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Paradise Dam Improvement Project: service needs, demand estimates and options assessment

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EXECUTIVE SUMMARY

20 second soundbite

An independent and detailed assessment was undertaken to:

(i) estimate the likely regional water requirements from Paradise Dam for irrigators (medium priority (MP) allocations) and residential and commercial/industrial water users (high priority (HP) allocations) over the next 30 years, and

(ii) (ii) analyse the options to safely meet this demand via the Paradise Dam Improvement Project.

While a long list of options was assessed, recommended options for assessment in the Detailed Business Case are:

- Lower the spillway crest level by 5 metres.
- An optimal lowering of the spillway crest level by between 5 and 10 metres.
- Lower the spillway crest level by 10 metres plus invest in alternative water projects within the Bundaberg Irrigation Scheme area (projects already identified by SunWater).

Context and project objectives

Paradise Dam is a 52-metre-high roller compacted concrete gravity-based structure on the Burnett River, approximately 80 kilometres southwest of Bundaberg. The Dam provides 124,000 ML of Medium Priority (MP) and 20,000 ML of High Priority (HP) water allocations. Recent technical investigations identified structural problems with the Dam. This creates a risk of dam failure under extreme weather events such as those that occurred in 2013. The key service needs identified for the Paradise Dam Improvement Project (PDIP) are:

- Meet dam safety requirements (i.e. formally assessed 'Limits of Tolerability').
- Meet likely water demand out to the year 2050.
- Meet subsidiary issues (e.g. recreational opportunities, environmental considerations and social/cultural considerations).

To address the service needs, several PDIP options have been identified and assessed. These included options that were identified prior to the commencement of this work as well as additional options that were identified as a consequence of this work. All options are briefly outlined below.

Table ES1. The complete list of PDIP options that were assessed during this investigation

Options	Description
Business case options	
Option 1	Full upgrade without lowering the spillway.
Option 1a	Full upgrade without lowering the spillway, to lower the dam safety risk to below the Limit of Tolerability for existing dams. Includes additional works above Option 1.
Option 2	Lowering of spillway crest level by 5m and other strengthening works to reduce the dam safety risk below the Limit of Tolerability for existing dams.
Option 3	Lowering of spillway crest level by 10m to pass 1:15,000 AEP flood event and other strengthening works to reduce the dam safety risk below the Limit of Tolerability for existing

Options	Description
	dams. This would allow for immediate needs to me met, but not allow demand growth in the longer-term.
Option 3a	Option 3 plus in-scheme alternative water supplies to match demand forecasts. These alternative storages have been identified and undergone a preliminary analysis under SunWater's Blueprint process.
Option 4	Optimal lowering of spillway crest level by between 5 and 10 m and other strengthening works to reduce the dam safety risk below the Limit of Tolerability for existing dams.
Option 5	Full dam decommissioning.
Option 5a	Option 5 plus alternative supply options to meet demand estimates (projects in the demand area)

This report summarises the process undertaken and findings from our independent assessment of long-term demand requirements and the options available to meet this need. This work scopes the preferred options for consideration in the Detailed Business Case (DBC).

Demand assessment and comparison to yields from PDIP options

The driver for the PDIP was to provide a reliable source of water for agriculture, industry and urban users in the Lower Burnett region. The ability to meet the water demand is seen as critical as it supports current and future economic and residential growth. A comprehensive and detailed demand assessment was undertaken involving several procedures, including:

- An assessment of broader macro factors driving demand (e.g. demographics and economy, broad trends in commodity markets and prices, land use change and climate change).
- Econometric analysis of historical usage.
- Detailed assessments of prospects, trends and water requirements for major irrigation crops. This comprises MP allocations, for example sugar, macadamias, avocadoes, citrus, other fruit, seasonal vegetables, pasture/fodder and other broadacre crops. These assessments consider water as a derived demand.
- Detailed assessments of urban and industrial demand for HP allocations.
- Consultation with key industry and stakeholders. This included stakeholders within the region, competing regions, and entities along the supply chain for key commodities (e.g. processors, supermarket chains).

One of the key findings from the analysis was that, despite significant recent growth in high value crops (particularly macadamia and avocadoes), this growth is occurring on former sugarcane farms. In effect, the growth in water demand is the net impact of requirements for perennial tree crops less the water requirements previously used for producing sugar. Furthermore, because perennial tree crops have a significantly greater downside risk of very low announced allocations, irrigators often hold more allocation than they would use in a typical year. Effectively, holding additional allocation is a risk management strategy.

Building on these findings, an independent assessment was undertaken using a detailed demand forecasting model. Given the variability in data and information, ranges of input parameters and assumptions were developed (outlined in Appendix B) a sensitivity analysis was conducted using Monte Carlo simulations (20,000 simulations across the key input variables). This enabled a probabilistic range of demand estimates to be developed for each year out to 2050. The estimates below show the most likely estimate from the modelling, the high estimate (95% of all modelled simulations were less than this estimate), and the low estimate (only 5% of all modelled simulations were less than this estimate). These estimates were benchmarked against the yield assessments for each of the PDIP options. The full range of yield estimates out to 2050 are the full supply level (FSL), 5m lowering, 10m lowering PDIP options (the horizontal lines), and a 10 m lowering plus alternative supply options.

This is depicted in Figure ES1 (below), where all HP allocations are converted to MP allocations to enable a consolidated analysis of the demand and supply relationships.[1]

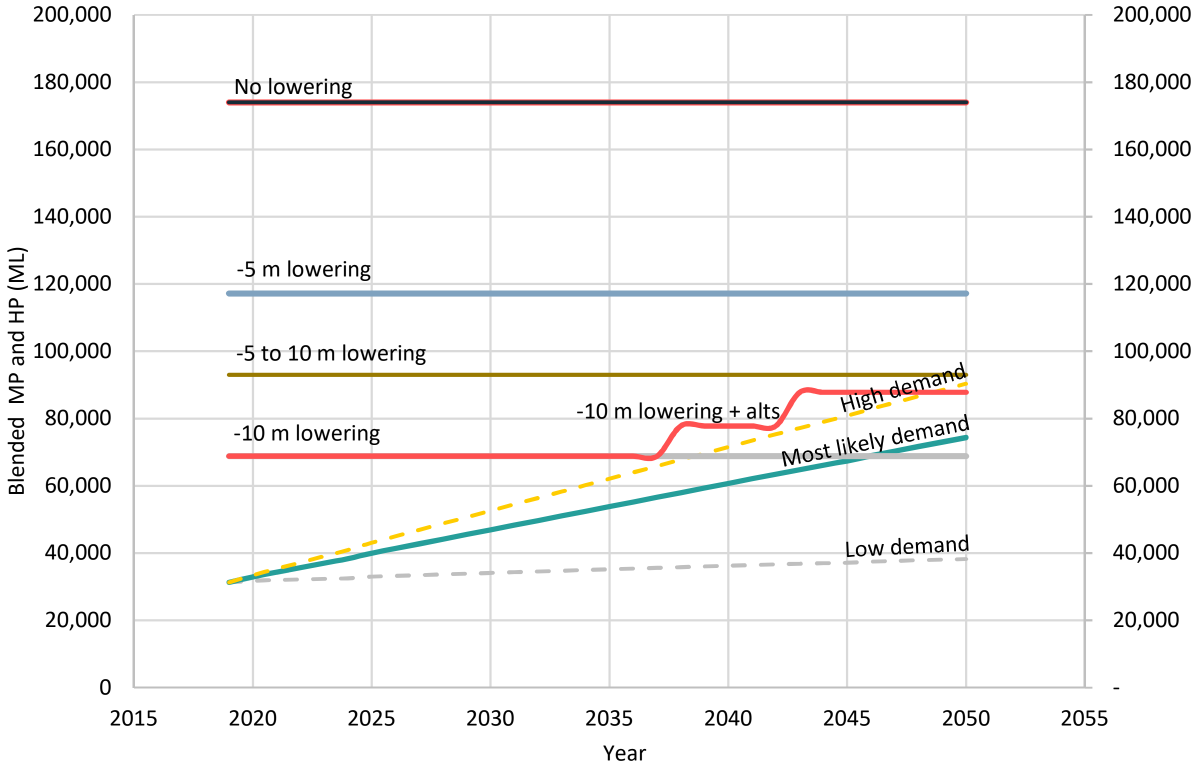

Figure ES1. Estimated demand and yield ML/year (demands converted to MP equivalent)

The high estimate is considered a well-informed and reasonable metric for benchmarking supply requirements out to 2050 as it includes an appropriate margin for demand estimation error. The high estimate is significantly influenced by the high irrigation requirements for macadamia and avocados and reductions in regional rainfall due to climate change, where climate change scenarios show rainfall reductions of up to 15% could be expected under some climate models. The high irrigation requirements represent the emerging practice of spray irrigation compared to more efficient drip irrigation for some crops to both save costs and mitigate the risk of leaf burn (see sections on macadamias and avocados in Appendix B).

Key points

The demand assessment found that a 5-metre lowering of the spillway crest level should meet the estimated demand requirements out to 2050 (provided that unused HP allocation can be converted and sold as MP allocations).

A 10-metre lowering of the spillway crest level would result in shortfalls in meeting the ‘most likely’ demand estimates around 2045, and significantly earlier if the high demand estimates are realised.

[1] Note: The conversion rate of 2.5:1 is the rate used in the relevant Resource Operations Plan. Recent modelling undertaken by SunWater suggests a rate of 2.32 may be more appropriate. However, the modelling has shown that the lower conversion rate makes negligible difference to the outcome. This is addressed in the sensitivity analysis section of Appendix B.

A 10-metre lowering in conjunction with alternative water supply projects should meet demand requirements, as would an optimal lowering between 5 and 10 m.

PDIP Options Assessment

An options assessment was undertaken for each of the PDIP options. This analysis utilised information from the demand assessment, independent modelling and reviews of the safety of the dam, previous analysis of Paradise Dam (including the Preliminary Business Case undertaken by SunWater), and other relevant information elicited through consultation. An initial assessment was undertaken by NCEconomics that was subsequently reviewed and amended during an Options Assessment workshop on 22 January 2020.

The criteria for the Options Assessment were:

- *Dam safety (primary service need).* This was a threshold criterion, where the options must be below the Limit of Tolerability to be acceptable. Each option received a pass or fail on this criterion.
- *Meeting water requirements (primary service need).* This was a threshold criterion, where the option must meet at least the p95 demand estimate in 2050 (i.e. the higher end of our demand estimates). Each option received a pass or fail on this criterion.
- *Establishment cost.* This was the range of actual preliminary cost estimates for each option. For each of the PDIP options a range of costs were estimated using a -20% to +40% range of the mid-point estimates developed by SunWater except for Option 1a that was less well developed and used a range of -50% to +100%. Where alternative storage options were considered, the range of estimates used were up to -50% to +100% of the mid-point estimates, all based on SunWater's estimates. Furthermore, where alternative storage options were not required immediately, the present value of establishment costs was used. It should also be noted that these costs are based on a permanent adjustment to the dam levels from the current levels, not the 5 m lowering that has is being undertaken as essential works.
- *Recreational opportunities.* The scope of recreational opportunities at the dam site from the preferred PDIP option are not materially different from current opportunities. This assessment used a Likert scale to elicit quantitative scoring from primarily qualitative information.
- *Residual environmental risks.* The potential environmental risks after each option meets all foreseen obligations, duties and conditions. This assessment used a Likert scale to elicit quantitative scoring from primarily qualitative information.
- *Residual social and cultural risks.* The potential environmental risks after each option meets all foreseen obligations, duties and conditions. This assessment used a Likert scale to elicit quantitative scoring from primarily qualitative information.

A two-stage approach was used for the Options Assessment:

- *Threshold analysis.* First, a threshold analysis was used to narrow down the options. This ruled out options which did not meet the dam safety or water supply threshold criteria.
- *Multi-criteria analysis.* Consistent with common practice, a multi-criteria analysis (MCA) was used to underpin the options assessment. MCA is a decision support tool that was developed as an approach for use in operations research, where decision makers attempt to assess multiple options across a range of decision factors (reasons or considerations) that may have different and inconsistent assessment measures, including non-monetary valuation.

The threshold analysis identified that options did not meet the service need requirements, specifically:

- *Option 1. (Full upgrade without lowering the spillway).* There is only limited confidence that this option meets the dam safety Limits of Tolerability. Note: Option 1a that includes additional dam safety features does meet the safety Limits of Tolerability.

- *Option 3 (Lowering of spillway crest level by 10 m).* Option 3 can supply a p95 high demand scenario until 2038 and meet a 'most likely' demand estimate until 2045, but not 2050.

- *Option 5 (Full dam decommissioning).* Option 5 immediately results in a large supply deficit in the Bundaberg Water Supply Scheme (BWSS).

- *Option 5a (Full dam decommissioning plus alternative supply options to meet demand estimates).* Option 5a was ruled out through the threshold analysis after an initial assessment of costs found it to be significantly more expensive than other options, while environmental risks and uncertainties are also very high.

Key point

Of the options to meet full supply level, Option 1 does not meet dam safety criteria, while Option 1a does. The 10m Lowering and Decommissioning options all fail the water supply requirement threshold test and are not considered suitable for inclusion in the DBC. Full dam decommissioning plus alternative supply options to meet demand estimates is also not feasible on cost and environmental grounds.

The FSL (Option 1a), 5m lowering option (Option 2), 5-10m lowering option (Option 4) and 10m lowering plus alternative supply option (Option 3a) remained after the threshold analysis. These options were then assessed using MCA. To perform this analysis, weightings were applied to each criterion[2]. Scores were given to each of the three remaining options against each of the criterion. These scores were normalised[3] to enable aggregation into an overall score (effectively the sum of the weighted and standardised criterion scores). Sensitivity analysis was also undertaken to account for the range of criterion scores and weightings.

The results of the MCA found that the 10-metre lowering of the spillway crest level plus alternative supplies option is considered to be superior, particularly based on costs. However, with the exception of Option 1a (FSL), which has a significantly higher cost, sensitivity analysis revealed that none of the remaining options were statistically different in their scoring. This was consistent with the expert consensus opinion from the Options Assessment workshop, particularly given the limitations of available data and information.

Key point

The MCA did not conclusively demonstrate a difference between the 5-metre lowering, 10-metre lowering plus alternative supplies, and the 5 – 10 metre lowering options.

It should be noted that there are limitations in data underpinning this analysis, particularly the robustness of the costing for each PDIP option and certainties of dam safety considerations. These are acknowledged throughout the report and are a key driver of the extensive use of sensitivity analysis in this report. These limitations will be addressed and mitigated through the DBC.

[2] Of a total 100% weightings, 30% was applied to dam safety, 30% to meeting water requirements, 25% to costs, and 5% to each of the other criterion (recreational, residual environmental and residual social / cultural risks).

[3] Through the normalisation procedure the option with the worst score for each criterion received a score of zero, the best option received a one, and the remaining option scored relative to the best option.

Recommended options for assessment in the Detailed Business Case

Based on this independent assessment, the options to be assessed in the DBC have been established.

> **Key recommendation**
>
> This assessment recommends that three options should be assessed in the DBC:
>
> - Option 2 – Lowering of spillway crest level by 5m.
> - Option 3a – Lowering of spillway crest level by 10m plus alternative water supply options within the BWSS area (previously identified by SunWater).
> - Option 4 – Optimal lowering of spillway crest level by between 5 and 10m.

Other issues for consideration in the DBC

A number of other issues have arisen during this project that warrant detailed consideration within the DBC, or concurrently to the DBC. These are:

- *Consistent approach to options costing.* This analysis is based on the initial cost estimates developed by SunWater and its advisors. There are some inconsistencies in the scope and robustness of these preliminary costings, including the ranges of cost estimates modelled. These inconsistencies will need to be addressed in the DBC. The key implication of this for the current work is the fact that it has not been possible to identify a single preferred option for the DBC. The implication for the DBC is that the incremental costs of the PDIP options (post essential works) could be significantly different to current estimates.

- *Alternative supply options and distribution scheme efficiency.* Option 3a includes a number of alternative water storages within the BWSS area. Consultation in the region revealed that there is some distribution 'bottlenecks'[4] in the BWSS that may be reducing irrigation efficiency in peak use periods and inhibiting development. Option 3a could both improve the efficiency of operations in relevant areas of the BWSS *and* may also mitigate an impediment to development (potentially accelerating growth in demand). This issue warrants consideration as a potential additional benefit of Option 3a within the DBC.

- *Correctly specifying benefits in the cost-benefit analysis (CBA).* The CBA to be undertaken for the DBC will need to assess the incremental benefits to downstream assets and economic activity associated with dam failure. This is particularly the case as dam safety failure is primarily attributable to extreme wet conditions, and under a wet weather scenario, much of the downstream area will already be impacted. This may also need to include the change in base-case flood risk attributable to the proposed levy on the east bank of the Burnett River in Bundaberg if that project is to be financed.

