01	0.01	0.01	0.05	0.05	0.03
		300	8.7	59	120		121	0.9		820	0.25			0.01	0.01	0.61	0.05	0.06	0.03
		300	8.8	61	120		127	0.6		810	0.25			0.01	0.01	0.09	0.05	0.06	0.03
		280	8.7	66	110		139	0.3		790	0.25			0.01	0.01	0.01	0.05	0.05	0.03
		260	8.3	68	100		152	1		720	0.25			0.01	0.01	0.01	0.05	0.06	0.03
		260	8.2	69	100		154	0.4		710	0.25			0.01	0.01	0.41	0.05	0.05	0.03
		250	7.9	68	96		159	0.5		680	0.25			0.01	0.01	0.01	0.05	0.05	0.03
		240	7.9	68	97		154	1.4		660	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		240	8.1	70	97		156	1.2		690	0.25			0.01	0.01	0.01	0.05	0.06	0.03
		240	8.2	69	96		165	0.5		650	0.25			0.01	0.01	0.01	0.05	0.05	0.03
		235	8.2	69	94		162	1		650	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		226	8.1	67	91		160	1.2		640	0.25			0.01	0.01	0.01	0.05	0.04	0
		225	8.2	67	90		164	1.1		610	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		227	8	66	89		161	1.2		620	0.25			0.01	0.01	0.01	0.05	0.04	0.03

		62	5.7	21	21		107	0.4		140	0.15			0.01	0.01	0.01	0.05	0.04	0.03
		224	8.2	66	88		162	0.9		620	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		223	8.1	67	89		158	1		610	0.25			0.01	0.01	0.02	0.05	0.04	0.03
		221	8.1	66	88		150	1.6		610	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		220	8	65	87		153	1.8		600	0.25			0.01	0.01	0.01	0.05	0.05	0.03
		221	8.2	65	88		157	0.8		610	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		231	8.1	62	84		152	0.8		590	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		212	8.2	62	83		146	1.3		590	0.25			0.01	0.01	0.01	0.05	0.03	0.03
		210	8.2	60	82		151	0.7		580	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		212	8.3	61	84		147	0.8		570	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		208	8.2	60	82		150	0.8		580	0.3			0.01	0.01	0.01	0.05	0.04	0.03
		209	8.2	60	82		147	0.9		570	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		208	8.1	59	82		142	1.4		580	0.25			0.01	0.01	0.03	0.05	0.06	0.03
		209	8.2	59	82		141	0.7		580	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		210	8.2	58	82		138	1.1		580	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		208	8.1	58	81		136	1.6		560	0.25			0.01	0.01	0.01	0.05	0.05	0.03
		205	8.1	57	80		135	0.7		560	0.25			0.01	0.01	0.01	0.05	0.05	0.03
		202	8	55	80		136	0.6		550	0.55			0.01	0.01	0.01	0.05	0.04	0.03
		202	8	54	79		134	0.5		560	0.025			0.01	0.01	0.01	0.05	0.05	0.03
		172	7.5	48	66		132	0.3		470	0.25			0.01	0.01	0.02	0.05	0.05	0.03
		237	8	55	78		142	0.3		560	0.25			0.01	0.01	0.04	0.05	0.07	0.07
		215	8	55	79		57	0		560	0.25			0.01	0.03	0.03	0.05	0.06	0.03
		200	7.9	55	78		133	0.3		570	0.25			0.01	0.01	0.07	0.05	0.04	0.03
		193	7.9	53	75		135	0.2		520	0.25			0.01	0.01	0.05	0.05	0.05	0.03
		188	7.6	53	74		125	1.2		530	0.25			0.01	0.01	0.04	0.05	0.05	0.03
		198	7.5	68	76		189	0.6		530	0.24			0.01	0.01	0.01	0.05	0.05	0.03
		189	7.1	67	75		178	0.3		520	0.18			0.01	0.01	0.01	0.05	0.05	0.03
		172	6.7	66	68		183	2		470	0.25			0.01	0.01	0.01	0.05	0.04	0.03
		111	6.7	42	42		135	0.6		290	0.22			0.01	2.6	0.01	0.05	0.04	0.03
5.7	1.5	330	16	83	130	0	660	5.3	0.1	910	0.55	13	30	1	6.1	0.61	0.67	0.09	0.07
1	0.9	16	5.5	4	0	0	55	0	0	30	0.025	0.2	1	0.01	0.001	0.001	0.03	0.03	0
4	1	185	9	53	70	0	144	1	0	495	0	1	13	0	0	0	0	0	0
3.4	1.1	172	8.2	56	66	0	146	0.6	0	470	0.22	1	13	0.01	0.01	0.01	0.05	0.05	0.03
		186.39	8.10	54.21	71.02		167.78	0.86		502.20	0.25			0.07	0.56	0.06	0.09	0.05	0.03
		330.00	16.00	83.00	130.00		660.00	5.30		910.00	0.55			1.00	6.10	0.61	0.67	0.09	0.07
		16.00	5.50	4.00	0.00		55.00	0.00		30.00	0.03			0.01	0.00	0.00	0.03	0.03	0.00

ECONOMIC ROAD MAP

Attachment F: West

Barambah Cost Estimate

pinion
ADVISORY
30 Mackenzie St
Wondai QLD 4606

2 August 2022

West Barambah Weir – Concept Assessment Memo Report

1. Introduction

KBR – Water Strategy Team are currently undertaking an Options Assessment of a number of water projects within the wider Burnett district. Pinion Advisory were engaged to undertake a highlevel concept assessment of one the proposed projects – West Barambah Weir.

West Barambah Weir is a proposed structure to be located on Barambah Creek, approximately 25km upstream from the confluence with Barker Creek. Bjelke Petersen Dam is located 1.5km upstream of this confluence. A locality plan is shown in Figure 1. The proposed weir inundation area is shown in Figure 2.

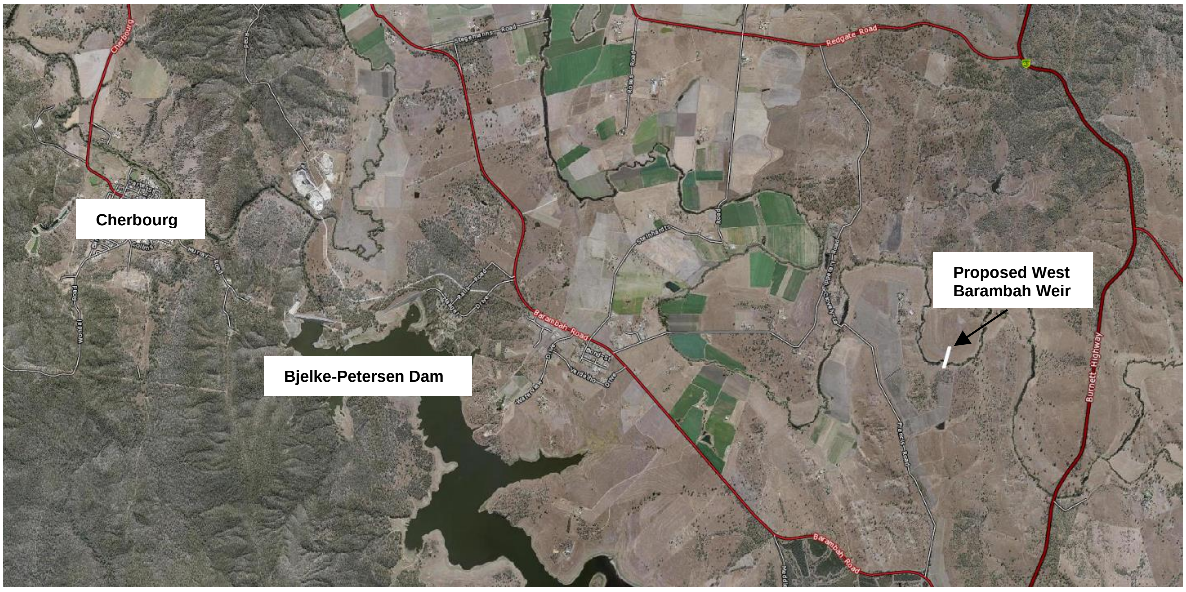

Figure 1: Locality Plan

2. Concept

In order to prepare an initial cost estimate, a concept design of the structure was sketched with some initial volumes and dimensions measured for quantities.

Pertinent details of the proposed structure are shown in Table 1.

Table 1: West Barambah Modelled Pertinent Details

Approx. Storage Volume	5000 ML
Aboveground Embankment Volume	35,500 m^3
Crest Level	RL 316
Full Supply Level (Spillway Invert)	RL 315
Embankement Height	12 m
Freeboard	1.0 m
Total Embankment Length	280 m
Impoundment Area (approx.)	200 Ha
Storage Ratio	140:1

The concept design assumes a 280m eathern embankment perpendicular to Barambah Creek. The structure is considered to be more an earthen dam rather than a weir structure. This is due to the proposed height of the

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structure (12m) and the nature of structure control. The concept design, material quantities and associated costings are therefore based on a dam structure.

A side excavated concreted spillway is proposed as the main flood routing structure. A preliminary freeboard of 1m is proposed, however no design assessment to this has been conducted, considering the nature of Barambah Creek is may be higher. Arrangement of the dam with the proposed full supply level inundation area is shown in Figure 2.

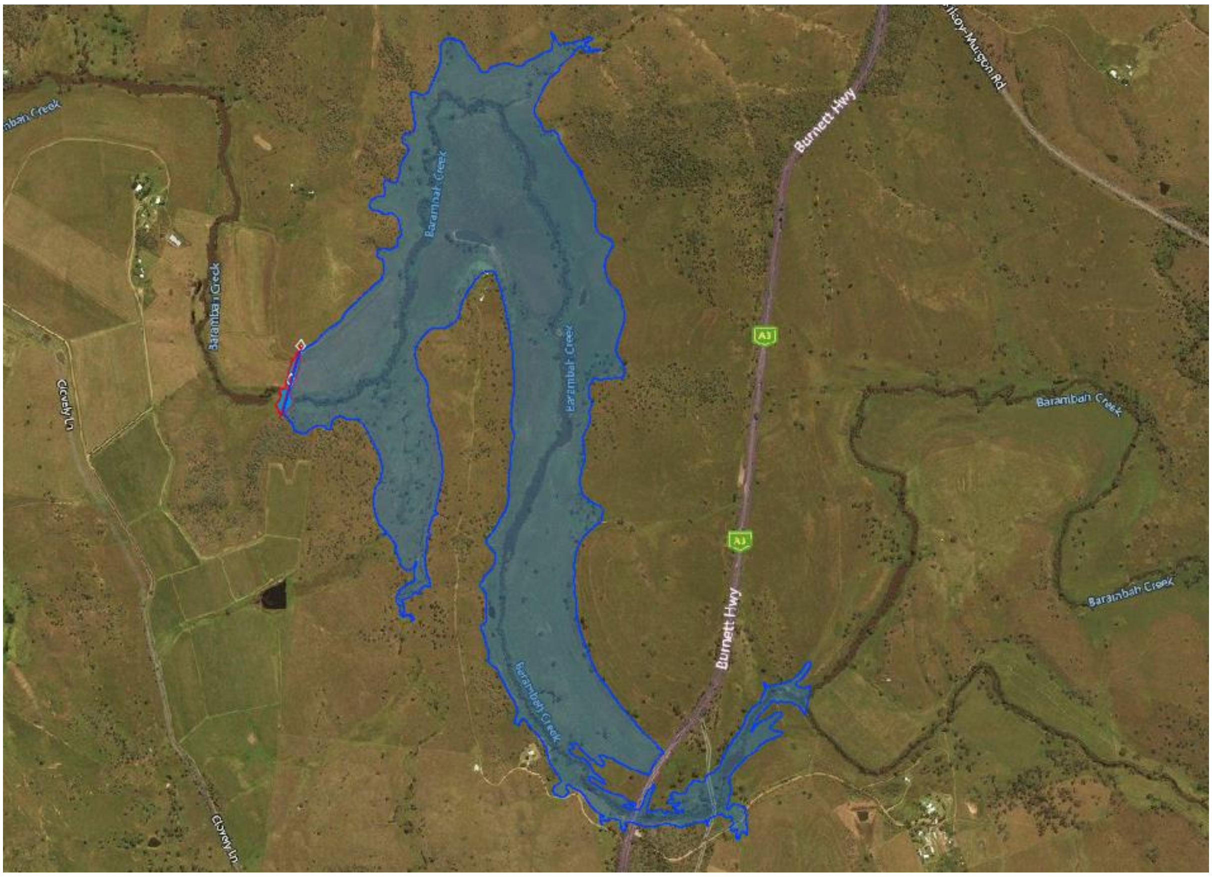

Figure 2: Proposed Weir and inundation area

The inundation area shows a wide and relatively shallow basin just upstream of the dam wall. Upstream of the Burnett Highway bridge and flow is largely contained to the defined creek area. The dam storage ratio (water stored vs. earth) is exceptional. However the storage does have a large surface area meaning annual evaporation loss will also be high.

The FSL determination of the structure was taken as high as possible not to impede on the existing bridge arrangement at the intersection of the Burnett Highway (estimated at RL 318). There is also an existing structure at Barambah homestead at RL 319 which was decided not to impact. While this infrastructure gives some restraint there could be options for road and bridge vertical realignment and building relocation to enable a large storage is desired. For the purposes of this assessment, they have not been included in the estimate and assumed to be left alone.

Figure 3: Approx. Alignment of West Barambah

Figure 4: Looking downstream of proposed alignment

Figure 5: Burnett Highway Bridge Crossing - Barambah Creek

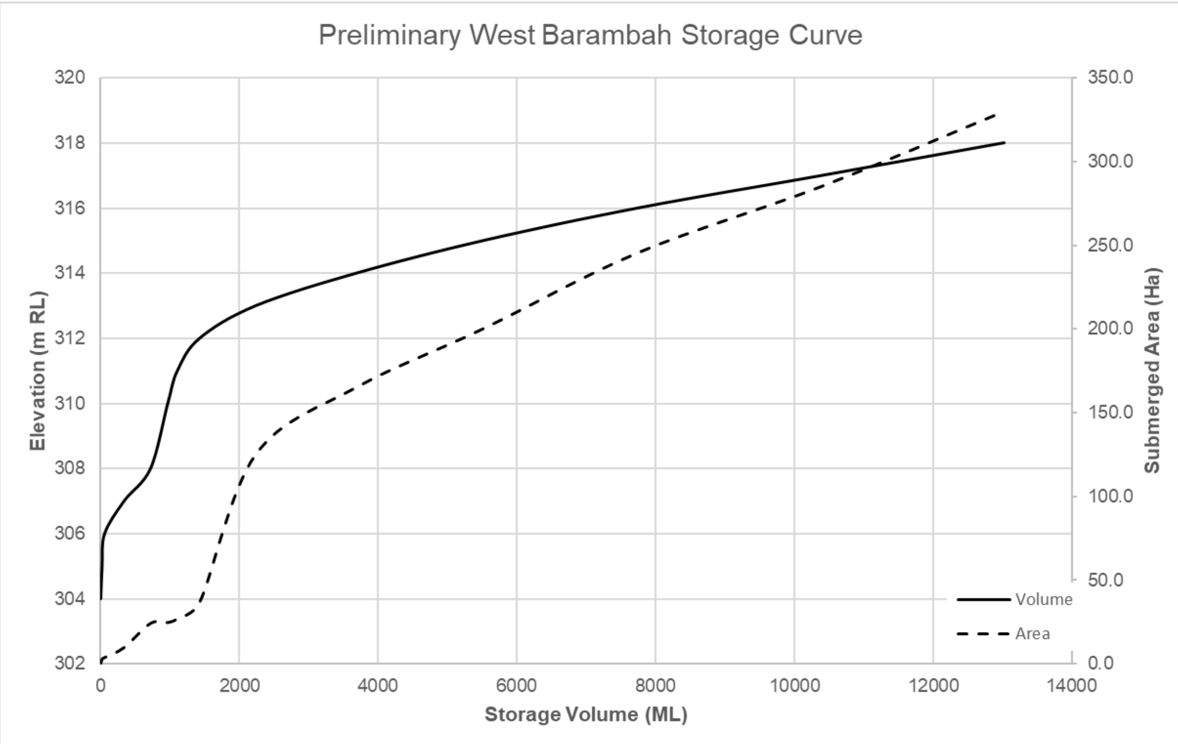

Figure 6: Preliminary West Barambah Storage Curve

3. Land Valuation Assessment

There are five properties that will be materially impacted by inundation. The value of unimproved land varies from $1,186 per hectare to $1,951 per hectare. The average is $1,266.

Real property description	Current valuation (A$)	Current valuation date	Hectares	$/Hectare
L28 RP7158	190,000	1-Oct-21	110	1,720
L29 FY1527	390,000	1-Oct-21	200	1,951
LA AP21165:RL 236395 & LB AP21165:RL 236396 & L1 RL8464:RL 21/8464 & L8 FTZ3716 & L1,4 FY2363 & L1 RP110072 & L1-3 RP141218 & L8 RP142301 & L2-3,5-6,8 RP57070 & L1 RP7162	1,900,000	1-Oct-21	1,601	1,186
PTJ L11 SP104382:SUBLEASED & L45 FY1509 & L26-27 RP7158 & L29,40 RP7168 & L2 RP911371 & L9 SP106951 & L3,8 SP119658 & L15-17 SP164032 & L13-14 SP164034	1,650,000	1-Oct-21	1,353	1,220
L34 FY1583:(NON-SPECIFIC) RESERVE 7:TL 239815 & L7 RP142301	35,000	1-Oct-21	24	1,430
Total	**4,165,000**		**3,289**	**1,266**

Source: Queensland land valuations (2021)

The above valuation relate to unimproved land, which is the low end for estimates. We have also compared this with recent sales for nearby agricultural properties. The weighted average price is $3,122 while the simple average of the five properties is $7,205. The simple average is heavily influenced by the sale of a small block. These properties also include homesteads, sheds and land improvements. The inundation area is not expected to impact on any structures. Therefore, these sale amounts are likely to be slightly overstated.

Sold Properties	Total Price	Date of Sale	Hectares	$/Hectare	Current Use
480 Steinhardts Road, Redgate	1,500,000	27-Jun-19	152	9,843	Cropping
350 Johnstown Road, Barambah	4,300,000	13-Dec-18	2,203	1,952	Mixed Farming
Lot 2 Kilocy-Murgon Road, Barambah	440,000	2/08/2021	146	3,014	Cropping
98 Silver Perch Road, Goomeri	1,700,000	3/06/2022	103	16,505	Livestock
149 Redgate Rd, Redgate	570,000	21/08/2020	121	4,711	Livestock
Weighted Average				**3,122**	
Simple Average				**7,205**	

Source: realestate.com.au

It is reasonable to use the weighted average of $3,122. However, to allow for a negotiation premium and transaction costs, a rounded up figure of $5,000 per hectare has been used.

4. Works Estimate

A costing estimate was prepared based on the concept described above. The purpose of the costing is to give an indicative approximation of the capital works costings as an input to the wider area options analysis.

This cost estimate is not intended to confirm to a class, however it would be considered to be higher level than a Class 5, with a 0% maturity level project definition and much judgement and analogy used in the building of the costs analysis.

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges at an 80% confidence interval
Class 5	0% to 2%	Concept screening	Cost/length factors, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Cost/length, factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Figure 7: Cost Estimate Classification Classes

Summary of the works estimate is included in Table 2. The works estimate is included in Attachment 1.

Table 2: Works Estimate Summary

West Barambah Dam Estimate	**$ million**
Embankment Earthworks	$1.8
Spillway	$2.0
Fish Ladder	$2.5
Auxiliaries	$0.9
Contractor Indirect Estimates	$1.1
Entity/Client Costs	$7.7
Contingency (40%)	$6.4
Works Estimate	**$22.5**

The infrastructure direct estimate quantities were derived from a basic civil 3D model. Rates were taken from recent previous projects in Tasmania, New South Wales and South Australia with judgement used to adjust for local conditions in the South Burnett locality.

Contract indirect estimates and entity/client costs were larger assumed for a small to medium sized dams project on a seasonal creek for an entity Principal.

A 40% contingency is included as a nominal allowance due to the coarseness and limited information within the estimate.

Attachment 1 – Works Estimate

	West Barambah Dam Base Estimate	Quantity	Unit	Rate/unit	SubTotal	Low	High
A	INFRASTRUCTURE DIRECT ESTIMATES	1	LOT		$ 7,261,000	$ 6,535,000	$ 10,951,000
1	Embankment Earthworks				$ 1,871,000	$ 1,684,000	$ 2,428,000
	Vegetation and Tree Clearing	1	Item	$ 300,000	$ 300,000	$ 270,000	$ 351,000
	Site Stripping and Borrow preps	12	Ha	$ 30,000	$ 360,000	$ 324,000	$ 421,200
	Construct dam keyway (Zone 1A) inc. excavation, placement, conditioning and compaction of suitable material	6,000	m^3	$ 30	$ 180,000	$ 162,000	$ 294,840
	Construct Dam Core (Zone 1A) inc. excavation, placement, conditioning and compaction of suitable material	11,800	m^3	$ 23	$ 271,400	$ 244,260	$ 381,046
	Construct Dam embankment (Zone 1) inc. excavation, placement, conditioning and compaction of suitable material	24,000	m^3	$ 20	$ 480,000	$ 432,000	$ 561,600
	Place and Install Rip Rap protection (Zone 3c & 4)	2,500	m^3	$ 100	$ 250,000	$ 225,000	$ 380,250
	Install access and embankment capping	350	m^3	$ 85	$ 29,750	$ 26,775	$ 38,288
2	Auxiliaries (Inc Spillway)				$ 5,390,000	$ 4,851,000	$ 8,523,000
	Construct Spillway chute (earthern excavated & concrete aprons & wingwalls)	1	Item	$ 2,000,000	$ 2,000,000	$ 1,800,000	$ 4,000,000
	Spillway Rip Rap Protection	2,000	m3	$ 100	$ 200,000	$ 180,000	$ 304,200
	Installation of outlet valve	70	m	$ 2,000	$ 140,000	$ 126,000	$ 163,800
	Structure furnishings	1	Item	$ 200,000	$ 200,000	$ 180,000	$ 234,000
	Gates and access fencing (allowance)	1	Item	$ 100,000	$ 100,000	$ 90,000	$ 117,000
	Dam instrumentation	1	Item	$ 50,000	$ 50,000	$ 45,000	$ 58,500
	Access Road	1	Item	$ 200,000	$ 200,000	$ 180,000	$ 270,000
	Dam Fish Ladder/Fishway	1	Item	$ 2,500,000	$ 2,500,000	$ 2,250,000	$ 3,375,000
B	CONTRACTOR INDIRECT ESTIMATES	1	LOT		$ 1,125,000	$ 962,000	$ 1,408,000
B1.1	Contractors Indirect & Site Overhead Costs		LOT		$ 620,000	$ 558,000	$ 743,400
	Site Mobilisation & Demobilisation	1	Item	$ 100,000	$ 100,000	$ 90,000	$ 117,000
	Site Facilities Establishment & Disestablishment	1	Item	$ 50,000	$ 50,000	$ 45,000	$ 58,500
	Onsight Project Supervision	1	Item	$ 200,000	$ 200,000	$ 180,000	$ 252,000
	QA Management plans, planning and IT allowances	1	Item	$ 50,000	$ 50,000	$ 45,000	$ 58,500
	Care of Environment	6	months	$ 20,000	$ 120,000	$ 108,000	$ 140,400
	Stream Diversion works	1	Item	$ 100,000	$ 100,000	$ 90,000	$ 117,000
B1.2	Contractors Assoicated Project Costs		LOT		$ 504,755	$ 404,320	$ 664,690
	Surveying, Setting out, pegging & As-Con pickups	1	Item	$ 30,000	$ 30,000	$ 27,000	$ 35,100
	Materials Testing Allowances	1	Item	$ 50,000	$ 50,000	$ 45,000	$ 58,500
	Dam Commissioning	1.0%	%	$ 7,261,000	$ 72,610	$ 36,305	$ 108,915
	Project As-Constructed Plans and Close Outs	1.5%	%	$ 7,261,000	$ 108,915	$ 108,915	$ 181,525
	Project Detailed Design, Geotechnical Investigation and Project management	13.0%	%	$ 1,871,000	$ 243,230	$ 187,100	$ 280,650
C	CONSTRUCTION COST ESTIMATE	1	LOT		$ 8,385,905	$ 7,497,355	$ 12,358,814
D	ENTITY/CLIENT COSTS	1	LOT		$ 7,721,000	$ 5,709,000	$ 11,391,000
D1.1	Construction Management & Overheads		LOT		$ 1,090,168	$ 838,591	$ 1,257,886
	Project Management, Contract Admin, Superintendence & OE	13.0%	%	$ 8,385,905	$ 1,090,168	$ 838,591	$ 1,257,886
	Entity Overheads	10.0%	%	$ 8,385,905	$ 838,591	$ 670,872	$ 1,257,886
D1.2	Design, Investigations & Other-Post DBC Activites		LOT		$ 4,792,000	$ 3,500,000	$ 7,000,000
	Pre-design site investigations and modelling including, geotechnical, hydrology, survey and preliminary energy applications	1	Item	$ 350,000	$ 350,000	$ 300,000	$ 500,000
	Environmental Impact Statement and assessment	1	Item	$ 1,500,000	$ 1,500,000	$ 1,000,000	$ 2,500,000
	Construction Contracts	1	Item	$ 300,000	$ 300,000	$ 200,000	$ 500,000
	Environmental offsets (vegetation, etc)	1	Item	$ 2,642,000	$ 2,642,000	$ 2,000,000	$ 3,500,000
D1.3	Land and Water Purchase		LOT		$ 1,000,000	$ 700,000	$ 1,875,000
	Easements and Land Compensation	200	Ha	$ 5,000	$ 1,000,000	$ 700,000	$ 1,875,000
E	BASE ESTIMATE	1	LOT		$ 16,107,000	$ 13,207,000	$ 23,750,000
F	CONTINGENCY	1	LOT		$ 6,443,000	$ 4,832,000	$ 8,054,000
F1.1	Contingency		LOT		$ 6,442,800	$ 4,832,100	$ 8,053,500
	Project Contingency	40%	%	$ 16,107,000	$ 6,442,800	$ 4,832,100	$ 8,053,500
G	PROJECT ESTIMATE	1	LOT		$ 22,500,000	$ 18,000,000	$ 32,000,000

ECONOMIC ROAD MAP

Attachment G:

Barambah Creek

Hydrological Assessment

badu advisory
water + environment

KBR / South Burnett Regional Council

Water availability and supply options for Barlil and West Barambah Weir

23 June 2022

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This report has been prepared in accordance with the scope of services described in the agreement between Badu Advisory and KBR / South Burnett Regional Council ('the client'). The report has been prepared solely for use by the client and Badu Advisory accepts no responsibility for its use by other parties. It is intended to provide high-level strategic advice regarding strategic water issues. Badu Advisory does not provide legal, engineering, financial services, or tax advice.

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List of Figures

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List of Tables

1 Introduction

1.1 Background

KBR was engaged by South Burnett Regional Council to undertake a feasibility study for water supply options in the South Burnett.

ODHydrology was engaged by KBR to undertake hydrologic modelling using the IQQM hydrologic model owned by Department of Regional Development, Manufacturing and Water (DRDMW). This model is used to assess compliance against the Water Plan (Burnett Basin) 2014 (the 'water plan').

Badu Advisory was engaged by KBR to provide strategic oversight of water availability and supply options for Barlil Weir and West Barambah Weir.

1.2 Purpose of this report

The purpose of this report is to summarise the key assumptions, inputs and outputs associated with the modelling of water availability and supply options for Barlil Weir and West Barambah Weir.

2 Model run specification

2.1 Simulation period

The simulation periods used in the modelling of scenarios was as follows:

- the simulation period (as defined in the water plan) and the predevelopment case (as provided by the department) was used when calculating / checking EFOs and WASOs – this is the period from 1 July 1890 to 30 June 2008
- the extended period as was currently available was used when reporting scheme performance in recent years – this is the same as the water plan simulation period (i.e. the model had not been extended by the department at the time of this study).

2.2 Infrastructural considerations

For Barlil Weir:

- The storage curve and other infrastructural aspects were unchanged from the configuration as per previous Sunwater modelling configuration
- The full supply volume of Barlil Weir was assumed to be 1,500 ML
- The dead storage volume was assumed to be 400 ML.

For West Barambah Weir:

- An additional new Weir was located on Barambah Creek at 188.8km AMTD
- The full supply volume of West Barambah Weir was assumed to be 7,000 ML[1]
- The dead storage volume was assumed to be 400 ML
- The storage curve for the West Barambah Weir was assumed to be based on a similar topography for the impounded area upstream of Barlil Weir.

[1] A limiting factor to the full supply volume was likely to be the level at Goomeri / Nanango highway bridge which is upstream.

2.3 Model runs

2.3.1 Summary of model run cases

A comparative summary of the model run cases is presented in Table 1 below.

Table 1 – Summary of model run cases

<table>
<tr><th>Case</th><th>Barlil Weir</th><th>Barambah West Weir</th><th>Change to NV of existing MP</th><th>Change to NV of MP+</th><th>HP performance</th><th>MP performance</th><th>MP+ performance</th></tr>
<tr><td>0</td><td>-</td><td rowspan="4">-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>1</td><td rowspan="6">FSV 1500 ML (DSV 400ML) etc. As per Sunwater config</td><td>-</td><td>-</td><td rowspan="6">No change to base case performance</td><td>Maximise</td><td>-</td></tr>
<tr><td>2</td><td>+3,000 ML</td><td>-</td><td rowspan="2">No change to base case performance</td><td>-</td></tr>
<tr><td>3</td><td>–3,000 ML</td><td>+3,000 ML</td><td>Maximise (target 90% monthly reliability)</td></tr>
<tr><td>4</td><td rowspan="3">FSV 7,000 ML</td><td>-</td><td>-</td><td>Maximise</td><td rowspan="2">-</td></tr>
<tr><td>5</td><td>+4,250 ML</td><td>-</td><td>Maximise (above the base case performance)</td></tr>
<tr><td>6</td><td>–6,000 ML</td><td>+6,000 ML</td><td>No change to base case performance</td><td>Maximise (target 90% monthly reliability)</td></tr>
</table>

2.3.2 Description of model run cases

Case 0 – base case

- As per departmentally approved base case for the Burnett (including the assumed treatment/inclusion of unallocated water in the water plan).
- MP and HP demand distributions as per the department's base case model.
- based on the pre-Paradise Dam-lowering base case (in order to checking effect of these runs on downstream EFOs and WASOs).

Case 1 – Barlil Weir with no additional allocation (reliability improvement only)

- the unallocated reserve for Barlil Weir was assumed to be removed from the model for this and all following cases
- Barlil Weir was added to the base case
- No new water allocations were added to the BBWSS – the aim was to improve MP performance (and not improve or reduce HP priority), to reduce the frequency and size of releases from the dam, and to conserve more water in storage for the critical periods
- scheme release / NOLs etc were adjusted to achieve the above whilst achieving downstream EFOs and WASOs.

Case 2 – Barlil Weir and additional MP allocations

- As per case 1 but 3,000 ML of new MP water allocation (distributed as per most recent configuration discussed by Sunwater with irrigators) were added to the MP priority group
- The performance of the new MP water allocations were assumed to be the same as the existing MP water allocations

- scheme release / NOLs etc were further adjusted to maximise MP performance whilst achieving downstream EFOs and WASOs (assuming new MPs were in the same location as the existing MP priority group).

Case 3 – Barlil Weir and additional "MP+" allocations

- As per case 1 but the nominal volume of existing MP water allocations were reduced by 3,000 ML and replaced by a new priority group of 3,000 ML of MP+ water allocations
- the MP+ water allocations were assumed to be distributed throughout the scheme similarly to the distribution of existing MP allocations
- the performance of the HP water allocations and the remaining MP water allocations were assumed to be the same (not increase or decrease) as the existing MP water allocations.
- The new MP+ water allocations aimed to achieve a monthly reliability of at least 85% (suggest target of 90%)
- The mechanism in the water sharing rules for distinguishing between MP and MP+ water allocations were conceptually based on a simple water level cut-off rule at Barlil Weir (similar to that in the Lower Fitzroy WSS and Fitzroy Barrage Water Supply Schemes). It was assumed that actually operationalizing this could result in a different way of providing differential access to MP and MP+ water allocations within the sharing rules.
- The scheme release / NOLs etc were adjusted to maximise MP performance whilst achieving downstream EFOs and WASOs (assuming new MPs are in the same as the existing MP priority group).

Case 4 – Barlil Weir and Barambah West weir with no additional allocation (reliability improvement only)

- As per case 1 but an additional 7,000 ML new weir was added at Barambah Creek at 188.8km AMTD
- No new water allocations were assumed for this case
- scheme release / NOLs etc were adjusted to improve MP performance (and not improve or reduce HP priority) whilst achieving EFOs and WASOs
- using the new weir to supplement downstream water supplies aimed to further reduce the extent to which releases from the dam would be required and thereby improve MP performance.

Case 5 – Barlil Weir and Barambah West weir with additional MP allocations

- As per case 4 but 4,250 ML of new MP water allocation (distributed similar to that assumed in case 2) were added to the MP priority group
- The performance of the new MP allocations was assumed to be the same as the existing MP
- The scheme release / NOLs etc were adjusted to maximise MP performance whilst achieving downstream EFOs and WASOs (and assumed that new MPs were in the same as the existing MP priority group).

Case 6 – Barlil Weir and Barambah West weir with additional MP+ allocations

- As per case 4 the nominal volume of existing MP water allocations was reduced by 6,000 ML and replaced with a new priority group of 6,000 ML of MP+ water allocations
- the MP+ water allocations were distributed throughout the scheme similarly to the distribution of existing MP allocations

- The performance of the HP water allocations and the remaining MP water allocations were assumed to be the same (not increase or decrease) as the existing MP water allocations
- The new MP+ water allocations aimed to achieve a monthly reliability of at least 85% (suggest target of 90%)
- The mechanism in the water sharing rules for distinguishing between MP and MP+ water allocations were conceptually based on a simple water level cut-off rule at Barlil Weir (similar to that in the Lower Fitzroy WSS and Fitzroy Barrage Water Supply Schemes). It was assumed that actually operationalizing this could result in a different way of providing differential access to MP and MP+ water allocations within the sharing rules
- The scheme release / NOLs etc were adjusted to maximise MP performance whilst achieving downstream EFOs and WASOs (and assumed new MPs are in the same as the existing MP priority group).

2.4 Model outputs

The model outputs included:

- EFOs for the downstream nodes down to EOS
- WASOs for BBWSS and BWSS
- WASOs for unsupplemented groups within the BBWSS and downstream
- Unallocated water node mean annual diversions (MADs)
- Existing and additional MP and HP water allocations in the BBWSS broken down into locations
- Annual diversions for each priority group (HP, MP, MP+) for the dry period at the end of the simulation period
- AAs at 1 Oct each water year for each priority group (HP, MP, MP+) for the dry period at the end of the simulation period.

3 Results

3.1 Environmental flow objectives and water allocation security objectives

The Environmental Flow Objectives and supplemented Water Allocation Security Objectives downstream of the Barker Barambah Water Supply Scheme (BBWSS) were met for the cases considered.

Modelling found that the West Barambah Weir options may impact the performance of existing unsupplemented water allocations downstream of that proposed weir. It is possible that such impacts might be mitigated (even negated) by optimising the way in which targeted releases might be made through West Barambah Weir during flow events to maintain the opportunity for these water allocations to access water. However, this might potentially reduce the extent of the increase to MP and MP+ reliability shown for cases 4 to 6.

A further option that was not modelled but may warrant future consideration is to introduce a MP+ product to a scenario that involves a larger Barlil Weir only. Such an option might avoid the impacts on unsupplemented water allocations because the weir would be located downstream of them.

3.2 Long-term performance of water allocations within the BBWSS

The implications for the long-term performance of water allocations within the BBWSS are summarised in Table 2 (as calculated over the available model simulation period from July 1890 to June 2008). Performance during critically dry periods would, of course, be less than the long-term results.

The results for cases 1 to 6 may be compared to the results of case 0 (which represents the do-nothing case).

Table 2 – Long-term hydrologic performance of model run cases

Case	BBWSS HP monthly reliability	BBWSS MP nominal volume	BBWSS MP monthly reliability	BBWSS MP MAD/NV (%)	BBWSS MP+ nominal volume	BBWSS MP+ monthly reliability	BBWSS MP+ MAD/NV (%)	Remarks re implications for unsupplemented water entitlements within BBWSS
0	99.8%	32,079 ML	78%	82.7%	0 ML	-	-	-
1	99.8%	32,079 ML	79%	84.3%	0 ML	-	-	WASOs met
2	99.8%	35,079 ML	77%	82.8%	0 ML	-	-	WASOs met
3	99.8%	29,079 ML	82%	80.6%	3,000 ML	91.2%	92.0%	WASOs met
4	99.8%	32,079 ML	86%	89.9%	0 ML	-	-	Some unsupplemented WASOs not met. Total mean annual diversions reduced by ~1,900 ML (~19% of total nominal volume of unsupplemented water allocations)
5	99.8%	36,329 ML	83%	88.0%	0 ML	-	-	Some unsupplemented WASOs not met. Total mean annual diversions reduced by ~1,900 ML (~19% of total nominal volume of unsupplemented water allocations)
6	99.8%	26,079 ML	86%	89.9%	6,000 ML	91.3%	91.4%	Some unsupplemented WASOs not met. Total mean annual diversions reduced by ~1,800 ML (~18% of total nominal volume of unsupplemented water allocations)

Note that the metric used by the department for MP reliability (i.e. the "% water sharing index") describes the percentage of months in which the MP users receive their full monthly demands. Modelling showed this measure to conceal the performance of MP users within months where monthly modelled water availability was just less than monthly modelled water demand. It is likely that this metric is particularly sensitive to such effects in situations such as this where the nominal volumes of supplemented water allocations being supplied are an order of magnitude greater than the volume of the local storage supplying them (e.g. Barlil Weir). In view of this, an alternative high-level measure of MP supply was also reported viz. "modelled mean annual demand as % of NV" which is a measure of the total overall long-term share of water going to the MP users.

3.3 Performance during a critically dry period

Long-term hydrologic performance statistics often conceal the relatively poor performance that might be experienced by MP water allocations in very dry periods. The model runs results were therefore examined to ascertain how the scheme might perform in an extended critically dry period. An example of such a period within the available simulation period was between 2001 and 2007.

The extent to which the MP+ concept might improve access during such a period was then examined. For each of the model run cases considered, Table 3 below presents the year-by-year hydrologic performance of MP and MP+ water allocations in terms of annual diversions expressed as a percentage of nominal volumes.

Comparing the MP+ performance (in the columns shaded green) with the base case MP performance (column shaded yellow) shows that MP+ might be expected to extend a water user's access to water supplies by around 18 months to two years within an extended critically dry period.

Table 3 – Long-term hydrologic performance of model run cases

	Year-by-year performance (Annual diversion / nominal volume)%								
	Case 0	**Case 1**	**Case 2**	**Case 3**		**Case 4**	**Case 5**	**Case 6**	
	MP	**MP**	**MP**	**MP**	**MP+**	**MP**	**MP**	**MP**	**MP+**
2001	100%	100%	100%	96%[i]	100%	100%	100%	100%	100%
2002	100%	100%	100%	95%[i]	100%	100%	100%	100%	100%
2003	55%	60%	50%	71%[i]	74%	98%	84%	99%	74%
2004	64%	74%	69%	79%	100%	102%	86%	101%	100%
2005	0%	5%	0%	0%	71%	5%	5%	1%	71%
2006	0%	0%	0%	0%	4%	5%	0%	0%	4%
2007	25%	20%	20%	20%	39%	35%	37%	37%	39%

4 Conclusions

In summary:

- The modelling analyses that were undertaken should be considered a preliminary nature only as they are based on limited availability of engineering details about the new weir infrastructure
- the concept of introducing a new product that is based on converting a limited volume of MP water allocation to MP+ appears to provide a way of delivering an improved MP+ performance whilst maintaining the existing long-term performance of the remaining MP water allocations and downstream water plan environmental flow objectives
- MP+ might be expected to extend a water user's access to water supplies by around 18 months to two years within an extended critically dry period
- all options that included a new West Barambah Weir were found have material impacts on existing unsupplemented water entitlements (flood harvesters). Active management of flow events through Barambah Creek to maintain access to existing unsupplemented water entitlements may be possible but would warrant further detailed investigation and consultation
- a further option that was not modelled but may warrant future consideration is to introduce a MP+ product to a scenario that involves a larger volume Barlil Weir only. Such an option might avoid the impacts on unsupplemented water allocations because the weir would be located downstream of them.

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[i] It is noted that the value of the annual diversion as a percentage of nominal volume for MP is less than the value for MP+ in Case 3 in 2001, 2002 and 2003. This suggests that the cut-off rule that was assumed in Case 3 (to differentiate between MP and MP+ access) may warrant future optimisation during operationalisation.

ECONOMIC ROAD MAP

Attachment H:

Gordonbrook pipeline cost estimate

GORDONBROOK CAPITAL COST ESTIMATE

Item		Description	Quantity	Unit	Rate ($/unit)	Cost ($)	Subtotal ($)	% of total
A		**Direct Costs**					11,937,735	59%
1		**PIPELINES**					9,700,340	48%
		Distribution mains					4,003,720	20%
1	4	Supply & Install distribution main - 90mm	0	m	90	0		
1	5	Supply & Install distribution main - 110mm	2,200	m	94	206,800		
1	6	Supply & Install distribution main - 125mm	0	m	99	0		
1	7	Supply & Install distribution main - 140mm	0	m	104	0		
1	8	Supply & Install distribution main - 160mm	6,400	m	112	716,800		
1	9	Supply & Install distribution main - 180mm	0	m	121	0		
1	10	Supply & Install distribution main - 200mm	0	m	131	0		
1	11	Supply & Install distribution main - 225mm	0	m	146	0		
1	12	Supply & Install distribution main - 250mm	10,760	m	163	1,753,880		
1	13	Supply & Install distribution main - 280mm	0	m	186	0		
1	14	Supply & Install distribution main - 315mm	6,140	m	216	1,326,240		
1	15	Supply & Install distribution main - 355mm	0	m	256	0		
		Spurs					4,435,690	22%
1	19	Supply & Install Spur 1 - 250mm	5,090	m	163	829,670		
1	20	Supply & Install Spur 2 - 110mm	1,700	m	94	159,800		
1	21	Supply & Install Spur 3 - 180mm	4,120	m	121	498,520		
1	22	Supply & Install Spur 4 - 280mm	13,700	m	186	2,548,200		
1	23	Supply & Install Spur 5 - 63mm	4,700	m	85	399,500		
		Pipeline allowances					1,260,930	6%

Item		Description	Quantity	Unit	Rate ($/unit)	Cost ($)	Subtotal ($)	% of total
1	24	Extra over allowance for isolation, scour and air valves; fittings; thrust blocks	10%		4,003,720	400,372		
1	25	Extra over allowance for road, rail and creek crossings; dealing with existing services, and making good existing infrastructure (e.g. fencing).	5%		4,003,720	200,186		
1	26	Extra over allowance for importation of pipeline bedding and embedment material.	10%		4,003,720	400,372		
1	27	Allowance for customer connections	26	No.	10,000	260,000		
2		**PUMP STATIONS**					**1,380,000**	**7%**
2	1	PS1 60m lift	1	Item	410,000	410,000		
2	1	PS2 65m lift	1	Item	370,000	370,000		
2	2	PS3 75m lift	1	Item	300,000	300,000		
2	3	PS4 75m lift	1	Item	150,000	150,000		
2	4	Balancing tank on pump station inlet	3	no.	50,000	150,000		
3		**SOLAR FARM**					**739,200**	**4%**
3	1	Solar farm - supply and install (panels, cabling, inverters, etc.)	480	kW	1,400	672,000		
3	2	Solar farm civils and structural	10%		672,000	67,200		
4		**OTHER**					**118,195**	**1%**
4	1	Testing and commissioning	1%		11,819,540	118,195		
B		**Contractor indirect costs**					**1,790,660**	**9%**
5		**CONTRACTOR INDIRECT COSTS**					**1,790,660**	**9%**

Item		Description	Quantity	Unit	Rate ($/unit)	Cost ($)	Subtotal ($)	% of total
5	1	Mob/Demob, preliminaries, site running, PM, risk	7.5%		11,937,735	895,330		
5	2	Detailed Design	7.5%		11,937,735	895,330		
C		CONSTRUCTION ESTIMATE SUBTOTAL					13,728,396	68%
D		Client indirect costs					796,420	4%
6		CLIENT INDIRECT COSTS					796,420	4%
6	1	Land / Easement Costs	4	No.	10,000	40,000		
6	2	Land acquisition for solar farm	1.40	ha	50,000	70,000		
6	3	Project Management, construction management, commissioning	2.5%		13,728,396	343,210		
6	4	Owners Fixed Overhead	2.5%		13,728,396	343,210		
E		BASE ESTIMATE SUBTOTAL					14,524,815	71%
F		Contingency					5,809,926	29%
7		Contingency					5,809,926	29%
7	1	Contingency	40%		14,524,815	5,809,926		
G		PROJECT CAPITAL ESTIMATE					20,334,742	100%

GORDONBROOK OPERATIONAL ESTIMATE

Item		Description	Comments	Quantity	Unit	Rate ($/unit)	Cost ($/annum)	Cost ($/ML/annum)
		-	-					
A		**OPEX - Fixed Costs**						
1		**Water Supply**						
1	1	Supply Charge	'Likely' demand rounded up to nearest 100ML	1,800	ML/year	-	-	-
2		**Maintenance**						
2	1	Pipelines		0.25%	% Capital Cost	9,700,340	**24,251**	**13**
2	2	Pump Stations		1.0%	% Capital Cost	1,380,000	**13,800**	**8**
3		**Labour**						
3	1	Staffing allowance		1.2	FTE	100,000	**120,000**	**67**
B		**OPEX - Variable Costs**						
4		**Power**						
4	1	Pumping cost - import power	16 hours per day, 270 days per year	683,915	kWh/y	0.20	**136,783**	**76**
4	2	Solar generation - export power	8 hours per day at full generation, 95 days per year + 8 hours per day at partial generation (i.e.	1,059,643	kWh/y	(0.05)	**(52,982)**	**(29)**

Item		Description	Comments	Quantity	Unit	Rate ($/unit)	Cost ($/annum)	Cost ($/ML/annum)
			minus pumping), 270 days per year					
C		**Annualised Replacement**						
5		**Annualised replacement**						
5	1	Pipelines	100 year design life	**1.0%**	/year	11,155,391	**50,492**	**28**
5	2	Pump Stations	40 year design life	**2.5%**	/year	1,587,000	**35,275**	**20**
5	3	Solar farm	30 year design life	**3.3%**	/year	850,080	**26,838**	**15**
D		**PROJECT OPERATIONAL ESTIMATE**					**354,457**	**197**

Note: The Annualised replacement costs have been calculated using a renewals annuity based on a 2.5% annual cost and 5% interest rate on positive balances in the asset renewal fund.

ECONOMIC ROAD MAP

Attachment I: Blackbutt

Pipeline Cost Estimate

BLACKBUTT CAPITAL COST ESTIMATE

Item		Description	Quantity	Unit	Rate ($/unit)	Cost ($)	Subtotal ($)	% of total
A		Direct Costs					8,722,636	58%
1		PIPELINES					5,133,074	34%
		Distribution mains					3,521,419	23%
1	1	Supply & Install distribution main - 110mm	0	m	94	0		
1	2	Supply & Install distribution main - 125mm	0	m	99	0		
1	3	Supply & Install distribution main - 140mm	2,620	m	104	272,480		
1	4	Supply & Install distribution main - 160mm	999	m	112	111,888		
1	5	Supply & Install distribution main - 180mm	601	m	121	72,721		
1	6	Supply & Install distribution main - 200mm	12,430	m	131	1,628,330		
1	7	Supply & Install distribution main - 225mm	3,120	m	146	455,520		
1	8	Supply & Install distribution main - 250mm	0	m	163	0		
1	9	Supply & Install distribution main - 280mm	0	m	186	0		
1	10	Supply & Install distribution main - 315mm	0	m	216	0		
1	11	Supply & Install distribution main - 355mm	3,830	m	256	980,480		
1	12	Supply & Install distribution main - 400mm	0	m	306	0		
		Spurs					501,300	3%
1	13	Spur 1 to demand parcel 2 - supply & install	830	m	90	74,700		
1	14	Spur 2 to demand parcel 5, 6 - supply & install	1,770	m	90	159,300		
1	15	Spur 3 to demand parcel 10, 11 - supply & install	2,220	m	90	199,800		
1	16	Spur 4 to demand parcel 16, 17, 18 - supply & install	750	m	90	67,500		
		Pipeline allowances					1,110,355	7%

Item		Description	Quantity	Unit	Rate ($/unit)	Cost ($)	Subtotal ($)	% of total
1	17	Extra over allowance for isolation, scour and air valves; fittings; thrust blocks	10%		3,521,419	352,142		
1	18	Extra over allowance for road, rail and creek crossings; dealing with existing services, and making good existing infrastructure (e.g. fencing).	5%		3,521,419	176,071		
1	19	Extra over allowance for importation of pipeline bedding and embedment material.	10%		3,521,419	352,142		
1	20	Allowance for customer connections	23	No.	10,000	230,000		
2		**PUMP STATIONS**					**1,070,000**	**7%**
2	1	PS1 80m lift	1	item	440,000	440,000		
2	2	PS2 80m lift	1	item	240,000	240,000		
2	3	PS3 85m lift	1	item	240,000	240,000		
2	4	Balancing tank on pump station inlet	3	no.	50,000	150,000		
3		**SOLAR FARM**					**2,433,200**	**16%**
3	1	Solar farm - network - supply and install (panels, cabling, inverters, etc.)	360	kW	1,400	504,000		
3	2	Solar farm- network - civils and structurals	10%		504,000	50,400		
3	3	Solar farm - bulk water - supply and install (panels, cabling, inverters, etc.)	1,220	kW	1,400	1,708,000		
3	4	Solar farm- bulk water - civils and structurals	10%		1,708,000	170,800		
4		**OTHER**					**86,363**	**1%**
4	1	Testing and commissioning	1%		8,636,274	86,363		
B		**Contractor indirect costs**					**1,308,395**	**9%**

Item		Description	Quantity	Unit	Rate ($/unit)	Cost ($)	Subtotal ($)	% of total
5		**CONTRACTOR INDIRECT COSTS**					**1,308,395**	**9%**
5	1	Mob/Demob, preliminaries, site running, PM, risk	7.5%		8,722,636	654,198		
5	2	Detailed Design	7.5%		8,722,636	654,198		
C		**CONSTRUCTION ESTIMATE SUBTOTAL**					**10,031,032**	**67%**
D		**Client indirect costs**					**731,552**	**5%**
6		**CLIENT INDIRECT COSTS**					**731,552**	**5%**
6	1	Land / Easement Costs	1	no.	10,000	10,000		
6	2	Land acquisition for solar farm - network	1	ha	50,000	50,000		
6	3	Land acquisition for solar farm - bulk water	3	ha	50,000	170,000		
6	4	Project Management, construction management, commissioning	2.5%		10,031,032	250,776		
6	5	Owners Fixed Overhead	2.5%		10,031,032	250,776		
E		**BASE ESTIMATE SUBTOTAL**					**10,762,584**	**71%**
F		**Contingency**					**4,305,033**	**29%**
7		**Contingency**					**4,305,033**	**29%**
7	1	Contingency	40%		10,762,584	4,305,033		
G		**PROJECT CAPITAL ESTIMATE**					**15,067,617**	**100%**

BLACKBUTT OPERATIONAL ESTIMATE

Item		Description	Comments	Quantity	Unit	Rate ($/unit)	Cost ($/annum)	Cost ($/ML/annum)
		-	-					
A		OPEX - Fixed Costs						
1		**Water Supply**						
1	1	Supply Charge	'Likely' demand rounded up to nearest 100ML	2,100	ML/year	-	-	-
2		**Maintenance**						
2	1	Pipelines		0.25%	% Capital Cost	5,133,074	**12,833**	**6**
2	2	Pump Stations		1.0%	% Capital Cost	1,070,000	**10,700**	**5**
3		**Labour**						
3	1	Staffing allowance		1	No.	100,000	**100,000**	**48**
B		OPEX - Variable Costs						
4		**Power**						
4	1	Network pumping cost - import power	16 hours per day, 270 days per year	507,401	kWh/y	0.20	**101,480**	**48**
4	2	Network solar generation - export power	8 hours per day at full generation, 95 days per year + 8 hours per day at partial	797,499	kWh/y	(0.05)	**(39,875)**	**(19)**

Item		Description	Comments	Quantity	Unit	Rate ($/unit)	Cost ($/annum)	Cost ($/ML/annum)
			generation (i.e. minus pumping), 270 days per year					
C		**Annualised Replacement**						
5		**Annualised replacement**						
5	1	Pipelines	100 year design life	**1.0%**	/year	5,903,035	**26,719**	**13**
5	2	Pump Stations	40 year design life	**2.5%**	/year	1,230,500	**27,351**	**13**
5	3	Bulk water solar farm	30 year design life	**3.3%**	/year	2,160,620	**68,214**	**32**
5	4	Network solar farm	30 year design life	**3.3%**	/year	637,560	**20,129**	**10**
D		PROJECT OPERATIONAL ESTIMATE					327,550	156

Note: The Annualised replacement costs have been calculated using a renewals annuity based on a 2.5% annual cost and 5% interest rate on positive balances in the asset renewal fund.

ECONOMIC ROAD MAP

Attachment J: Risk Assessment

1 Summary

1.1 BACKGROUND AND PURPOSE

This risk assessment report was prepared as part of the South Burnett Economic and Sustainability Roadmap (Roadmap). The Roadmap identified opportunities for sustainable economic develop for the South Burnett Region, including the development of water infrastructure to support expansion in agriculture and industry. This preliminary risk assessment report identifies and considers the top ten risks related to the proposed water infrastructure.

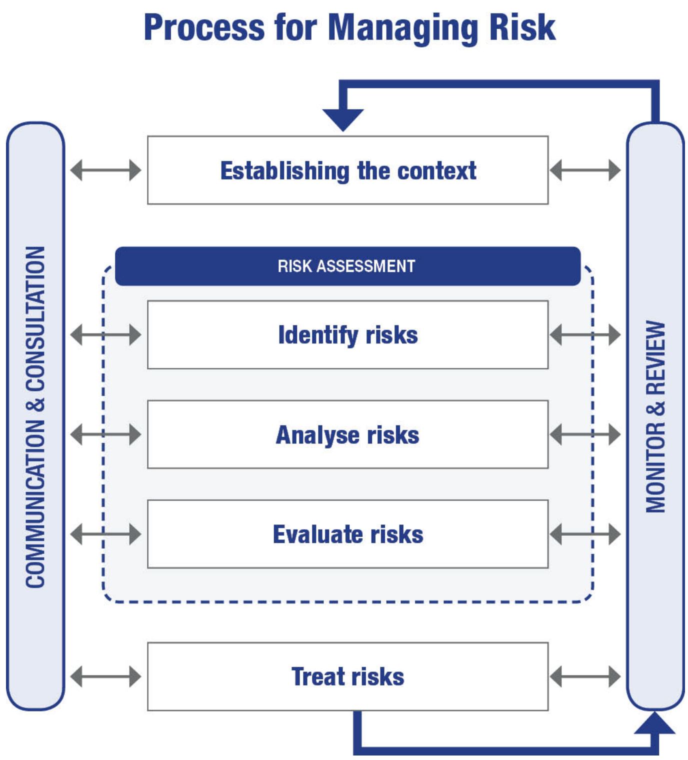
This risk assessment is not comprehensive and considers the proposed water infrastructure at a conceptual level only. Any detailed business case, or other assessment of the viability of the proposed water infrastructure must include a detailed risk assessment for the feasibility study, infrastructure design and delivery, and operation of any agricultural or industrial scheme.

2 Methodology

2.1 RISK APPROACH

The risk management approach in the is illustrated at Figure 2-1. The process for the identification, assessment and management of risks conforms with the Queensland Government risk management framework and the relevant Australian Standard AS/NZS ISO 31000:2009 Risk Management—Principles and Guidelines.

Figure 2-1: Risk management process adopted



2.1.1 Risk criteria

The criteria used in the risk assessment process align with best practice criteria utilised in water infartrscture projects in Queensland, and the requirements of Infrastructure Australia.

The risk criteria are composed of three parts: likelihood; consequence; and analysis/scoring.

2.1.1.1 Risk likelihood

The risk criteria establish and assess the probability of a particular risk materialising. Table 2.1 provides the risk likelihood categories with examples to assist stakeholders to understand the application of this measurement. It is considered that the range from ‘yearly’ to ‘every 100 years’ is appropriate for water-infrastructure-related risks.

Table 2.1: Risk likelihood categories

Likelihood	Description	Example to assist stakeholders
Almost certain	The event is expected to occur in most circumstances	May occur once a year or more
Likely	The event will probably occur in many circumstances	May occur once every 3 years
Possible	Identified factors indicate the event could occur at some time	May occur once every 10 years
Unlikely	The event could occur at some time but is not expected	May occur once every 30 years
Rare	The event may occur only in exceptional circumstances	May occur once every 100 years

2.1.1.2 Risk consequences

The risk consequences measure the impact of the occurrence of the risk on the realisation of the benefits of the proposed water infrastructure. The risk consequences are set out in Table 2.2.

Table 2.2: Risk consequences—impact on realisation of benefits

Insignificant	Minor	Moderate	Major	Catastrophic
Negligible impact on realisation of project benefits	Minor impact on realisation of project benefits	Moderate impact on realisation of project benefits	Major impact on realisation of project benefits	Catastrophic impact on realisation of project benefits—cannot be realised

2.1.1.3 Risk analysis/scoring

The Risk Analysis and Scoring Matrix at Table 2.3 provides a score for each risk based on the likelihood of occurring and the consequence if it does occur.

Table 2.3: Risk Analysis and Scoring Matrix

Likelihood / consequence	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium (11)	Medium (16)	High (20)	Extreme (23)	Extreme (25)
Likely	Low (7)	Medium (12)	High (17)	High (21)	Extreme (24)
Possible	Low (4)	Medium (8)	Medium (13)	High (18)	High (22)
Unlikely	Low (2)	Low (5)	Medium (9)	Medium (14)	High (19)
Rare	Low (1)	Low (3)	Low (6)	Medium (10)	Medium (15)

2.1.2 Risk identification

Risk identification is the process of determining what risks may impact on the project outcome, and the circumstances under which each risk may materialise. This preliminary risk assessment considered the top ten risks that may impact the proposed water infrastructure, and which may be common across the project options or specific to an individual project option.

2.1.3 Outcome of risk assessment

The Risk Register is set out in Section 3 of this Report. The Risk Register sets out the findings of the risk identification and assessment, including the recommended control strategy for the mitigation and management of each risk.

3 Risk Register

	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Risk	Demand for water is lower than projected in the demand assessment for a particular project	Water is too expensive for local irrigators	Unexpected ground conditions	Construction market prices are high for due to demand	Failure to secure water planning approval (where required)
Trigger	Binding water sales	Cost assessment of final infrastructure	Throughout construction of the project	Tendering process to build infrastructure	Application process
Consequence	Small difference in demand will have a minimal impact Large difference in demand could result in the project being unaffordable and unviable	Local investors in water infrastructure are unable to afford water	Increased construction and delivery costs	Delays and cost increases in procurement costs	Project cannot proceed due to restrictions in Water Plan
Risk level	Medium (13)	Medium (13)	Medium (14)	High (18)	High (19)
Mitigation activities	▪ Conduct a second demand assessment to confirm and verify findings as part of a detailed business case ▪ Engage with potential customers to assess risks ▪ Implement a deposit-based security for prospective buyers	▪ Adopt efficiency practices when developing infartrscture to ensure it is fit for purpose ▪ Business planning and mentoring to local investors. ▪ Consider price strategies to attract locals.	▪ Geotechnical studies and risk management strategies implemented as part of any detailed business case ▪ Strategic staging of project to identify and manage risks ▪ Provide for uncertainty in contract model	▪ Identify flexible procurement models to share risk and reward with contractors ▪ Strategic decision-making regarding timing of project and flexibility	▪ Close engagement with regulator ▪ Develop strategic plan for seeking approval for project

	Risk 6	Risk 7	Risk 8	Risk 9	Risk 10
Risk	Failure to secure planning approval from State and Federal Governments	Significant environmental impacts identified, and projects fail to achieve approvals	Market prices and/or yield for crops is materially different to model	Climate change impacts on the project (right crops, adaption, yield, crop yield)	Project does not meet requirements and aspirations of Traditional Owners
Trigger	Application process	Application for approval	Operation of the scheme	Operation of the scheme	Operation of the scheme
Consequence	Project cannot proceed	Project unable to proceed	The benefits of the project are not realized	Failure to meet financial output and targets	Project fails to provide social and economic outcomes
Risk level	High (19)	High (18)	Medium (13)	High (18)	High (18)
Mitigation activities	▪ Close engagement of State and Federal Government ▪ Develop strategic plan for seeking approval for project	▪ Further assessment as part of detailed business case ▪ Development of the best strategic approvals pathway and process ▪ Engagement with Government	▪ Further assessment as part of detailed business case ▪ Flexibility for irrigators to change crops. ▪ Design to allow flexibility. ▪ Provide for diversity in crops in the scheme ▪ Layout of the farming needs to be strategic to provide flexibility. ▪ Irrigation training / mentoring / processes	▪ Investigate technology solutions ▪ Include climate change scenarios in hydrological modelling ▪ Build flexibility into the network ▪ Consider large scale project solutions ▪ Strategic pricing to accommodate future changes ▪ Alternative water sourcing options / solutions (GAB, alluvial, etc)	▪ Consider Traditional Owner allocations ▪ Explore Traditional Owner enterprises ▪ Explore Traditional Owner management of offsets ▪ Develop CHMP ▪ Close engagement with Traditional Owners

ECONOMIC ROAD MAP

Attachment K:

Sustainability

Opportunity Statement

1 Summary

This Sustainability Strategy and Opportunity Statement has been prepared to build on the findings from the previous Water Supply Requirements in the North and South Burnett Options Analysis and supports the Economic Road Map for South Burnett. The strategy identifies initiatives, programs, policy changes and capital projects that can enhance both the sustainability and economic opportunity for the region.