- *Alternative priority allocation water products.* Perennial tree crops (e.g. macadamias, avocadoes) have significantly different risk characteristics to low announced water allocations when compared to annual crops. For this reason, many irrigators have purchased additional allocations as a contingent supply. This is also a partial explanation for the major historical gap between total allocations and typical water usage. It would be prudent to investigate the possibility of establishing an 'interim' allocation product (e.g. a product that is more reliable than MP, but less reliable than HP) and subsequent prices. This product could enable irrigators of perennial tree

[4] Note: While SunWater regional staff agreed there were occasional challenges in meeting peak demand through the distribution system, the quantitative extent of these bottlenecks is not well understood.

crops to purchase and use an efficient portfolio of water allocations that better meets their needs and risk profile than the current MP allocation regime. This issue is likely to be relevant across several SunWater schemes. In addition, consultation at the Community Reference Group indicated an interest in a product of a lower reliability (and price) to the current MP allocations.

- *Market sounding and demand assessment.* A detailed market sounding approach is advisable for the DBC. This could include a number of specific elements including testing the sensitivity of demand to price and alternative water products.

- *Implication of groundwater water resource for Bundaberg Regional Council (BRC).* BRC currently has over 6,000 ML of groundwater allocations that are preferred for urban and industrial use due to cost. The level of uncertainty of the water resource's performance in the long-term should be considered more formally in the final demand assessments.

- *Sugar mill viability.* The development of new high-value crops in the region, particularly perennial tree crops, is effectively reducing sugarcane production areas and subsequently throughput through the mills. The base case for the economic and social impact assessment conducted as part of the DBC will need to be cognisant of the risk to mill viability. Similarly, impacts along the supply chain will need careful investigation.

CONTENTS

FIGURES

TABLES

Abbreviations

AA	Announced Allocations
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AEP	Annual Exceedance Probability
ALARP	As Low As Reasonably Practicable
ANCOLD	Australian National Committee on Large Dams
BoM	Bureau of Meteorology
BQ	Building Queensland
BRC	Bundaberg Regional Council
BWSS	Bundaberg Water Supply Scheme
CBA	Cost-Benefit Analysis
CO	Carry-over
CRA	Comprehensive Risk Assessment
DBC	Detailed Business Case
DoA	Department of Agriculture
DSR	Dam Safety Review
FAO	Food and Agriculture Organisation
FSL	Full Supply Level
FTE	Full-Time Equivalent
HP	High Priority
LGA	Local Government Area
LoT	Limit of Tolerability
MCA	Multi-criteria analysis
ML	Megalitre
MP	Medium Priority
NIEIR	National Institute of Economic and Industry Research
OECD	Organisation for Economic Co-operation and Development
p5	5th percentile
p95	95th percentile
PBC	Preliminary Business Case
PDIP	Paradise Dam Improvement Project
QEAS	Queensland Economic Advocacy Solutions
RCP	Representative Concentration Pathway
TT	Temporary Trade
WAE	Water Allocation Entitlements

1 CONTEXT AND APPROACH

1.1 Background

The Paradise Dam (previously called the Burnett River Dam) is a 52-m high concrete gravity-based structure on the Burnett River, approximately 80 kilometres southwest of Bundaberg. The Dam provides 124,000 ML of Medium Priority (MP) and 20,000 ML of High Priority (HP) water allocations. Sales to date have been around 20% and 14% of total MP and HP allocations, respectively. Construction of the Dam was finalised in 2005. At this time SunWater took ownership of Burnett Water Pty Ltd, which included Paradise Dam. The Dam creates a 45km long narrow reservoir with a surface area of 3,000ha and storage volume of 300,000 ML (SunWater, 2018).

One of the original drivers for the Paradise Dam project was to provide a reliable source of water for agriculture, industrial and urban users in Lower Burnett region. The need to meet demand for water to support the current and future economic and residential growth remains unchanged (SunWater, 2018). Consequently, each of the proposed options considered under the Paradise Dam Improvement Plan (PDIP) has been assessed for their ability to meet water demand to support agricultural production, residential and commercial and uses.

Agriculture, Forestry and Fishing accounts for 15.7% of value add in Bundaberg compared to 3.6% for Queensland (Australian Bureau of Statistics, 2018). Cane growing is the traditional key agricultural activity, however, more recently there has been some growth in the horticultural and vegetable production. Horticultural production includes macadamia nuts, avocados and citrus fruits.

Paradise Dam was built to meet the high priority urban water needs of Bundaberg and to support future growth in the agricultural industry in the Burnett River catchment (SunWater, 2018). Key users include:

- Urban water supplies (for Bundaberg and communities in the Burnett, Kolan and Isis Shires).
- Irrigated sugar (the dominant use by volume).
- Horticulture (e.g. tomatoes, rockmelons, beans, macadamia nuts and avocados, accounting for a relatively small volume, but for higher margin crops).
- Industrial use (including sugar mills).

Paradise Dam is a one of two major storages (the other being Fred Haigh Dam) that provide water to the Bundaberg Water Supply Scheme (BWSS). The BWSS includes 600km of channels and pipelines across seven district systems to supply in excess of 1,000 properties and a number of bulk and industrial customers. A schematic of the BWSS is shown in Figure 1.

While there has been some limited uptake in the water allocation, demand has been significantly lower than expected, which has in turn resulted in lower than anticipated revenue (SunWater, 2018).

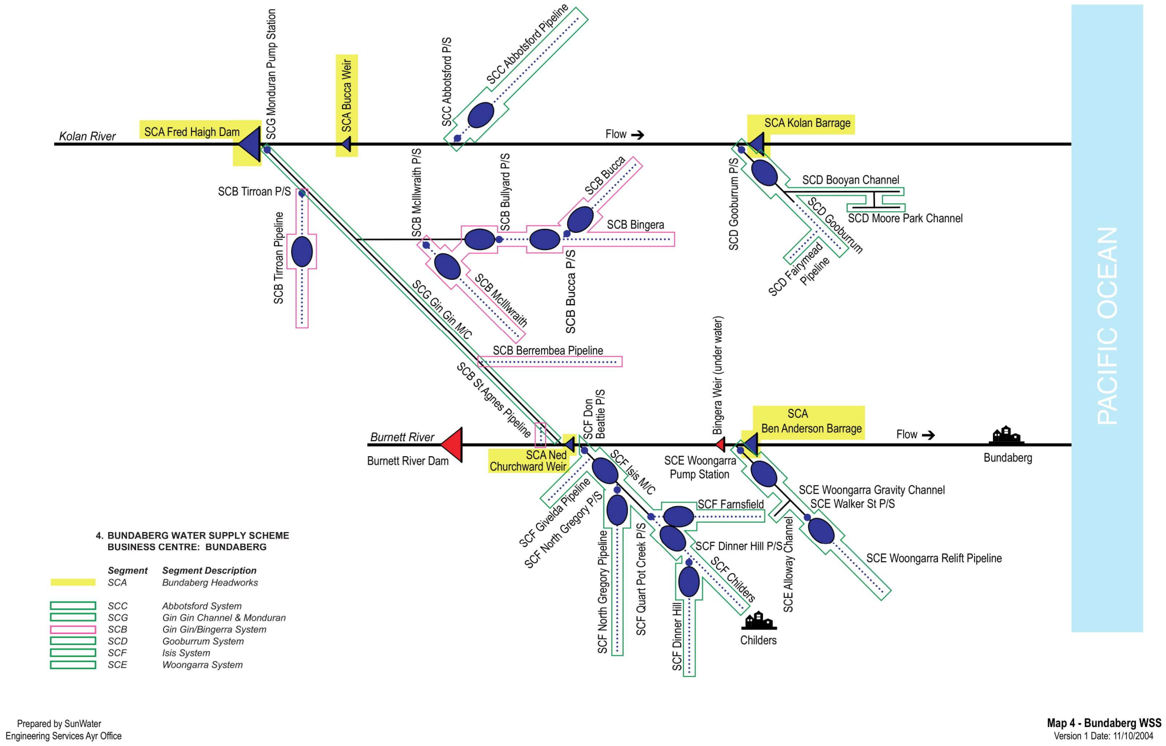

Figure 1. Schematic of Bundaberg Water Supply Scheme

Source: SunWater (no date) Bundaberg Water Supply Scheme overview manual.

1.2 Dam safety risks

Recent technical investigations identified structural problems with the Dam. This creates a risk of dam failure under extreme weather events such as those that occurred in 2013. The 2013 flood event caused extensive damage (approximately $67 million over the past five years) to the spillway dissipater and the rock foundation (SunWater, 2018). To reduce risk of failure the supply level of the Dam is being lowered by 5 m in the short-term, while a program of technical assessments and the development of options for the future of the Dam are being developed. Recent assessments have also indicated that upgrades to meet safety requirements will require substantial additional expenditure. Therefore, SunWater brought forward the 20-year Dam Safety Review (DSR) and Comprehensive Risk Assessment (CRA). The CRA report (2016) concluded that the current individual and societal risks are unacceptable and recommended that dam safety improvement works be undertaken to reduce the level of risk of failure.

In 2018 SunWater prepared a preliminary business case (PBC) that presented the evidence and rationale for upgrading the Dam to meet regulatory requirements and reduce the risk of dam failure as soon as practicable. Several options were considered, and two options were identified for detailed analysis under the Detailed Business Case (DBC). These were:

- Fully upgrade the Dam (retaining existing supply capacity, but at a higher cost).
- Lower the primary spillway (resulting in a reduction in fully supply levels but at a lower cost).

The key service needs identified for the PDIP are:

- Meet dam safety requirements (i.e. formally assessed 'Limits of Tolerability').

- Meet water demand out to the year 2050.
- Meet subsidiary issues (e.g. recreational opportunities, environmental considerations and social/cultural considerations).

The base case for the DBC will be PDIP options against a base case of a 5 m lowering (reflecting the immediate works to be commenced in 2020).

1.3 Options for assessment

To address the service needs, several PDIP options have been identified and assessed. These have been recorded in Table 1. Additionally, this assessment has briefly examined alternative portfolios of water supply options that could be used to achieve yields equivalent to the current FSL yield.

Table 1. The complete list of PDIP options that were assessed during this investigation

Options	Description
Business case options	
Option 1	Full upgrade without lowering the spillway.
Option 1a	Full upgrade without lowering the spillway crest level, to lower the dam safety risk to just below the Limit of Tolerability for existing dams.
Option 2	Lowering of spillway crest level by 5m and other strengthening works to reduce the dam safety risk below the Limit of Tolerability for existing dams.
Option 3	Lowering of spillway crest level by 10m to pass 1:15,000 AEP flood event and other strengthening works to reduce the dam safety risk below the Limit of Tolerability for existing dams.
Option 3a	Option 3 plus in-scheme alternative water supplies to match demand forecasts. These alternative storages have been identified and undergone a preliminary analysis under SunWater's Blueprint process.
Option 4	Optimal lowering of spillway crest level by between 5 and 10 m and other strengthening works to reduce the dam safety risk below the Limit of Tolerability for existing dams.
Option 5	Full dam decommissioning.
Option 5a	Option 5 plus alternative supply options to meet at least p95 demand estimate (projects in the demand area)
Non-business case options	
Option 2a	Option 2 plus alternative supply options to meet current yield
Option 3b	Option 3 plus alternative supply options to meet current yield
Option 5b	Option 5 plus alternative supply options to meet current yield

1.4 Purpose and structure of this report

As part of the development of a DBC, it is necessary to undertake a service needs of the Dam and a comparative options analysis. The purpose of this report is to scope the preferred option(s) for greater detailed analysis in the DBC (e.g. the 'project case' for the cost-benefit analysis). The options analysis requires the use of a number of methodologies to address the desired service needs, including dam safety, water supply (rural, urban, industrial), social (including recreation and amenity) and environmental.

Key point

This report summarises the process and findings from an independent assessment of long-term demand requirements and the options available to meet this need. This work scopes the preferred options for consideration in the Detailed Business Case (DBC).

This report is structured to allow decision makers to quickly read the key issues, findings and recommendations in the body of the report and refer to a series of appendices when more detailed information is required. The body of the report is structured as follows:

- Section 2 summarises the service need for Paradise Dam.
- Section 3 summarises the findings from the demand estimates assessment for both MP and HP allocation needs (out to the year 2050).
- Section 4 summarises the findings from the Options Assessment.
- Section 5 briefly provides our recommendations for the DBC.

Detailed appendices are provided, specifically:

- Appendix A: Service needs.
- Appendix B: Demand estimates.
- Appendix C: Alternative supply options.
- Appendix D: Options assessment.
- Appendix E: Non-business case options.

These appendices document in detail the approaches used, information and data, assumptions, and findings from the analysis and consultation, including comprehensive sensitivity testing.

2 SERVICE NEEDS

The service needs for the PDIP assessment consist of two core service needs (i.e. dam safety and water supply) and three secondary service needs (i.e. recreation, environmental and social/cultural). The number of service needs has been deliberately limited to avoid overcomplicating the consultation and decision-making process.

Figure 2 articulates these service needs through the framework of a partial investment logic mapping exercise, which includes a problem statement, the associated opportunities and the multiple benefits sought that could be addressed by the PDIP options.

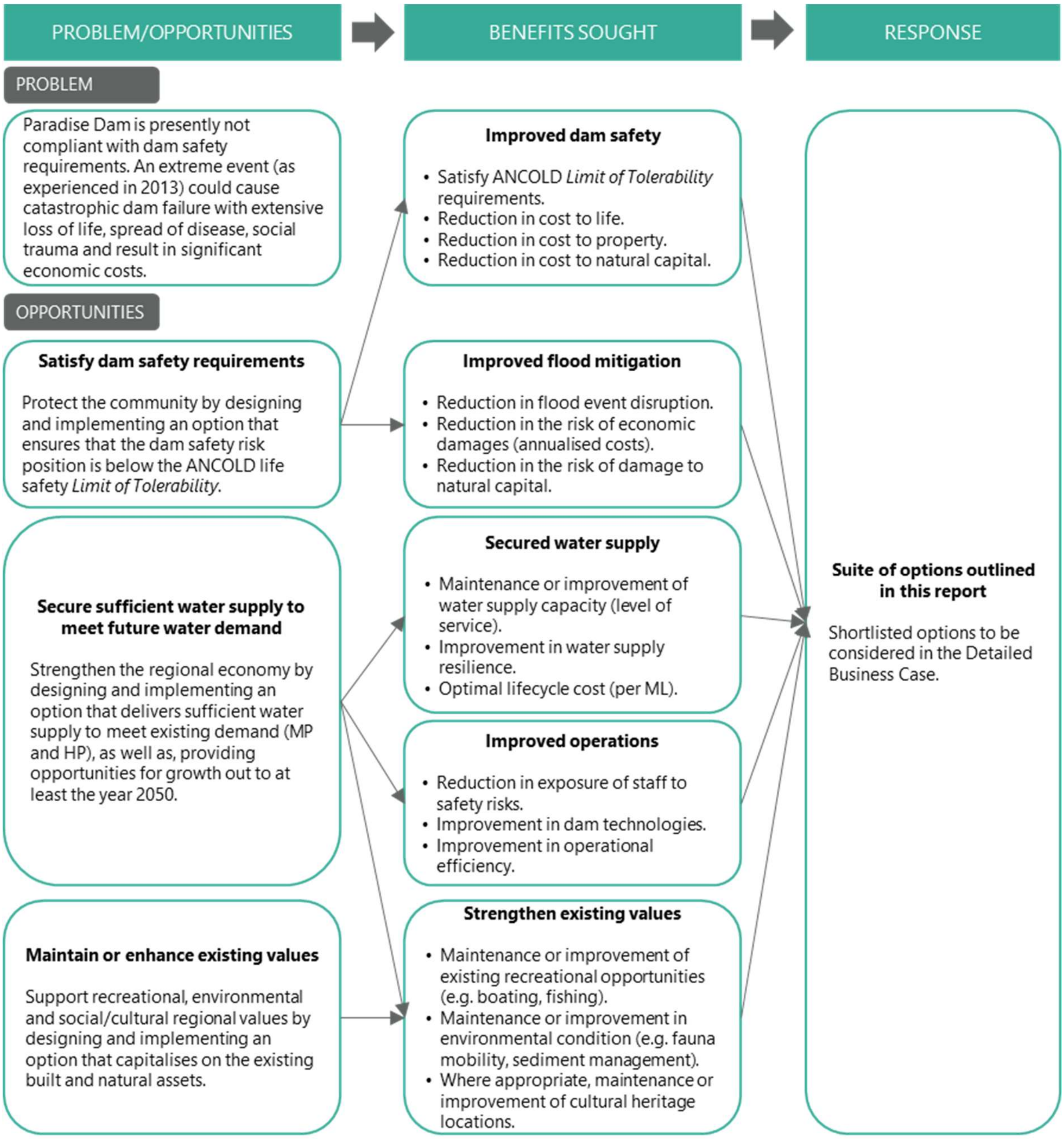

Figure 2. Articulating service needs through a partial investment logic map

Additional explanation of the service needs is included in Table 2. These service needs, in conjunction with an assessment of establishment cost for each PDIP option, forms the basis of the Options Assessment (see Section 4). Service needs are outlined in more detail in Appendix A.