The Strategy includes three main sections:

- Overview of the risks and opportunities that exists for the South Burnett region generated by the closure of the Tarong Power Plant in 2037
- Analysis of the transition for the region after the Tarong Power Plant closure. The alignment to “Just Transition” is explored as well as the region’s position to achieve United Nations Sustainable Development Goals
- Recommendations of business initiatives that achieves the strategy objective of maintaining and improving employment levels in South Burnett beyond 2037.

2 Introduction

2.1 BACKGROUND

In November 2018, the Australian Government announced a grant via the National Water Infrastructure Fund to conduct a feasibility study to examine a range of options to increase water supply, reliability and security, which would underpin an expansion of irrigated agriculture and delivering new jobs and economic growth in the North Burnett and South Burnett regions of Queensland.

Using this funding, the South Burnett Regional Council (the Council), together with the North Burnett Regional Council, commissioned a Strategic Business Case and an Options Analysis which identified opportunities to increase agricultural production and urban resilience to generate substantial economic value. The Options Analysis made several recommendations regarding further study and investigation in South Burnett, including:

- Developing an Economic Road Map that identifies opportunities and strategies to utilise water resources that will become available because of reduced water usage, and eventual closure, of the Tarong Power Station.
- Conducting a feasibility study and assessment of a potential irrigation scheme in Blackbutt.
- Conducting a feasibility study and assessment of the uses for Gordonbrook Dam including for urban usage and irrigated agriculture.

Key considerations of these studies are to recognise the eventual closure of the Tarong Power Plant in 2037 and to ensure that South Burnett council position itself such that the community continues to thrive beyond the power plant closure. The Options Analysis shortlisted initiatives for the South Burnett region that could target sustainable agricultural processes and improve community and economic resilience in the area.

2.2 METHODOLOGY

This Strategy proposes three initiatives in line with the Sustainable Development Goals (SDGs), and which enable a Just Transition (JT) for the South Burnett council. A high-level qualitative analysis of the initiatives is offered (refer to Section 4) to highlight both synergies and risks with respect to the successful progression towards SDGs and JT.

The Just Transition (JT) framework was developed to reflect the many definitions and perspectives on socially and ecologically just transitions to a low-carbon, climate resilient future[1]. As more countries have been mobilising to set increasingly more ambitious climate and energy goals, it is paramount to develop plans for the people and communities that will be most affected by policy changes.

[1] Just Transitions Initiative Team. 2021. *A Framework for Just Transitions*. Just Transitions Initiative. https://justtransitioninitiative.org/a-framework-for-just-transitions/

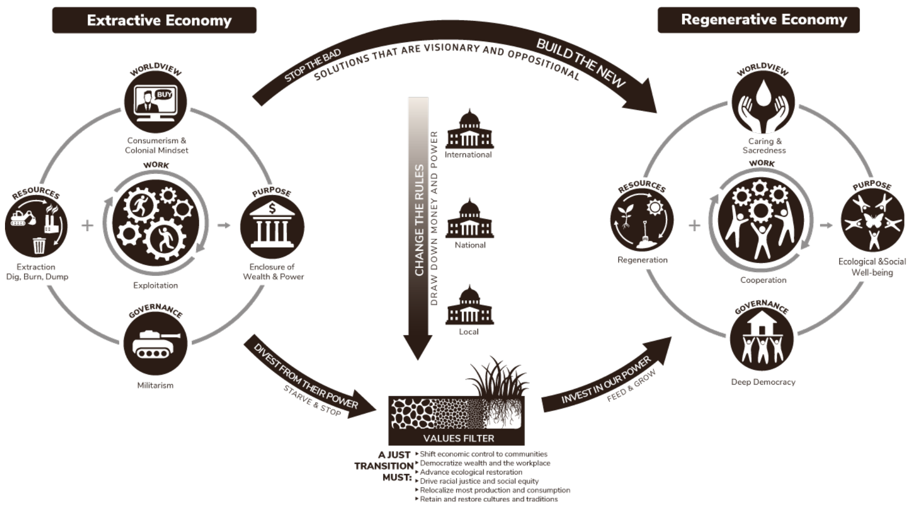


Figure 1: Just Transition Framework Design, https://climatejusticealliance.org/just-transition/

The Just Transition Framework can be used to assess principles and processes to support transformative practices. It can be applied at different geographical scales (local, national, regional, and global) and time horizons (short-, medium-, and long-run) to achieve a global ambition of limiting the rise in climate change-related temperature to below 2°C. The framework requires that actions are taken across two fundamental dimensions: social inclusion and distributional impacts.

A Just Transition is one that eliminates and replaces environmentally degrading activities with innovative and sustainable industries. It therefore enables community-led initiatives to address environmental injustice and develop a sustainable local economy that promotes social equity by including and empowering all community groups.

Figure 2: Sustainable Development Goals, https://www.un.org/en/sustainable-development-goals

An inclusive and just transition can catalyse transformation co-benefits for the achievement of the Sustainable Development Goals (SDGs). The SDGs framework includes 17 Goals and 169 targets to tackle the world's most pressing social, economic, and environmental challenges in the lead-up to 2030. While originally developed for national governments to implement, it is recognised that social and environmental issues require action by local and regional governments. This is because they hold a unique position as they make decisions around resource management and infrastructure development that have long-term impacts on current and future conditions.

3 South Burnett: Regional Overview, Transition Impacts and Sustainability Opportunities

3.1 SOUTH BURNETT

The South Burnett Regional Council aims foster economic development, growth, and regional sustainability by investigating known water supply and demand options. The South Burnett region has highly fertile soils that are suitable for agricultural production through irrigated cropping. Furthermore, the region's existing transport infrastructure and potential labour forces provide a strong avenue for product distribution in both the international and domestic markets.

While South Burnett has several large employment industries including agriculture, utilities, retail, manufacturing (which includes abattoir workers) and health, however unemployment has risen due to a shrinking employment base of key sectors. The closure of the Tarong Power Station represents an additional hurdle for the region.

3.2 RISKS AND OPPORTUNITIES OF TARONG POWER STATION CLOSURE

3.2.1 Impacts on the community

The water environment in South Burnett will be subject to a significant transformation over the next 15–25 years due to the scheduled closure of Tarong Power Station in 2036–37, potentially impacting the local community. Mainly, the closure poses a risk to the largest non-government employer in the region. This, if not managed appropriately, may result in the loss of hundreds of jobs and salaries, potentially causing economic displacement as families may move to urban areas in search of new employment. Reduced financial investments in the area may also follow, if the necessary conditions to attract appealing investments were missing.

3.2.2 Opportunities for the region

Several opportunities for sustainable and just regional growth arise from the closure of the Tarong power station as the plant closure may provide economic opportunities associated with plant decommissioning, water and environmental reclamation, and economic diversification.

The power plant closure will leave behind 30,000ML of high priority water that can be distributed for other more sustainable uses. For example, the water that flows from the Tarong and Boyne River can be made available for purchase to the industrial and agricultural sectors.

Further, the closure of the power stations will potentially facilitate the removal of the critical water supply arrangements for medium priority allocation holders. By supporting the establishment of new industries, the surge in water availability can create the foundations for new economic wealth in South Burnett that will prevent current residents from leaving in search of employment opportunities in metropolitan areas.

From a human health perspective, the shut-down of coal plants eliminates significant health hazards caused by long-term exposure to air pollutants[2] . This is true not only for those, like employees, directly exposed to coal extraction, transport and handling processes, but also for individuals living in surrounding neighbourhoods who are indirectly but chronically exposed to a diversity of environmental air pollutants. The closure of the power station will therefore benefit the quality of life for all in South Burnett and has the potential to reduce the occurrence of a variety of serious cardiological[3], respiratory[4], and reproductive diseases[5] amongst others. Additionally, this can contribute to reducing the burden on public budgets of healthcare.

A further environmental opportunity exists whereby the decommissioning of coal plants can support the conservation and regeneration of the local biodiversity, if skilfully planned to integrate Nature-Based Solutions (NBS). In fact, as deconstruction activities will already be accounted for, the cost of additional earth-moving activities can be absorbed into existing budgets, resulting in minor incremental expenses[6]. Obtaining relevant approvals would also be simplified as the land would already be under ownership of the facility owner. Alternatively, old power plants have been re-commissioned and turned into commercial and retail precincts, therefore leading to economic diversification and industrial rejuvenation[7].

[2] J. Gasparotto, K. Da Boit Martinello. 2021. *Coal as an energy source and its impacts on human health*. Energy Geoscience, Vol. 2 (2), pp. 113-120.

[3] M. Hendryx, K.J. Zullig. 2009. *Higher coronary heart disease and heart attack morbidity in Appalachian coal mining regions.* Prev. Med., Vol. 49 (5), pp. 355-359.

[4] J.L. Perret, B. Plush, P. Lachapelle, T.S. Hinks, C. Walter, P. Clarke, A. Stewart. 2017. Co*al mine dust lung disease in the modern era*. Respirology, Vol. 22 (4), pp. 662-670.

[5] B.P. Mohanty, M.R. Mahananda. 2015. *Reproductive health hazards of coal mine male workers in Lakhanpur open cast mines*. Int. J. Biomed. Res., Vol. 6 (12).

[6] Black & Veatch. 2021. *Nature-Based Solutions when retiring coal plants*. https://www.bv.com/perspectives/nature-based-solutions-when-retiring-coal-plants

[7] K. Maize. 2022. *New Life for dead and dying coal plants?* Powermag. https://www.powermag.com/new-life-for-dead-and-dying-coal-plants/

4 Sustainability Initiatives

4.1 REGIONAL SUSTAINABILITY OBJECTIVES

Regional sustainability describes the ability of a region to grow economically and socially without compromising the ecological environment. This Strategy explores ways in which South Burnett can successfully transition into reliable new industries after the closure of the Tarong Power Station, which is currently the region's primary source of employment.

By upgrading the regional infrastructure to improve urban and agricultural water supply and ensure community health and well-being and economic expansion, combined with the development of the oversight entity to manage the new irrigation scheme, the Council intends to progress towards the quadruple-bottom line of environmental, social, economic, and governance prosperity that the theory of sustainable development aspires to achieve.

4.2 CROP PRE-SCREENING

A key step for the successful achievement of South Burnett's regional sustainability goals was the assessment and identification of suitable new industries to be established in the region to minimise the possible detrimental impacts arising from the closure of the Tarong coal power station in 2037, and take full advantage of the water supply available to the region after 2037. In fact, the Burnett region has both good quality and very good quality soil for agriculture.

Across the region, approximately 14,000–36,000 hectares are currently used for irrigation, leaving over 600,000 hectares of fertile soil available for irrigation. Importantly, crops grown in the Burnett region, and those that could be grown on the available soil with additional water, are high-value crops, generating high economic returns to the state and scoring high on suitability for export.

To identify the most favourable crops, fourteen options were investigated and assessed against a set of eight criteria to determine their viability in supporting South Burnett through its post-coal transition.

The identified options include cotton, peanuts, beans, chickpeas, corn, pumpkin, watermelon, macadamias, citrus, stone fruit (peaches and nectarines), wine grapes, intensive pig and dairy farming, and pig processing (refer to Figure 3). The options underwent a high-level multi-criteria assessment conducted against a set of eight criteria including suitability to soil and climate conditions, export potential, net margin, sustainability, availability of existing infrastructure and local knowledge, and job creation. Options were given a score from 1 to 5 for each criterion, which was then averaged out to identify the most suitable alternatives (refer to Figure 4).

	Crop Suitability (Soil and Climate)	Domestic Market	Export Potential	Net Margins	Job creation	Sustainability	Existing Infrastructure and local knowledge	Benefits from scale / coordination	Average
Cotton	5	1	3.5	2	2	2.5	4	2	2.8
Peanuts	5	5	4	2.5	3	4.5	5	5	4.3
Beans (pulses)	5	2	4	2	2	4	5	5	3.6
Chickpeas	5	2	4.5	2	2	4	5	5	3.7
Corn / Maize	5	3.5	3	2	1.5	3	5	5	3.5
Pumpkins	5	2	2	2	2.5	3.5	4	3	3.0
Watermelons	5	2	2.5	2	2.5	3	4	3	3.0
Macadamias	5	2.5	4.5	4	4.5	4	3	4	3.9
Citrus	5	2.5	5	5	5	4	3	5	4.3
Stone Fruit (Peaches and nectarines)	5	3	2.5	4	4.5	3.5	5	5	4.1
Avocadoes	5	2	4	5	5	3	5	5	4.3
Wine Grapes (vertical integration)	5	2	1	3	3.5	3.5	3	5	3.3
Intensive Livestock (Piggery and Diary)		5		5	5	2.5	5	5	**4.6**
Meat Processing (Pigs)		5		5	5	2.5	5	5	**4.6**

Figure 3: multi-criteria assessment of possible new industries

4.3 SHORTLISTED OPTIONS

The multi-criteria assessment revealed that intensive livestock farming and meat processing have the highest potential, and were therefore selected as viable new business opportunities for South Burnett to pursue.

Additionally, the option of avocado farming underwent a full-scope economic feasibility assessment (refer to Appendix 1). This revealed this option's high potential value and was therefore selected as the third proposed industry for consideration.

Section 4.2 below provides a qualitative sustainability assessment of the alignment of the three options against the SDG Targets, and the principles of Just Transitions.

4.3.1 Alignment with UN SDGs

A high-level assessment of the proposed business initiatives for South Burnett, provided in Table 1, reveals that progress towards 12 of the SDGs can be expected from the establishment of the three proposed initiatives of avocado farming, livestock farming and meat processing.

Instead of being limited to linking the three proposed initiatives to the Goals themselves, the assessment went one level deeper and looked at the SDG Target. These provide SMART (Specific, Measurable, Achievable, Relevant, and Time-Bound) metrics that have been used to assess progress towards a more sustainable future by entities, public and private, since the launch of the SDGs framework in 2015.

Table 1: Options alignment with UN SDGs

	United Nations Sustainable Development Goals																
UN SDGs Targets Addressed	No Poverty	No Hunger	Good Health and Well-Being	Quality Education	Gender Equality	Clean Water and Sanitation	Affordable and Clean Energy	Decent Work and Economic Growth	Industry, Innovation and Infrastructure	Reduced Inequalities	Sustainable Cities and Communities	Responsible Consumption and Production	Climate Action	Life Below Water	Life On Land	Peace, Justice and Strong Institutions	Partnership For the Goals
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	1.4 1.5	2.3 2.4	3.9	4.7		6.3 6.4 6.5		8.2 8.5 8.8	9.1 9.4		11.5 11.7	12.2 12.4 12.6	13.1	14.3			17.17

The official SDGs Targets are provided below to provide context to the results presented in Table 1.

1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance.

1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

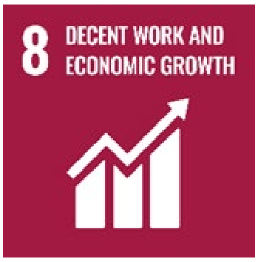
3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate



8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors

8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value

8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

11 SUSTAINABLE CITIES AND COMMUNITIES

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

12.2 By 2030, achieve the sustainable management and efficient use of natural resources
their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle

13 CLIMATE ACTION

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

14 LIFE BELOW WATER

14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

17 PARTNERSHIPS FOR THE GOALS

17.17 encourage and promote effective public, public- private, and civil society partnerships, building on the experience and resourcing strategies of partnerships

The results of the assessment demonstrate that the project aligns with and promotes the SDG in the following ways:

- **Goal 1 No Poverty** by reducing the region's exposure to climate-related events and other economic, social and environmental shocks
- **Goal 2 Zero Hunger** by enabling increased investment, including through enhanced international cooperation, in rural infrastructure
- **Goal 3 Good Health and Well-Being** by reducing the number of illnesses from hazardous chemicals and air, water and soil pollution and contamination
- **Goal 6 Clean Water and Sanitation** by reducing pollution and minimizing the release of hazardous chemicals and materials, and implementing integrated water resource management
- **Goal 8 Decent Work and Economic Growth** by creating the conditions to achieve higher levels of economic productivity through diversification, technological upgrading, and innovation, including through a focus on high value sectors; fostering full and productive employment and decent work for all women and men; and enabling a shift to safer working environments for all workers
- **Goal 9 Industry Innovation and Infrastructure** by developing quality, reliable, sustainable, and resilient infrastructure to support economic development and human well-being
- **Goal 11 Sustainable Cities and Communities** by providing universal access to safe and liveable public spaces, and supporting positive economic, social, and environmental links between urban, peri-urban, and rural areas
- **Goal 12 Responsible Consumption and Production** by moving towards a more sustainable use of natural resources and reducing toxic waste generation
- **Goal 13 Climate Action** by enhancing education, awareness-raising and human and institutional capacity on climate change mitigation measures
- **Goal 17 Partnerships for the Goals** by promoting effective public-private partnerships to generate and disseminate new knowledge about sustainable development

A Just Transition is then enabled as the project aims to support the people of South Burnett, and especially those most vulnerable to the transition such as those currently employed by the Tarong power station, by facilitating employment opportunities in new sectors, offering re-skilling opportunities, and creating new and cleaner jobs. The project also supports companies and sectors, by creating attractive conditions for public and private investment, as well as the wider region by supporting the transition to low-carbon and climate-resilient activities, investing in economically viable initiatives to support the economy of the region.

4.3.2 Sustainability risks

While the water infrastructure upgrades will create the conditions for the emergence of new sustainable industries in South Burnett, it is important to highlight that a number of risks exist that must be quantified and managed from project design, during construction and through to operations, to avoid generating detrimental effects that might counteract the benefits gained.

For example, to ensure progress towards *SDGs 15 Life on Land* isn't compromised, agricultural activities must be performed in a way that preserves soil quality, while delivering the promised economic benefits. Similarly, livestock farming should adopt all feasible measures to avoid ground, water, and air contamination, necessary to guarantee progress towards *SDG 3 Good Health and Well-Being*, *SDG 6 Clean Water and Sanitation* and *SDG 14 Life Below Water*.

Lastly, as all proposed activities have been chosen partly for their export potential, it is important to quantify and minimise all greenhouse gas emissions generated by processing and transport, to ensure progress towards *SDG 13 Climate Action*.

Appendix A

AVOCADO FARMING ECONOMIC VIABILITY ASSESSMENT

Economic Outputs

Blackbutt Economic Assessment

Indicative water demand by option (ML)

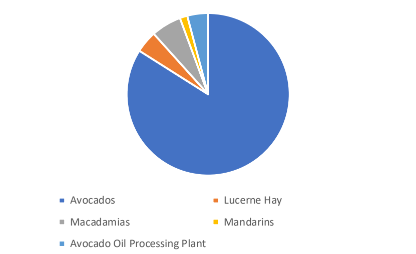
Demand Scenario	Total
Scenario 1 - Likely Demand at $1,000 per ML	2,020
Scenario 2 -Likely Demand at $2,000 per ML	710
Scenario 3 - Likely Demand at $5,000 per ML	535
Scenario 4 - Maximum Demand at $1,000 per ML	3,470

Demand Scenario	Assumed likely demand (ML)	Direct Economic Benefit (NPV of 30-year net margin ($M)	Annual jobs in agriculture (FTE)	New agricultural revenue ($ million per annum)
Scenario 1 - Likely Demand at $1,000 per ML	2,020	55.8	205	17.6
Scenario 2 -Likely Demand at $2,000 per ML	710	31.8	121	10.4
Scenario 3 - Likely Demand at $5,000 per ML	535	28.6	107	9.2
Scenario 4 - Maximum Demand at $1,000 per ML	3,470	82.3	293	25.2

Parameter	Unit	Value
Starting Year	Year (period)	2022

Discount rate	Real discount rate, pre tax (%)
Low	4%
Medium	7%
High	10%

Economic Benefit	Perecentage of Demand	Net margin ($/ML)	Revenue ($/ML)
Avocados	84%	2,957	5,978
Lucerne Hay	4%	359	1,046
Macadamias	6%	1,730	4,107
Mandarins	2%	4,239	10,416
Avocado Oil Processing Plant	4%	32,703	101,920
Total (weighted)	**100%**		



Reliability	High priority Ag
Assumed Reliability	90%

	Annual Total (mm pa)
Low (last 15 years)	846
Medium (last 30 years)	829
High (last 100 years)	862

Crop type	Rainfall effectiveness (%)
Avocados	60%
Fodder and Small Crops	80%
Tree crops and Macadamias	55%

Enterprise	Irrigation Water use required (ML/ha)	Revenue ($/ML)	Gross Margin ($/ML)	Net Margin ($/ML)	Yield per ha (t/ha)
Avocados	7.0	5,977.8	4,696.8	2,956.7	10.6
Lucerne Hay	9.4	1,046.1	405.6	359.2	14.0
Macadamias	6.0	4,107.2	3,277.5	1,730.3	4.5
Mandarins	7.4	10,416.0	6,720.0	4,238.9	50.0
Avocado Oil Processing Plant	-	101,920.0	37,586.7	32,703.0	-
Total (weighted)	**7.1**	**9,674.4**	**5,811**	**4,016**	

	Direct	Indirect	Total
Scenario 1 - Likely Demand at $1,000 per ML	48	157	205
Scenario 2 -Likely Demand at $2,000 per ML	28	93	121
Scenario 3 - Likely Demand at $5,000 per ML	25	82	107
Scenario 4 - Maximum Demand at $1,000 per ML	68	225	293

	Total Agriculutral Jobs	Industry value add ($ million)	Additional agriculutral revenue ($ million)
Scenario 1 - Likely Demand at $1,000 per ML	205	16.1	17.6
Scenario 2 -Likely Demand at $2,000 per ML	121	9.5	10.4
Scenario 3 - Likely Demand at $5,000 per ML	107	8.4	9.2
Scenario 4 - Maximum Demand at $1,000 per ML	293	23.0	25.2

Water use	Volume (ML)
Low	50.0
Medium	75.0
High	100.0

Input	Unit	Low	Medium	High
Avocado Yield	tonnes per ha	10	11	12
Oil extraction	percentage of weight	12%	14%	16%
Total oil extraction	tonnes per ha	1.2	1.5	1.9
Total oil extraction	**litres per ha**	**1,200**	**1,540**	**1,920**
Required number of ha for centrefuge	Hectares	190	191	192
Total oil extraction	**litres per centrifuge**	**228,000**	**294,000**	**368,000**

Demand Scenario	Assumed likely demand (ML)	Direct Economic Benefit (NPV of 30-year net margin $M)	Annual jobs in agriculture (FTE)	New agricultural revenue ($ million per annum)
Scenario 1 - with No Avocado Oil Processing	2,020.0	37.0	115.9	9.9

Avocados - Net margin

Blackbutt Economic Assessment

WATER USE (IRRIGATION AND EFFECTIVE RAINFALL)

Total crop requirement (ML per month)

	Annual (ML per annum)
Low	11.00
Medium	12.00
High	13.00

Total effective rainfall (ML per year)

	Annual (ML per annum)	Portion of rainfall that is effective	Annual effective rainfall (ML per annum)
Low	8.46	45.00%	3.81
Medium	8.29	60.00%	4.97
High	8.62	70.00%	6.03

Irrigation Water use required (total requirement less effective rainfall)

	Annual (ML per annum)
Low	4.97
Medium	7.03
High	9.19

CROP MARGIN

ASSUMPTIONS

	Low	Medium	High
Yield	-10%	0%	10%
Variable Costs	-5%	0%	5%
Upfront Fixed Costs	-5%	0%	5%

Input		Low	Medium	High	Source
Water					
Total water required	ML/ha	11.00	12.00	13.00	
Effective rainfall	ML/ha	6.03	4.97	3.81	
Total Irrigation Water use required	ML/ha	**4.97**	**7.03**	**9.19**	
Check	ML/ha	-	-	-	
Revenue					
Price	$/5.3kg carton	18	21	24	
Yield	trays/ha	1,800	2,000	2,200	
Total Revenue	$/cartons	**32,400**	**42,000**	**52,800**	
Variable costs					
Spare	$/ha				
Spare	$/ha				
Spare	$/ha				
Total Variable Costs	$/ha	8,500	9,000	9,500	
Total Variable Costs	$/ha	8,500	9,000	9,500	
Gross margin	$/ha	**23,900**	**33,000**	**43,300**	
Gross margin	$/ML	**4,813**	**4,697**	**4,710**	
Capital Costs (Upfront)					
Spare	$/ha				
Land Preparation	$/ha	750	850	950	
Sheds	$/ha	4,750	5,000	5,250	
Cost of trees	$/ha	10,500	11,000	11,500	
Cost of planting	$/ha	150	200	250	
Irrigation system	$/ha	3,500	4,000	4,500	
Total	$/ha	**19,650**	**21,050**	**22,450**	
Fixed Costs (Ongoing)					
Fixed Labour	$/ha	1,000	1,000	1,000	
Fixed Repairs & Maintenance	$/ha	750	1,000	1,250	
Depreciation	$/ha	-	-	-	
Interest Costs	$/ha	-	-	-	
Administration	$/ha	200	250	300	
Other	$/ha	250	300	350	
Total	$/ha	2,200	2,550	2,900	
Net margin	$/ha	**20,116**	**28,754**	**38,591**	
Net margin	$/ML	**4,051**	**4,092**	**4,198**	
Net margin annualised	$/ha	**14,325**	**20,774**	**28,135**	
Net margin annualised	$/ML	**2,885**	**2,957**	**3,060**	
Annualised fixed cost payment	$/ha/year	**- 1,584**	**- 1,696**	**- 1,809**	
Escalation rate	%	3	3	3	
Discount rate (real)	%	7	7	7	
Asset Life - Irrigation System	Years	10	10	10	
Number of Periods	Years	30	30	30	

Medium Scenario (Most Likely)		NPV	0	1	2	3	4	5
Upfront fixed costs	$/ha	- 21,050	(21,050)	-	-	-	-	-
Ongoing fixed costs	$/ha	- 31,643	-	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)
Growth in revenue	$/ha		0%	0%	0%	25%	50%	75%
Revenue	$/ha	396,022	-	-	-	10,500	21,000	31,500
Growth in variable costs	$/ha		0%	4%	4%	26%	51%	75%
Variable costs	$/ha	- 85,545	-	- 318	- 318	- 2,319	- 4,546	- 6,773
Gross margin	$/ha	310,478	-	- 318	- 318	8,181	16,454	24,727
Discounted values	$/ha		(21,050)	(2,680)	(2,505)	4,597	10,607	15,812
Total NPV		257,785						
Capacity to pay upfront for water		**$ 36,690**						

Medium Scenario (Most Likely)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Upfront fixed costs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ongoing fixed costs	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)	(2,550)
Growth in revenue	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Revenue	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000
Growth in variable costs	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Variable costs	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000	- 9,000
Gross margin	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000
Discounted values	20,290	18,963	17,722	16,563	15,479	14,467	13,520	12,636	11,809	11,036	10,314	9,640	9,009	8,420	7,869	7,354	6,873	6,423	6,003	5,610	5,243	4,900	4,580	4,280	4,000

Low Scenario		NPV	0	1	2	3	4	5
Upfront fixed costs	$/ha	- 19,650	(19,650)	-	-	-	-	-
Ongoing fixed costs	$/ha	- 27,300	-	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)
Growth in revenue	$/ha		0%	0%	0%	25%	50%	75%
Revenue	$/ha	305,503	-	-	-	8,100	16,200	24,300
Growth in variable costs	$/ha		0%	4%	4%	26%	51%	75%
Variable costs	$/ha	- 80,792	-	- 300	- 300	- 2,190	- 4,293	- 6,397
Gross margin	$/ha	224,711	-	- 300	- 300	5,910	11,907	17,903
Discounted values	$/ha		(19,650)	(2,337)	(2,184)	3,028	7,405	11,196
Total NPV		177,761						
Capacity to pay upfront for water		**$ 35,796**						

Low Scenario	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Upfront fixed costs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ongoing fixed costs	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)	(2,200)
Growth in revenue	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Revenue	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400	32,400
Growth in variable costs	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Variable costs	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500	- 8,500
Gross margin	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900	23,900
Discounted values	14,460	13,514	12,630	11,803	11,031	10,310	9,635	9,005	8,416	7,865	7,351	6,870	6,420	6,000	5,608	5,241	4,898	4,578	4,278	3,998	3,737	3,492	3,264	3,050	2,851

High Scenario		NPV	0	1	2	3	4	5
Upfront fixed costs	$/ha	- 22,450	(22,450)	-	-	-	-	-
Ongoing fixed costs	$/ha	- 35,986	-	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)
Growth in revenue	$/ha		0%	0%	0%	25%	50%	75%
Revenue	$/ha	497,857	-	-	-	13,200	26,400	39,600
Growth in variable costs	$/ha		0%	4%	4%	26%	51%	75%
Variable costs	$/ha	- 90,297	-	- 336	- 336	- 2,448	- 4,799	- 7,149
Gross margin	$/ha	407,560	-	- 336	- 336	10,752	21,601	32,451
Discounted values	$/ha		(22,450)	(3,024)	(2,826)	6,410	14,267	21,069
Total NPV		349,124						
Capacity to pay upfront for water		**$ 37,977**						

High Scenario	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Upfront fixed costs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ongoing fixed costs	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)	(2,900)
Growth in revenue	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Revenue	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800	52,800
Growth in variable costs	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Variable costs	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500	- 9,500
Gross margin	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300	43,300
Discounted values	26,920	25,159	23,513	21,975	20,537	19,194	17,938	16,765	15,668	14,643	13,685	12,790	11,953	11,171	10,440	9,757	9,119	8,522	7,965	7,444	6,957	6,502	6,076	5,679	5,307

Comparison ($/ha)	PV	0	1	2	3	4	5
Cash Flow ($/ha)	257,785		(4,564)	(4,564)	3,935	12,208	20,481
Annualised margin ($/ha)	257,785		20,774	20,774	20,774	20,774	20,774
Comparison ($/ML)	PV						
Cash Flow ($/ML)	36,690		(650)	(650)	560	1,737	2,915
Annualised margin ($/ha)	36,690		2,957	2,957	2,957	2,957	2,957

Comparison ($/ha)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Cash Flow ($/ha)	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754	28,754
Annualised margin ($/ha)	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774	20,774
Comparison ($/ML)																									
Cash Flow ($/ML)	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092	4,092
Annualised margin ($/ha)	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957	2,957

ECONOMIC ROAD MAP

Attachment L: Export Analysis

1 Summary

1.1 BACKGROUND AND PURPOSE

This report was prepared as part of the development of the Economic Roadmap for the South Burnett region. The purpose of this Report is to assess the export market potential for a selection of agricultural crops identified in the Economic Roadmap and assess the viability and marketability in the domestic and international consumer markets.

1.2 STRUCTURE OF THIS REPORT

This Report assesses each agricultural crop in relation to the following:

- Australian production volume and trends
- Domestic consumption
- Existing international exports
- Future export opportunities for Australian produce

1.3 SUMMARY OF FINDINGS

Table 1.1 provide a summary of the overall assessment of the viability for each crop in relation to both domestic market capacity for additional production and export opportunity. The basis for these measurements is set out in the analysis for each crop.

Table 1.1 Summary of findings by crop

Crop	Domestic capacity and demand	Export opportunity
Peanuts	High	High
Fodder	Medium	High
Cotton	Low	High
Avocados	Medium	High
Macadamias	Medium	High
Mandarins (Citrus)	High	High
Lemon (Citrus)	Medium	High
Peaches and Nectarines	Medium	Medium

2 Peanuts

2.1 KEY POINTS

- 92% of Australia's peanut production occurs in Queensland
- Almost all production is consumed domestically, and excess demand is met through high volume imports
- Australia is currently a small exporter of peanuts – predominantly to New Zealand – and future export potential is significant, particularly to Asia
- There is tariff-free access to almost all Australia's potential peanut export markets

2.2 DATA ASSUMPTIONS

The data in this chapter is derived from a range of publicly available sources and has been assessed through consultation with the peanut producers and processors in Queensland. Consultations identified challenges with the accessibility and reliability of data relating to the peanut industry in Australia. The data in this chapter has been carefully researched and sourced. It is acknowledged that there is likely to be conflicting data available from other sources.

2.3 AUSTRALIAN PEANUT PRODUCTION

Currently, South Burnett accounts for approximately 20% of Australia's total peanut production output. Almost all of Australia's peanut production - approximately 92% - occurs in Queensland in North and South Burnett, the Atherton Tablelands and Bundaberg. Bundaberg contributes 30% of total output. Outside of Queensland, peanut production is undertaken in northern New South Wales, Katherine in the Northern Territory, and the Ord River area of Western Australia.

Table 2.1 shows that in 2020–21, approximately 18,000 tonnes of peanuts were grown in Australia, while the average production was approximately 17,000 tonnes in the preceding 5-year period.

Table 2.1: Australia Peanut Area, Yield and Production

Market Year	Area (1000 Ha)	Production (1000 Tons)	Yield (T/Ha)
2011/2012	11	20	1.82
2012/2013	8	15	1.88
2013/2014	12	16	1.33
2014/2015	11	14	1.27
2015/2016	12	17	1.42
2016/2017	6	17	2.83
2017/2018	12	17	1.42
2018/2019	12	17	1.42
2019/2020	10	13	1.30
2020/2021	11	18	1.64
2021/2022	11	18	1.64
5-year Average (2017/18 - 2021/22)	**11**	**17**	**1.48**

2.4 AUSTRALIAN PEANUT CONSUMPTION

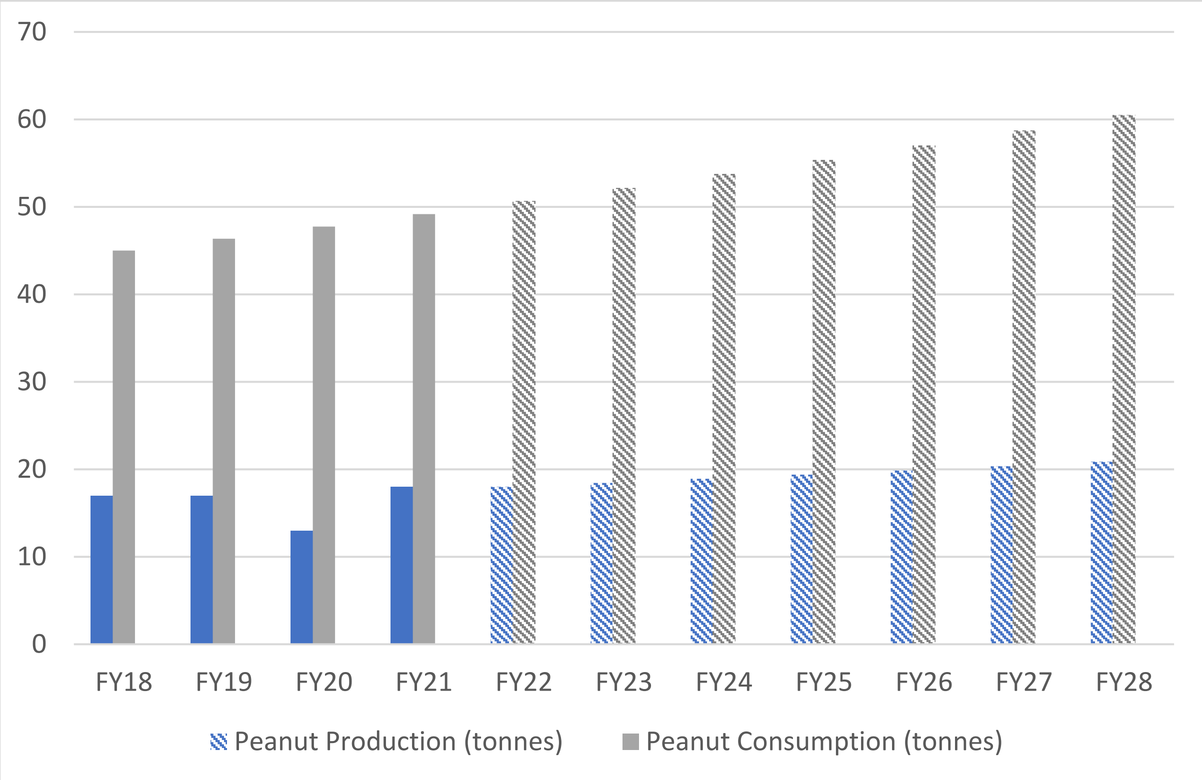
Domestic consumption of peanuts grew significantly in 2020, and demand for peanuts is projected to increase by 2–3% per year.

Peanuts are most commonly consumed as:

- nut-in-shell raw, boiled or roasted
- kernels raw, roasted, blanched or salted
- kernels manufactured into peanut butter or used in confectionery
- peanut oil for cooking, food processing and margarine
- peanut meal, the residue after oil extraction—a high-protein stock feed
- shells for stock feed, potting mix and soil conditioners.

Almost all Australia's peanut crop is consumed domestically. Even in high-yield years, Australian peanut production cannot fulfil domestic demand and this trend is projected to continue. Figure 2.1 shows that consumption will be more than the double production capacity until 2028, and that there is significant capacity in the domestic market.

Figure 2.1: Peanuts – domestic capacity and market



Most peanuts produced in Australia are consumed in Australia. This is common globally, with around 95% of the world's peanut production consumed within the country of origin, including more than 50% crushed for oil and used for cooking and only around 5% being traded on the world market[1].

[1] https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/peanutgrownotes/GrowNote-Peanuts-North-15-Marketing.pdf

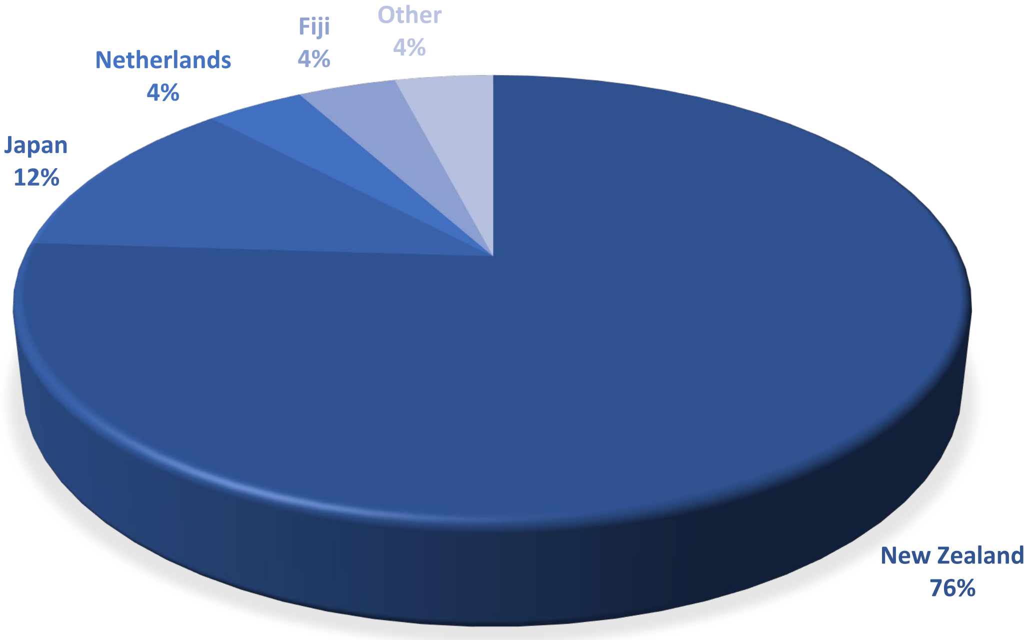
According to the Grains Research and Development Corporation (GRDC), Australia is one of the few peanut-producing countries with minimal import tariffs[2]. In 2021, Australia imported approximately 23,000 tonnes of peanuts, the main import sources being Argentina, Brazil, and China[3].

Domestic prices for peanuts are generally lower than imported peanuts. In 2019, the import price for peanuts in 2019 was USD 1,290 per tonne, which was 23 % higher than the domestic farmgate price.

2.5 AUSTRALIAN EXPORTS OF PEANUTS

Australia currently exports a small volume of peanuts. Between 2016 and 2019, the annual average exports were valued at only USD 5.61 million. In 2021, Australia exported only 1,549 tonnes of peanuts, which was dominated by exports to New Zealand at 1,446 tonnes. Figure 2.2 shows the percentage share of average Australian peanut exports from 2017 to 2019.

Figure 2.2: Average export percentage for 2017 to 2019



2.6 EXPORT OPPORTUNITY FOR AUSTRALIAN PEANUTS

2.6.1 Major import markets

Global consumption of peanuts is increasing at a rate of approximately 3% per year. Australia currently contributes less than 0.3% to global exports.

While the price of peanuts on the world market has tended to remain relatively stable, increased demand for oilseeds has resulted in a price increase in recent years. This price increase has been reflected in the price of Australian peanut exports:

- In 2017, 1kg of peanuts received US$2.00 and US$2.16 in 2018.
- In 2019, the export price increased to $2.36 per kilo – an increase of 8.83%.

[2] https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/peanutgrownotes/GrowNote-Peanuts-North-0A-Introduction.pdf

[3] UN Comtrade Database

Table 2.2 shows that the largest importers of peanuts globally, by volume, are China, the Netherlands and Indonesia. Table 2.2 also highlights that Australian peanut exports are exposed to low, or no, tariffs in almost all the major peanut import markets – with the notable exception of India. Australia presently exports small volumes to the major peanut importing countries.

Table 2.2: Major importers of peanuts

Partner Country (Ranked by import volume)	Volume (Tonnes)	Import tariff in partner country	Australian exports to Partner country: 2017-2021 average (Tonnes)
1. China	1,085,200	0%	12.65
2. Netherlands	374,955	0%	100
3. Indonesia	299,277	0%	0
4. United Kingdom	162,171	0%	37
5. Russian Federation	149,883	0%	0
6. Germany	140,798	0%	0
7. Canada	115,742	0%	0
8. Viet Nam	100,370	0%	0
9. Poland	68,836	0%	0
10. Thailand	67,460	0%	0
20. Philippines	21,633	0%	0
30. Chile	11,334	0%	0
31. USA	9,605	0% (Except HS Code: 1202.10.40 (tariff of 0.0935 USD/kg) and HS Code: 1202.20.40 (tariff of 0.066 USD/kg).	0
45. Singapore	5,733	0%	0
73. India	1,123	30%	1

Source: https://comtrade.un.org/data

2.6.2 Australian trade arrangements

Australia has existing trade agreements – that cover tariff provisions relating to peanuts – with multiple markets, including the United Kingdom, other ASEAN member states, other EU nations, India and the USA.

The market access opportunities, including relevant tariffs, for peanuts exports under each of Australia's current trade agreements are:

China: Under the China–Australia Free Trade Agreement (ChAFTA) duty free access has been granted for peanut imports to China since 2019. Between 2017 and 2021 Australia exported an average of 12 tonnes of peanuts per year to China.

Chile: After the Australia-Chile Free Trade Agreement entered into force from January 2021, peanuts could enter Chile with duty free access. The tariff rate was previously 6%. Australia does not currently export peanuts to Chile.

EU: The prospective EU-Australia Trade Agreement is currently being negotiated. However, the EU currently applies 0% duty on peanut imports. Of the EU member states, Australia has exported primarily to the Netherlands, with average annual exports being approximately 100 tonnes between 2017 and 2021.

United Kingdom: There is no tariff on Australian peanut exports to the United Kingdom. Australia's most recent export of peanuts to the UK was 37 tonnes in 2018.

Indonesia: Since the Indonesia-Australia Comprehensive Economic Partnership Agreement (IACEPA), peanut imports can enter Indonesia duty free. Australia is not exporting peanuts to Indonesia at present.

Singapore and Philippines: Under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff on peanuts has been eliminated and there is duty free access.

USA: Under the Australia-United States Free Trade Agreement (AUSFTA) the tariff for most peanut product exports (under HS Code 1202) has been eliminated and there is duty free access. There is an exception with HS Code: 1202.10.40, which has a tariff of 0.0935 USD/kg, and HS Code: 1202.20.40, which has a tariff of 0.066 USD/kg. Australia currently does not export peanuts to the United States.

India: Australia is currently negotiating a Free Trade Agreement with India. India currently imports no peanuts from Australia and maintains a tariff rate of 30% on all peanut products. Since 2017 Australia only exported 1 tonne of peanuts to India in 2021.

2.7 FODDER

2.7.1 Key points

- Queensland produces 11% of Australia's fodder output. Victoria is the highest producer with 41% of national output.
- Most fodder produced in Australia is consumed domestically (89%) and a small volume is exported (11%)
- Australia is the second highest global exporter of fodder behind the United States.
- Australia's main export destinations are Japan (33%), South Korea (24%), the Netherlands (15%) and China (13%)
- Australia faces minimal tariff barriers with major trading partners in the Asian region, expect for India, which currently imposes tariffs on Australian fodder.

2.7.2 Data and Methodology

Trade data for fodder crops tend to be grouped together and not reported by individual commodity. For this export market analysis, we have used HS Code 121490 covering forage products including swedes, mangolds, fodder roots, hay, sainfoin, clover, forage kale, lupines and vetches – whether or not in pellet form. For evaluating domestic production, the data used has been for pastures cut for hay and silage.

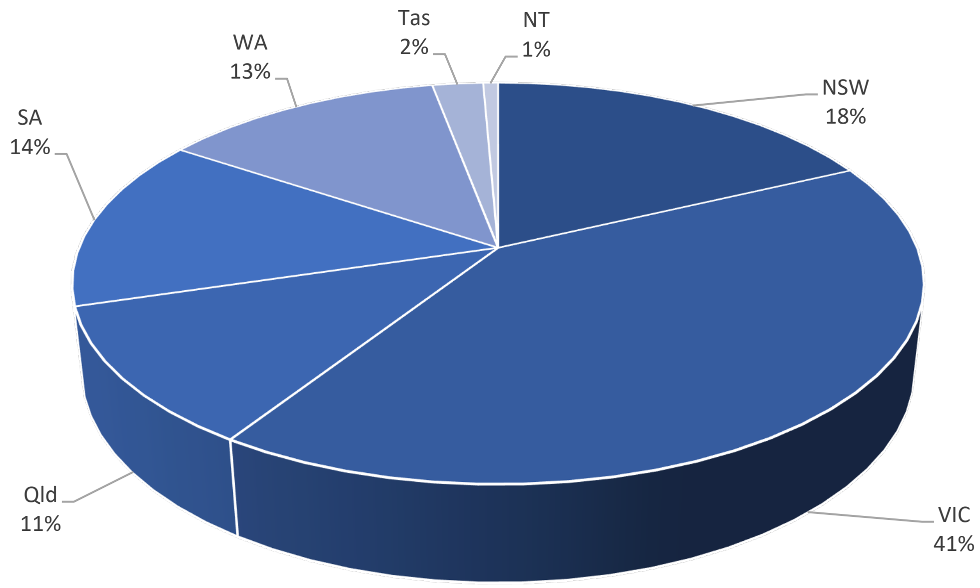
2.7.3 Australian fodder production

The Australian fodder industry include a range of crop and pastures in the form of hay and straw used as animal feed. In 2019/20 Australia produced 10 million tonnes of hay and silage from 2.3 million hectares of pasture, which was comprised of 7 million tonnes produced of hay and 3 million tonnes of silage[4].

[4] ABS, Agricultural Commodities, Australia 2019-20

Fodder is produced under both irrigated and dryland cropping systems and is often integrated into farming systems and operations. As a result, most fodder produced in Australia does not leave the farm gate as it is difficult to accumulate, store and transport[5]. About 38,000 properties are involved in commercial production of fodder crops each year in most states and territories, with the main production occurring in Victoria (41%), New South Wales (18%) and Queensland (11%) as represented in Figure 2.3.

Figure 2.3 Hay and Silage Production by State/Territory 2019/20



2.7.4 Australian fodder consumption

Most fodder produced in Australia is consumed domestically and a relatively small volume is exported. In 2019/20 approximately 89% of fodder was used domestically and 11% was exported. The supply chain for fodder is shown in Figure 2.4.

Figure 2.4: Fodder Supply Chain

Source: AgriFutures Export Fodder Program Strategic RD&E Plan (2021-2026)

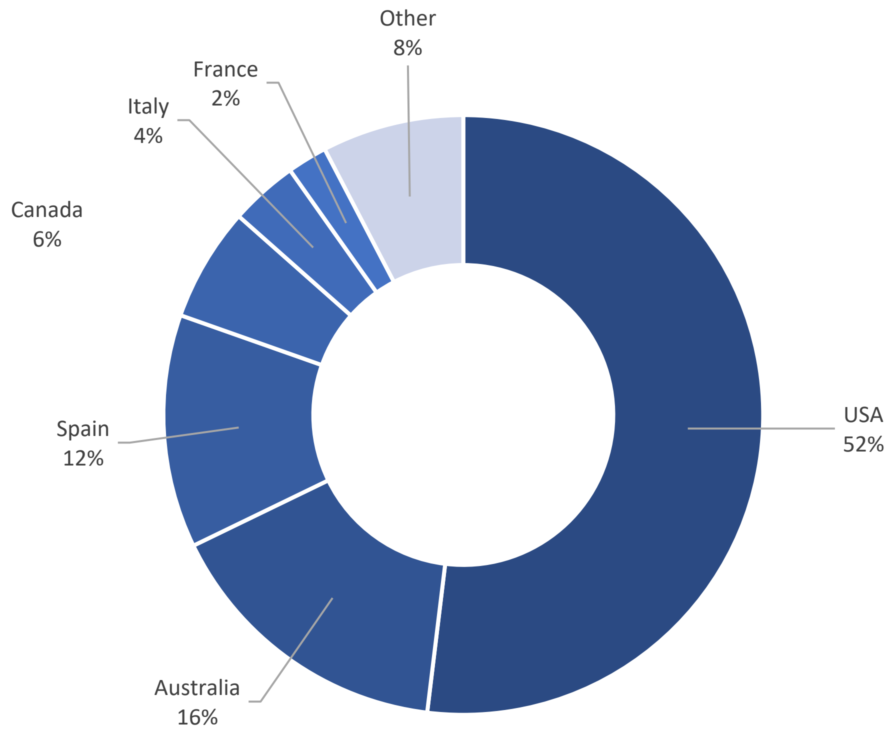
[5] Dairy Australia, Buying Fodder it's a domestic market

Most hay and silage are consumed on the farm on which it was produced, although there is significant trading of hay, and some trading of silage and crops for silage production, particularly in the beef feedlot sector and the dairy industry[6].

2.7.5 Australian exports of fodder

In 2021 Australia was the second largest exporter of fodder, as shown in Figure 2.5 below.

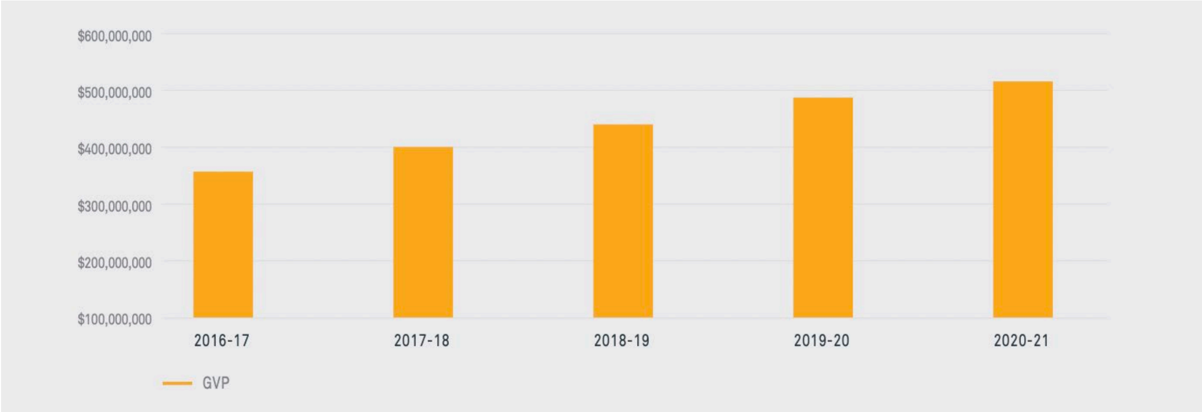
Figure 2.5: World fodder exporters, 2021



In 2021 Australia exported 1.5 million tonnes of fodder valued at approximately $5 million. Figure 2.6 shows that the volume of exports having been consistent over the past five years while the GVP of fodder exports has increased. It is estimated that approximately 1,500 to 2,000 growers are involved in production for export.

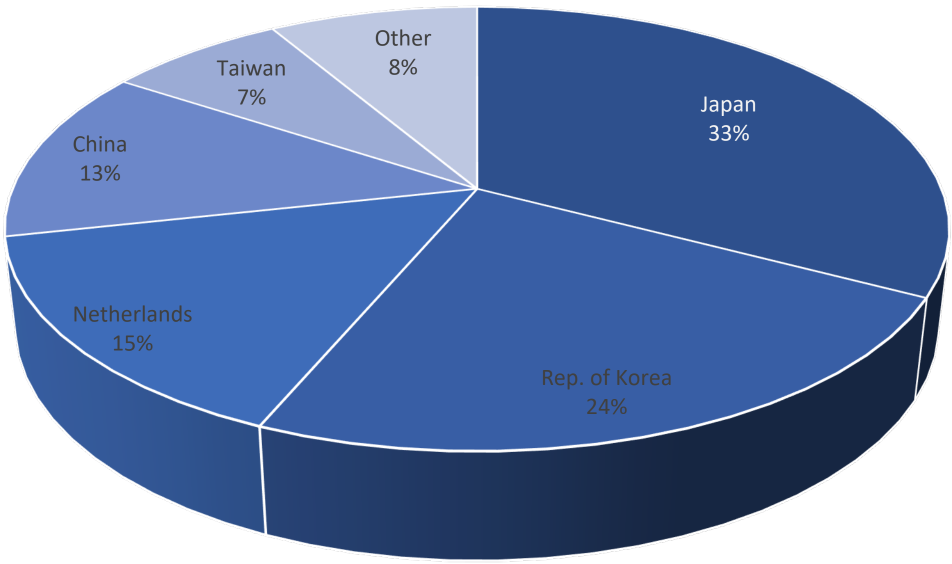
[6] https://afia.org.au/about-fodder/

Figure 2.6 GVP of Australian Export Fodder



Australia's main destinations for its fodder exports are Japan (33%), South Korea (24%), the Netherlands (15%) and China (13%) as shown in Figure 2.7.

Figure 2.7 Australian exports of fodder by destination 2021



Historically Japan and China have been the top two destinations for Australian fodder exports, however recent geopolitical and trade tensions with China resulted in non-renewal of export licences and a diversion of trade away from China to other markets.

2.7.6 The future export opportunity for Australian fodder

As a major global exporter of fodder, Australia has a strong platform to increase the volume of exports. Australia's trade agreements with key partner countries have, and will continue to, support exports by Australian fodder producers. Table 2.2 shows the world's top fodder importers, the tariff they impose at the border and Australia's recent export volume.

Table 2.2: Major importers of Fodder, 2021

Partner Country (Ranked by import volume)	Volume (Tonnes)	Import tariff in partner country	Australian exports to Partner country: 2019 (Tonnes)
1. Japan	2,154,091	0%	498,296
2. China	1,992,185	0%	192,609
3. USA	329,535	0%	425
4. Taiwan	271,005	0%	110,953
5. Switzerland	205,849	2.35%	0
6. Netherlands	180,221	1.93%	231, 679
7. Canada	118,289	0%	0
8. Belgium	111,402	1.93%	295
9. Germany	70,794	1.93%	0
10. France	56,737	1.93%	308
17. Indonesia	10,254	0%	4,513
18. Philippines	7,398	0%	6,859
21. Malaysia	5,743	0%	1,152
22. United Kingdom	4,540	0%	71
23. Hong Kong	4,501	0%	270
36. India	1,303	30%	26

There are new market access opportunities for fodder through potential increases in market share in established Asian markets as well as building new markets in the region. The opportunities for key market are outlined below:

Canada: Australia currently enjoys tariff free access on fodder imports to Canada, under the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). Australia does not currently export fodder crops to Canada as Canada obtains almost 100% of its requirements from the USA.

China: Prior to the China-Australia Free Trade Agreement (ChAFTA) the base rate for fodder products was 9%. Under the China-Australia Free Trade Agreement (ChAFTA) the tariff decreased to 0% on 1 January 2019. China continues to be one of Australia's largest export markets for fodder and accounts for 10% of total fodder imports to China, although competing with US imports of approximately 70%.

European Union: Australia is currently negotiating a Free Trade Agreement with the European Union and aiming for full tariff elimination on a range of agricultural products which could include forage crops on which a duty of 1.93% is levied. Australia supplies approximately 30% of the EU's fodder requirements and with a tariff decrease there is potential for this volume to increase.

Hong Kong: Under the Australia-Hong Kong Free Trade Agreement (AHKFTA) there is no tariff applied on the import of fodder. Australia only supplies a small volume of fodder to Hong Kong (3%) compared to the USA (84%).

Indonesia: Prior to the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the base rate for fodder products was 5%. Under AANZFTA this was eliminated on day one of the agreement. Indonesia now imports the largest proportion of its fodder requirements (44%) from Australia, compared to other global suppliers such as the USA (24%).

India: India currently applies a 30% tariff on the import of fodder. As Australia is currently negotiating a free trade agreement with India there is potential for the tariff to be reduced or removed to increase Australia's exports from the current low levels. India currently imports fodder predominantly from European sources.

Japan: No tariff is levied on imported fodder in Japan and it is Australia's largest export market for fodder. Of Japan's total fodder imports 23% is sourced from Australia and 67% from USA.

Malaysia and Philippines: Under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff on fodder has been eliminated and there is duty free access to both of these markets. Australia supplied 20% of the Malaysia's fodder import requirements and dominates the Philippines' import requirements of fodder at 97%.

Taiwan: Australia currently supplies 41% of Taiwan's fodder import requirements and this increase has increased steadily over the past 5 years. There is potential for Australia to improve its position in this market now that it has gained a significant foothold.

United Kingdom: There is currently no tariff on fodder exports to the UK. Australia ships negligible volumes of fodder to the UK compared with its supply from the USA (providing 62%).

USA: Under the Australia-United States Free Trade Agreement (AUSFTA) the tariff for this product has been eliminated. As the world's largest fodder producer, the US sources 70% its import requirements regionally from Canada and 28% from Mexico.