Table 2. Service needs summary

Problem/s	Benefits of PDIP	Service need	Service need definition
Primary service needs			
Existing dam is not compliant with dam safety requirements.	PDIP will address and rectify risks.	Dam safety.	An option will satisfy the dam service need once the risk position is below the ANCOLD life safety limit of tolerability. This is a threshold test that must be met for any option to be acceptable.
Some options may result in shortfalls in water supply for community and commercial use.	PDIP (and potential complementary projects) will ensure water supply needs are met.	Meet future water requirements.	Ranges of demand estimates (MP, HP and aggregate standardised estimates (e.g. all MP equivalent)) for all key water use categories over the forward period. All measures in ML/annum. Benchmarking service needs estimates against yields from PDIP options.
Secondary service needs and considerations			
Dam safety risk could constrain recreational opportunities at the site.	A safe dam site will ensure recreational opportunities can continue.	Recreational use opportunities.	The scope of recreational opportunities at the dam site from the preferred PDIP option are not materially different from current opportunities.
Failure of existing dam creates environmental risks and results in costs. There are environmental risks inherent to the preferred PDIP option.	PDIP will mitigate dam failure risks and subsequent environmental risks of a failure. PDIP will address environmental risks associated with construction and future operations.	Environmental risks.	Environmental risks are not materially different from current levels.
Failure of existing dam creates social and cultural risks and results in costs. Minor social and cultural risks may be inherent in the preferred PDIP option.	PDIP will mitigate dam failure risks and subsequent social and cultural risks of a failure. PDIP will address social and cultural risks associated with construction and future operations.	Social and cultural risks.	Social and cultural risks are not materially different from current levels.

Key points

The service needs for the PDIP assessment consist of two core service needs (i.e. dam safety and water supply) and three secondary service needs (i.e. recreation, environmental and social/cultural).

These service needs, in conjunction with an assessment of establishment cost for each PDIP option, forms the basis of the Options Assessment.

3 DEMAND ESTIMATES

A key driver for the PDIP is to continue to provide a reliable source of water for agriculture, industry and urban users in the Lower Burnett region. The ability to meet the water demand is seen as critical as it supports current and future economic and residential growth.

A comprehensive and detailed demand assessment was undertaken involving several procedures, including:

- An assessment of the broader macro factors driving demand (e.g. demographics and economy, broad trends in commodity markets and prices, land use change and climate change).
- Econometric analysis of historical usage.
- Detailed assessments of prospects, trends and water requirements for major irrigation crops using MP allocations including: sugarcane, macadamias, avocadoes, citrus, other fruit, seasonal vegetables, pasture/fodder and other broadacre crops. These assessments considered water as a derived demand, that is water demand is a function of the demand for the crops produced under irrigation.
- Detailed assessments of urban and industrial demand for HP allocations.
- Consultation with key industry and stakeholders. This included stakeholders within the region (a sample of smaller to larger individual farmers via confidential meetings and interviews, larger operators undertaking value-adding, representative of industry bodies, Council) competing regions (particularly industry representatives in northern NSW for perennial tree crops), and entities along the supply chain for key commodities (e.g. processors and supermarket chains). Unlike many other demand assessments, there is a wealth of historical data available to underpin consultation, although more extensive consultation will be required for the DBC.

A detailed documentation of the demand assessment is provided in Appendix B. The following sections summarise the key point and findings of the demand assessments.

3.1 Macro factors impacting on demand assessment

There are a number of macro-economic factors and trends that influence current and future demand.

Demographics and economic factors

The Queensland Government Statistician's Office estimate the Bundaberg regional population will grow from around 93,500 in 2018 to between 106,000 to 135,000 by 2041 (Queensland Treasury, 2018). Consultation with Bundaberg Regional Council's (BRC) Economic Development group indicated that the population growth outcomes will be highly dependent on maintaining current economic activity, while the higher growth prospects are reliant on irrigated agricultural intensification and associated value adding. In effect, agriculture has been the region's competitive advantage and this is expected to be the case into the future.

Of the estimated 31,100 employed in the BRC LGA, the dominant sector is heath care and social assistance (14% of total employment). However, agriculture, forestry and fishing (largely irrigated agriculture) at 12% and manufacturing at 11% (dominated by food manufacturing) are the next major categories.

Key points

The local economy is highly reliant on irrigated agriculture for economic prosperity and employment.

Population growth is tied to economic prospects in agriculture and associated sectors and will also drive water demand.

Trends in key commodity prices

While sugarcane has been the dominant irrigation crop in the region for decades and accounts for the vast majority of irrigated land use and water, there have been changes in irrigated crop use in recent years in response to the relative performance of commodity markets. Figure 3 shows an index of farm gate commodity prices since the completion of Paradise Dam. The underlying trends in commodity prices over the past 10 years are consistent with changes in land use and subsequent changes in irrigation water demand.

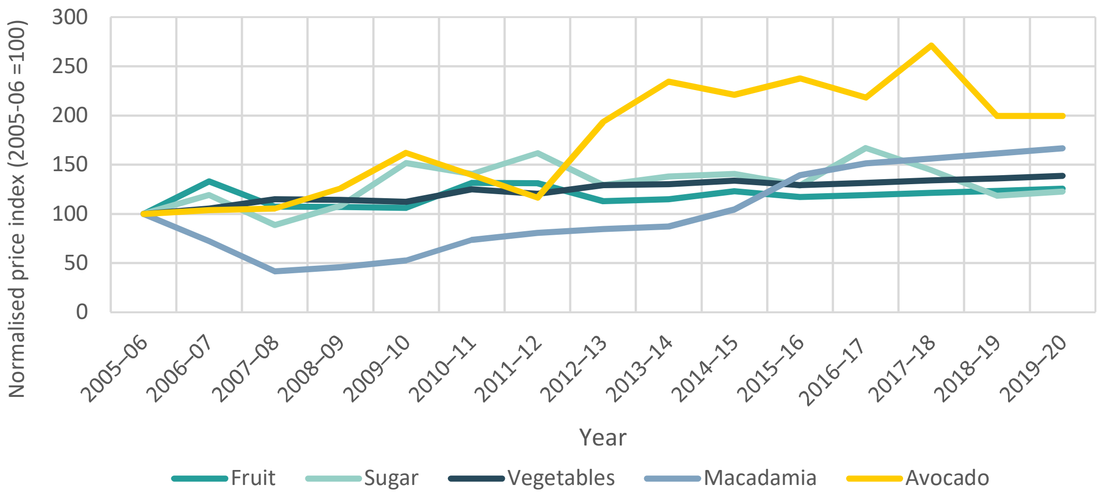

Figure 3. Index of farm gate commodity price index (2005/06 = 100)

Sources: ABARES (2019). Agricultural commodities: September quarter 2019; Australian Macadamia Society (2019). Factsheet. Farm Gate Prices; Avocados Australia. Facts at a Glance for the Australian Avocado Industry 2018/19.

Key points

Recent results and market prospects for alternative commodities across the region differ. While the medium-term international outlook for sugarcane is subdued, the outlook for tree crops (e.g. avocado and macadamia) is strong.

Furthermore, the outlook for fruit and vegetables is also relatively strong, as the Bundaberg region continues to exploit counter-seasonal production opportunities to meet consumer preferences for continuity of supply for fruit and vegetables throughout the entire year.

Changes in land use

The nature of irrigated agriculture in the region is changing as the economic viability of some crops is reduced through market pressures, while other opportunities emerge. Consultation in the region indicated that the actual expansion of irrigation areas in recent years has been negligible. Rather, the trend is for existing irrigated sugarcane land within the BWSS to be converted to higher value crops. The conversion from sugarcane to other crops was mapped for the period 1999 to 2017 (latest data) and is presented in Figure 4. While the accuracy of this State land use mapping could be improved, the trends shown are consistent with consultation in the region. Consultation revealed that there has always been a degree of crop substitution, but until recently this has been between annual crops depending on short-term market conditions. However, in recent years, the trend is towards perennial tree crops.

The rate of land use change to higher-value tree crops is somewhat constrained by:

- Financial factors, specifically the large investments required and significant lags between tree crop establishment and harvestable product.
- Physical constraints in the availability of tree stock.

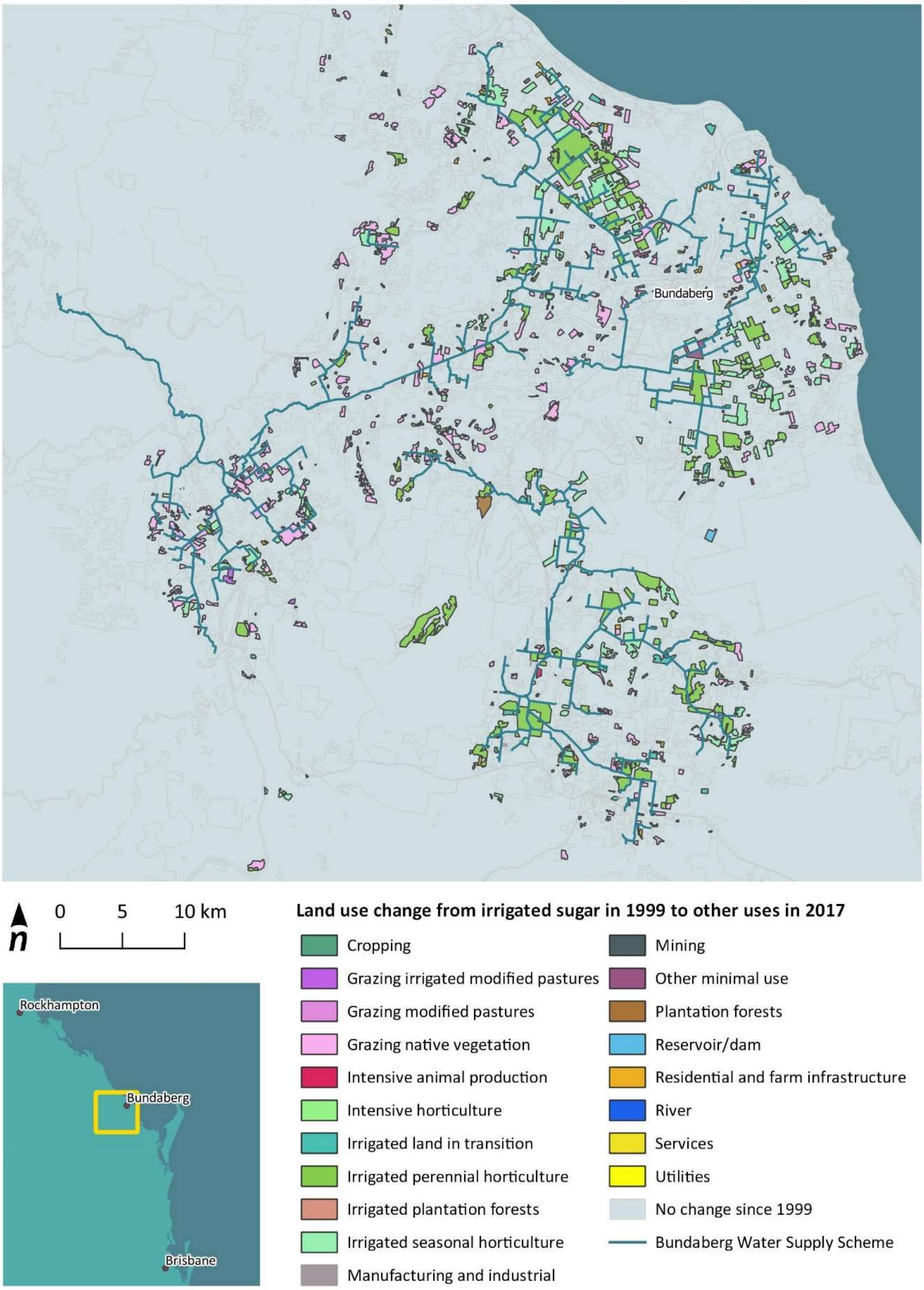

Figure 4. Change in irrigated cropping (sugarcane to other crops 1999 to 2017)

Source: Queensland Land Use Mapping Program.

Processing and other value adding capacity is not seen as a major constraint as many larger producers are seeking to establish their own capacity to capture greater revenues, while also acting as aggregators and processors for smaller producers. Larger producers have also tended to employ experienced senior staff from southern states with detailed knowledge of perennial tree crops. This have overcome a key impediment to industry growth.

Key point

Estimates of growth in water demand attributable to expanded areas of horticulture crops need to be net of reductions in water demand from sugarcane.

Climate and climate change

Climate has always been one of the region's historical advantages. Agriculture has benefited from reasonable levels of rainfall and temperatures to meet the requirements of multiple agricultural activities including crops and livestock. For horticulture crops, this advantage has often resulted in an ability to meet counter-seasonal market demand (i.e. typical summer crops grown in the winter months). This is largely in response to consumer demand for continuity of supply of fresh fruit and vegetables throughout the calendar year.

In the longer-term, climate change will have an impact on the region's competitive advantages, productivity, and irrigation requirements. By 2050, the expected peak temperatures will have a detrimental impact on the productivity and viability of some crops, while irrigation rates will likely need to increase to compensate for declines in long-term rainfall expectations.

Key point

In the longer-term, climate change will have an impact on the region's competitive advantages, productivity, and irrigation requirements. This may moderate longer-term rates of development.

3.2 Demand for medium priority allocations

Since the establishment of Paradise Dam in 2005, the sales of allocations and use of water has been significantly lower than what would have been used to justify the original investment in the Dam. The use of water for irrigation is a derived demand, with demand for irrigation water being highly dependent on current and expected commodity and market prospects. Table 3 provides an overview of the prospects for the key irrigation crops in the region.

Table 3. Summary of crop trends and prospects

Crop		Summary of trends and prospects
Sugarcane	(red)	Export and 'price-taker'. Dominant crop by area and use, but declining due to market conditions. Other crops being established on former sugarcane farms. Risk of decline.
Macadamias	(green)	Major growth (around 300 ha/yr). Reasonable domestic prospects, but investment driven by export opportunities. Processing / logistics investments in place. Constraints in growth relate to working capital needs and a shortage of grafted tress. Climate change (heat stress) risks in longer-term.
Avocado	(green)	Counter-seasonal opportunities. Rapid growth in recent years (around 120 ha/yr.), but growth slowing as domestic market approaches saturation. Export opportunities slowly expanding. Climate change (heat stress) risks in longer-term.
Citrus	(amber)	Negligible growth in recent years.
Other fruit	(amber)	Counter-seasonal opportunities. Largely focussed on domestic market and growth. Berries experienced significant growth, but prices and export volumes have stalled.
Vegetables	(amber)	Counter-seasonal opportunities with domestic fresh market focus. Climate change risks in long-term.

Crop		Summary of trends and prospects
Broadacre, fodder		Often used as 'swing crops' responding to short-term market conditions or as a crop between final sugarcane ratoon and replanting.

Source: NCEconomics analysis and consultation

Table 3 is a summary of detailed analysis outlined in Appendix B. Appendix B includes crop-specific assessments of:

- The current situation and water use.
- Demand drivers and market opportunities.
- A range of key data inputs and assumptions used as input parameters within the demand forecasting model. This includes rates of land use change, crop requirements, water allocation reliability requirements, and the impacts of climate change.

One of the key findings from the analysis was that despite significant recent growth in high value crops (particularly macadamia and avocadoes), this development is occurring on former sugarcane farms. In effect, the growth in water demand is the net impact of requirements for perennial tree crops and the water requirements previously used for growing sugarcane.

Many farmers are deliberately undertaking a gradual conversion to ensure cashflow from annual sugarcane crops is available to offset the 5 – 10 year lags between tree establishment and a full crop from perennial tree crops.

Furthermore, because perennial tree crops have a significantly greater downside risk of very low announced allocations, irrigators often hold more allocations than they would use in a typical year. Effectively, holding additional allocations is a risk management strategy.

The implications of such strategies are supported by econometric analysis, which found that while irrigators use more water in dryer years, the additional water use is less than the reductions from average rainfall in the region.

Key points

Much of the growth in demand for high value crops is not significantly increasing water demand as this development is occurring in areas that were previously irrigated sugarcane. Hence only the net change between crop requirements per ha impacts on aggregate water demand.

Perennial tree crop development is driving an emerging trend towards some irrigators holding additional MP allocations as a risk management strategy for years of low announced allocations.