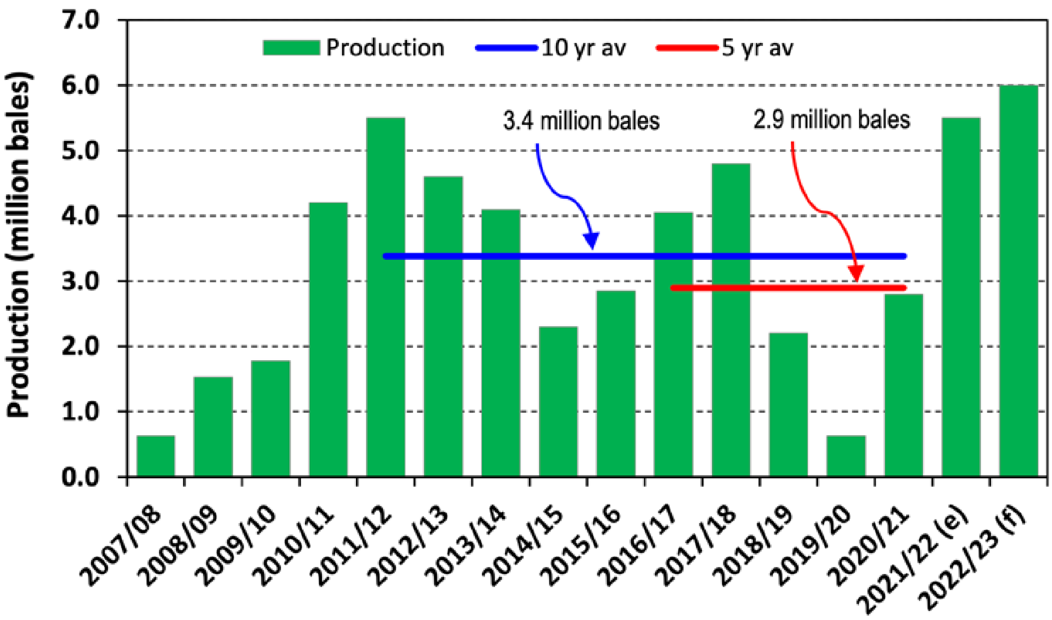
Given the low tariff barrier levels faced by Australian fodder exporters into the major fodder importing nations, especially those in Asia, there is a significant opportunity to expand export levels.

2.8 COTTON

2.8.1 Australian cotton production

As one of the world's major cotton producers, Australian cotton production was estimated at a record high of 5.5 million in 2021/22 and predicted to increase to 6 million bales in 2022/23. This represents a 96% increase on the 2.8 million bales harvested in 2019/20. Much of this production increase has resulted from greater crop harvest areas and availability of irrigation water, both of which cotton production are highly dependent on and can result in volatile production years. Figure 2.8 shows cotton production levels over the past decade.

Figure 2.8: Australian Cotton growing production

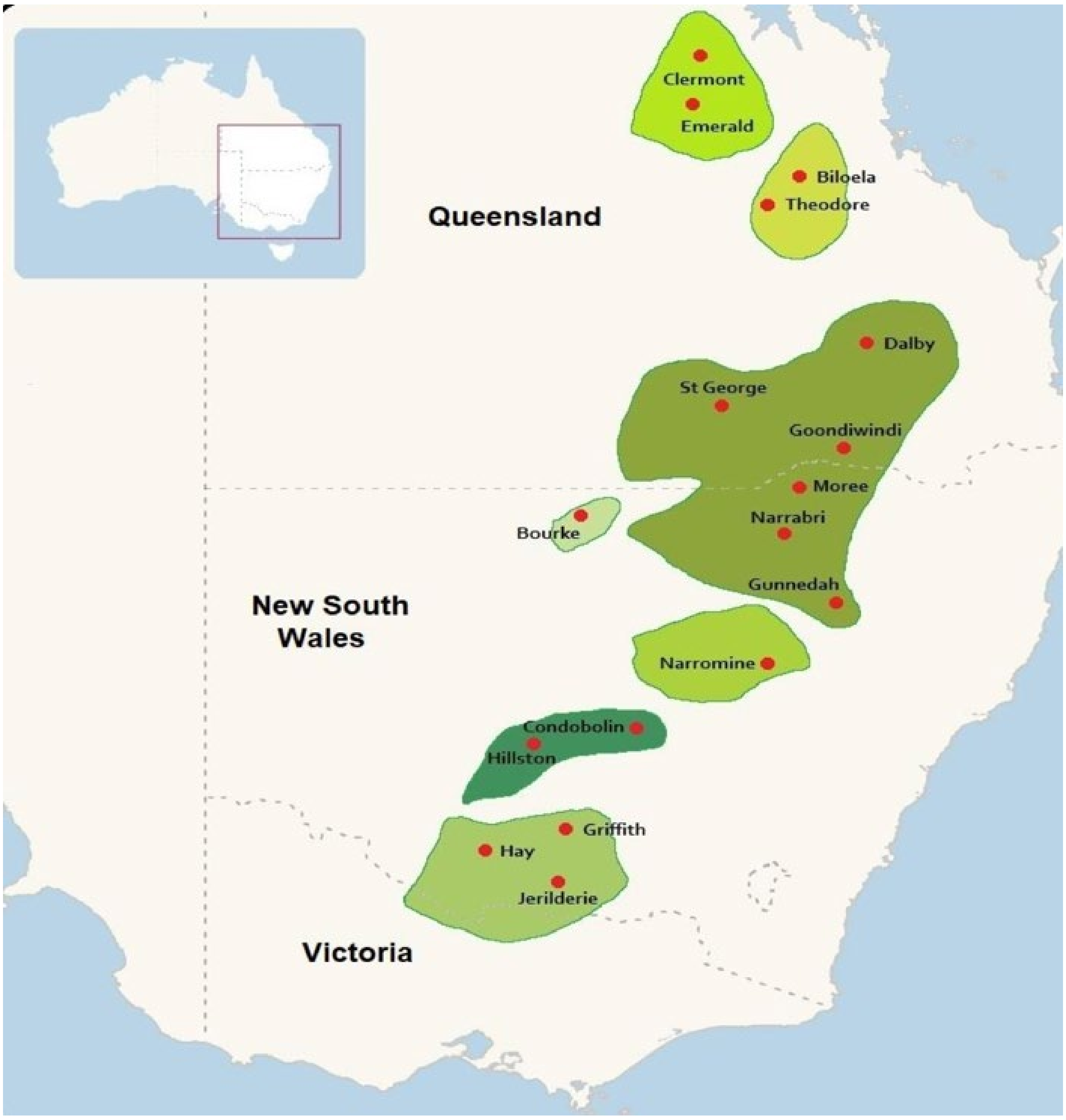


Source: USDA FAS, Cotton and Products Annual 2022

Cotton is predominantly grown in New South Wales and Queensland, with approximately two-thirds of production being in New South Wales and remaining one-third in Queensland. Figure 2.9 shows the cotton growing areas of central and southern Queensland as well as the north and central regions of New South Wales. Access to irrigation is critical to cotton production – approximately, 90 percent of cotton production is irrigated while the remaining 10 percent is dryland[7].

[7] USDA FAS, Cotton and Products Annual 2022

Figure 2.9: Cotton growing areas



Source: USDA FAS, Cotton and Products Annual 2022

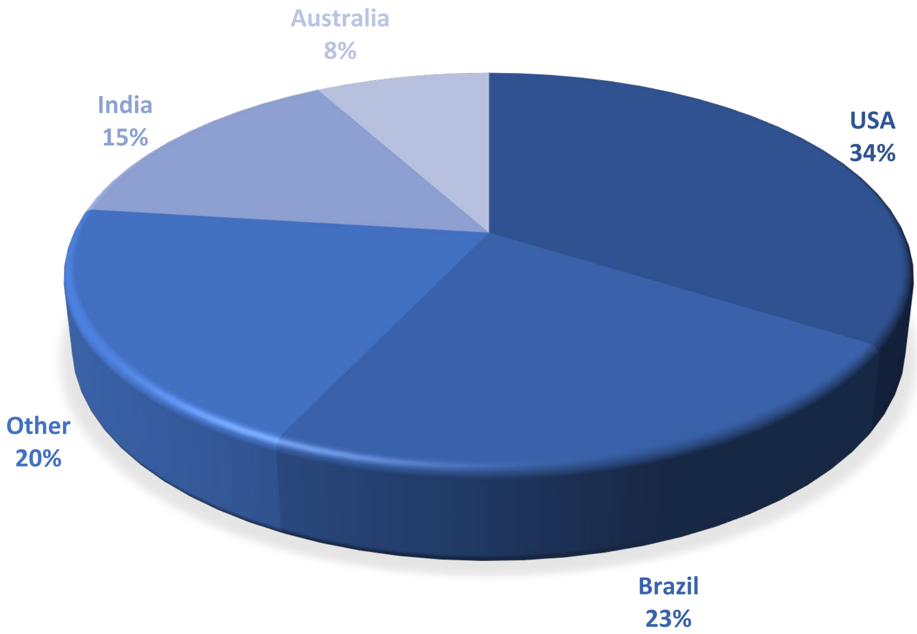
2.8.2 Australian cotton consumption

There is no domestic consumption of cotton as there is no remaining manufacturing in Australia. Cotton produced in Australia is exported and processed offshore in countries, including China, Vietnam, Bangladesh, and India.

2.8.3 Australian exports of cotton

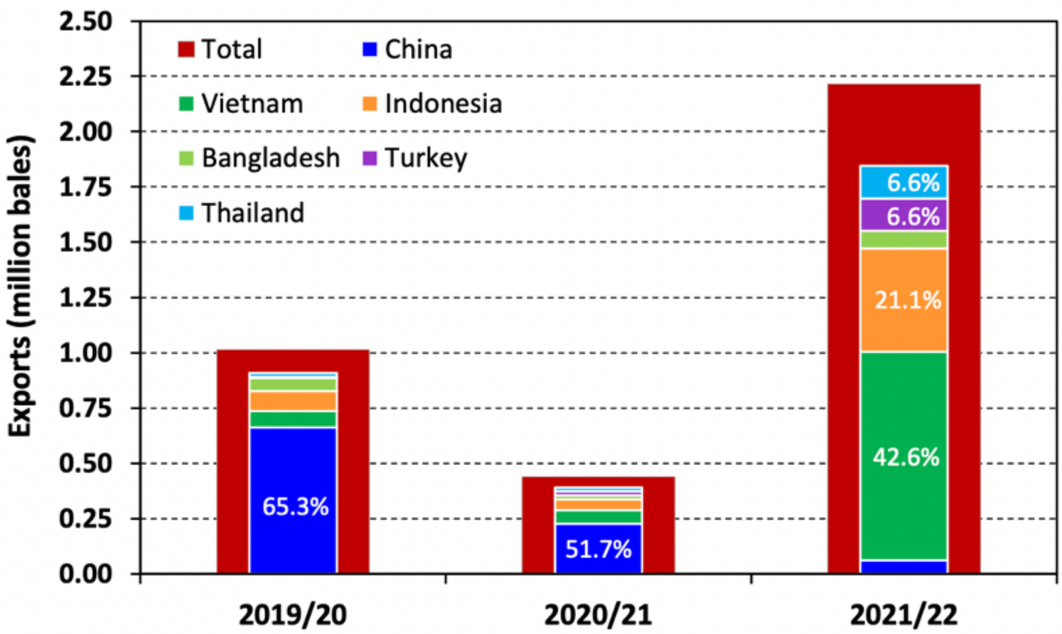
Australia is the fourth largest exporter of cotton, contributing 8 percent of exports – equivalent to 716,000 tonnes. Figure 2.10 shows the largest cotton exporters.

Figure 2.10: Leading global exporters of cotton in 2020/21



Historically, China has been a primary export market for Australian cotton. However, due to trade tensions between Australia and China, Australian exporters have shifted large volumes of cotton exports to Vietnam and Indonesia, while increasing exports to Turkey and Thailand, as shown in Figure 2.11.

Figure 2.11: Cotton export destinations Aug to Jan 2019/20 to 2021/22



Source: USDA FAS, Cotton and Products Annual 2022

As Australia exports almost all of the cotton it produces, cotton prices received at the farm gate have been closely correlated to world cotton prices and those of large exporters such as the US. Cotton prices received by Australian producers have reached historically high levels recently – 65 percent higher than the previous 10-year average[8].

2.8.4 The future export opportunity for Australian cotton

Australia has an opportunity to expand cotton exports. Australia's trade agreements with key partner countries have and continue to support Australian exports. Table 2.3 sets out the world's top cotton importers, the tariff they impose at the border and Australia's recent export quantities to that country.

Table 2.3: Major importers of Cotton, 2021

Partner Country (Ranked by import volume)	Volume (Tonnes)	Import tariff in partner country	Australian exports to Partner country: 2019 (Tonnes)
11. China	2,142,264	1% (in-quota tariff)	36,228
12. Turkey	1,191,084	0%	58,981
13. Pakistan	903,459	3% (reducing to 0% Dec 2022)	23,865
14. Indonesia	561,788	0%	131,905
15. India	193,021	0%	31,666
16. Mexico	128,827	0%	0
17. Malaysia	114,081	0%	18,286
18. Egypt	98,928	0%	0
19. Taiwan	60,689	0	11,202
20. El Salvador	39,169	0%	0
21. Japan	38,376	0%	6,145
18. Philippines	9,923	0%	2,127
36. Hong Kong	692	0%	0

Market access opportunities with each of Australia's trading partners is summarised here:

China: Under the China–Australia Free Trade Agreement (ChAFTA) Australia faces an in-quota tariff of 1% as it was a commodity not subject to tariff reductions under any of China's FTAs. China imports cotton predominantly from the USA (39%), Brazil (30%) and India (19%). Australia currently exports 36,228 tonnes of cotton to China.

Hong Kong: Under the Australia-Hong Kong Free Trade Agreement (AHKFTA) there is no tariff applied on the import of cotton. Australia does not currently supply cotton to Hong Kong and is instead imported from India (73%) and Brazil (27%).

India: There is currently no tariff applied on the import of cotton to India. Australia is the 3rd largest source of cotton imports (16%), after the USA (38%) and Egypt (27%). Australia currently exports 31,666 tonnes of cotton to India.

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8 Source: USDA FAS, Cotton and Products Annual 2022

Indonesia: Australian cotton has duty free access into Indonesia under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) and is currently the 2nd largest source of cotton imports (at 21%), after Brazil (31%), followed closely by the USA (20%). Australia exported 131, 905 tonnes of cotton to Indonesia in 2021.

Japan: Australia faces duty free access for cotton exports to Japan and is the second largest source of cotton (at 16%) after the USA (47%) which dominates the import market for cotton.

Malaysia: Under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff on cotton has been eliminated. Malaysia's cotton imports are dominated by the USA (47%) and Brazil (38%). Australia's cotton imports constitute 13% of Malaysia's total imports.

Philippines: Similarly, under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff on cotton has been eliminated and there is duty free access to the Philippines. The Philippines' cotton imports are sourced primarily from Pakistan (34%), Pakistan (32%) and the USA (32%). Australian imports of cotton amount to 9% of total imports.

The potential for expansion in Australian cotton exports is significant considering Australia's premier export status, the low tariff environment and high demand in regional apparel manufacturing countries.

2.9 AVOCADOS

2.9.1 Key points

- Australia is a small exporter of avocados
- 69% of Australia's avocados are produced in Queensland
- Domestic demand for avocados is one of the highest in the world and local production does not currently meet domestic demand requirements
- Australia imports approximately 30 percent of its avocado requirements – primarily from New Zealand
- Australia exports only 4% of its production mainly to Hong Kong, Singapore, Malaysia and Indonesia

2.9.2 Australian avocado production

In 2020/21 Australian avocado production reached just over 78,085 tonnes. While this was an 11 percent reduction on the previous year, production is predicted to increase to 120,000 tonnes in 2021/22.

Queensland has increased its production notably and consistently contributed the most to total Australian avocado output at 69 percent in 2020/21 - with South Qld recording a contribution of 3 percent in the same period. In comparison, North Queensland saw the largest production increase of all regions, growing by 47 percent compared with the previous year, followed by Central New South Wales at 30 percent.

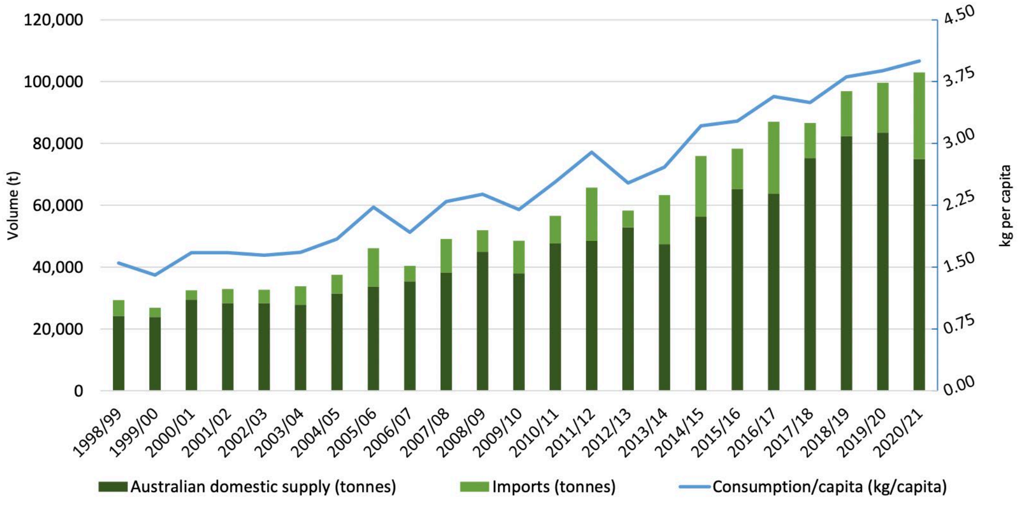
Over the 5-year period up to 2020, Australian avocado production increased by approximately 56 percent. Production is forecast to increase over future years with an average of approximately 170,000 tonnes per annum expected to be produced by 2026[9].

2.9.3 Australian avocado consumption

In terms of demand for avocados, it has been consistently increasing over the past decade and in 2020/21 consumption of the fruit was just over 100,000 tonnes, with imports of approximately 28,000 tonnes supplementing local production – as highlighted in the following chart. Avocado consumption in Australia remains at one of the highest in the world at 4kg per capita and predicted to increase to 5kg per capita. This increased consumption trend is expected to also ease downward pricing pressure in the domestic market because of recent increases in production.

Avocado imports for year ending June 2020 were 28,027t and valued at was AUD 184.7m which were almost exclusively from New Zealand. While Chile, Mexico and Peru are seeking to export to Australia, import volumes from those destinations remains negligible.

Figure 2.12: Domestic avocado consumption

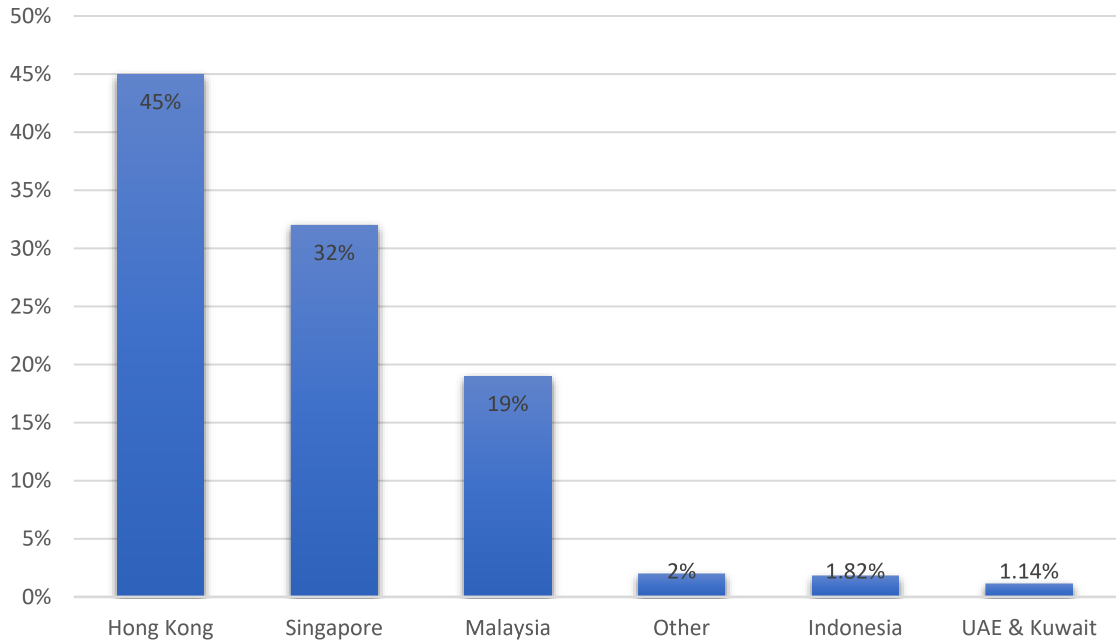


2.9.4 Australian exports of avocados

Australia remains a small player in terms of global avocado exports with total avocado exports being 3,155 t and valued at AU$22m in 2020/21 – amounting to approximately 4% of Australia's total production. Of those exports, approximately 2,111t (AU$13.6m) were exported from Queensland.

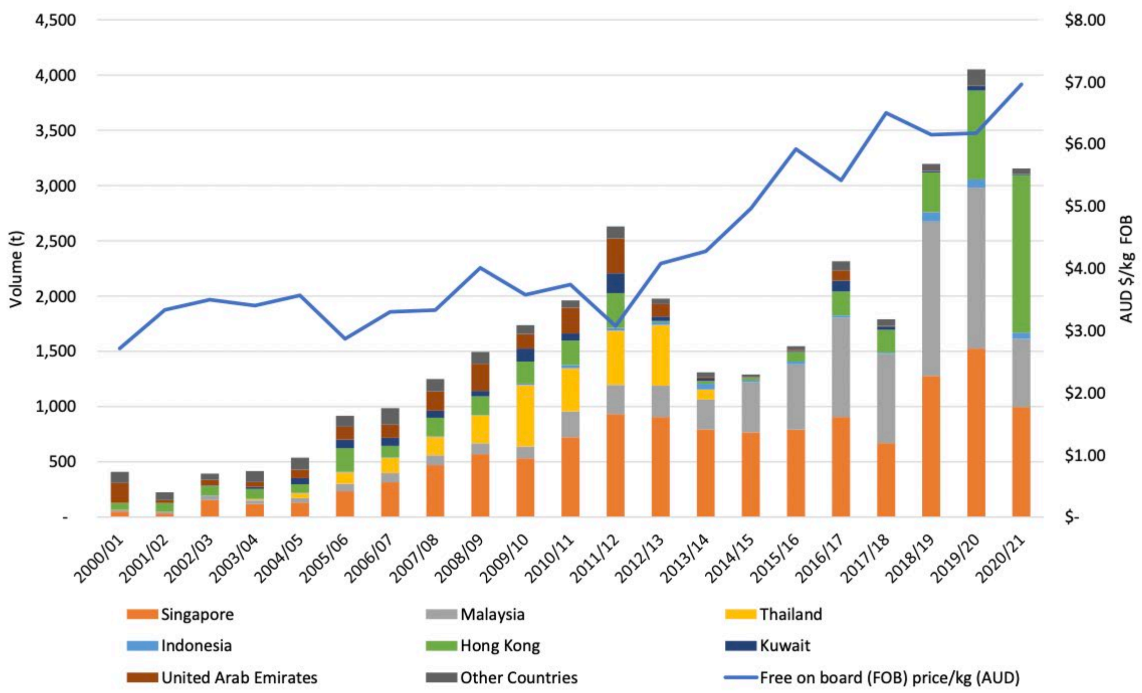
Australia's main export markets are Hong Kong, Singapore, Malaysia and Indonesia as highlighted in the chart ahead:

Figure 2.13: Australia's export markets 2020/21



The following chart further illustrates the increased potential for Australian exports, differentiated by export partner and price received – the export price has been on an upward trajectory over the past decade. Also in Australia's favour is the fact that avocados are produced all year round due to the range of climates and conditions in the major avocado growing regions.

Figure 2.14 Australian annual export volumes



2.9.5 The future export opportunity for Australian avocados

Australia's trade agreements with key partner countries places it in a favourable position to take advantage of future export opportunities. Table 2.4 sets out the world's major avocado importers, the tariff they impose at the border and Australia's recent export quantities to that country. Australia faces virtually no tariff barriers to the markets of the major international consumers of avocados and the opportunity to expand exports – particularly in the Asian region is judged as significant by the avocado industry and it is actively pursuing an export strategy. The major impediment to these exports at present is the existence of Queensland fruit fly in some of the major production areas and the Sanitary and Phytosanitary restrictions placed by the major Asian importers of avocados. This is being actively negotiated on by the Australian Government.

Table 2.4: Major importers of Avocados, 2019

Partner Country (Ranked by import volume)	Volume (Tonnes)	Import tariff in partner country	Australian exports to Partner country: 2019 (Tonnes)
11. USA	1,105,375	0%	0
12. Netherlands	278,913	0%	0
13. France	165,281	0%	0
14. Spain	136,013	0%	0
15. United Kingdom	112,664	4% (moving to 0% end 2022)	0
16. Germany	97,102	0%	0
17. Canada	94,956	0%	0
18. Japan	77,287	0%	37
19. Russian Federation	35,631	%	0

20. China	32,627	0%	0
18. Hong Kong	17,738	0%	659
20. Chile	17,325	0%	0
30. Republic of Korea	8,243	12%	0
35. Singapore	5,469	0%	1,676
40. Malaysia	3,914	0%	1,653
87. Indonesia	155	4%	91

Source: https://comtrade.un.org/data

The market access opportunities for avocados with each of the relevant trading partners that Australia has trade arrangements with in the region, is also summarised here:

China: Under the China–Australia Free Trade Agreement (ChAFTA) duty free access has been granted for avocado imports to China since 2019. Between 2017- 2021 Australia does not currently export avocados to China. China is both a significant producer as well as consumer of avocados and predominantly imports from Chile, Mexico and Peru. Of note, in 2020 China imported 118 tonnes from New Zealand.

Hong Kong: Under the Australia-Hong Kong Free Trade Agreement (AHKFTA) there is no tariff applied on the import of avocados. Australia currently only supplies 4 % of the market compared to dominant suppliers such as Chile (41%), Mexico (29%) and Peru (24%).

Indonesia: Australian avocados currently face a 4% tariff at the Indonesian border. However, under the Indonesia-Australia Comprehensive Economic Partnership Agreement (IACEPA), avocado imports will be able to enter Indonesia duty free from January 2026. While Australia is exporting relatively small volumes (approximately 90t) of avocados to Indonesia currently, from 2019-2021 it averaged approximately 66% of Indonesia's total avocado imports. As Indonesia is a significant avocado producer and consumer, there is scope to further increase Australia's export to this market.

India: Under the Australia-India Economic Cooperation and Trade Agreement avocado tariffs are to be phased out over a 7-year period from the current level of 30 %, providing considerable scope for Australian exports in the future. In spite of the tariff, India's imports of avocados have been steadily increasing from 380,000 tonnes in 2019 to 881,000 tonnes in 2021, with its major sources of imports being Peru and the Netherlands. Of note is that imports from New Zealand increased by 146% over the same period.

Japan: Prior to the Japan-Australia Economic Partnership Agreement (JAEPA) the base rate for avocados was 3%. Under JAEPA the tariff was eliminated on day one of the agreement. Australia currently exports minimal volumes of avocados (37t) to Japan but it is a significant potential export market going forward. Currently over 80% of Japan's avocado imports are from Mexico, which is the world's largest and most consistent avocado producer, supplying all year round.

Malaysia and Singapore: Under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff on avocados has been eliminated and there is duty free access. Australia has had considerable export success into these two markets and supplies over 65% into each. As avocado consumption levels are still relatively low, the industry deems there to be significant potential, including by driving consumption up.

South Korea: Prior to the Korea-Australia Free Trade Agreement (KAFTA) the base rate for avocados was 30%. Under the Korea-Australia Free Trade Agreement (KAFTA) the tariff is being eliminated over time. It is currently at 12% and is due to incrementally reduce to 0% in 2028. Currently Mexico and Peru dominate as avocado suppliers into South Korea.

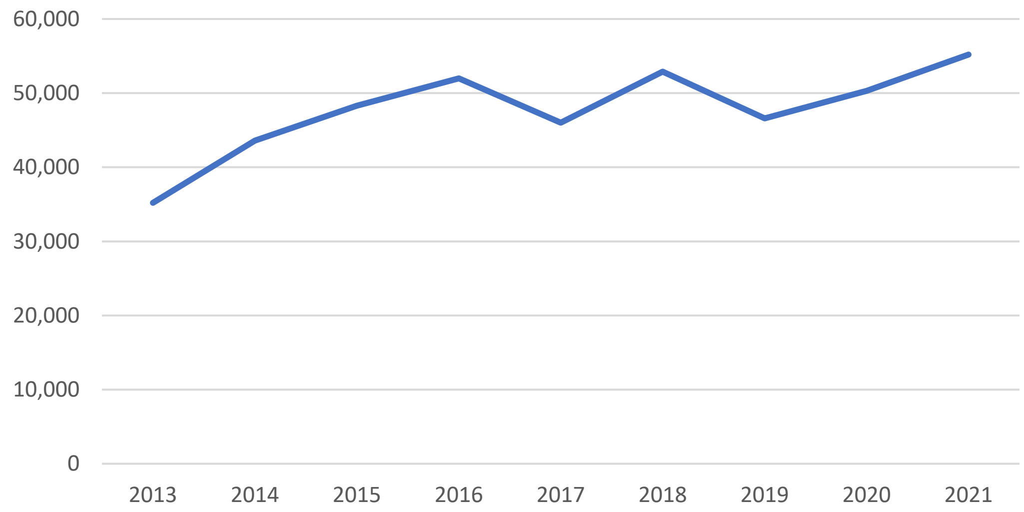
Thailand: Under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff for this product has been eliminated. While Australia was a significant supplier of avocados to Thailand, trade halted in 2014 due to the introduction of import protocols to manage pests and diseases. As a result, Australian avocados were shut out of the market. Negotiations are continuing to improve Australia's pest and disease-free status to support future exports to Thailand. New Zealand and Peru are currently the dominant suppliers of avocado to Thailand.

2.10 MACADAMIAS

2.10.1 Australian macadamia production

In 2021 Australian production of macadamias totalled 55,200 tonnes which was a 10% increase on the 2020 crop (52,000 tonnes). Generally, 80% of production is processed and sold as kernel. The Australian industry is the largest producer of macadamia kernels, delivering 30% of global supply and demonstrating an industry farm gate value of $334 million (2020).

Figure 2.15: Australian Macadamia Production

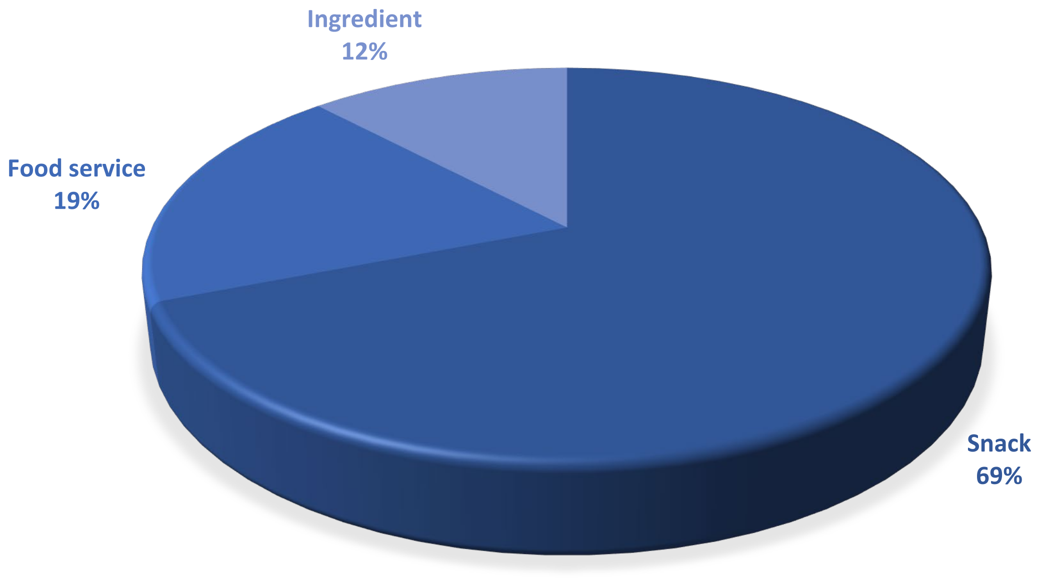


Macadamias are grown along the eastern coast of Australia from Nambucca Heads in the south to Mackay in the north. Both the Bundaberg and Northern Rivers regions produce around 80% of the Australian crop.

2.10.2 Australian macadamia consumption

Australia is the second largest consumer of macadamia kernel globally and consumes approximately 30% of total production (16,000 tonnes). In 2019, 19% of Australian households purchased macadamias and the per capita consumption of the nut was 159g. In 2021, sales to the domestic market increased by 10%. Demand for macadamias is driven by the food service, ingredient and snack sectors as demonstrated in the chart below.

Figure 2.16: Macadamia kernel usage by segment

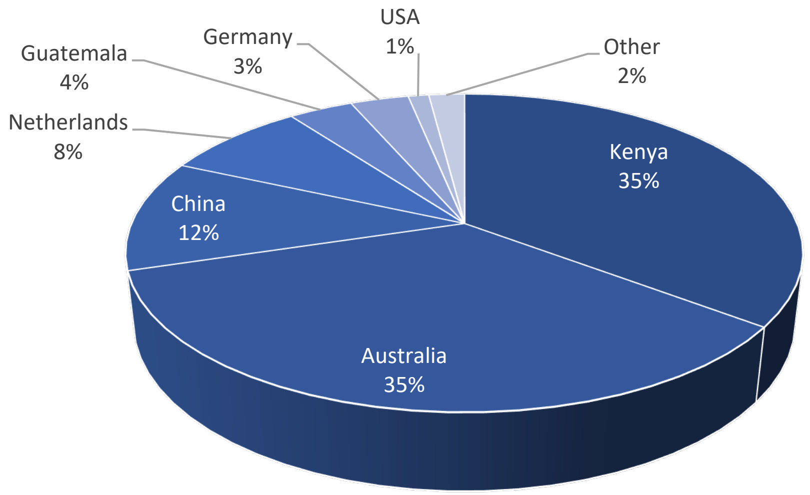


Consumption of macadamias is continuing to rise as a result of the protein and health benefits of macadamias and its use in snacks and is predicted to exceed supply. With demand starting to outstrip supply, this has been reflected over the past 5 years by macadamia prices being on an upward trajectory and settling at approximately $5/kg in 2021.

2.10.3 Australian exports of macadamias

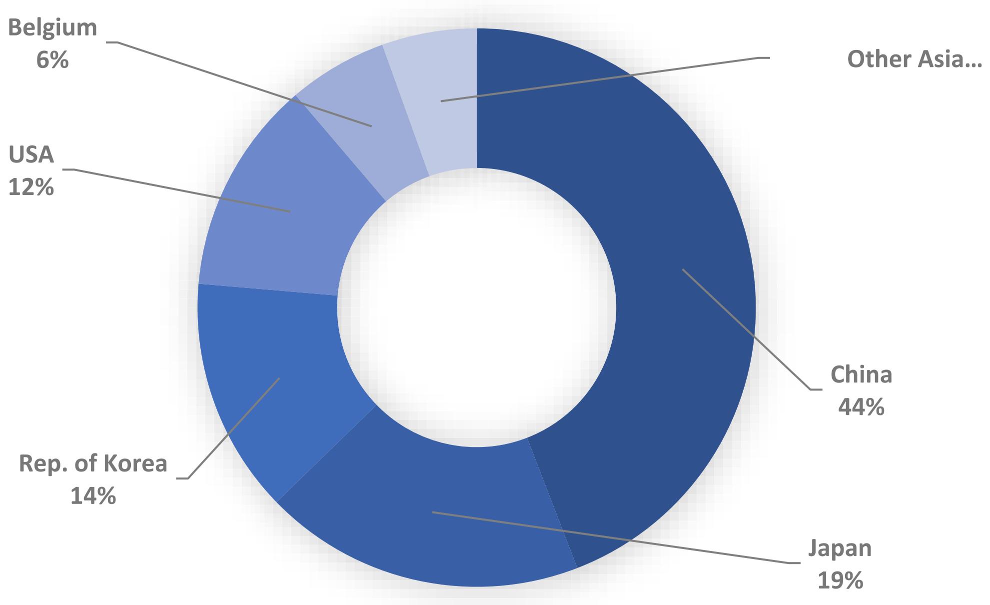
Australia is the largest exporter of macadamias, alongside Kenya and followed by China as demonstrated below.

Figure 2.17: Macadamia Exporters 2021



As the world's largest exporter of macadamias, Australia exports approximately 80% of its production (9,081 tonnes of kernel valued at $151 million) primarily to China, Japan and Korea as shown below. Other major exporters of macadamias in 2021 were Kenya, China and the Netherlands.

Figure 2.18: Australian Macadamia Exports 2021



2.10.4 The future export opportunity for Australian macadamias

The future export opportunity for Australian macadamias is assessed by the industry as significant. The greatest demand growth is visible in the Asian region where consumers are shifting their eating patterns towards snacking and leaning towards less traditional snacks sch as macadamia nuts.

The Australian macadamia industry has been credited with being instrumental in driving global demand for macadamias and contributes to over 80% of the generic macadamia industry marketing worldwide. The industry has invested in consumer campaigns beyond Australia – in Germany, Japan, Korea, China and Taiwan[10].

Table 2.5: Major importers of Macadamias, 2021

Partner Country (Ranked by import volume)	Volume (Tonnes)	Import tariff in partner country	Australian exports to Partner country: 2019 (Tonnes)
22. USA	8,642	0%	940
23. Germany	4,155	2%	0
24. China	3,703	0%	3,344
25. Netherlands	2,662	2%	347
26. Japan	2,617	0%	1,410
27. Spain	983	2%	41
28. Other Asia	921	-	-
29. Canada	523	0%	33
30. France	351	2%	0

[10] Source: Australian Macadamias 2021 Yearbook

31. Malaysia	343	0%	148
32. United Kingdom	323	2% (moving to 0 in Dec 2022)	16
17. Hong Kong	160	0%	55
18. New Zealand	135	0%	83
32. Philippines	19	0%	7
36. Indonesia	7	0%	0
38. India	3	30%	0

The market access opportunities for macadamias are likely to improve further with negotiated outcomes through Australia's Free Trade Agreements with the UK and EU as well as increasing existing market shares in high consumption Asian markets such as China and Japan where Australian macadamias already have the dominant market position. Access for macadamias with each of the relevant trading partners that Australia has trade arrangements within the region is summarised here:

Canada: Under the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) Canada does not impose a tariff on the import of macadamias. Australia currently only exports a small volume of 33 tonnes of macadamias to Canada in comparison with Kenya (52%) and South Africa (30%).

China: Prior to the China-Australia Free Trade Agreement (ChAFTA) the base rate for macadamias was 24% and it was reduced to 0% on 1 January 2019. In In 2021 China was Australia's largest export market for macadamias and in turn Australia was China's largest source of macadamia imports at 83%.

European Union: Australia is currently negotiating a Free Trade Agreement with the European Union and is aiming for full tariff elimination on a range of agricultural products including macadamias from its current duty of 2%. Australia's share of EU macadamia kernels was 18.6% in 2018 and with a tariff reduction there would be significant scope to increase its share.

Hong Kong: Under the Australia-Hong Kong Free Trade Agreement (AHKFTA) there is no tariff applied on the import of macadamias. In 2021, Australia (14%) was the third largest supplier of macadamias to Hong Kong after China (30%) and Malawi (24%).

India: While Australia is in the process of negotiating a Free Trade Agreement with India, India currently imports no macadamias from Australia and maintains a tariff rate of 30 percent on their import. India imports all of its macadamias exclusively from Kenya.

Indonesia: Prior to the Indonesia-Australia Comprehensive Economic Partnership Agreement (IACEPA) the base rate for this product was 5%. Under IACEPA this was eliminated on day one of the agreement. Australia did dominate as the source of Indonesian imports until 2019 supplying almost 100% of macadamia requirements. In 2020 Singapore took over as the market leader with a 60% market share and then moving to 100% market share in 2021.

Japan: Prior to the Japan-Australia Economic Partnership Agreement (JAEPA) the base rate for this product was 5%. Under JAEPA this was eliminated on day one of the agreement. Australia dominates as a macadamia import source in the Japanese market having a 60% share of total imports in 2021.

Malaysia and Philippines: Under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff on macadamias has been eliminated and there is duty free access to both of these markets. While Australia supplies Malaysia and the Philippines with macadamias, it has consistently been the largest importer (at small volumes) in the Philippines and supplied larger volumes in Malaysia but ranked second to South Africa (43% in 2021) and China (22% in 2021) as import sources.

United Kingdom: There is currently a 2% tariff on Australian macadamias into the UK. On entry into force of the Australia-United Kingdom Free Trade Agreement, the tariff will be eliminated (expected Dec 2022). In spite of the tariff barrier, Australia is the 2nd largest import source for macadamias in the UK at 11% after South Africa with 63% of the market share. Once the tariff is eliminated there is potential to increase this share significantly.

USA: Under the Australia-United States Free Trade Agreement (AUSFTA) the tariff for macadamias has been eliminated. The US market for macadamias is dominated by Kenya (supplying 42% of the market), followed by South Africa (36%) and Australia ranks as the 6th largest importer with 4% of the market share.

In light of the low tariff barriers faced by Australian macadamia exporters, Australia's high brand awareness and rising demand there is significant opportunity to expand macadamia exports.

2.11 MANDARINS

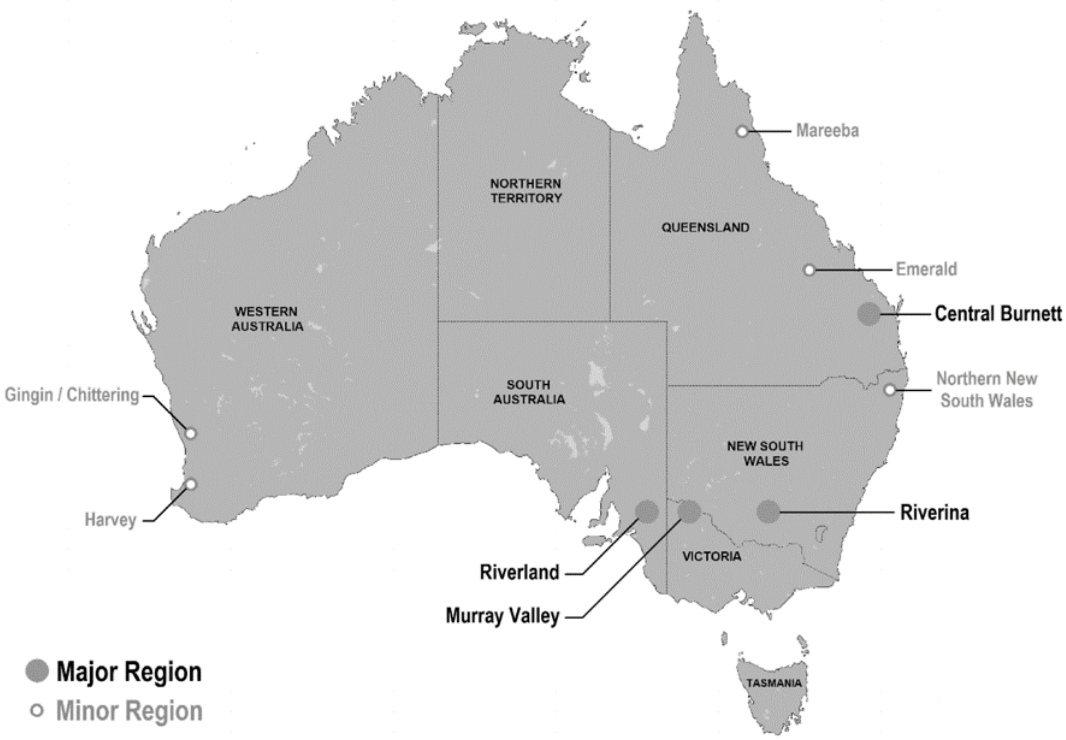
2.11.1 Key points

- Mandarin production contributes to approximately 11% of Australian citrus production.
- Queensland is the largest contributor to Australian mandarin production and the most significant mandarin producing area is the Central Burnett region.
- Approximately 57% of mandarin production is consumed domestically and out of season imports account for approximately 4% of consumption
- Australia is a net exporter of mandarins and the main markets are China, Japan, Thailand and New Zealand, in spite of some countries imposing tariffs.
- Future domestic demand and export potential are both assessed as significant with any yield and production increases as a result of the project.

2.11.2 Australian mandarin production

In 2020/21 Australian production of mandarins was approximately 175,000 tonnes with an increase of 190,000 tonnes estimated in 2021/22 as a result of increased tree plantings coming into production (and a shift towards growing seedless mandarins). Queensland is the largest contributor to Australian production with the most significant mandarin producing area being the Central Burnett region. Mandarins are also produced in South Australian Victoria, New South Wales and Western Australia as highlighted in the following map.

Figure 2.19: Mandarin producing regions in Australia



2.11.3 Australian mandarin consumption

On the demand side, mandarin consumption levels are at approximately 100,000MT which is marginally higher than average consumption over the past 5 years[11] . Mandarin consumption highlights include:

- Approximately 2% of mandarin production are used in processing
- 65% of Australian household buy mandarins.
- Consumption per capita is approximately 3.7 kg
- Approximately 7% of supply is consumed by the food service industry

Consumption of mandarins is expected to increase with higher production being directed to seedless mandarins. Imports of mandarins have averaged approximately 3700 tonnes over the 2019-2021 period[12] and are approximately 4% of total domestic consumption. These imports tend to be for out of season consumption and cater to the low level of consumer demand during that time. The main sources of imports are the USA, Egypt and Israel.

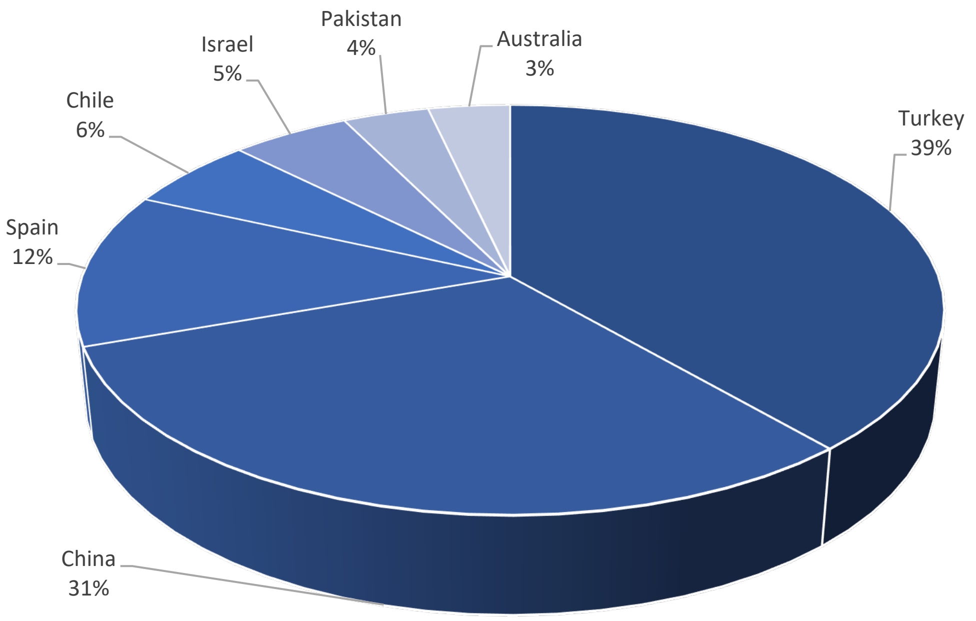
2.11.4 Australian exports of mandarins

Australia is a net exporter of mandarins and in 2021 exported 77,000 tonnes of mandarins as the 7th largest exporter in the world as shown below. The value of Australian mandarin exports in 2021 totalled $137 million.

[11] Source: USDA FAS (2021), Citrus Annual Australia

[12] Source: https://comtrade.un.org/data

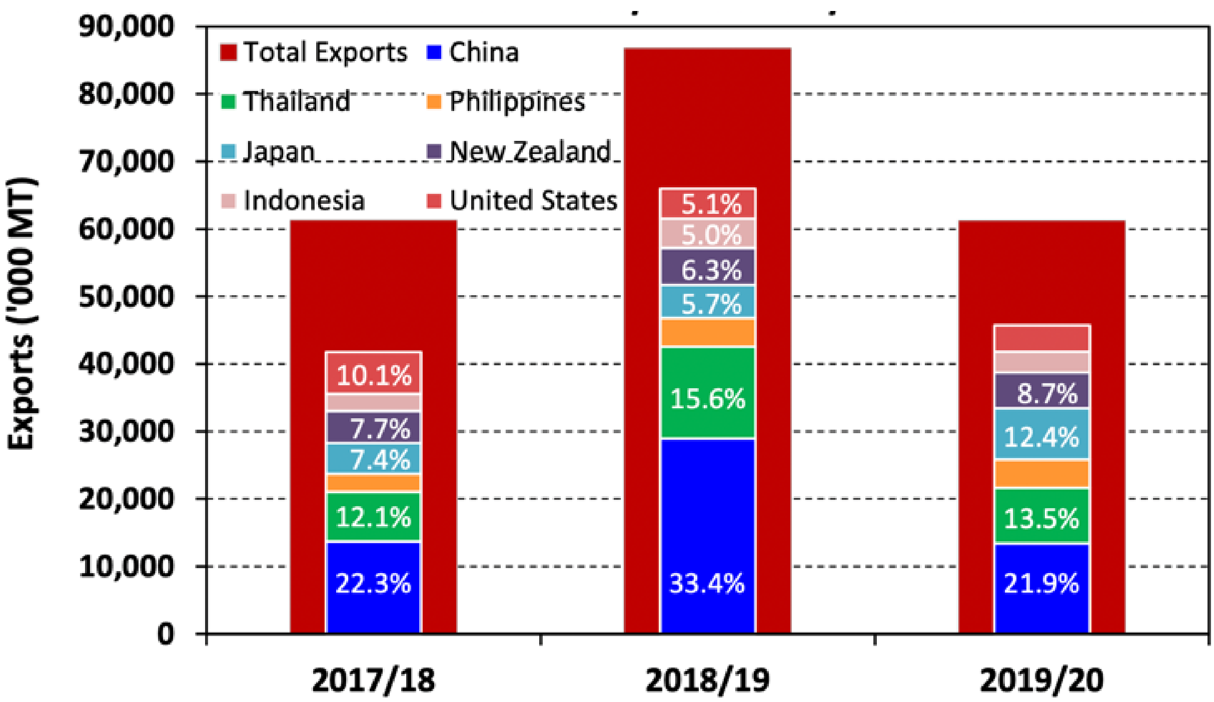
Figure 2.20: Leading mandarin exporters



Australia's main export markets for mandarins are primarily in the Asian region as set out here, with the top 7 export destinations accounting for approximately 75% of all exports. China is Australia's top destination for exports accounting for approximately 22%m followed by Thailand (14%) and Japan (12%). The Philippines, New Zealand, Indonesia and the US have accounted for 5-10% of total exports during the past 3-year period[13].

13 Source: USDA FAS (2021), Citrus Annual Australia

Figure 2.21: Australian mandarin export destinations:



Source: USDA FAS (2021), Citrus Annual Australia

Exports of mandarins are predicted to be on an upward trajectory as a result of increased plantings in recent years and likely to be directed to existing export markets. Approximately 99 percent of all exports are between April and October. Recent export increases have been China, Thailand and Indonesia.

2.11.5 The future export opportunity for Australian mandarins

As a top ten international mandarin exporter, Australia has significant potential to increase its volume of exports further. Australia's trade agreements with key partner countries have and continue to support producers in taking advantage of future export opportunities. The table ahead sets out the world's top mandarin importers, the tariff they impose at the border and Australia's recent export quantities to that country.

Table 2.6: Major importers of Mandarins, 2020

Partner Country (Ranked by import volume)	Volume (Tonnes)	Import tariff in partner country	Australian exports to Partner country: 2019 (Tonnes)
33. Russian Federation	641,689	5%	0
34. USA	251,975	0%	2,981
35. United Kingdom	160,221	16% (reducing to 0% Dec 2022)	203
36. Germany	129,413	16%	0
37. France	128,650	16%	0
38. Thailand	103,295	0%	12,964
39. Ukraine	101,967	0%	0

40. Poland	99,736	0%	37
41. Philippines	99,441	0%	7,915
42. United Arab Emirates	89,191	0%	3,814
43. Canada	68,144	0%	3,243
44. Netherlands	58,403	16%	0
45. Indonesia	57,199	10%	5,214
46. Malaysia	49,353	0%	1,317
47. China	35,303	6.7%	16,403
20. Hong Kong	27,599	0%	1,629
28. Singapore	16,199	0%	2,326
34. Viet Nam	11,991	0%	2,557
37. Japan	10,645	2.8% (reducing to 0% Apr 2023)	5,118
47. New Zealand	6,691	0%	6,089

Source: https://comtrade.un.org/data

The market access opportunities for mandarins are likely to improve further with negotiated outcomes through Australia's Free Trade Agreements with the UK and EU as well as existing open access to a number of Asian markets where Australian mandarins already have a market presence. Access for mandarins with each of the relevant trading partners that Australia has trade arrangements with in the region, is also summarised here:

Canada: Australia currently enjoys tariff free access on mandarin imports to Canada, including within the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). Canada has a diverse range of import sources for its mandarins including the USA (30%), Peru (15%), China (13%), South Africa (11%), Morocco (9%) and Australia (5%).

China: Under the China–Australia Free Trade Agreement (ChAFTA) a tariff of 6.7% is being levied on the imports of mandarins from Australia. In spite of this, China is Australia's largest export market. China is both a producer as well as consumer of mandarins and predominantly imports from South Africa, Australia and Peru.

Hong Kong: Under the Australia-Hong Kong Free Trade Agreement (AHKFTA) there is no tariff applied on the import of mandarins. Australia is the second largest supplier of mandarins to Hong Kong after South Africa, and is followed by Peru.

Indonesia: Australian mandarins currently face a 10% tariff at the Indonesian border, which will reduce to 0% in 2035. Regardless of the tariff, Australia is the third largest exporter of mandarins to Indonesia after China and Pakistan.

Japan: Prior to the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) the base rate for mandarins was 17%. The tariff is currently 2.8% and is due to be reduced to 0% in April 2023. Australia currently exports 5000 tonnes of mandarins annually to Japan and is the second largest supplier into the market after Peru.

Malaysia, Philippines, Singapore, Thailand and Vietnam: Under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff on mandarins has been eliminated and there is duty free access to all of these markets. China dominates as the importing destination of choice for all of Malaysia (79% of imports), Philippines (63%), Singapore (57%), Thailand (92%) and Vietnam 67%). Australia has the strongest foothold in Vietnam, supplying 27% of its mandarin market.

United Kingdom: There is currently a 16% tariff on Australian mandarins into the UK. On entry into force of the Australia-United Kingdom Free Trade Agreement, the tariff will be eliminated (expected Dec 2022). Australia only exports a small volume (203 tonnes) to the UK (which is one of the world's largest mandarin importers. The UK imports primarily from South Africa (35%), Morocco (24%), Peru (18%) and Spain (14%)

USA: Under the Australia-United States Free Trade Agreement (AUSFTA) the tariff for this product has been eliminated. The US market for mandarins is dominated by regional import sources such as Chile (36%), Peru (30%), Uruguay (8%) as well as South Africa (13%).

Given the low tariff barrier levels faced by Australian mandarin exporters into the major mandarin consuming nations, including those in the Asian region, there is a significant opportunity to expand export levels.

2.12 LEMONS

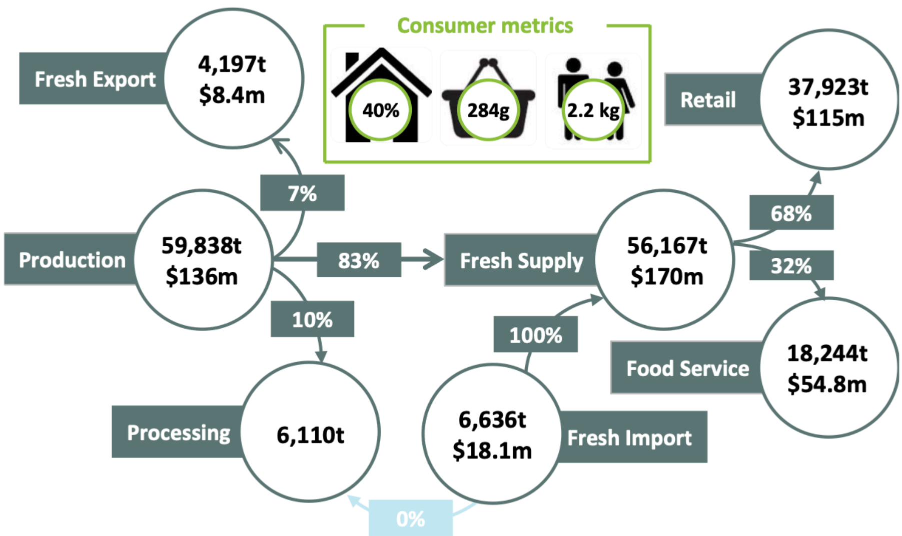
2.12.1 Data specification

It is important to note from the outset that disaggregated data for lemons is not readily available. Data for the sector is grouped collectively as lemons and limes. However, lemons accounted for 70% of production and limes 30%. For this chapter reference to the term lemons will also include data for limes.

2.12.2 Australian lemon production

In 2021 Australia produced approximately 59,838 tonnes of lemon (to end June 2021) at a value of $135.8 million which was a 16% decrease on the previous year of 71,432 tonnes of lemon, valued at $152.3 million. Of this production, 10% was used for processing; predominantly for juicing and the supply chain is set out in the diagram below.

Figure 2.22 Fresh lemons and limes supply chain



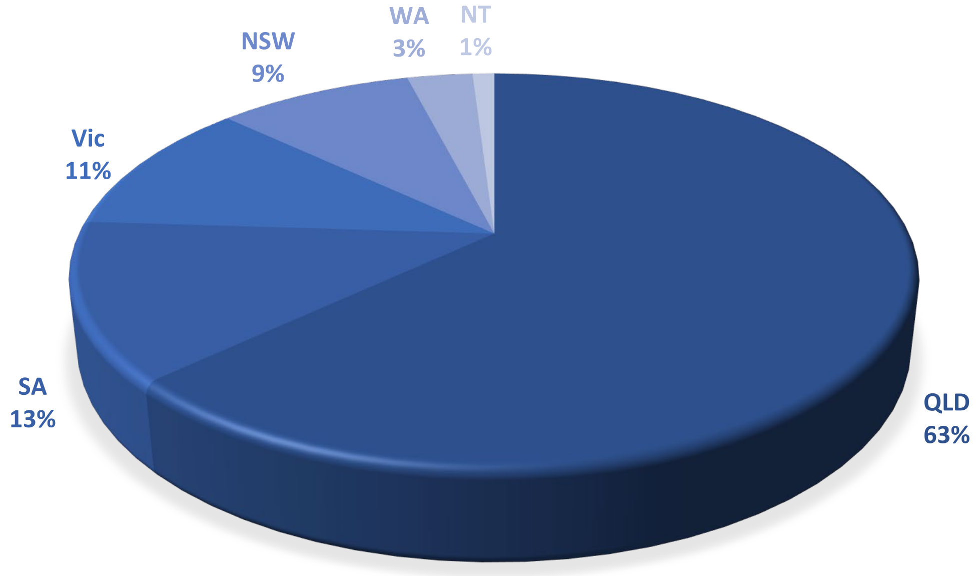
Source: Source: 2020/21 Australian Horticulture Statistics Handbook

Lemon is mainly grown in Queensland (especially in the Bundaberg and Burnett regions) with some production also in "Sunraysia" as well as in the Riverland areas around the border of South Australia, Victoria and New South Wales as depicted in the following diagrams.

Figure 2.23: Lemon and lime production areas

Source: Source: 2020/21 Australian Horticulture Statistics Handbook

Figure 2.24: Australian production of lemons and limes



The main production period in Australia is during winter (when domestic market prices are at their lowest). In recent years there has been an increase in both lemon plantings (including of seedless varieties) as well as an increase in new industry entrants.

2.12.3 Australian lemon consumption

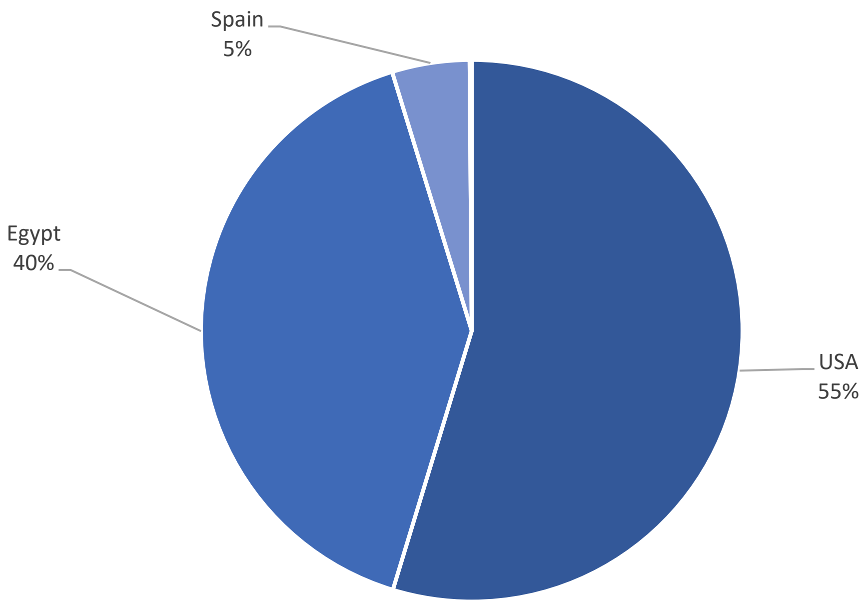
Total annual domestic consumption of lemons was approximately 62,803 tonnes at June 2021. The majority of lemons produced in Australia are consumed domestically – in 2021 approximately 95%.