Aggregate MP estimates

Using the data, insight from consultation and other information, aggregate MP demand for every year to 2050 was modelled. Given the significant range of input data and the need for assumptions, stochastic modelling was used to develop a probabilistic range of estimates based on a number of key data inputs and the range of values for each one.

The aggregate MP allocations estimates are based on the net change associated with the change in crop mix within the BWSS. In effect, this is the effect of growth in high value crops (predominantly trees), net of the reduction in water use attributable to declining sugarcane production. The full range of estimates out to 2050 against yields for the FSL, 5 m lowering and 10 m lowering (the horizontal lines) are outlined in Figure 5 (overleaf).

The green demand line shows the mid-point of estimates. The yellow and grey lines show the high and low demand estimates from the sensitivity analysis. The extremes are significantly impacted by the wide range of possible outcomes in current climate modelling, and the broad range of future development scenarios.

The high demand estimate is significantly influenced by the high irrigation requirements for macadamia and avocados. These high requirements represent the emerging practice of spray irrigation versus more efficient drip irrigation.

Key points

- A *10 m lowering* does not provide an opportunity for growth in sales of MP allocations. Any future growth of crops would require greater utilisation of existing allocations (e.g. facilitated by trade),or would require the development of one or more of the alternative supply options currently under consideration by SunWater.
- A *5 m lowering* would be sufficient to meet the mid-point demand estimates out to 2050. However, the high demand estimate would exceed yield in around 2045. The high demand estimate could be lowered significantly through more efficient pricing of water service charges and / or the establishment of a new form of allocation that reflects the reliability requirements of perennial tree crops.
- *Current full supply level* vastly exceeds all possible growth scenarios.

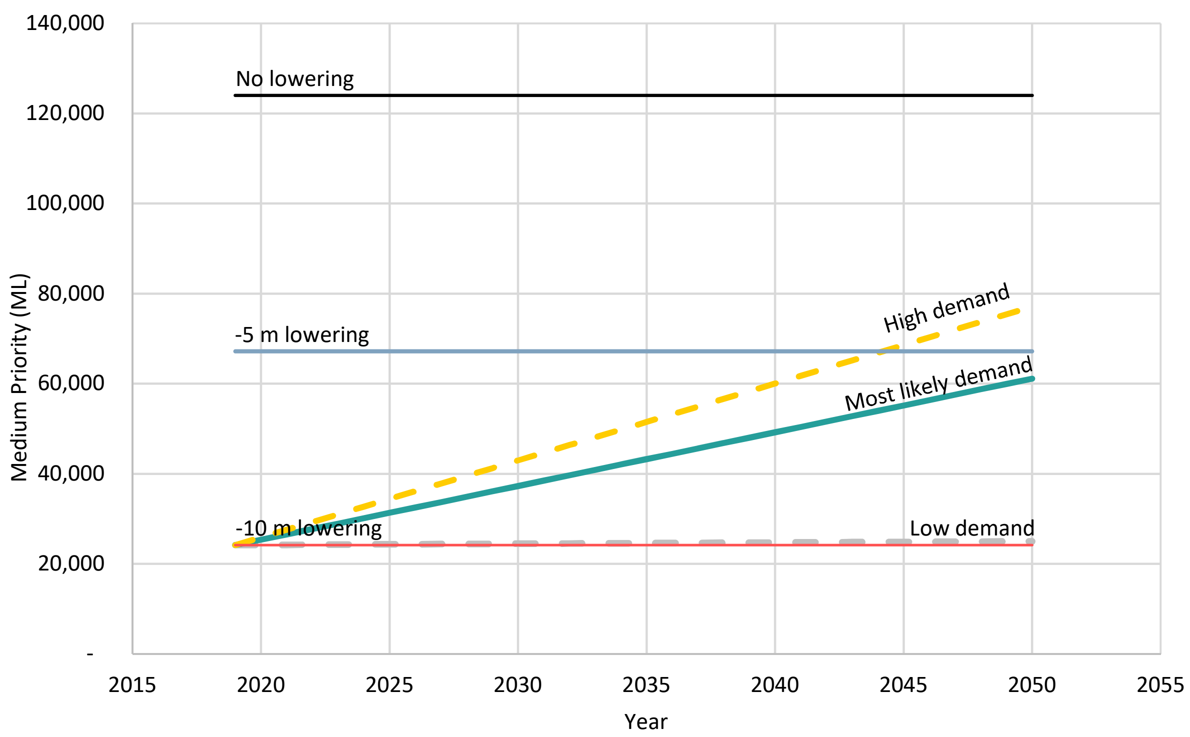

Figure 5. Estimates medium priority (MP) demand vs options yield (ML/year)

3.3 Demand for high priority allocations

The HP demand profile is serviced from multiple sources (Paradise Dam, Fred Haigh Dam and groundwater). BRC holds a groundwater allocation of 6,430 ML and 9,588 ML in surface water allocations (from Paradise and Fred Haigh dams).

BRC's strong preference is to utilise groundwater whenever possible as this source is relatively more cost-effective to treat to potable water standards. Allocations from Fred Haigh Dam face supply and reliability constraints and high costs to use within the BRC serviced network. Therefore, it is most likely that future HP needs would be met through Paradise Dam allocations.

Residential demand has historically grown in line with population (with short-term variability around the mean growth rate). It is assumed this general relationship and applied it to the future population projection to establish a range of estimates for residential use.

Consultation undertaken as part of the analysis indicated that there were no major commercial/industrial projects in the future that would cause a step-change in water demand.[5] Therefore, it has been assumed that commercial/industrial water demand growth will continue to grow at the same rate as population.

Aggregate HP estimates

The full range of estimates out to 2050 against yields for each of the PDIP options (the horizontal lines) are outlined in Figure 6. It shows that even with a 10 m lowering (the black horizontal line) there is a significant excess of HP yield.

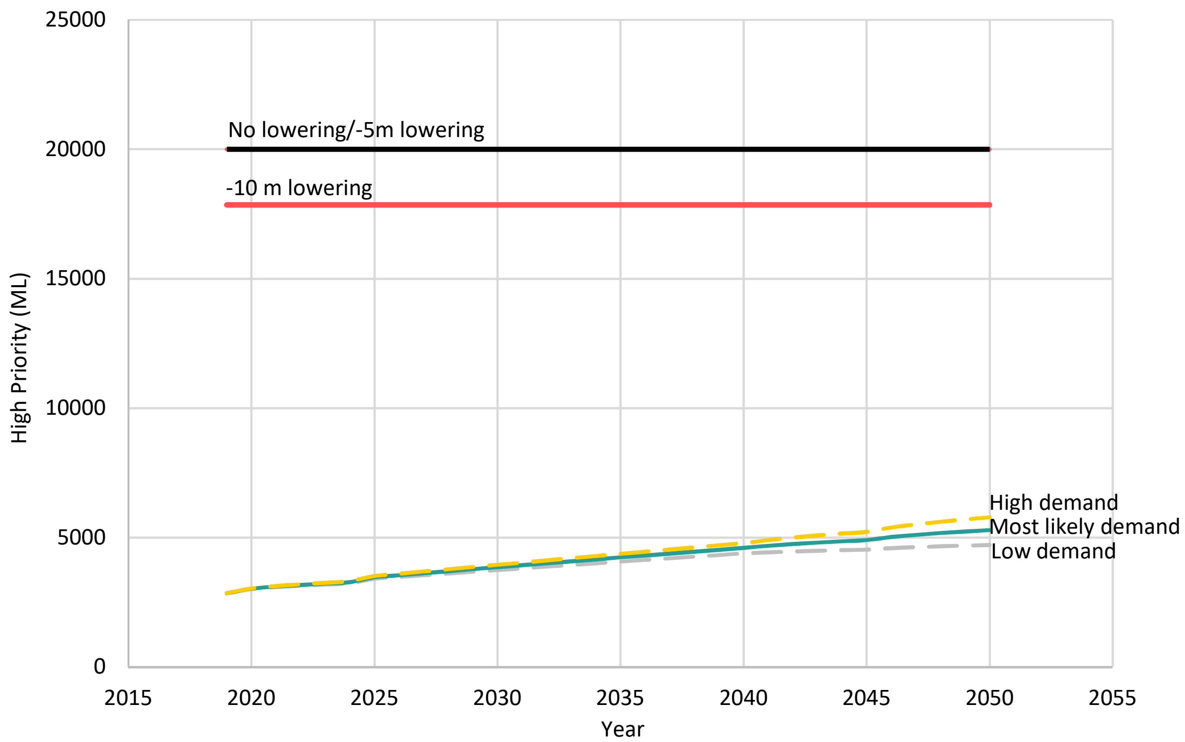

Figure 6. Estimated high priority (HP) demand vs options yield (ML/year)

Source: NCEconomics analysis and consultation

Key point

All PDIP options assessed (excluding decommissioning) meet even the highest HP demand estimate.

[5] The Bundaberg Beverages soft drink factory is not predicted to cause a step-change. The BRC Economic Development group were not aware of any other major projects in the investment pipeline that could trigger a major increase in water requirements.

3.4 Implications for the options assessment

The analysis has a number of implications for the Options Assessment, particularly with respect to the outlying probability that demand for MP allocations could exceed the yield from a 5m lowering. There are two options to address this risk:

- **Portfolio of options.** Consider a potentially more cost-effective portfolio of options to meet demand. This could include the option to lower Paradise Dam by 10m, with the cost reductions used to establish a more cost-effective supply augmentation (e.g. Ned Churchill Weir).
- **Conversion of excess HP to MP** allocations. Under this option, HP allocations that will not be required could be converted to MP allocations at a later date if the higher end of the demand estimates materialise. Under the Burnett Basin Resource Operations Plan (Queensland Government, 2003), the rate of conversion of HP to MP is a factor of 2.5:1. Figure 7 shows the findings of an analytical exercise where all allocations are converted to MP equivalents. It shows the estimated aggregated MP + HP demand and yields in MP equivalents (ML/year). The 5m lowering option would meet even the high demand scenario if conversions were undertaken. The 10m lowering option would meet the high demand scenario to 2033 and the most likely demand estimates until 2045.

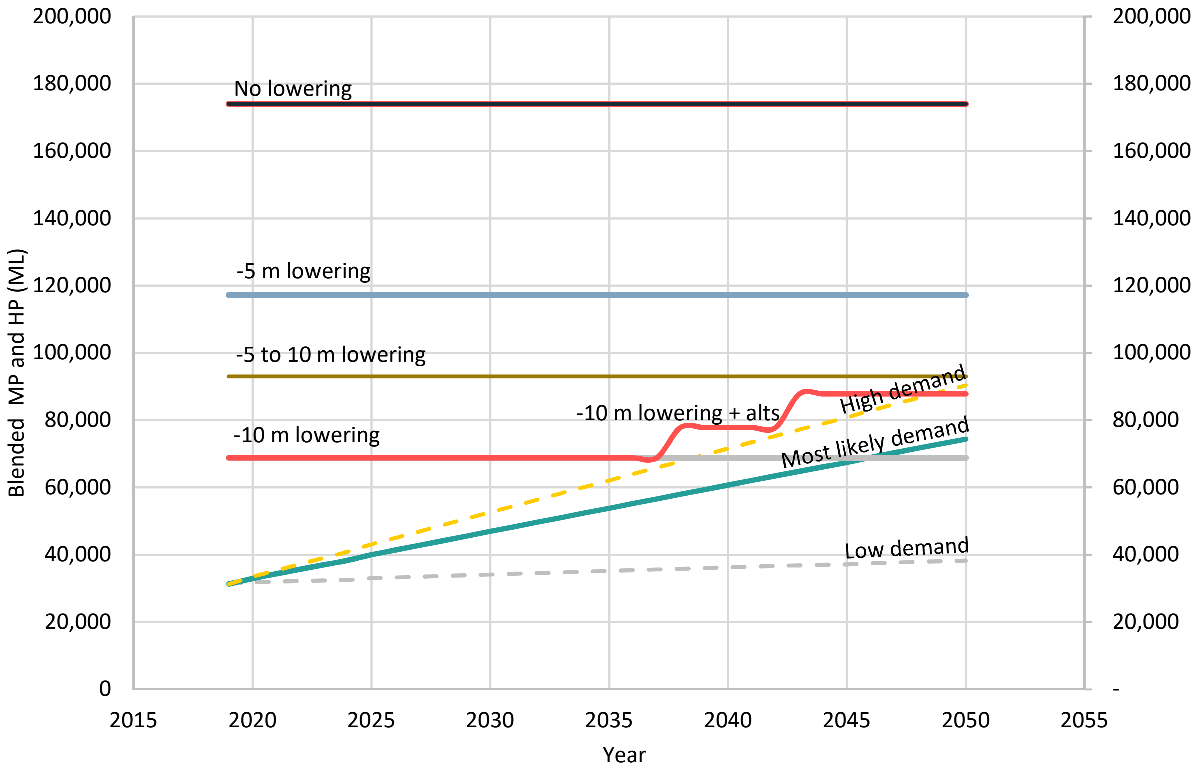

Figure 7. Estimated aggregated MP + HP demand and yields (all in MP equivalents) (ML/year)

Source: NCEconomics analysis and consultation.

Key points

The conversion of some unsold HP allocation to MP would enable a 5m lowering of the dam wall to meet demand growth for the short to medium-term.

The assessment found that a 5m lowering of the spillway crest level is estimated to meet the demand requirements out to 2050 (provided that unused HP allocations are converted and sold as MP allocations).

A 10m lowering of the spillway crest level would result in shortfalls in meeting the 'most likely' demand estimates around 2045, and significantly earlier if the higher end of the demand estimates are realised. It is this finding that has resulted in the development of Option 3a for assessment.

4 OPTIONS ASSESSMENT

4.1 Options assessed

As part of the development of the DBC, a comparative analysis of each of the options identified and scoped for the PDIP has been undertaken.

This section briefly outlines the assessment approach and findings for each of the options contained in Table 4. Further detail relating to the approach, data and information, findings and sensitivity analysis is provided in Appendix D.

Table 4. Overview of options

Option	Yield (in MP equivalents)	Description
Option 1 – Maintaining full supply level	174,000 ML	Post tension anchoring: • Primary Spillway 98 No. 91 Strand PT anchors • Secondary Spillway monos L-R 24 No. 82 strand PT anchors. Monos S-W 10 No. 55 strand anchors • Left Abutment 10 No. 73 Strand PT anchors 60m Long Stilling basin New Gravity Training Walls Secondary Spillway Side Channel and Gravity Wall Outlet works modifications Left abutment and Basalt pimple erosion protection
Option 1a- Full upgrade without lowering the spillway	174,000 ML	Post tension anchoring: • Primary Spillway 98 No. 91 Strand PT anchors. • Secondary Spillway monos L-R 24 No. 82 strand PT anchors. Monos S-W 10 No. 55 strand anchors. • Left Abutment 10 No. 73 Strand PT anchors. 60m stilling basin. New gravity training walls. Secondary spillway side channel and gravity wall. Outlet works modifications. Left abutment and basalt pimple erosion protection. Temporary coffer dam upstream of secondary spillway Demolition of Monoliths R-W Removal of 5-8m of poor foundation material Rebuild Monoliths R-W
Option 2 – Lowering of spillway crest level by 5m and other strengthening works	117,186 ML	Primary spillway lowering by 5m. Raising of the secondary spillway by 5m. Post tension anchoring: • Primary Spillway 84 No. 91 Strand PT anchors. • Secondary Spillway monos L-S 57 No. 55 strand PT anchors. Monos R-W 73 No. 27 strand anchors. 55m stilling basin. Capping of the secondary spillway channel. New gravity training walls Lowering of Intake tower and fishway. Remediation of reservoir rim. Outlet works modifications.

Option	Yield (in MP equivalents)	Description
		Left abutment and Basalt pimple erosion protection.
Option 3 – Lowering of spillway crest level by 10m and other strengthening works	68,809 ML	Primary spillway lowering by 10m. Post tension anchoring: • Primary Spillway 35 No. 91 Strand PT anchors. • Secondary Spillway monos L-R 30 No. 82 strand PT anchors. Monos S-W 10 No. 24 strand anchors. 50m stilling basin. New gravity training walls. Lowering of Intake tower and fishway. Remediation of reservoir rim. Outlet works modifications. Left abutment and Basalt pimple erosion protection.
Option 3a plus alternative supplies	87,809 ML	Option 3 plus in-scheme alternative water supplies to match demand forecasts. These alternative storages have been identified and undergone a preliminary analysis under SunWater's Blueprint process.
Option 4 – Optimal lowering of spillway crest level by between 5 and 10m, and other strengthening works	92,997 ML	No detailed description developed to date. However, this option will lie somewhere between options 2 and 3.
Option 5 – Full decommissioning	0 ML	Dewatering of the reservoir. Removal of the dam structure, outlet works and associated facilities. Removal/treatment of sediments which have accumulated in the reservoir. Rehabilitation and revegetation of the reservoir area.