Lemon Consumption (Year Ending June)	2019 (tonnes)	2020 (tonnes)	2021 (tonnes)
Retail supply	42,065	44,280	37,923
Food service	19,488	19,926	18,244
Fresh Imports	4,403	3,902	6,636
Total Consumption	**65,956**	**68,108**	**62,803**
vs. Production	*66,378*	*71,432*	*58,838*

Lemon consumption levels are on the rise with an increased trend of lemons being used to enhance flavour and minimise the amount of salt in cooking. In particular, the demand for seedless lemons is also increasing.

In the high demand months of summer Australia imports (approximately 6,636 tonnes in 2021 or 11% of total domestic consumption) to satisfy increased demand that cannot be met by local production. These seasonal imports of lemons are predominantly sourced from the United States, Egypt and Spain.

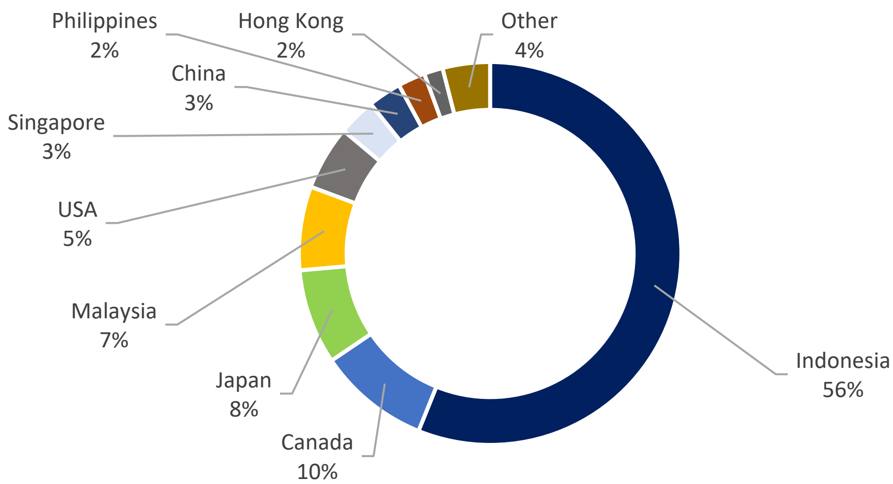
Figure 2.25: Lemon imports into Australia



2.12.4 Australian exports of lemons

In 2021, Australia exported 4,590 tonnes of lemons which constituted just 7% of total production. Over half of Australia's lemon exports are destined for Indonesia, followed by Canada, Japan and Malaysia as set out in the chart below.

Figure 2.26: Australia lemon exports



The industry is currently striving to increase exports with a concerted export strategy to capitalise on increased plantings and new growers in the sector.

2.12.5 The future export opportunity for Australian lemons

In addition to likely production increases and industry export marketing efforts, Australia's trade agreements with key partner countries places it in a favourable position to take advantage of future export opportunities. Except for EU nations, Australia faces virtually no tariffs at the border of the major lemon importers, including in the Asian region. The table ahead sets out the world's major lemon importers, the tariff they impose at the border and Australia's recent export quantities to that country.

Major global importers of Lemons, 2021

Partner Country (Ranked by import volume)	Volume imported (Tonnes)	Import tariff in partner country	Australian exports to Partner country: (Tonnes)
21. USA	891,841	0%	249
22. Netherlands	259,574	11.36%	0
23. Germany	240,708	11.36%	0
24. France	167,883	11.36%	2
25. United Kingdom	146,846	6% (moving to 0% in Dec 2022)	0
26. Poland	139,788	11.36%	0
27. Italy	115,544	11.36%	0
28. Canada	109,369	0%	433
29. Romania	63,021	11.36%	0
30. Portugal	56,540	11.36%	0
12. Japan	44,152	0%	369
15. Hong Kong	38,359	0%	73
18. Malaysia	33,373	0%	325
28. China	15,621	1.2% (moving to 0% in 2023)	130
32. Indonesia	9,284	0%	2,575

The market access opportunities for lemons with each of the relevant trading partners that Australia has trade arrangements with in the region, is also summarised here:

Canada: Under the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) the tariff rate for lemons was bound at 0%. While Australia imports a small volume of lemons to Canada, it is competing against imports from Mexico (29%), South Africa (24%) and the USA (23%).

China: Prior to the China-Australia Free Trade Agreement (ChAFTA) the base rate for lemons was 11%. Under the ChAFTA the tariff will decrease to 0% on 1 January 2023. As a producer of lemons, China imports predominantly from Chile (43%) and Argentina (33%). With an impending tariff reduction, the scope to export to China is likely to increase from the current 130 tonnes.

Hong Kong: Under the Australia-Hong Kong Free Trade Agreement (AHKFTA) the tariff on lemons was bound at 0%. Australia currently only supplies 73 tonnes per annum of the market compared to dominant suppliers such as South Africa (40%), Chile (13%) and Peru (12%) and China (8%).

Indonesia: Prior to the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the base rate for lemons was 5%. Under AANZFTA the tariff was eliminated on day one of the agreement. While Indonesia is Australia's largest export market for lemons (2, 575 tonnes and 56% of total Australian lemon exports), it is the 2nd largest source of imports for Indonesia constituting 28% of total lemon imports, following China (57%).

Japan: The tariff applying to lemons at the border is 0% under a number of free trade agreements, including the Japan-Australia Economic Partnership Agreement (JAEPA).. Australia currently exports a small volume of avocados (369 tonnes) to Japan but it is a significant potential export market going forward. Currently Japan's lemon imports are predominantly sourced from the USA (45%) and Chile (39%).

Malaysia: Under the ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) the tariff on lemons has been eliminated and there is duty free access. Australia only exports a small volume of lemons to Malaysia (325 tonnes) and competes against significant lemon imports from South Africa (43%), China (20%), Vietnam (15%) and Egypt (9%).

United Kingdom: Prior to the Australia-United Kingdom Free Trade Agreement (AUKFTA) which is not yet in force the base rate for lemons was 6%. Upon entry into force of AUKFTA the tariff will be eliminated on day one of the agreement. Australia currently does not export lemons to the UK and would compete with significant producers such as Spain (42%), South Africa (25%) and Brazil (15%).

USA: Under the Australia-United States Free Trade Agreement (AUSFTA) the tariff for this product has been eliminated. While Australia exports a small volume of lemons to the US (249 tonnes), other regional producers such as Mexico (80%), Argentina (8%) and Chile (7%) dominate the US market.

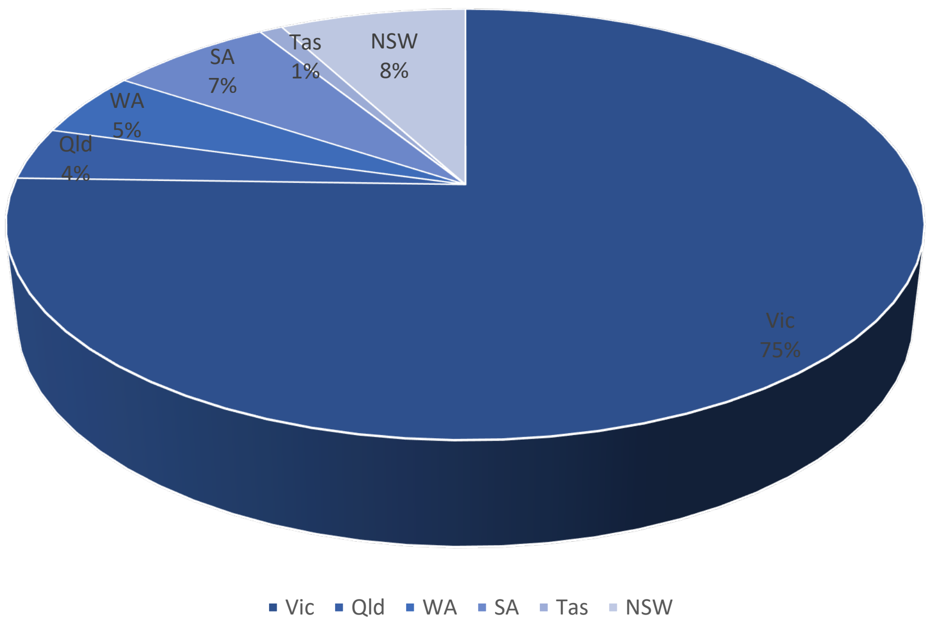
2.13 PEACHES AND NECTARINES

2.13.1 Australian peach and nectarine production

In 2021 Australian production of peaches and nectarines totalled 85,819 tonnes which was a 17% reduction on the 2020 crop (103,094 tonnes). The total production value for peaches and nectarines in 2021 was $236.1 million.

Peaches and nectarines are primarily grown in Young and Orange, in south-western New South Wales, and in the Victoria regions of Sunraysia and Goulburn Valley. Figure 2.27 shows that most Australian peaches and nectarines are grown in Victoria.

Figure 2.27: Growing regions for peaches and nectarines in Australia



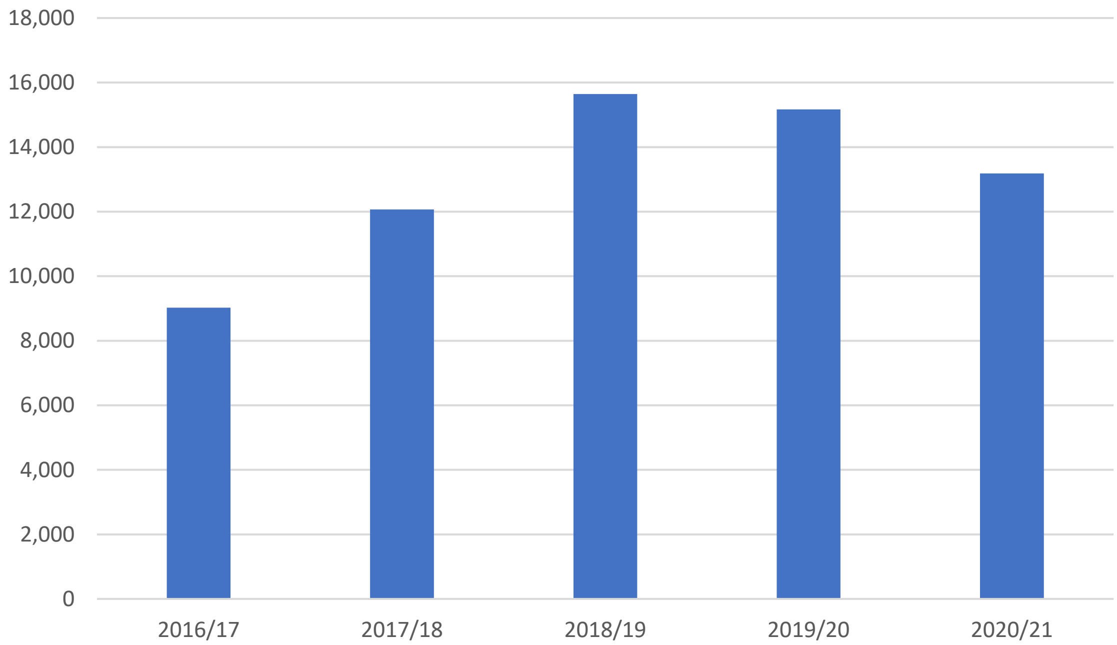
2.13.2 Australian peaches and nectarines consumption

Domestic consumption of peaches and nectarines is over 60% fresh supply, with 45% of Australian households purchasing peaches and nectarines and averaging 544g per shop. The fresh domestic supply of peaches and nectarines reduced by 16% from 2020 to 2021, although this is attributable to the reduction in production.

2.13.3 Australian exports of peaches and nectarines

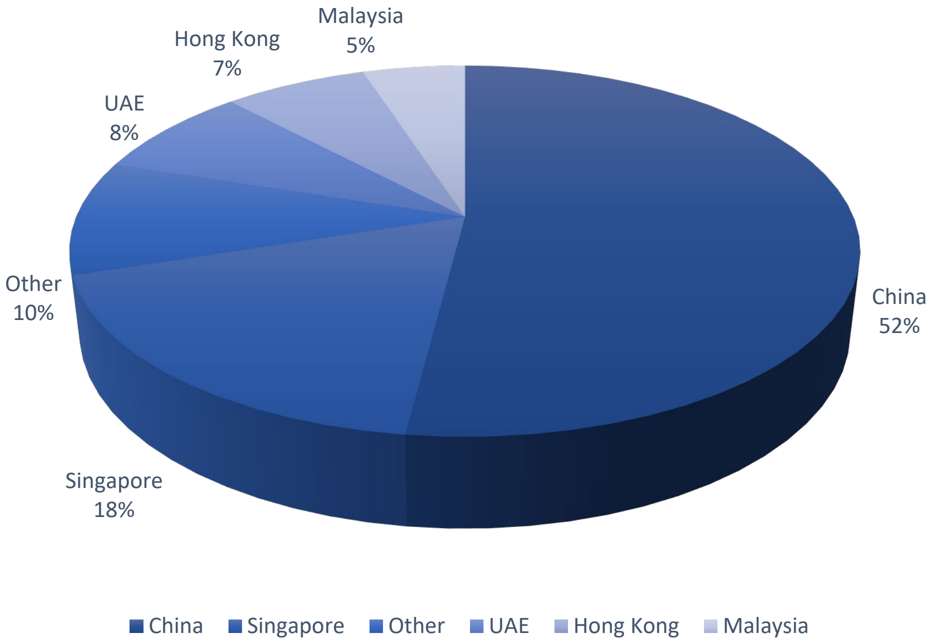
In 2021 Australia exported 13,187 tonnes of peaches and nectarines at a total value of $59.3 million. Figure 2.28 shows the export performance of peaches and nectarines over the past five years, where Australian exports have experienced stead growth until the production-based reduction in 2020/21.

Figure 2.28: Australia exports of peaches and nectarines 2016/17 to 2020/21



Most of Australia exports of peaches and nectarines go to China (52%) with the remaining volume primarily in Asia. Australia peaches and nectarines are primarily exported fresh, which results in the higher viability of Asian markets as export destinations. Figure 2.29 shows Australian peaches and nectarines by country.

Figure 2.29 Australian peaches and nectarines by country



2.13.4 The future export opportunity for Australian peaches and nectarines

There are significant opportunities for Australia to increase its export of peaches and mandarins. Globally in 2021, 1.78 million tonnes of fresh peaches and nectarines were exported with a total value of $2.72 billion. Table 2.7 shows the top exporters of peaches and nectarines, including the export volumes and total value for 2021.

Table 2.7 Top exporters of peaches and nectarines

Exporter	Volume (tonnes)	Value ($ million)
Spain	690,901	1,105.17
European Union	137,215	243.72
Turkey	170,419	169.12
Italy	97,070	162.52
United States	84,234	160.31
Chile	96,504	137.23
Jordan	78,369	128.98
China	44,709	64.82
Greece	58,967	57.47
France	25,603	53.53

Due to the limitations related to exporting fresh peaches and nectarines, it is anticipated that future export growth markets for Australia will be primarily location within Asia. There is significant growth potential for Australian exports in key Asia markets, including markets where Australia is already exporting peaches and nectarines. Table 2.8 shows the key Asian import markets for peaches and nectarines.

Table 2.8 Top exporters of peaches and nectarines

Importer	Volume (tonnes)	Value ($ million)	Australian exports (tonnes)	Tariff on Australia products (%)
Hong Kong	34,885	84	951	0%
China	33,299	79	6,899	0%
Other Asia	16,330	53	3,647*	0%
UAE	12,475	20	1025	
Malaysia	1,909	5	665	0%

** Exports to Other Asia is estimated based on comparative analysis of data.*

Australia has significant opportunities to increase it exports of peaches and nectarines to Hong Kong, China and UAE, where it has a preferential tariff position and currently only accounts for a relatively small percentage of the important volume for each market.

ECONOMIC ROAD MAP

Attachment M:

Net Zero

Key Points

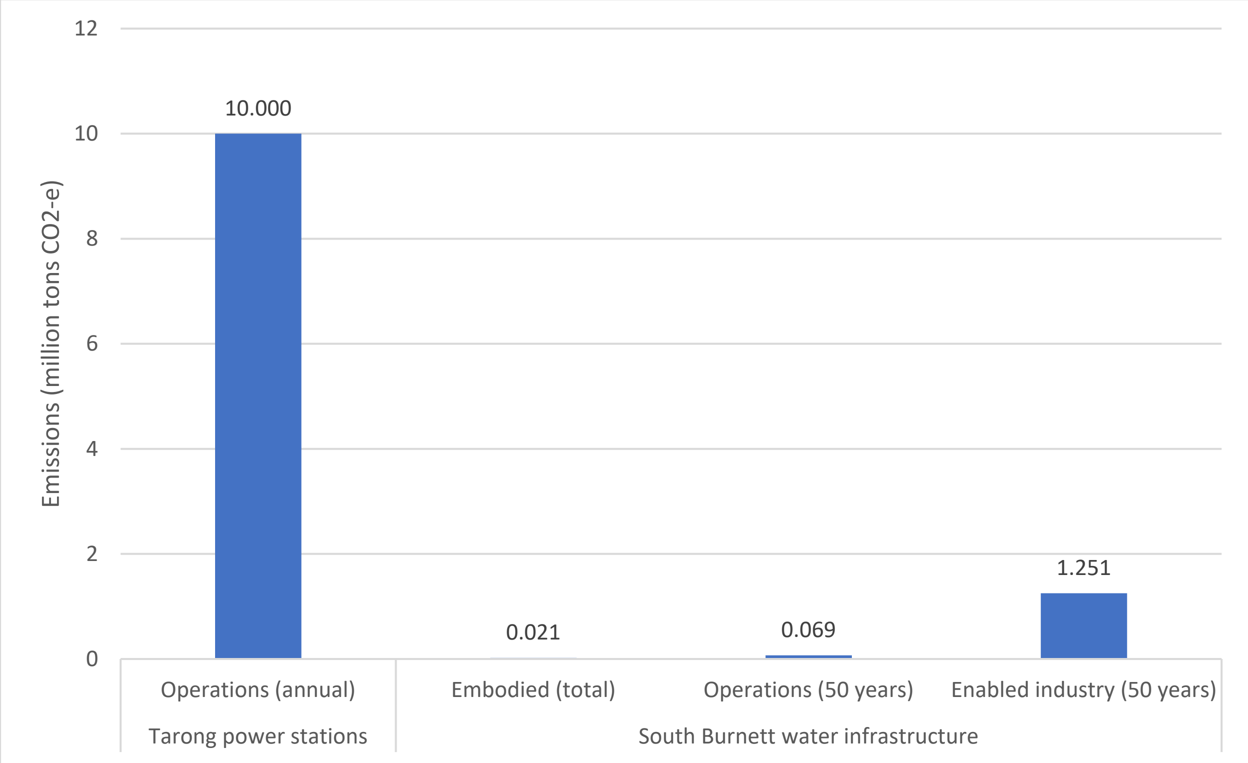
- The Australian Government has increased Australian's greenhouse gas emissions reduction target from 26-28% reduction from 2005 emission levels by 2030 to a 43% reduction in the same timeframe. In addition, there is now a target of net zero emissions by 2050.
- The trajectory of reduction is steep, requiring a 4% annual reduction till 2030 and a 5% average reduction from 2030 to 2050.
- The emissions reduction target has also been explicitly included in the priorities of Infrastructure Australia so it likely that that new guidelines to align Infrastructure Australia with the national emissions target will include alignment with the emissions reductions target.
- The water infrastructure proposed for the South Burnett is to replace the economic benefits associated with the closing the Tarong power station in 2036.
- The Tarong power station emits 10 million tons of carbon dioxide equivalent (CO2-e) per annum, representing 6% of Queensland's annual emissions.
- Net zero emissions is the achievement of emissions reductions or offsetting so that the net emissions associated with the project are zero on an annual basis.
- Net zero emissions infrastructure is proposed by the Infrastructure Sustainability Council to include the following sources:
  - Embodied: production of materials used in the construction of infrastructure, as well as those from the construction process itself
  - Operating: ongoing operations of infrastructure assets
  - Enabled: activities of infrastructure's end-users (agricultural production and processing)
- The annual emissions associated with the three infrastructure projects are shown in Table 1.

Table 1 Total emissions per year – tons CO2-e rounded

	Blackbutt (t CO2-e)	Gordonbrook (t CO2-e)	Barlil and West Barambah weirs (t CO2-e)
Embodied (annualised over 50 years)	130	260	30
Operations (annual)	710	1,050	30
Enabled industry (annual)	2,320	17,960	4,740
Total	**3,160**	**19,270**	**4,800**

- The Gordonbrook project has the greatest emissions per annum due to the proposed use of water by animal protein producers.
- The emissions of the entire South Burnett water infrastructure program compared to the annual emissions of the Tarong power stations is shown in Figure 1.

Figure 1 Tarong annual missions vs. South Burnett water infrastructure over 50 years emissions



- The entire emissions of the proposed South Burnett water infrastructure projects over 50 years is 13% of the current annual emissions of the Tarong power stations.
- The annual emissions, including annualised embodied emissions, for the water infrastructure is 0.3% of annual emissions of the Tarong power station, representing a 99.7% decrease in annual emissions.
- Net zero emissions for the infrastructure and enabled industry could be achieved through applying a carbon mitigation framework (avoid, reduce or offset) to each of the emissions sources.

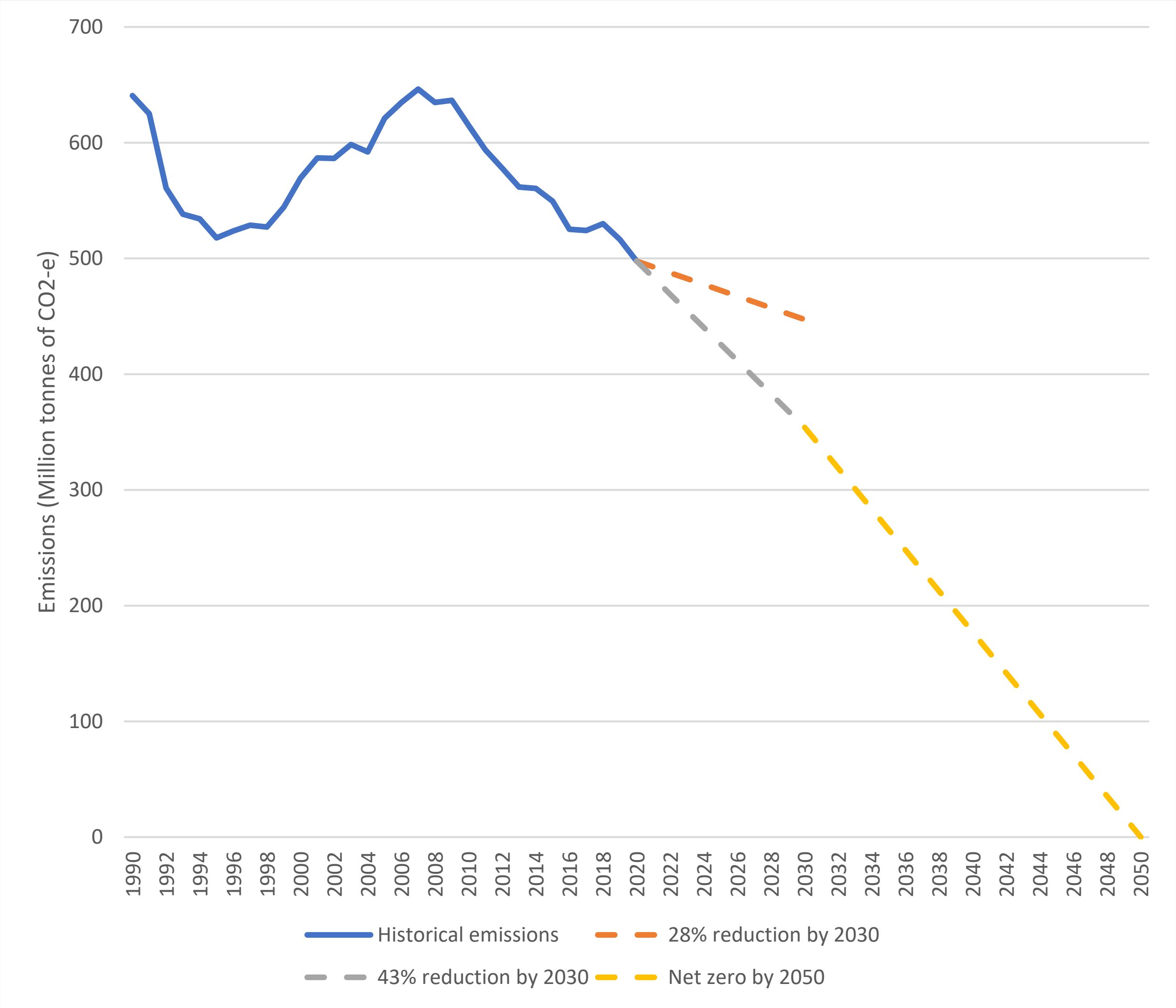
1.1 NEW CLIMATE CHANGE LEGISLATION AND INFRASTRUCTURE AUSTRALIA

The new climate change legislation has now integrated the increased national emissions target in the considerations of Infrastructure Australia.

The *Climate Change Act 2022*, passed in August 2022, extended Australia national emissions reduction commitment from a 26-28% reduction from 2005 emission levels by 2030 to a 43% reduction in the same timeframe. In addition, the Act included the target of net zero emissions by 2050 (Figure 2).

Net zero means cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, by oceans and forests. The Australian Net Zero target states that the nation, as a whole, will not emit any emissions above what the country absorbs by 2050.

Figure 2 Australian emissions targets – previous 28% reduction target by 2030, new 43% reduction target by 2030 and net zero by 2050



Source: Australian Government, AGEIS Trend Graph, 2022

The accompanying *Climate Change (Consequential Amendments) Act 2022* inserted the national target into a range of existing legislation including the *Infrastructure Australia Act 2008* which governs Infrastructure Australia. This means that consideration of Australia's emissions reduction target will inform decision-making, including evaluating infrastructure proposals, by Infrastructure Australia. There was previously no reference to climate change as part of evaluating infrastructure projects and only a brief reference to Infrastructure Australia providing advice on the impact of climate change policies on infrastructure.

Infrastructure Australia will likely develop new guidelines for its evaluation of infrastructure projects to consider the likely impact of each project on the Australian Government's emissions target.

1.2 AUSTRALIAN GOVERNMENT FUNDED INFRASTRUCTURE PROJECTS AND NET ZERO EMISSIONS

Currently, there is no formal requirement for infrastructure funded by the Australian Government, reviewed and recommended by Infrastructure Australia, to be net zero emissions.

However, the Figure 2 trajectory of emissions under the Australian Government's targets indicate that any project with a long project life (i.e. up to and beyond 2050) will have to be net zero so that it does not negatively impact the net zero target.

It is likely that that new guidelines to align Infrastructure Australia with the national emissions target will include a net zero by 2050 requirement at a minimum.

Infrastructure projects that support the achievement of the 2030 and 2050 target through a reduction in emissions will also likely be prioritised.

1.3 NET ZERO WATER INFRASTRUCTURE PROJECTS AND AGRICULTURAL PRODUCTION

The lack of current guidance from Infrastructure Australia on net zero means that there is some uncertainty about the coverage of emissions to be included in a net zero emissions reduction plan.

Guidance in other areas, including corporate net zero plans under the SBTi Net-Zero Standard[1], define net-zero as:

- reducing scope 1, 2, and 3 emissions[2] to zero or to a residual level that is consistent with reaching net-zero emissions at a defined time
- neutralizing any residual emissions at the net-zero target year and any GHG emissions released into the atmosphere thereafter

Infrastructure creates emissions through its construction (including embodied emissions from materials), operation and enabling industries. There are detailed standards for sustainable infrastructure from the Infrastructure Sustainability Council which include guidance on emissions reductions.

Each of the emissions categories are described in Table 2 along with example emissions sources from a water infrastructure project.

[1] https://sciencebasedtargets.org/resources/files/Net-Zero-Standard.pdf

[2] Scope 1 emissions: all emissions from on-site fuel use and greenhouse gas leakage; scope 2:all emissions from electricity use and Scope 3: all emissions from supply chain and customers

Table 2 Infrastructure emissions

Categories	Description	Example of emissions from water infrastructure projects
Embodied	Production of materials used in the construction of infrastructure, as well as those from the construction process itself	• Pipe production • Concrete production • Transportation • On-site generation using diesel or gas • On-site vehicles that use fossil fuels
Operating	Ongoing operations of infrastructure assets	• Electricity sourced from fossil fuel generation • Asset renewals • On-site vehicles that use fossil fuels
Enabled	Activities of infrastructure's end-users	• Emissions from end-user's agricultural production • Emissions from end-user's industrial production

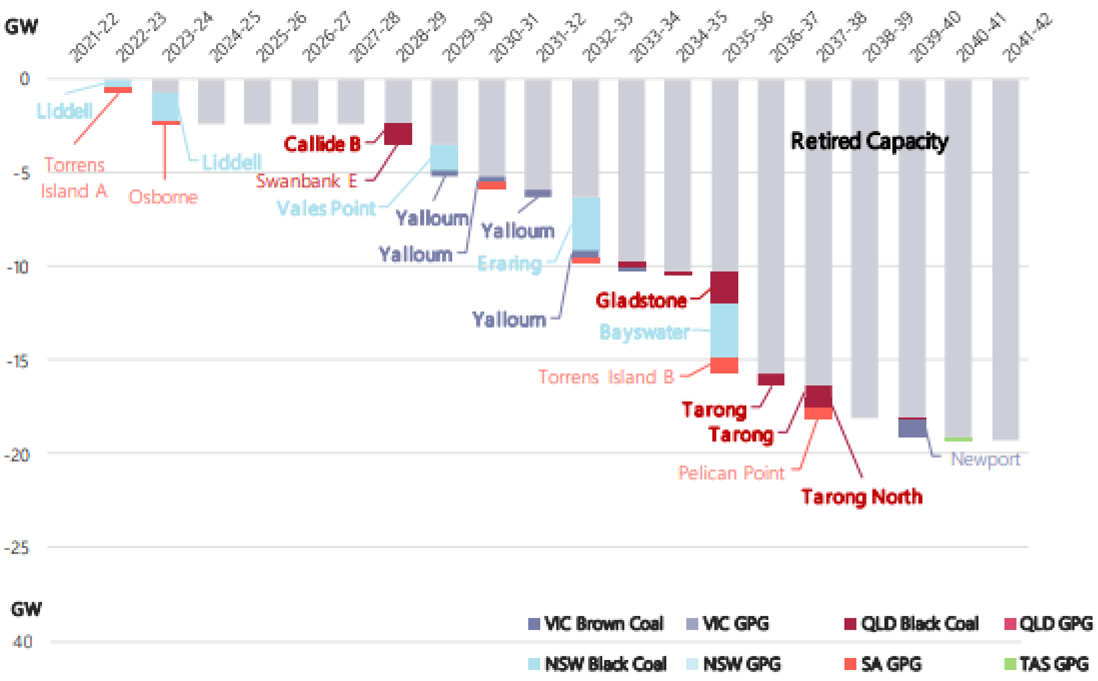
Source: ISCA, ClimateWorks. Australia and ASBEC (2020) Issues Paper: Reshaping Infrastructure for a net zero emissions future

Achieving net zero emissions for the water infrastructure project would involve reducing or offsetting the emissions associated with the three categories.