Source: Provided directly by SunWater. Craig Hillier pers. Comms.

In addition to these options, where an option falls short of the estimated current and future demand, the demand shortfall can be met by either:

- Considering a PDIP option with a higher yield (e.g. a 5m lowering compared to a 10m lowering), or
- Supplementing dam supply with alternative supply option(s)[6] to provide sufficient yield to cover the current and future demand estimates.

The decision to use alternative options is made in consideration of the incremental cost of selecting a more expensive PDIP option versus the cost of the alternative water supply option(s). In this way, the analysis is consistent with good practice water supply planning (i.e. meeting water demand at the lowest cost).

[6] The list of alternative supply options was provided by SunWater. A brief assessment of these options is provided in Appendix C.

Key point

The options assessment analysed all PDIP options and alternative supply options as identified and scoped by SunWater.

4.2 Approach

A two-stage process was used for the Options Assessment, specifically:

1. A threshold approach to eliminate any options that did not meet the critical service need (i.e. dam safety or water supply requirements).
2. A multi-criteria analysis of all remaining options to identify the recommended options for consideration in the DBC.

Threshold Analysis

Threshold analysis was employed to eliminate unacceptable options. The thresholds that were applied were:

- Ability to meet dam safety requirements.
- Ability to meet current and future demands.

The remaining options were assessed further through a multi-criteria analysis (MCA).

Broad framework: multi-criteria analysis

Consistent with common practice, a MCA was used to underpin the Options Assessment. MCA is a decision support tool that was developed as an approach for use in operations research, where decision makers attempt to assess multiple options across a range of decision factors (reasons or considerations) that may have different and inconsistent assessment measures, including non-monetary valuation.

MCA has been widely adopted in the fields of water and environmental management as it is valuable in assessing unique elements of a project that do not include financial components.

Figure 8 provides an overview of the MCA structure used for the Options Assessment, including alignment with the PDIP service needs.

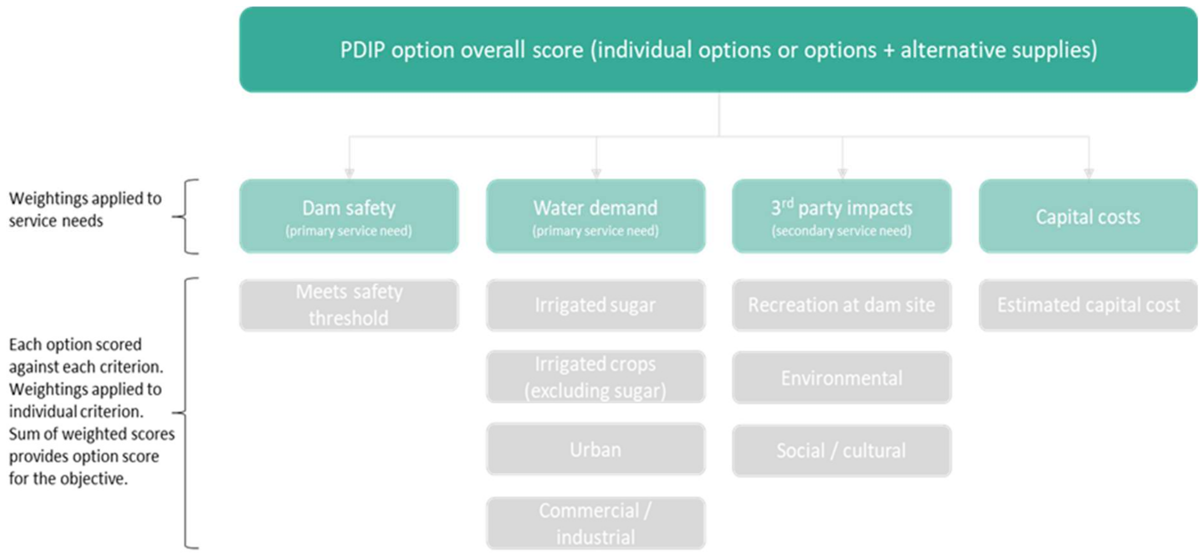

Figure 8. Structure of the MCA to underpin the Options Assessment

The MCA involved a systematic analysis of each options including:

- Establishment of weights for each of the service needs/criteria.
- Assignment of scores for each of the options.
- Normalisation of assigned scores.
- Estimating weighted average scores for each of the options.
- Sensitivity analysis.

An initial assessment was undertaken by the project team. This assessment was subsequently reviewed through an options assessment workshop with the Project Steering Group and Project Working Group. This included amending the scoring of individual options and specifying the range of key parameters underpinning the sensitivity analysis.

4.3 Key metrics summary

Key metrics underpinning the analysis for the primary service needs and costs are outlined below.

Dam safety

The assessment of dam safety risk against the Limits of Tolerability are shown Figure 9. It generally shows that options to maintain the FSL are only acceptable with the significant additional works. Options that involve the lowering by 5 m will meet the Limits of Tolerability, while the option to lower by 10 m comfortably meets requirements. It is assumed that the alternative supply options (i.e. for Option 3a) will meet safety requirements.

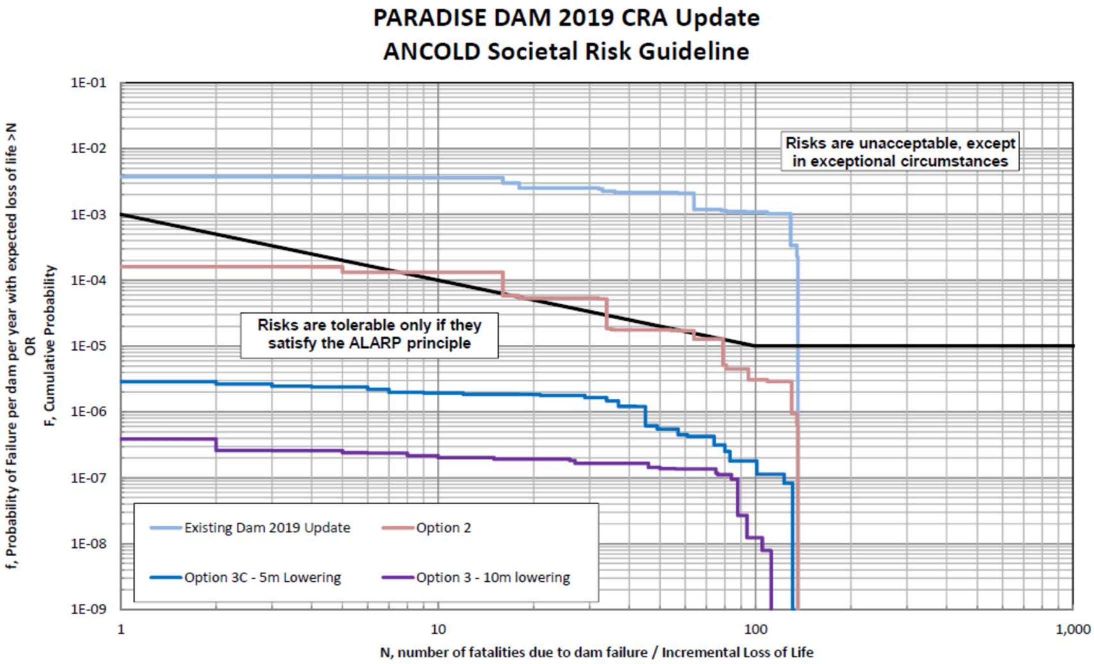

Figure 9. Dam safety assessment[7]

Source: Aurecon (2020). Paradise Dam upgrade options assessment: independent design, cost and risk review. Prepared for Building Queensland.

[7] NB – Pending updated chart for final report.

Demand estimate and supply yield

Table 5 summarises the estimates of demand and supply yield for each option in five-year increments. These data underpin the assessment of water supply service needs within the options assessment.

Table 5. Estimated aggregated MP+HP demand (ML) at 5-year intervals and supply yield as at 2050

Year	2020	2025	2030	2035	2040	2045	2050
Demand (all MP equivalent)							
Low (p5)	31,761	32,960	34,028	35,061	36,073	36,912	37,966
Most likely	32,935	40,003	46,941	53,843	60,724	67,433	74,356
High (p95)	33,485	43,301	52,987	62,636	72,266	81,722	91,393
Supply yield (all MP equivalent)							
Option 1a- Full upgrade	174,000	174,000	174,000	174,000	174,000	174,000	174,000
Option 2 – Lowering by 5m	117,186	117,186	117,186	117,186	117,186	117,186	117,186
Option 3 – Lowering by 10m	68,809	68,809	68,809	68,809	68,809	68,809	68,809
Option 3a plus alternative supplies*	68,809	68,809	68,809	68,809	77,809	77,809	87,809
Option 4 –Optimal lowering	92,997	92,997	92,997	92,997	92,997	92,997	92,997
Supply yield (% of high demand)							
Option 1a- Full upgrade	520%	402%	328%	278%	241%	213%	190%
Option 2 – Lowering by 5m	350%	271%	221%	187%	162%	143%	128%
Option 3 – Lowering by 10m	205%	159%	130%	110%	95%	84%	75%
Option 3a plus alternative supplies*	205%	159%	130%	110%	108%	95%	96%
Option 4 –Optimal lowering	278%	215%	176%	148%	129%	114%	102%

* Includes addition of Bucca Weir 1.5m raising in 2038 and Ned Churchward Weir 2.m raising in 2043

Estimated establishment costs

The estimated establishment costs for each option are shown in Table 6 and includes the most likely estimates provided by SunWater. Effectively the greater the degree of lowering of the dam wall, the lower the additional engineering requirements required to meet dam safety requirements (i.e.

additional costs of lowering the actual wall are more than offset by costs reductions to meet dam safety thresholds).

Table 6. Range of estimated establishment costs (present values)

Year	Low (p5)	Most likely	High (p95)
Option 1a- Full upgrade	$555,000,000	$800,000,000	$1,381,000,000
Option 2 – Lowering by 5m	$524,000,000	$597,000,000	$770,000,000
Option 3 – Lowering by 10m	$448,000,000	$510,000,000	$658,000,000
Option 3a plus alternative supplies	$431,000,000	$527,000,000	$744,000,000
Option 4 –Optimal lowering	$486,000,000	$554,000,000	$714,000,000

Source: NCEconomics modelling using data supplied by SunWater.

The low (p5) and high (p95) estimates are based on the Monte Carlo simulations of cost data. This data has been used to assess the costs effectiveness of each option in the Options Assessment.

4.4 Findings

This section summarises the key findings from the analysis.

Threshold analysis

The threshold analysis identified that two options do not meet service need requirements, specifically:

- Option 3 *(Lowering of spillway crest level by 10 m)*. Option 3 can supply a p95 high demand scenario until 2038 and meet a 'most likely' demand estimate until 2045, but not 2050 and is therefore not considered acceptable.
- Option 5 *(Full dam decommissioning)*. Option 5 immediately results in a large supply deficit in the BWSS and is therefore not considered acceptable.

Key point

The 10m Lowering (Option 3), and Decommissioning (Option 5) both fail threshold tests and are therefore not considered suitable for inclusion in the DBC.

Multicriteria analysis

The FSL (Option 1a), 5m lowering option (Option 2), 5-10m lowering option (Option 4) and 10m lowering plus alternative supplies (Option 3a) remained after the threshold analysis. These options were assessed using MCA.

After scoring, normalising and weighting, the MCA provided comparable scores and rankings for the 4 assessed options. A total weighted score of 1 would mean that the option is ranked the best (or equal best) for every criteria and a total weighted score of 0 would indicate that an option is ranked the worst (or equal worst) for every criteria. Table 7 shows that the total weighted scores are all close to 0.5. Option 3a has the best total weighted score (0.632) for the most likely scenario followed by Option 2 (0.609), Option 4 (0.510) and Option 1a (0.440). The scores are not significantly different from each other and no option is clearly superior.

Table 7. Scores and rankings summary

	Option 1a Full Supply Level	Option 2 Less 5 m	Option 3a Less 10m + in-scheme alternatives	Option 4 Less 5 to 10 m
Weighted average scores				
Dam safety	0.000	0.000	0.300	0.150
Meets future water requirements	0.300	0.290	0.082	0.000
Recreation use opportunities	0.050	0.025	0.000	0.025
Environmental risks	0.040	0.050	0.000	0.050
Social and cultural risks	0.050	0.050	0.000	0.050
Cost	0.000	0.193	0.250	0.235
Total (maximum = 1)	0.440	0.609	0.632	0.510
Ranking	**4**	**2**	**1**	**3**

Figure 10 shows the weighted score results for each of the assessed options with the contributions of each objective shown.

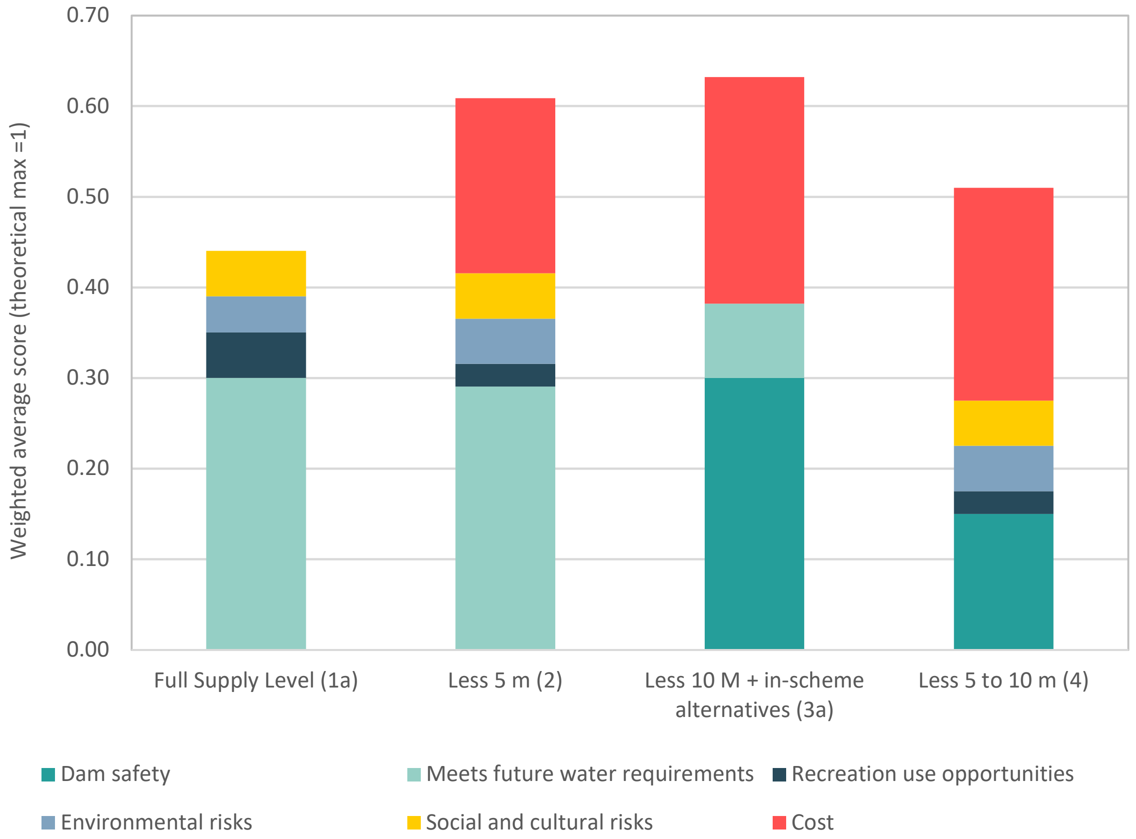

Figure 10. Weighted score results breakdown (most likely results)

Key point

The initial assessment using the MCA indicates that Option 3a is superior. However, there is little difference between the weighted scores across the options assessed. Option 1a was ranked last under this assessment.

4.5 Sensitivity analysis

Sensitivity analysis was undertaken across a number of parameters in the MCA to determine how sensitive the superior scored option was to changes in input data, specifically:

- The weightings to the individual objectives (alternative weightings were tested).
- The assigned scores for each option against each objective (a range of scores was used either side of the most likely value as the basis for this sensitivity test).
- Alternative approaches to normalising scores were tested.
- Alternative ratios for the conversion of HP to MP allocations (reflecting the ratio used in the Resource Operations Plan and recent work by SunWater).

The key issues to note from the sensitivity analysis are:

- With large alterations, weightings can influence the rankings; however, for the feasible values discussed in the Options Assessment workshop, the effect is minimal.
- Scores have some effect on the final rankings, with the scores of objectives with higher weightings (dam safety, water supply and cost) having greater effects than those with lower weightings. These effects are considered relatively minimal.
- While normalisation did have an impact on the rankings, the spread of scores across all options was insufficient to differentiate between the more superior options.
- A change in the MP:HP ratio does not have a significant impact on the MCA results; however, it results in changes in the timing of alternative supply projects for Options 3a and 4, where the projects would need to be brought forward by a year under the conversion ratio recently estimated by SunWater.
- Option 1a was almost always the least preferred options under all sensitivity tests.

Key point

The sensitivity analysis found that the ranking of options was somewhat sensitive to the range of inputs used. However, results were generally consistent with the pre-sensitivity analysis results.

Option 1a consistently ranked poorly under almost every sensitivity test conducted.

4.6 Summary

The Options Assessment, through a multi-step process including a threshold analysis, multi-criteria analysis and an expert workshop was able to narrow the list down to three possible options.

Options 3 and 5 were ruled out through threshold analysis and Option 3a was developed to be compared against Options 1b, 2 and 4 in the MCA. Of the options assessed through the MCA, Option 3a is highly ranked across all objectives, including those with increased weighting on cost, best-case and worst-case scores and a lower MP:HP ratio. Option 4 was mostly ranked second while Option 2 almost always performed last.

Despite this, the scores are not significantly different across the options therefore, it is recommended that options 2, 3a and 4 be taken forward to the DBC.

Key point

The Options Assessment found that options 2, 3a and 4 are not sufficiently different. Therefore, each option is recommended for consideration in the DBC.

5 RECOMMENDATIONS FOR DETAILED BUSINESS CASE

Based on the analysis presented in prior sections of this report and outlined in detail in the appendices, this section provides two recommendations for the DBC, specifically:

- The preferred options for consideration in the DBC.
- Issues identified through this report that require additional attention in the DBC, noting this list is not exhaustive.

5.1 Recommended options for the Detailed Business Case

The service needs for the PDIP are clear, and there is sufficient evidence to suggest demand growth opportunities exist and would likely be realised given the region's competitive advantage in some high value crops (e.g. macadamias and avocadoes). This growth will not be instantaneous as there are a number of market and physical factors that will temper the growth rate.

The independent Options Assessment found that options 2, 3a and 4 are not sufficiently different therefore it is recommended that all three are assessed in the DBC.

Key recommendation

This assessment recommends that the following options should be assessed in the DBC:

- Option 2. Lowering of spillway crest level by 5m.
- Option 3a. Lowering of spillway crest level by 10m plus alternative water supply options within the BWSS area (previously identified by SunWater).
- Option 4. Optimal lowering of spillway crest level by between 5 and 10m.

5.2 Issues requiring additional attention in the Detailed Business Case

A number of other issues have arisen during this project that warrant detailed consideration within the DBC, or concurrently to the DBC. The issues are outlined below, but should not be considered an exhaustive list.

Consistent approach to options costing

This analysis is based on the initial cost estimates developed by SunWater and its advisors. There are some inconsistencies in the scope and robustness of these preliminary costings, including the ranges of cost estimates modelled.

The inconsistencies in input cost data need to be addressed in the DBC. Within the DBC, the scope should cover all owners, establishment (including contingencies), operations and maintenance costs associated with each option. Furthermore, ranges of input parameters should be established to underpin robust and detailed probabilistic cost assessments.

Alternative supply options and distribution scheme efficiency

Option 3a includes a number of alternative water storages within the BWSS area. Consultation in the region revealed that there is some distribution 'bottlenecks'[8] in the BWSS that may be reducing irrigation efficiency in peak use periods and inhibiting development. Option 3a could improve the

[8] Note: While SunWater regional staff agreed there were occasional challenges in meeting peak demand through the distribution system, the quantitative extent of these bottlenecks is not well understood.

efficiency of operations in relevant areas of the BWSS *and* may also mitigate an impediment to development (potentially accelerating growth in demand)).

It is recommended that, within the DBC, technical analysis of the performance of the distribution system is undertaken, and the potential improvements that could be achieved if the alternative supply options are adopted. This should include consideration of the irrigation requirements of perennial tree crops. To the extent possible, these benefits should be incorporated into the cost-benefit analysis (CBA).

Expanding the scope and depth of the demand assessment

The demand assessment in this report has benefitted from the ability to undertake statistical analysis of historical sales of allocations and actual water demand. For the DBC, a more detailed approach is recommended that builds on and complements the current assessment through:

- More insightful econometric analysis. In the current assessment, we undertook an econometric analysis of water allocations and use. This utilised actual (deidentified) data provided by SunWater. This allowed analysis of relationships between key variables (e.g. rainfall) and water use at the whole regional scale only. This only provides limited insight for demand estimates. However, analysis of individual account data over time would enable a more sophisticated approach to the econometric analysis, insight into the range of water use behaviour, and significant improvements to quantitative insights to future demand estimation. For example, the sophisticated econometric analysis will be able to estimate how an individual farmer might change their watering regime as a response to lower than average rainfall amounts. This will enable better insight to the potential impacts of climate change on demand for allocations and actual use.

- Detailed consultation and market sounding. A detailed consultation and market sounding process is warranted. This should include opportunities for sales of alternative water products (see below) and the impacts of pricing. Because water will essentially be available very soon after the completion of the dam safety works, the approach to market sounding could encompass a more realistic approach than the typical 'expression of interest' approach. A genuine market mechanism could be used that is more akin to buying an option to purchase the water within a time-bound period for a specific price. Furthermore, given the growing preference for alternative water products, a combinatorial auction approach could be utilised that allows irrigators to bid for combinations of parcels of allocations that best meets their requirements.

- Impacts of prices on demand. The current demand assessment has assumed no change in water prices from the current price. However, the recent discounted water sale (unsurprisingly) triggered sales higher than the long-term average. In the DBC it would be worthwhile exploring the impact of prices for both allocations and service charges on the uptake of new demand. This could be tested through both the market sounding exercise and through economic modelling.

- Consideration of distribution system constraints. Consultation revealed there are some potential constraints in the distribution system that may be inhibiting growth in water demand. These potential constraints should be identified, investigated and incorporated into any extended demand assessment.

- Sub-regional demand estimates. Further consultation to assess the likely spatial distribution of demand is warranted. This could be undertaken through the market sounding and consultation phase, while building on and being cognisant of issues such as soil types, constraints in the distribution system and the pros and cons of Option 3a vs Option 2.

- Crop-specific economic thresholds and modelling. Detailed crop modelling is potentially warranted, particularly for macadamias and avocados to test key thresholds (e.g. commodity market prices, or climate variables) that may materially impact on the current demand estimates.

These issues all warrant consideration within the scope of the demand assessment for the DBC to test the veracity of the existing estimates.

Groundwater failure and implications for Bundaberg Regional Council

BRC currently hold a groundwater allocation of 6,430 ML as part of their conjunctive supply. Consultation revealed that BRC has a preference for using groundwater due to cost considerations. However, there remains an unknown risk to BRC's water security relating to the reliance on groundwater. I.e. what if the groundwater source was not available, and what would be the implications for demand from Paradise Dam.

Because it is difficult to assign a probability to the failure of the groundwater system and a probabilistic approach to estimating this demand may not be appropriate to reflect the criticality of this need, this uncertainty warrants more detailed consideration in the DBC. There are two options to address this uncertainty in the DBC:

- Undertake a comprehensive groundwater risks assessment, including the future risks of climate change (changes to recharge, changes to sea level risk and saltwater intrusion).

- Incorporate a contingency allocation (or a strategic reserve) within the demand assessment, but *additional* to the probabilistic demand estimate. In effect this would treat the uncertainty relating to the groundwater resource with BRC's conjunctive supply in a similar fashion to a contingency to deal with unknown risks in a costing exercise. If we assume that HP surface water allocations are the closest substitute to the groundwater, this would trigger a contingency requirement equivalent to 16,075 ML of MP. Within our blended demand assessments, the yield for the 5 m lowering is 25,793 ML MP greater than our high estimate. Hence, it would easily cover any contingency requirement.

The treatment of groundwater failure will need consideration within the DBC, particularly when determining what an 'optimal' dam yields.

Alternative water products

Consultation revealed an emerging need for alternative water products.

Perennial tree crops (e.g. macadamias and avocadoes) have significantly different risk characteristics to low water allocations when compared to annual crops. For this reason, many irrigators have purchased additional allocations as a contingent supply. This is also a partial explanation for the major gap between total allocations and typical water usage.

This issue was raised that the Community Reference Group meeting on 13 February. Participants in that meeting also recommended consideration of a lower reliability water product (e.g. a product that is less reliable than MP) that would be most useful for low value and opportunistic cropping opportunities (e.g. fodder).

Concurrent with the DBC, it would be prudent to investigate the possibility of establishing an 'interim' allocation product (e.g. a product that is more reliable than MP, but less reliable than HP) and subsequent prices. This product could enable irrigators of perennial tree crops to purchase and use an efficient portfolio of water allocations that better meets their needs and risk profile than the current MP allocation regime. This issue is likely to be relevant across several of SunWater schemes. In addition, a product that has a lower reliability than current MP also warrants some consideration.

This analysis would likely require:

- Hydrology assessments to establish conversion ratios and to establish yields across four separate allocation products (HP, MP and the two new products).
- Economic and financial analysis to establish indicative capital values for the new water product and water service tariffs.
- Agronomic analysis to better understand and specify the downside risks of very low irrigation rates (e.g. minimum irrigation requirements to keep trees alive during extreme droughts).
- Consultation (e.g. workshops) with potential users to better understand how they might incorporate these new water products into their portfolio of supplies (e.g. would they hold some 'interim' allocations to manage downside risks while holding a balance of MP allocations and what ratios of allocations are optimal?).

Incremental value of flood risk

The CBA to be undertaken for the DBC will need to assess the *incremental* benefits to downstream assets and economic activity associated with dam failure. This is particularly the case as dam safety failure is primarily attributable to extreme wet conditions, and under a wet weather scenario, much of the downstream area will already be impacted.

This will require the use of well-informed and robustly-developed stage damage curves for different typologies of built assets. It will also require a robust assessment of economic costs to industry as well as indirect and intangible costs.

Furthermore, the Queensland Government is also currently considering a business case for a flood levy on the east bank of the Burnett River in Bundaberg. This would have a material impact on the incremental cost of inundation attributable to any future dam failure. This may need to be incorporated into the base case for the CBA.

Sugar mill viability

The development of new high-value crops in the region, particularly perennial tree crops, is effectively reducing sugarcane production areas and subsequently throughput through the mills. The base case for the economic and social impact assessment conducted as part of the DBC will need to be cognisant of the risk to mill viability.

6 REFERENCES

This is a general reference list, capturing the key resources referred to above. Please see each appendix for a detailed reference list.

ANCOLD [Australian National Committee on Large Dams] (2003). Guidelines on Risk Assessment.

Aurecon (2020). Paradise Dam upgrade options assessment: independent design, cost and risk review. Prepared for Building Queensland.

GHD (2020). Paradise Dam spillway improvement project: concept design for Option 9 – 5m lowering. Prepared for SunWater Limited.

Queensland Government (2003) Burnett Basin Resource Operations Plan, May 2003

Queensland Treasury (2018) Queensland Government population projections: Regions, 2016 to 2041 (table). Online<https://www.qgso.qld.gov.au/statistics/theme/population/population-projections/regions. Accessed 28 November 2019.

SunWater (2018). Preliminary Business Case: Paradise Dam – Facility strategy and options analysis project. Prepared for SunWater Limited Board of Directors.

SunWater (2019). Burnett Basin alternative storage options: concept study. December 2019.

APPENDIX A: SERVICE NEEDS

A1. Service needs snapshot

The service needs for the PDIP assessment consist of two core service needs (i.e. dam safety and water supply) and three secondary service needs (i.e. recreation, environmental and social/cultural). The number of service needs has been deliberately limited to avoid overcomplicating the consultation and decision-making process.

A summary of the service needs is outlined in Table 8 and explained further within this Appendix.

Table 8. Service needs summary

Problem/s	Benefits of PDIP	Service need	Service need definition
Primary service needs			
Existing dam is not compliant with dam safety requirements.	PDIP will address and rectify risks.	Dam safety.	An option will satisfy the dam service need once the risk position is below the ANCOLD life safety limit of tolerability. This is a threshold test that must be met for any option to be acceptable.
Some options may result in shortfalls in water supply for community and commercial use.	PDIP (and potential complementary projects) to ensure water supply needs are met.	Meet future water requirements.	Ranges of demand estimates (MP, HP and aggregate normalised estimates (e.g. all MP equivalent)) for all key water use categories over the forward period. All measures in ML/annum. Benchmarking service needs estimates against yields from PDIP options.
Secondary service needs and considerations			
Dam safety risk could constrain recreational opportunities at the site.	A safe dam site will ensure recreational opportunities can continue.	Recreational use opportunities.	The scope of recreational opportunities at the dam site from the preferred PDIP option are not materially different from current opportunities.
Failure of existing dam creates environmental risks. There are environmental risks inherent to preferred PDIP option.	PDIP will mitigate dam failure risks and subsequent environmental risks of a failure. PDIP will address environmental risks associated with construction and future operations.	Environmental risks.	Environmental risks are not materially different from current levels.
Failure of existing dam creates social and cultural risks and results in costs. Minor social and cultural risks may be inherent in preferred PDIP option.	PDIP will mitigate dam failure risks and subsequent social and cultural risks of a failure. PDIP will address social and cultural risks	Social and cultural risks.	Social and cultural risks are not materially different from current levels.

Problem/s	Benefits of PDIP	Service need	Service need definition
	associated with construction and future operations.		

Importantly, all measures were also specifically designed to provide information and data that will be required for the completion of a robust DBC. For example, quantitative water demand estimates can be applied to margins to estimate economic benefits, and estimates of recreation visits could support the development of a travel-cost model as part of the cost-benefit analysis underpinning the DBC.

A2. Investment logic

Figure 11 articulates these service needs through the framework of a partial investment logic mapping exercise, which includes a problem statement, the associated opportunities and the multiple benefits sought that could be addressed by the PDIP options.

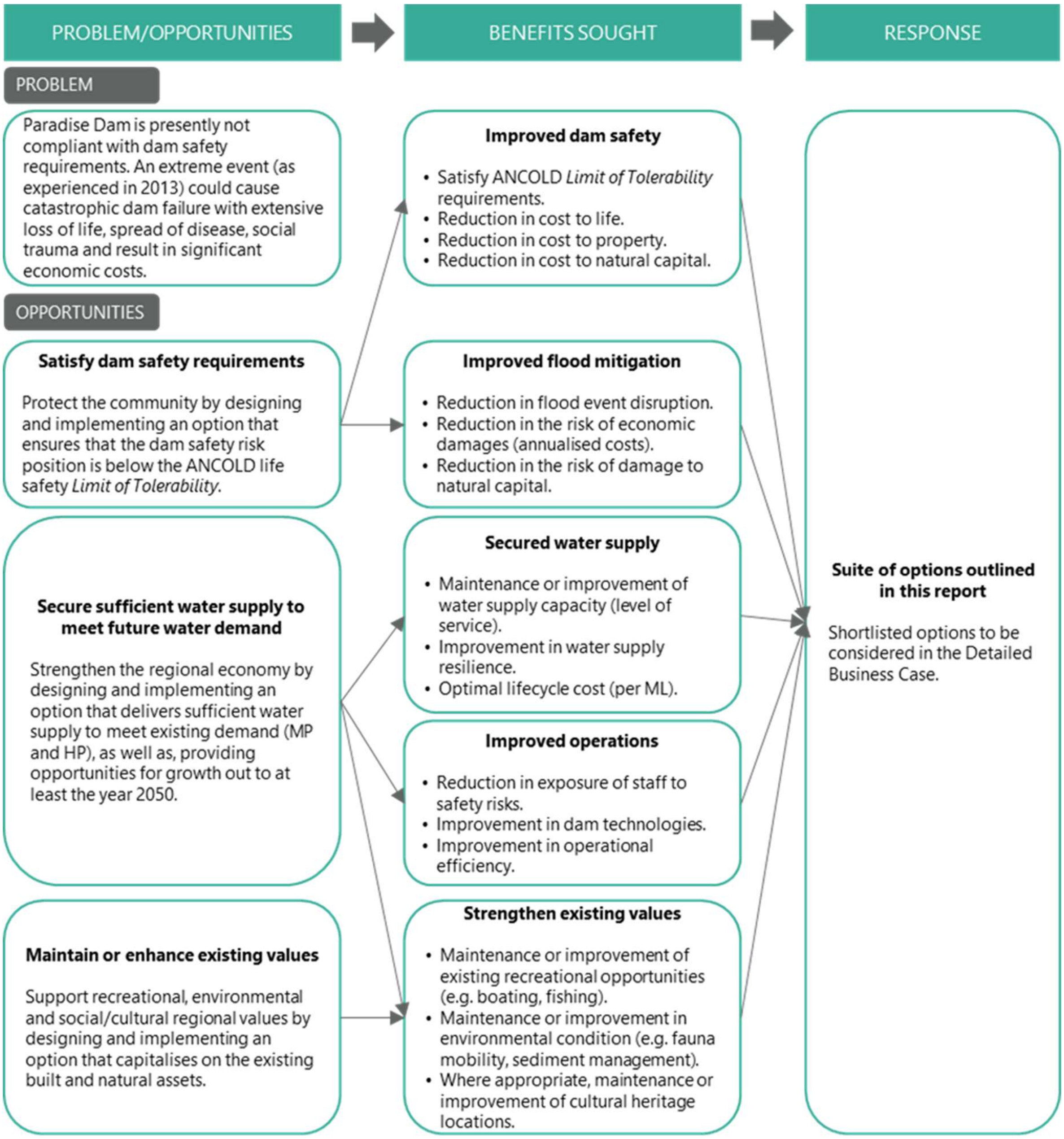

Figure 11. Articulating service needs through a partial investment logic map

A3. Background and context

The service needs may be collectively thought of as the problem/s that need to be addressed through a project. In this case the problem is the risk of failure of the Paradise Dam. The risks are major at both the local and regional scale, with any dam failure impacting on:

- The safety of communities downstream.
- Downstream built and natural assets.
- Water supplies for irrigated agriculture, urban and commercial uses.
- Social/cultural values (such as recreation).