1.4 SOUTH BURNETT WATER INFRASTRUCTURE PROJECTS AND THE JUST TRANSITION

The South Burnett water infrastructure projects are proposed to replace the economic benefits provided by the existing Tarong power station as part of a Just Transition strategy. This power station is slated to be closed in 2036 as shown in the figure below.

Figure 3 Coal and gas fired power plant closures



Source: AEMO, 2021

The closure of Tarong power stations will result in a reduction of 10 million tons of carbon dioxide equivalent per year according 2022 Australian Government emissions data . The current emissions of Tarong account for 6% of Queensland's 171 million tons per year.

The three proposed water infrastructure projects to provide economic benefits to the community are:

1. Blackbutt pipeline
2. Gordonbrook dam conversion and pipeline
3. Barlil and West Barambah weirs.

The projects provide a Just Transition to assist communities that are negatively affected by the closure of fossil fuel industries in their area to achieve the Australian emissions reduction targets.

1.5 EMISSIONS ASSOCIATED WITH SOUTH BURNETT JUST TRANSITION WATER INFRASTRUCTURE

The first step in achieving net zero is to footprint the emissions associated with the infrastructure.

The process of foot printing the emissions of the water infrastructure involves collecting data on the key emissions sources, identifying appropriate emissions factors and calculating the likely emissions for each category.

The preliminary nature of the projects means that there is reasonable uncertainty about the final composition of emissions. The following emissions footprints are, therefore, indicative of the potential emissions but not complete.

1.6 EMBODIED EMISSIONS FROM WATER INFRASTRUCTURE

Embodied emissions include emissions from the production of materials for the infrastructure and the construction process itself. A preliminary assessment on the key sources of emissions provides the following total footprint for embodied emissions (Table 3).

Table 3 Total embodied emissions

	Blackbutt (t CO2-e)	Gordonbrook (t CO2-e)	Barlil and West Barambah weirs (t CO2-e)
Pipes	6,149	12,901	0
Concrete	120	120	1,080
Pump stations	0	0	0
Diesel use in construction	45	72	179
Total emissions	6,314	13,092	1,259
Annualised emissions (50 years)	126	262	25

The emissions associated with Gordonbrook and Blackbutt are higher than the weirs due to the emissions associated with production of the proposed HDPE plastic pipes. The weirs are largely compacted soil with a concrete shell.

1.7 OPERATION EMISSIONS

The operation emissions associated with the three infrastructure options result from two key emission sources:

1. Electricity use for pumping
2. Emissions from renewals activities including materials.

The calculated emissions based on forecast pumping and renewals are shown in Table 4

Table 4 Operation emissions per year

	Blackbutt (t CO2-e)	Gordonbrook (t CO2-e)	Barlil and West Barambah weirs (t CO2-e)
Electricity	586	790	-
Renewals	125	260	22
Total emissions	**711**	**1,050**	**22**

The operation emissions for the pipeline projects are far higher than the weir projects due to the electricity use.

1.8 ENABLED EMISSIONS

The final emissions category is the emissions associated with the end use of the water provided by the infrastructure projects. There are a range of enterprises that have requested water for the projects as part of the Round 1 demand assessment.

Specific emissions calculations has not undertaken on the actual enterprise in the South Burnett but the emissions associated with each of the enterprises has been approximated using the emission factors in Table 5. The factors include emissions from:

- Fertilizer application
- Animal digestion
- Fuel use
- Energy for fertiliser production
- Animal feed production
- Processing (where applicable).

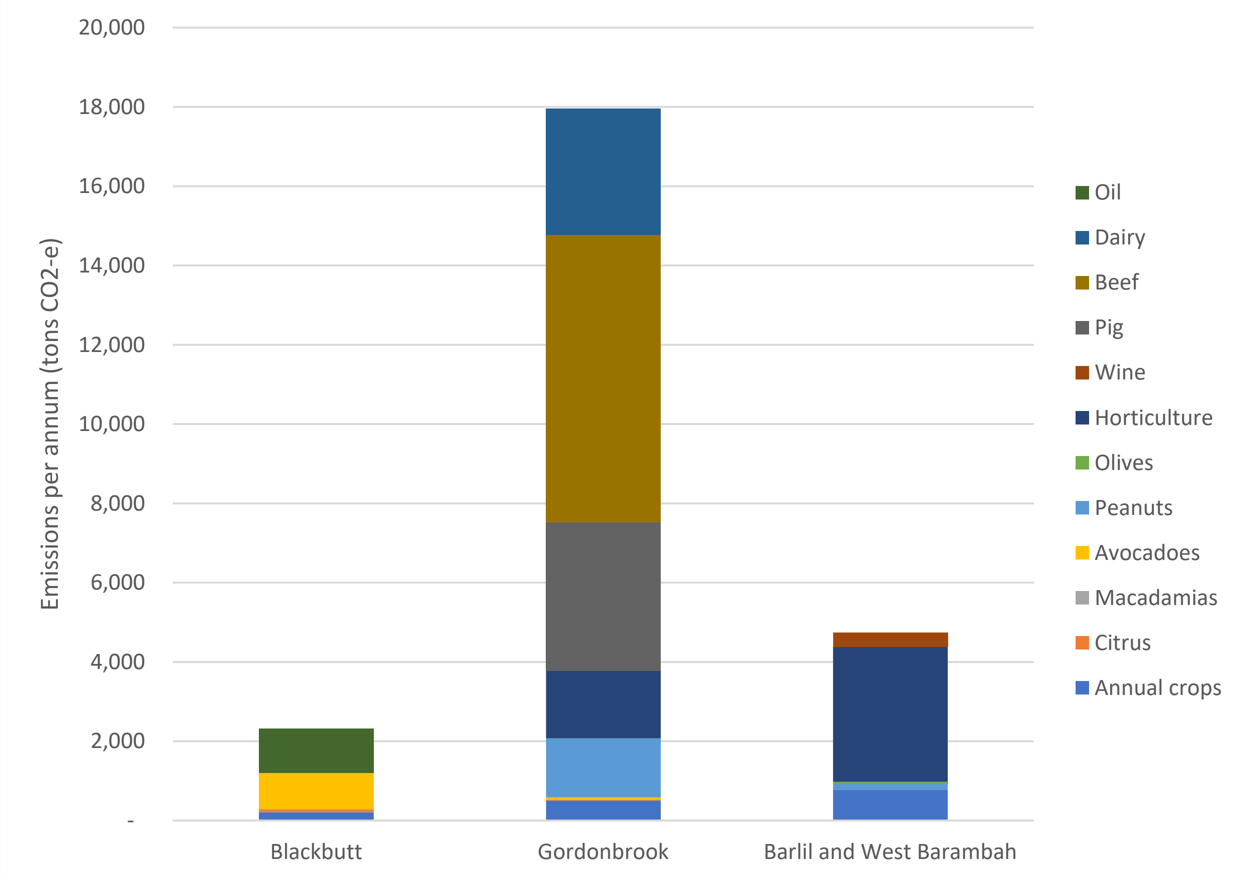
Table 5 Agricultural enterprise emission factors

	Emissions factor (CO2-e t/kg)
Annual crops	1.4
Citrus	0.3
Macadamias	0.3
Avocadoes	0.4
Peanuts	2.5
Olives	0.4
Oil	4.1
Horticulture	1.4
Grapes	1.9
Pig	8.0
Beef	58.0
Dairy	3.0

Source: Our World in Data, Environmental Impacts of Food Production, 2021, Farm, animal feed and processing emissions

The annul enabled emissions, based on the proposed crop mixes of each project, is shown in Figure 4.

Figure 4 Enabled emissions by water project



The chart shows that animal protein enterprises are the highest emitting enterprises in the projects. The beef feedlot, piggery and dairy enterprises generate substantial emissions for the Gordonbrook project.

Avocado oil production in Blackbutt, using the olive oil emissions factor, contributes more than 50% of Blackbutt's emissions.

The Barlil and West Barambah weirs have no processing enterprises but a high proportion of horticulture with associated fertiliser emissions.

1.9 OVERALL EMISSIONS FOOTPRINT

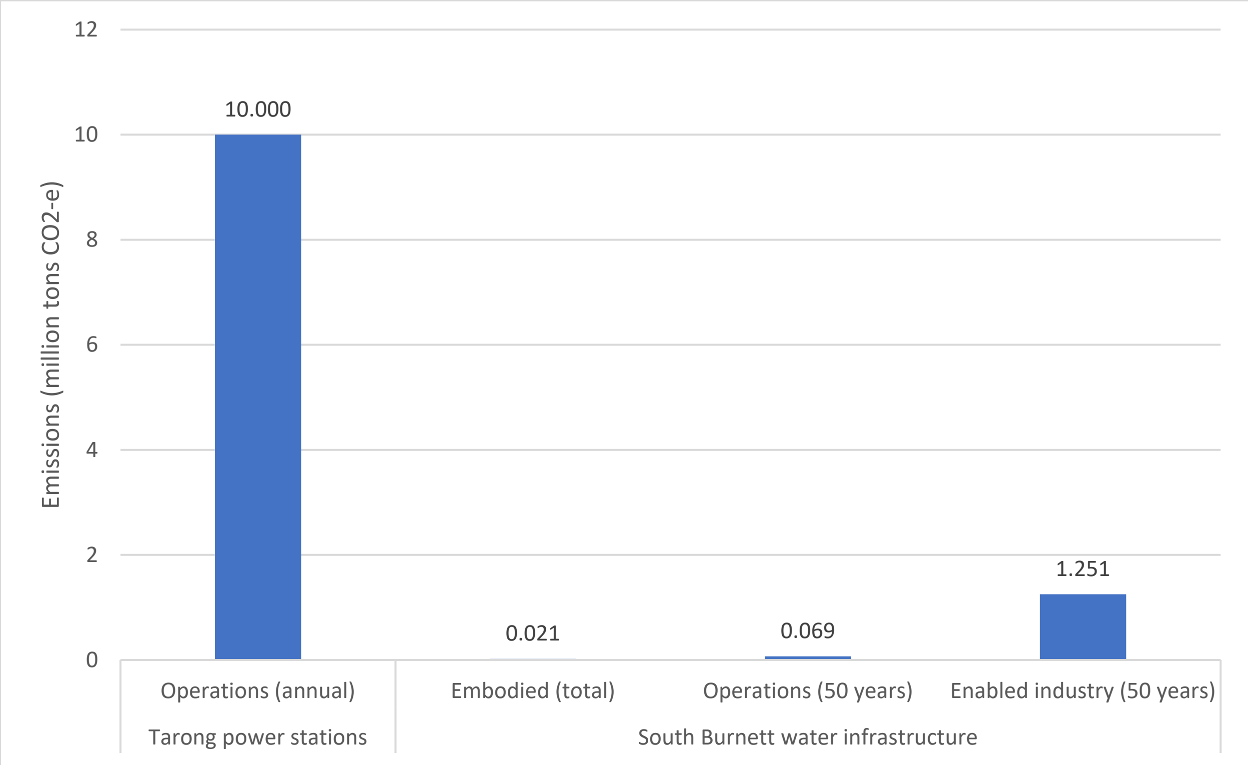
The overall emissions footprint for the three projects are shown in Table 6.

Table 6 Total emissions per year

	Blackbutt (t CO2-e)	Gordonbrook (t CO2-e)	Barlil and West Barambah weirs (t CO2-e)
Embodied (annualised over 50 years)	130	260	30
Operations (annual)	710	1,050	30
Enabled industry (annual)	2,320	17,960	4,740
Total	**3,160**	**19,270**	**4,800**

The Gordonbrook project has the greatest emissions per annum due to the proposed use of water by animal protein producers. The emissions of the entire South Burnett water infrastructure program compared to the annual emissions of the Tarong power stations is shown in Figure 5.

Figure 5 Tarong annual missions vs. South Burnett water infrastructure over 50 years emissions



The entire emissions of the proposed South Burnett water infrastructure projects over 50 years is 13% of the current annual emissions of Tarong power station. The annual emissions, including annualised embodied emissions, for the water infrastructure is 0.3% of annual emissions of the Tarong power station, representing a 99.7% decrease in emissions.

1.10 ACHIEVING NET ZERO

Net zero water infrastructure and enabled industry requires that all emissions are mitigate using the emissions mitigation framework:

1. Avoid emissions
2. Reduce emissions
3. Offset emissions

The following table provides potential mitigation measures for the key emissions identified in the preliminary emissions footprint.

Table 7 Infrastructure emissions

Categories	Description	Example of emissions mitigation
Embodied	Production of materials used in the construction of infrastructure, as well as those from the construction process itself	• Carbon neutral or recycled plastic pipes • Green steel • Electric construction vehicles using renewable energy • Carbon offsets
Operating	Ongoing operations of infrastructure assets	• Electricity sourced from renewable energy • Carbon offsets • On-site vehicles that use fossil fuels
Enabled	Activities of infrastructure's end-users	• Soil and tree carbon projects • Emissions reduction technologies for animal protein production

		• Electricity from renewable energy

A detailed net zero plan can be developed for the final composition of infrastructure and enabled industries.

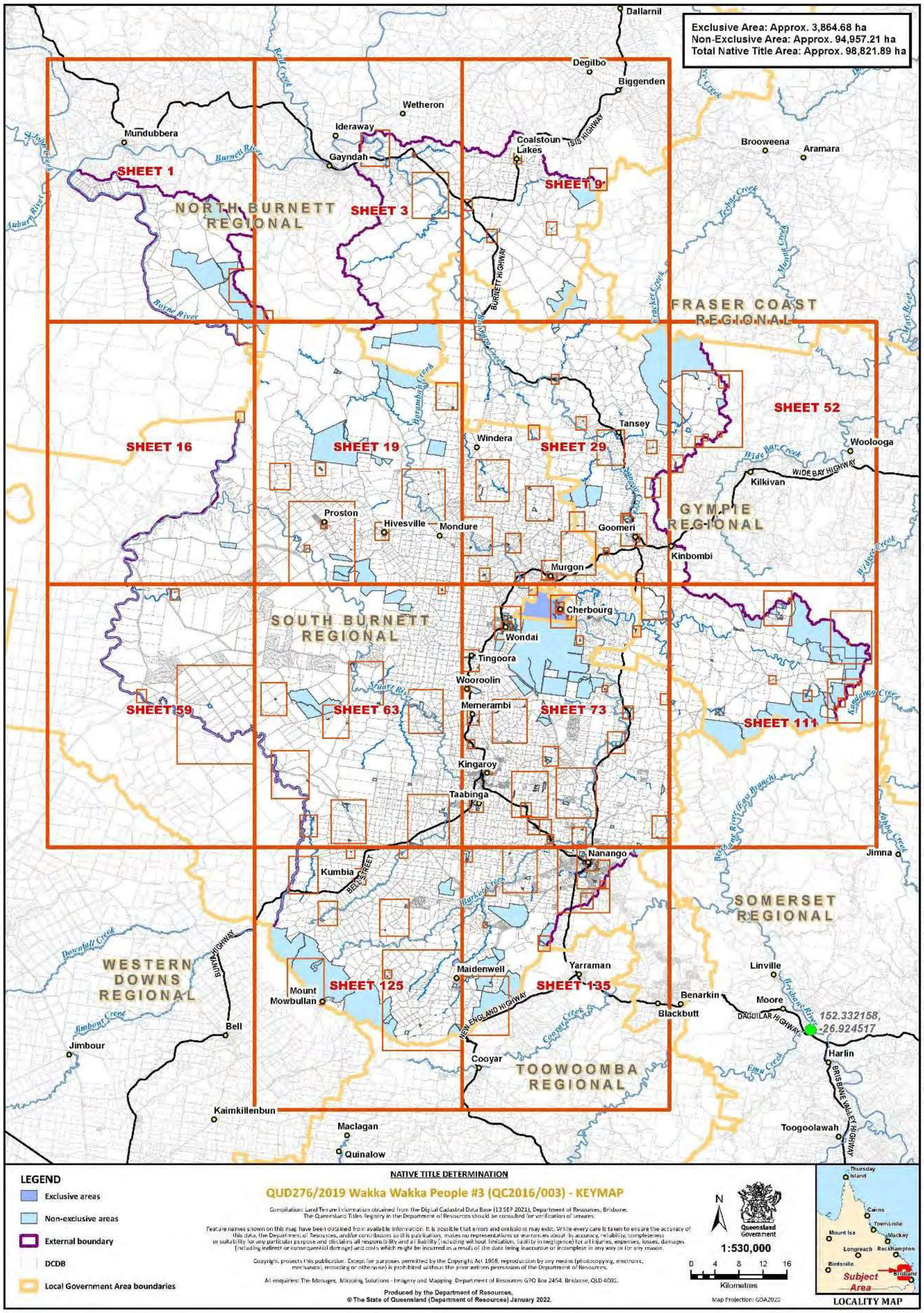
ECONOMIC ROAD MAP

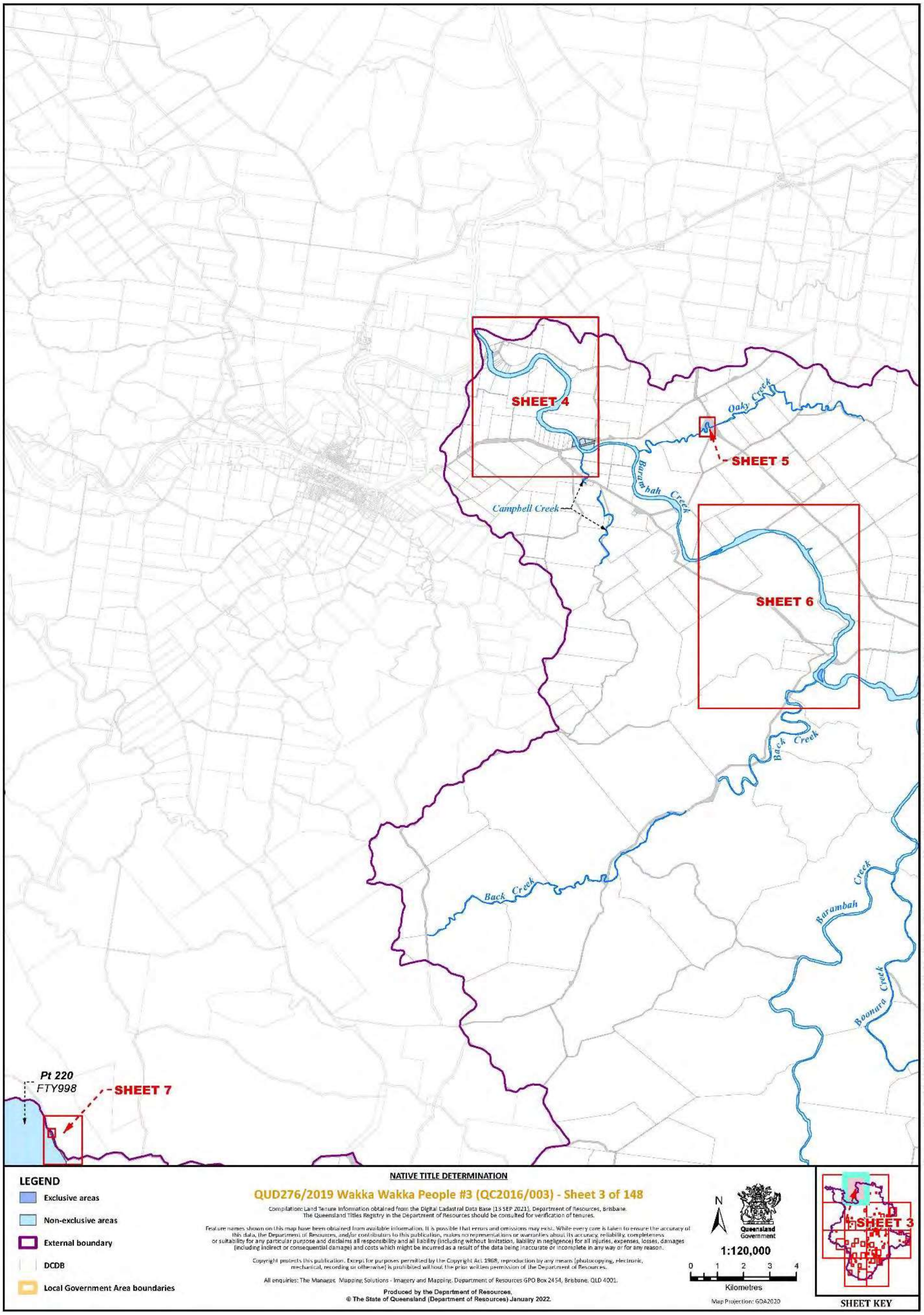
Attachment N:

Native Title Maps

SCHEDULE 6

MAP OF DETERMINATION AREA




SHEET 4
SHEET 5
SHEET 6
SHEET 7
Oaky Creek
Barambah Creek
Campbell Creek
Back Creek
Back Creek
Barambah Creek
Boonara Creek
Pt 220
FTY998
LEGEND
Exclusive areas
Non-exclusive areas
External boundary
DCDB
Local Government Area boundaries
NATIVE TITLE DETERMINATION
QUD276/2019 Wakka Wakka People #3 (QC2016/003) - Sheet 3 of 148
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The Queensland Titles Registry in the Department of Resources should be consulted for verification of tenures.
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Queensland Government
1:120,000
0 1 2 3 4
Kilometres
Map Projection: GDA2020
SHEET 3
SHEET KEY

SEAL OF THE FEDERAL COURT OF AUSTRALIA
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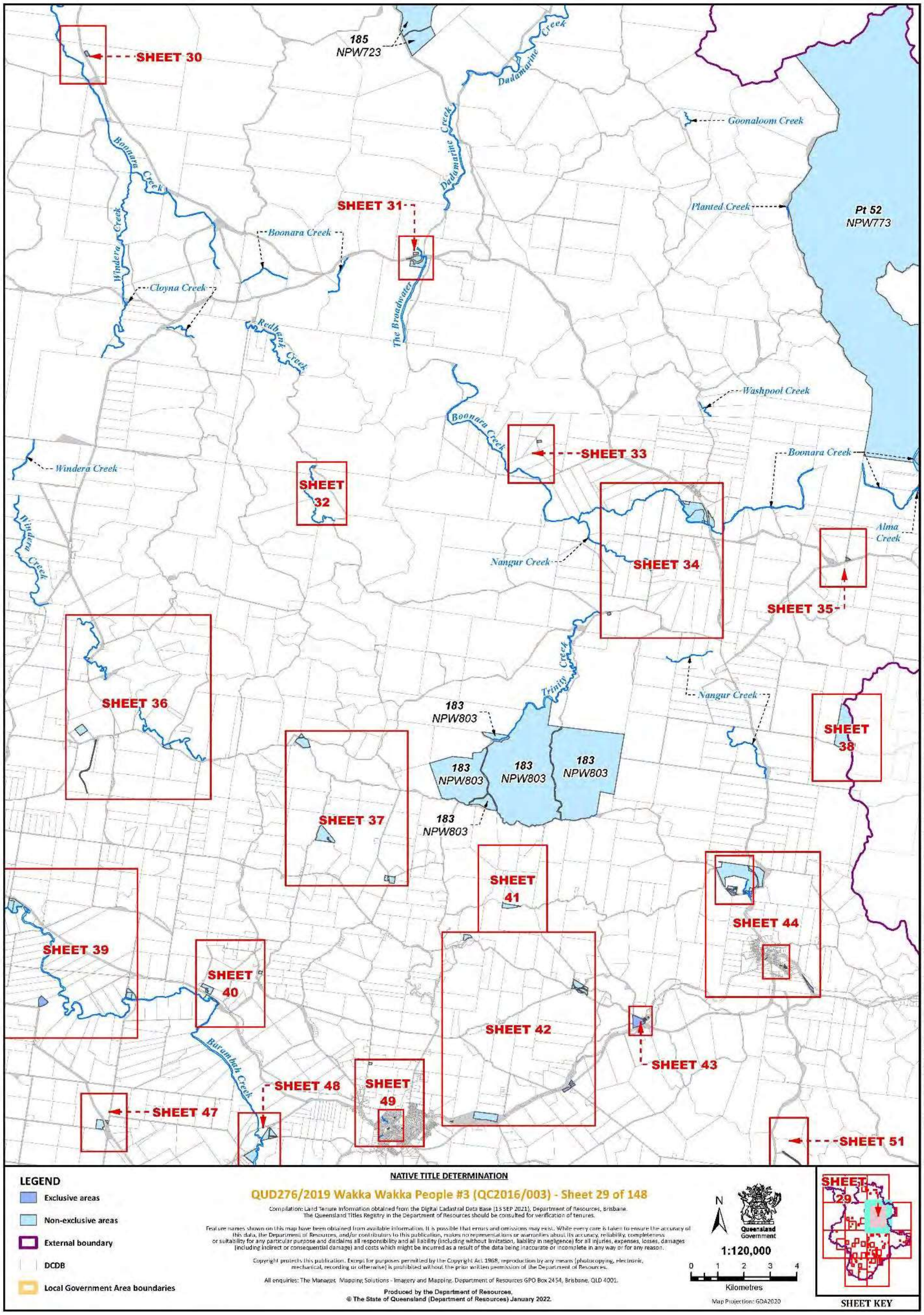

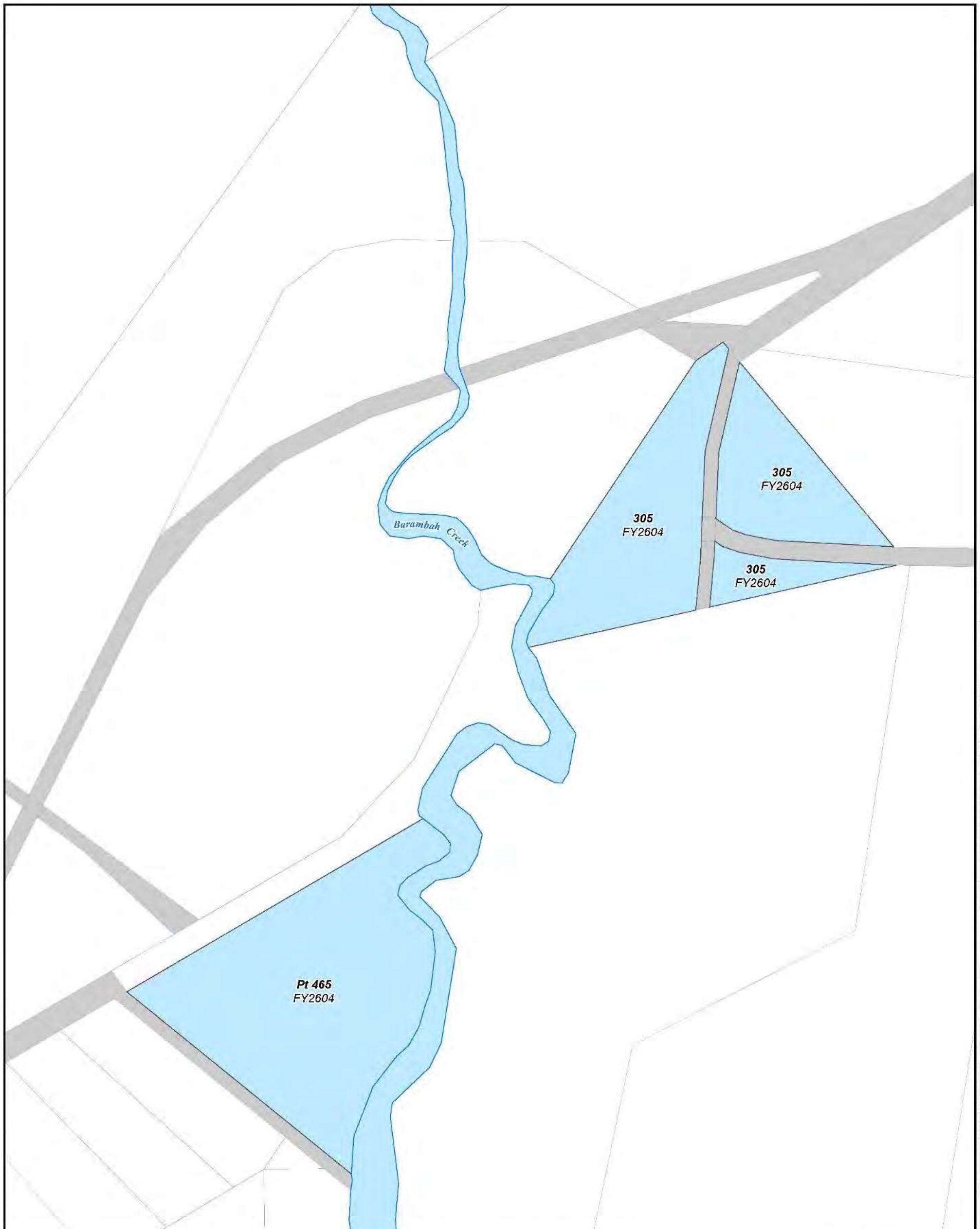

LEGEND

- Exclusive areas
- Non-exclusive areas
- External boundary
- DCDB
- Local Government Area boundaries

NATIVE TITLE DETERMINATION

QUD276/2019 Wakka Wakka People #3 (QC2016/003) - Sheet 48 of 148

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Map Projection: GDA2020

SHEET KEY