Previous identification of service needs

It was stressed in the PBC that each problem, and the corresponding service needs, must be considered as part of the options assessment and identification of the preferred project solution. Table 9 provides a snapshot of the service needs that were included in the PBC.

Table 9. Service needs for PDIP included in the PBC

Problem	Overview	Service Needs
Failure to meet current standards creates an unacceptable level of risk.	SunWater has an obligation to ensure that the storages it owns and operates (including Paradise Dam) comply with the relevant industry recognised standards, specifically the *Limit of Tolerability* requirements.	Improve Dam safety
		Reduce overall risk profile (legal, organisational and reputational risk)
		Meet regulatory compliance requirements
Low demand is contributing to financial non-viability of dam.	SunWater has recorded that water demand from the Dam has been significantly lower than anticipated, resulting in lower than expected revenue.	Reduce potential economic and financial losses.
		Meet existing and future demand for water.
		Review water pricing to increase overall uptake and productive use of water.
Current Dam structure is resulting in higher than expected whole-of-life asset management costs.	Since the Dam commenced operation in 2005 approximately $67 million (or 25% of the original capital investment) has been spent on emergency repairs and dam strengthening work. Further, the Comprehensive Risk Assessment identified that additional works are required to upgrade both the primary and secondary spillways (which are valued at approximately half of SunWater's estimated capital expenditure for all Dam Safety Improvement Program investments).	Reduce whole-of-life costs.
		Improved predictability of asset maintenance costs.

SunWater (2018). Preliminary Business Case: Paradise Dam – Facility strategy and options analysis project. Prepared for SunWater Limited Board of Directors.

Key points

This independent analysis builds on the previously identified service needs in the PBC. Yet, it also considers a wider suite of service needs that are more reflective of the role of the Dam in the broader community and economy.

These service needs align with the criteria underpinning the Options Assessment.

A4. Service needs for the PDIP

This section summarises the service needs for the PDIP. These service needs, in conjunction with the estimated project costs, formed the basis of the Options Assessment for the PDIP (see Appendix D).

The service needs were based on a review of previous technical work, consultation and our assessment of the key elements of success for the PDIP.

Service needs summary

The service needs for this assessment consisted of two core service needs (i.e. dam safety and water supply) and three secondary service needs (i.e. recreation, environmental and social/cultural).

While these service needs have a broader scope than the previous PBC, we kept the service needs to a minimum to avoid overcomplicating the consultation and decision-making process.

A summary of the service needs is outlined in Table 10 and explained further within this Appendix.

Table 10. Service needs summary

Problem/s	Benefits of PDIP	Service need	Service need definition
Primary service needs			
Existing dam is not compliant with dam safety requirements.	PDIP will address and rectify risks.	Dam safety.	An option will satisfy the dam service need once the risk position is below the ANCOLD life safety limit of tolerability. This is a threshold test that must be met for any option to be acceptable.
Some options may result in shortfalls in water supply for community and commercial use.	PDIP (and potential complementary projects) will ensure water supply needs are met.	Meet future water requirements.	Ranges of demand estimates (MP, HP and aggregate normalised estimates (e.g. all MP equivalent)) for all key water use categories over the forward period. All measures in ML/annum. Benchmarking service needs estimates against yields from PDIP options.
Secondary service needs and considerations			
Dam safety risk could constrain recreational opportunities at the site.	A safe dam site will ensure recreational opportunities can continue.	Recreational use opportunities.	The scope of recreational opportunities at the dam site from the preferred PDIP option are not materially different from current opportunities.
Failure of existing dam creates environmental risks and results in costs. There are environmental risks inherent to the	PDIP will mitigate dam failure risks and subsequent environmental risks of a failure. PDIP will address environmental risks	Environmental outcomes.	Environmental risks are not materially different from current levels.

Problem/s	Benefits of PDIP	Service need	Service need definition
preferred PDIP option.	associated with construction and future operations.		
Failure of existing dam creates social and cultural risks and results in costs. Minor social and cultural risks may be inherent in the preferred PDIP option.	PDIP will mitigate dam failure risks and subsequent social and cultural risks of a failure. PDIP will address social and cultural risks associated with construction and future operations.	Social and cultural outcomes.	Social and cultural risks are not materially different from current levels.

Key point

The service needs for the PDIP assessment consist of two core service needs (i.e. dam safety and water supply) and three secondary service needs (i.e. recreation, environmental and social/cultural).

Service need 1: dam safety

The first service need is dam safety, the key driver of the PDIP.

Definition

A failure of Paradise Dam could result in the loss of life, and damage built and natural assets. If this were to occur the community would likely experience considerable loss and SunWater would suffer significant financial, reputational and legal repercussions. Therefore, the primary service need is to reduce this risk of failure to an acceptable level. The Australian National Committee on Large Dams (ANCOLD) guidelines explain what is meant by an 'acceptable' level. An acceptable level is defined as reducing risk to *as low as reasonably practicable* (ALARP), meaning:

> *"...risks, lower than the limit of tolerability, are tolerable only if further risk reduction is impracticable or if its cost is grossly disproportionate (depending on risk level) to the improvement gained" (ANCOLD, 2003)*

Dam safety service needs are considered to be achieved once the regulatory requirements that are specified in the Australian National Committee on Large Dams (ANCOLD) guidelines and the stipulations of the *Water Supply (Safety and Reliability) Act 2008 (Qld)* (specifically the requirements in Chapter 4: Referable dams and flood and drought mitigation) are met. Consistent with the regulation and legislation, for Paradise Dam this service need focuses on the *Limit of Tolerability* assessment, which is a threshold test. This means that it must be met for an option to be acceptable.

Service need definition

An option will satisfy the dam service need once the risk position is below the ANCOLD life safety limit of tolerability. This is a threshold test that must be met for any option to be acceptable.

Measurement

The metrics used to measure the dam safety service need have been outlined in Table 11.

Table 11. Metrics used to measure dam safety service need

Metric	How is this used?
The risk position must be below the ANCOLD life safety limit of tolerability.	Findings of the dam safety assessment. This metric must be satisfied (i.e. this is a pass/fail measure).

Key point

The *Limit of Tolerability* metric was used to measure the dam safety service need for each of the options assessed.

Sensitivity analysis

The preliminary designs for each option aimed to satisfy the limit of tolerability criterion. They were subjected to professional internal peer reviews as well as independent review by international dam safety experts from Aurecon. The Dam safety assessments and their review incorporated significant testing of the assumptions and calculations underpinning the preliminary design. Where potential fatal flaws were identified, these were addressed in subsequent iterations of the preliminary designs.

Service need 2: meet future water requirements

One of the original drivers for the PDIP was to provide a reliable source of water for agricultural, industrial and urban users in Lower Burnett region. The need to meet demand for water to support the current and future economic and urban growth remain unchanged (SunWater, 2018). Consequently, each of the options were assessed for their ability to meet water demand to support agricultural production, urban and industrial uses.

Agriculture is a key economic driver in the region. Agriculture, Forestry and Fishing accounts for 15.7% of value-add in Bundaberg (compared to 3.6% for Queensland). Cane growing is the traditional key agricultural activity, however, more recently there has been some growth in the horticultural and vegetable production. Horticultural production includes macadamia nuts, avocados and citrus fruits. Changes to water demand potentially impacts on viable agricultural intensification, diversification and expansion.

Agricultural water demand was based on current usage and trends in water application rates by sugarcane growers and changes in areas for horticultural and vegetable production.

While there are many small industrial and commercial water users in the region, sugar milling/processing is by far the more significant user. Isis Central Sugar Mill and Bundaberg Sugar are the main industrial water users. Future water demand by sugarcane milling and processing facilities will be a function of sugarcane production levels in the region. Further consultation with the Bundaberg Regional Council was undertaken to identify industrial growth prospects that could have a material impact on current service needs. No major projects were identified.

Given the variability in historical data, input data for modelling and the need to make assumptions, a range of estimates for each water use category were developed. Significant use of statistical analysis was required, and probabilistic ranges of estimates were produced using Monte Carlo simulations. Furthermore, the Monte Carlo simulations were used to better understand which inputs (data and/or assumptions) explain the most variation in the demand estimates. This assisted in identifying areas for more detailed assessment in the DBC.

Key point

Significant use of statistical analysis was required to develop demand estimates, and probabilistic ranges of estimates were produced using Monte Carlo simulations.

The demand estimates were then compared to the estimated yields for each of the options prepared by SunWater to identify whether demand estimates can be met by the different options (or a Paradise Dam option plus one or more of the 12 alternative supply options already identified by SunWater (see Appendix C).

This approach provided insight for:

- Identifying the degree of underutilisation of existing allocations and the variability of allocation use.
- Identifying which PDIP options meet likely service needs and for how long.
- Identifying indicative time periods of when supply augmentations may be required (i.e. when the demand curves exceed the supply curves). These demands could be met by a number of alternative options or a PDIP option (whichever is the most cost effective). This formed the basis of the options assessment.
- Providing a baseline estimate against which actual growth can be benchmarked to underpin future water supply planning.

This approach incorporated uncertainty through running project-specific scenarios for demand that is outside the current BWSS but could utilise yield from Paradise Dam if distribution infrastructure were also developed. The Coalstoun Lakes proposal is an example of this requirement (Coalstoun Lakes Development Group, 2015).

Because Paradise Dam provides both HP and MP water, it was useful to assess demand and supply in a common metric. Under the Burnett Region Resource Operations Plan, the 'conversion rate' for HP to MP is 2.5: 1 (i.e. 1 ML of HP = 2.5 ML of MP).[9] This enabled the assessment of an aggregate demand curve against an aggregate yield curve. In addition, in the options assessment, where one water product demonstrated a deficit (e.g. HP), but the other showed a surplus, there was an opportunity to optimise the mix of MP and HP allocations through conversions in lieu of expensive infrastructure augmentations.

Definition

The definition for the water demand service need includes consideration of current and future demand for water to meet agricultural, industrial and urban demand from Paradise Dam. It also enabled the assessment of demand and supply balances.

Service need definition

The estimated water demand (MP, HP and/or aggregate blended estimates (e.g. all MP equivalent)) for all key water use categories over the current and future periods. All measured in ML/annum.

This allows for benchmarking service need estimates against yields from PDIP options.

[9] Note: SunWater has recently commissioned hydrological analysis that suggests the conversion rate should be 2.32. The model was also run the demand model using this rate as part of the sensitivity analysis (see Appendix B).

Measurement

To better capture actual demand, current water demand estimates considered both allocations and actual usage rather than only relying current allocations levels. Table 12 provides a measurement of current and future water demand (ML per annum).

Table 12. Measurement of current and future water demand (ML per annum)

<table>
<tr><th>Service need</th><th>Current HP* demand</th><th>Current MP* demand</th><th>Forecasted HP demand in 2030</th><th>Forecasted MP demand in 2030</th><th>Forecasted HP demand in 2050</th><th>Forecasted MP demand in 2050</th></tr>
<tr><td>Agriculture</td><td rowspan="6" colspan="2">Ranges (ML per annum) based on historical analysis.</td><td rowspan="6" colspan="4">Ranges (ML per annum) based on forecasts. Mid-point of range provided most likely estimate, while the upper and lower ends of the confidence intervals (see sensitivity analysis below).</td></tr>
<tr><td>Sugarcane</td></tr>
<tr><td>Horticulture</td></tr>
<tr><td>Other broadacre crops</td></tr>
<tr><td>Urban</td></tr>
<tr><td>Commercial / industrial</td></tr>
</table>

*Where: HP=high priority and MP=Medium priority

Sensitivity analysis

The current and future demand for water was estimated using input data parameters and assumptions that have a degree of uncertainty. Where relevant, a range of input values were used in the modelling as part of the sensitivity analysis (e.g. future household water usage (ML), area cropped with macadamia nut trees (ha) and irrigation rates for the various crops (ML/ha)).

The key approach to addressing risk and uncertainty in the analysis was by using Monte Carlo simulations. This was performed by undertaking 20,000 iterations of the model to investigate the impact of variability for key input parameters. Triangular distributions were used for all analysis, noting that the input ranges for many assessments were not normally distributed. This enabled the establishment of confidence intervals around the estimated values and the identification of input parameters that explain the most variability in the economic estimates. Using Monte Carlo simulations for sensitivity analysis provided a better understanding of the range in the value of the estimated benefits. Furthermore, the sensitivity analysis provided useful insight to future research, project design and ongoing targeting for monitoring and evaluation of project outcomes.

Service need 3: recreation

Paradise Dam on the Burnett River provides one of two inland lake destinations for the Bundaberg region (the other being Fred Haigh Dam at Lake Monduran) that can be used for recreational activities. To some degree they are substitutes for day recreation.

Paradise Dam allows for recreation including boating, camping, water skiing and fishing. There is an existing Paradise Dam Recreation Park and the Mingo Crossing Caravan Park that have facilities and boat ramps. The Bicentennial National Trail runs along the edge of the Paradise Reserve.

Table 13 summarises the key recreational assets and activities available at Paradise Dam and Fred Haigh Dam. The key point to note is that Paradise Dam generally has a broader scope of recreational assets and activities, with fishing being the exception (not allowed at Paradise Dam).

Table 13. Recreational assets and opportunities

Asset	Paradise Dam	Fred Haigh Dam
Road access	Yes	Yes
Car Park	Yes	Yes
Boating (motorised)	Unrestricted except within 200m of Dam wall	Unrestricted
Boating (non-motorised)	Yes	Yes
Boat ramp	Only accessible in high water conditions. Alternative access at Mingo Crossing.	Two boat ramps.
Lookout	Yes	Yes
Fishing allowed	No	Yes. Stocked fish include Australian Bass, Golden Perch, Saratoga, solver perch and sooty grunter.
Kiosk	Yes	No
Picnic areas	Maintained by North Burnett Regional Council	No
BBQs	Maintained by North Burnett Regional Council	No
Camping	Yes. Camping, caravan sites, cabins. Maintained by North Burnett Regional Council	Yes. Camping, caravan sites, cabins.
Swimming	Yes	Yes
Toilets	Maintained by North Burnett Regional Council	No
Treated water	Yes	No
Rubbish bins	Yes	No
Pets allowed	On leash only.	On leash only.

Source: SunWater website. Accessed 29 Nov 2019

The PBC indicates that short-term interruptions and prohibition of some recreational activities near the Dam wall will be required during the process of decommissioning or construction of any PDIP option.

In terms of ongoing disruptions, the PBC found that:

- A full upgrade will not impact on existing recreational uses.
- A partial spillway reduction (of 17m) will not support current recreational activities, including boating (motorised) and skiing. The loss of those activities would jeopardise the viability of the Paradise Dam Recreation Park and Mingo Crossing Caravan Park. Furthermore, the Bicentennial National Trail would no longer be on the edge of the Paradise Dam reservoir and may require relocation. Opportunities potentially exist for alternate recreational activities and ecotourism ventures.
- A partial spillway reduction (of 10m) will require some upgrades to infrastructure (e.g. boat ramps) to align with permanently lower water levels. Generally, reservoir areas are likely to continue to support current recreational activities.

Presumably, a lowering of less than 10m would have a similar, but smaller, impact on recreation to the 10m lowering.

Definition

The recreational values of the Dam are attributable to both the recreational assets and possible opportunities at the site. These assets and opportunities are the drawcard for visitation, and ultimately, benefit realisation. Therefore, the service need definition focuses on the maintenance of the scope of current recreational assets and opportunities.

Service need definition

The scope of recreational opportunities at the dam site from the preferred PDIP option are not materially different from current opportunities.

Measurement

Measurement for this needs assessment was qualitative. It was based on an assessment of the recreational assets and opportunities of the site, and a qualitative assessment of change to those opportunities (positive or negative). This was informed by key documents including the SunWater PBC and consultation.

Table 14. Recreational assets and opportunities measurement

Measurement	Pre-PDIP	Post-PDIP
Recreational assets and opportunities	Description and count	Description and count

Service need 4: environmental

The establishment of Paradise Dam has already resulted in a material change to the environment of the region in terms of flow regimes, aquatic processes and inundation of terrestrial habitat. These impacts were all identified, assessed and managed at the time the Dam was established.

The extent, condition and risks to environmental assets and processes differ between PDIP options, and impacts will occur during the construction phase of the preferred option. In effect, there will be a change in environmental outcomes attributable to each PDIP option. Impacts that may arise as a result of the implementation of the options include:

- Change in construction / demolition – related resource consumption (e.g. waste generated, greenhouse gas emissions (GHG) generated).
- Change in reservoir area (e.g. increased terrestrial habitat, reduced aquatic habitat).
- Change in water quantity and quality (e.g. in the dam and downstream environmental flows, change in turbidity).
- Change in fauna mobility (e.g. ability for fish migration).
- Change in downstream flood likelihood.

Definition

The service need considered the following environmental impact areas, as identified in the PBC (SunWater, 2018). The issue associated with each environmental impact are presented in parentheses:

- Land use planning (e.g. sediment management, revegetation).

- Geomorphology (e.g. dewatering, erosion and scouring, bank slumping).
- Water resources (e.g. upstream and downstream peak water levels (flooding events)).
- Waste management (e.g. demolition).
- Water quality (e.g. dewatering, water storage and management, turbidity).
- Terrestrial flora and fauna (e.g. rehabilitation, operations).
- Aquatic flora (e.g. establishment rehabilitation).
- Aquatic fauna (e.g. operations, dewatering, rehabilitation, fish passage).
- Carbon dioxide emissions associated with the demolition and establishment of each option (e.g. emissions associated with concrete production).

Risks to environmental assets and processes will need to be considered as part of the DBC of the preferred PDIP option. These risks can be complex to quantify, and typically result in needing to meet environmental obligations, duties and conditions. In effect, this is a threshold of acceptability: is the option likely to meet environmental obligations, duties and conditions? This was used as the basis for the service need definition.

Service need definition

An option satisfies the environmental service need if it is likely that the option can meet all foreseen environmental obligations, duties and conditions. This is a threshold test that must be met for any option to be acceptable. Residual environmental risks were then assessed qualitatively.

Measurement

Assessment of environmental impacts was qualitative and based on pre-existing analyses, including the PBC (SunWater, 2018).

Sensitivity analysis

The preliminary designs for each option are cognisant of meeting environmental obligations, duties and conditions. Furthermore, for the preferred option, a full environmental impact statement (EIS) will likely be required. Where potential material environmental risks are identified, these will be addressed in subsequent iterations of the detailed design and implementation of the preferred option.

Service need 5: social and cultural

The establishment of Paradise Dam has already resulted in a material change to the region (e.g. land use). This included changes to the region that had both social and cultural heritage impacts. These impacts were all identified, assessed and managed at the time the Dam was established.

The social and cultural heritage impacts of each PDIP option were considered. Impacts that may arise as a result of the implementation of the options include:

- Construction / demolition-related modification of areas of social and cultural heritage (e.g. potential impacts to indigenous cultural heritage artefacts).
- Construction / demolition-related activities affecting aesthetics (e.g. dust, noise, vibration and visual amenity).

It should be noted that during investigations undertaken to support the PBC, no places of cultural heritage were identified on the Register of the National Estate, the Queensland Heritage Register and Local Government Registers relative to Paradise Dam and the reservoir (SunWater, 2018).

Definition

The definition for social and cultural heritage service needs relates to the needs of the preferred PDIP option to be cognisant of impacts during the construction and operational phases of the project. This includes the mitigation of risks and impacts through both the design of the option and ongoing management of the infrastructure.

Service need definition

An option will satisfy the social and cultural safety service need if it is likely that the option can meet all foreseen social and cultural heritage obligations, duties and conditions. This is a threshold test that must be met for any option to be acceptable. Residual environmental risks were then assessed qualitatively.

Measurement

Assessment of social and cultural impacts was qualitative and based on pre-existing analyses, including the PBC (SunWater, 2018).

Sensitivity analysis

The preliminary designs for each option were cognisant of meeting social impact and cultural obligations, duties and conditions. Furthermore, for the preferred option, a social impact assessment and cultural heritage assessment will likely be required. Where potential material social or cultural heritage risks are identified, these are addressed in subsequent iterations of the detailed design and implementation of the preferred option.

A5. References

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Saaty, T. (1980). The Analytical Hierarchy Process. New York, McGraw-Hill.

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APPENDIX B: DEMAND ESTIMATES

B1. Meeting future water requirements

One of the original drivers for the Paradise Dam project was to provide a reliable source of water for agricultural, industrial and urban users in Lower Burnett region. The need to meet demand for water to support the current and future economic and residential growth remain unchanged (SunWater, 2018). Consequently, each of the proposed options has been assessed for their ability to meet water demand to support agricultural production, commercial and residential uses.

Agriculture is a key economic driver in the region. Agriculture, Forestry and Fishing accounts for 15.7% of value add in Bundaberg compared to 3.6% for Queensland (Australian Bureau of Statistics, 2018). Cane growing is the traditional key agricultural activity, however, more recently there has been some growth in horticultural and vegetable production. Horticultural production includes macadamia nuts, avocados and citrus fruits. Impacts on water demand from the potential for viable agricultural intensification, diversification and expansion has also been considered.

Future agricultural water demand estimates are based on current usage and trends in water applications rates by sugarcane growers and changes in areas for horticultural and vegetable production.

While there are many small commercial and industrial water users in the region, sugar milling / processing is the most significant user. Isis Central Sugar Mill and Bundaberg Sugar are the main industrial water users. Future water demand by sugarcane milling and processing facilities is a function of sugarcane production levels in the region. Consultation with the Bundaberg Regional Council has been used to identify any commercial/industrial growth prospects that may have a material impact on current service needs.

Broad approach

A number of approaches were necessary for establishing water demand forecasts and estimating service needs. Statistical analysis of available data on recent historical water use underpinned the approach. This was assessed against available data on exogenous factors (such as rainfall) to better isolate short-term variations from underlying trends. Because the Dam has been in operation for several years, data sources and analysis relied on observed demand patterns (revealed preferences for water), rather than undertaking 'market sounding' exercises (stated, but unverifiable preferences for water). While in the DBC, it would be prudent to also undertake a 'market sounding' exercise, the reliance on actual historical usage should provide a more accurate suite of estimates for the purposes of the current information needs.

Other approaches used included:

- **Irrigated sugar demand** estimates incorporate basic crop modelling and assessment of gross margins to better understand commercial viability of any expansions. Two other key factors were considered in measuring agricultural water demand: 1) trends in the market (price and demand volumes), and 2) climate change. Changes in the climate (leading to drier and more unreliable rainfall) will also impact on forecasted agricultural water demand. Consultation with industry and some producers was undertaken as part of this analysis. This included representatives of the sugar production districts and a number of individual farmers (confidential discussions).

- **Irrigated horticulture** demand estimates include high-level analysis of supply chains and likely growth in demand. The broader supply-chain and supply continuity attributes of regions are often more important than a simple ability to produce a horticulture crop. Bundaberg reflects this trend, with much of the horticulture product meeting counter-seasonal requirements for produce that is grown in warmer climates during summer and the Bundaberg region in winter. Furthermore, we are cognisant of broader demand and supply data for emerging crops and the risks of market saturation (e.g. as has recently occurred in blueberries). Current land use mapping and agricultural census data provides point-in-time snapshots of areas of production (ha) and production volumes. Data and analysis by Horticulture Innovation Australia (Horticulture Australia Limited, 2018) has been used to understand the market context for key crops. Consultation with industry and some producers was undertaken as part of this analysis. This included stakeholders within the region (a sample of smaller to larger individual farmers via confidential meetings and interviews, larger operators undertaking value-adding, representative of industry bodies) competing regions (particularly industry representatives in northern NSW for perennial tree crops), and entities along the supply chain for key commodities (e.g. processors and supermarket chains). Unlike many other demand assessments, there is a wealth of historical data available to underpin consultation, although more extensive consultation will be required for the DBC.

- **Residential demand** builds on Queensland Treasury and Bundaberg Regional Council population forecasts. Detailed water sales and production data were provided by Bundaberg Regional Council. Future residential developments are most likely to be in smaller lots with relatively more water efficient appliances and smaller backyards. The shift towards smaller lots, more water efficient appliances, and smaller backyards will have an impact on water consumption per household. Direct consultation with Council staff (water supply and planning) was undertaken as part of this analysis.

- **Commercial and industrial demand** primarily utilised historical data. However, consultation with the local economic development agency was undertaken to identify any major industrial developments that could occur in the medium term.

Given the variability in historical data, input data for modelling, and the need to make assumptions, a range of estimates for each water use category have been developed. Significant use of statistical analysis has been undertaken, and probabilistic ranges of estimates were produced using Monte Carlo simulations. Furthermore, the Monte Carlo simulations provide a better understanding of which inputs (data and / or assumptions) explain the most variation in the demand estimates. This will assist in identifying any areas for more detailed assessment in the DBC.

Key point

Significant use of statistical analysis was undertaken to develop demand estimates, and probabilistic ranges of estimates were produced using Monte Carlo simulations.

Assessing demand vs. supply yield

The demand estimates were then compared to the estimated yields for each of the PDIP options to identify the extent to which they meet demand estimates.

This approach provides insight for:

- Identifying the degree of under-utilisation of existing allocations and the variability of allocation use.

- Identifying which PDIP option/s meet likely service needs and for how long.

- Identifying indicative time periods of when supply augmentations may be required (i.e. when the demand curves exceed the supply curves). These demands could be met by a number of alternative options (being identified by SunWater) or a PDIP option (whichever is the most cost effective). This will form the basis of much of the options assessment.

- Providing a baseline estimate against which actual growth can be benchmarked to underpin future water supply planning.

This approach can also incorporate uncertainty by running project specific demand scenarios for demand that is outside the current Bundaberg Water Supply System (BWSS) but could utilise yield from Paradise Dam if distribution infrastructure were also developed. The Coalstoun Lakes proposal is an example of a project development area that could theoretically benefit from water from Paradise Dam piped to the proposed development area.

Because Paradise Dam provides both HP and MP water, it is useful to assess demand and supply in a common metric. Under the Burnett Region Resource Operations Plan, the 'conversion rate' for HP to MP is 2.5: 1 (i.e. 1 ML of HP = 2.5 ML of MP). This enables the assessment of an aggregate demand curve against an aggregate yield curve. Where one water product demonstrates a deficit (e.g. MP), but the other shows a surplus, there may be an opportunity to optimise the mix of MP and HP allocations through conversions in lieu of infrastructure augmentations.

Sensitivity analysis

The current and future demand for water has been estimated using input data parameters and assumptions that have a degree of uncertainty. A range of input values have been used in the modelling as part of the sensitivity analysis (e.g. future household water usage (ML), area cropped with macadamia nuts trees (ha) and irrigation rates for the various crops (ML/ha)).

Monte Carlo simulations underpins the sensitivity analysis. This was performed by undertaking 20,000 iterations of the model to investigate the impact of variability for key input parameters. This enables the establishment of confidence intervals around the estimated values and the identification of input parameters that explain the most variability in the economic estimates. Using Monte Carlo simulations for sensitivity analysis provides a better understanding of the range in the value of the estimated benefits. Furthermore, the sensitivity analysis can provide useful insight to future research, project design and ongoing targeting for monitoring and evaluation of project outcomes.

B2. Broader macro factors and trends, and the implications for water demand

This section briefly outlines some of the macro-economic factors and trends, and their implications for water demand. This includes:

- Demographics and economy.
- Trends in commodity markets and prices.
- Land use change.
- Climate and climate change.

Demographics and economy

The Local Government Area (LGA) most relevant to the use of water from Paradise Dam is Bundaberg Regional Council (BRC). BRC had an estimated residential population of around 95,300 in 2018. BRC is typified by an older age profile than both regional Queensland and Queensland as a whole. Migration data from the Census for the period 2011 to 2016 shows an overall positive contribution to population growth from migration. This was a net impact of overseas inward migration being partially offset by a net outward migration to other parts of Australia.

The Queensland Government Statistician's Office estimate the population will grow to between 106,000 to 135,000 by 2041 (mid-range scenario), shown in Figure 12. Consultation with BRC's Economic Development group suggests that the population growth outcomes will be highly dependent on maintaining current economic activity, while the higher growth projects are reliant on irrigated agricultural intensification and associated value adding.

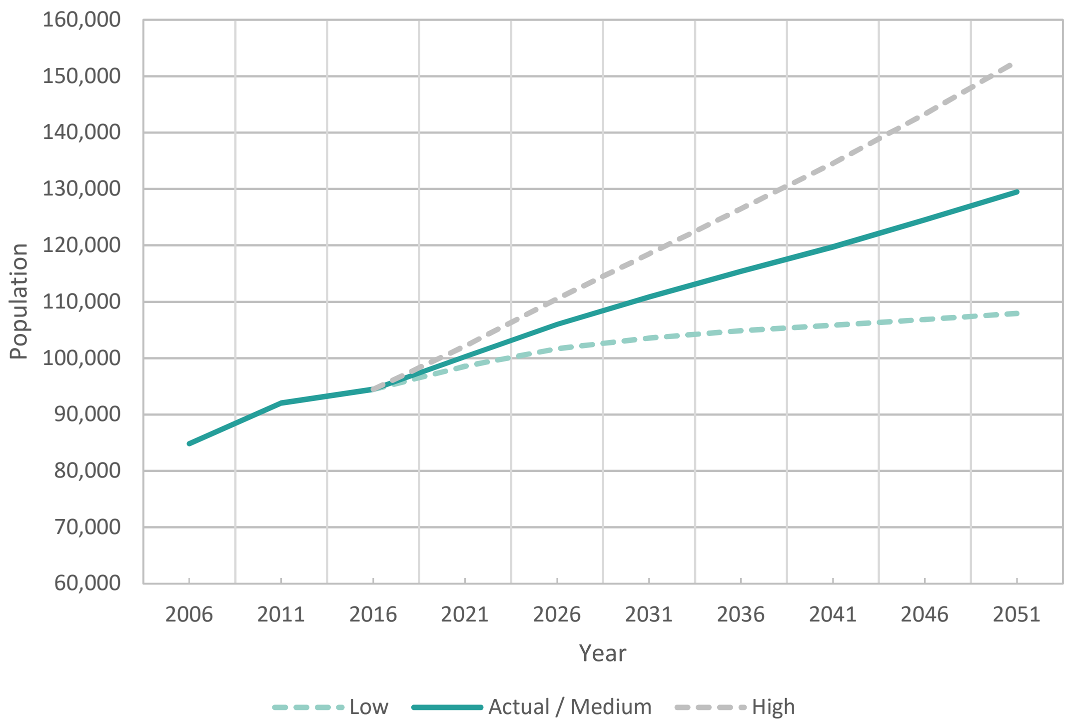

Figure 12. BRC population (historic and projections)

Sources: Australian Bureau of Statistics, Regional Population Growth, Australia (3218.0), Queensland Government Statistician's Office.

The proportion of workers in full-time work in BRC and the labour force participation rate are both lower than the State average, while unemployment and under-employment are both higher than regional Queensland and Queensland as a whole. Education and qualification outcomes are as expected for regional Queensland, with a higher proportion of vocationally trained workers than the State as a whole and a lower proportion of tertiary trained workers.

The region has a higher proportion of low-income households (<$650 per week) than both regional Queensland and Queensland as a whole. This reflects both the age profile of the region and the fact that the region has a lower proportion of mine workers in the workforce than many regional centers.

BRC's estimated Gross Regional Product was $4.2 billion in 2018/19, marginally down on the previous year due to the drought. Estimated economic value added in the regional economy was around $3.5 billion in 2018/19. Of this, over $480 million (13.8% of the total economy) was directly attributable to primary industries, while a further $160 million was attributable to food and beverage manufacturing (e.g. sugar mills, value adding to horticulture, the Bundaberg distillery and soft drink factories).

Of the estimated 31,100 employed in the BRC LGA, the dominant sector is heath care and social assistance. However, agriculture, forestry and fishing (largely irrigated agriculture) and manufacturing (dominated by food manufacturing) are the next major categories. The relative proportion of full-time equivalent (FTE) employment in key sectors in the BRC and Queensland are shown Figure 13. The data indicate that the economy in BRC is significantly more concentrated towards agriculture and associated economic activity than the State as a whole. This lack of diversity can be a significant constraint on economic resilience as the local economy is overly sensitive to exogenous and endogenous shocks that may impact on irrigated agriculture.

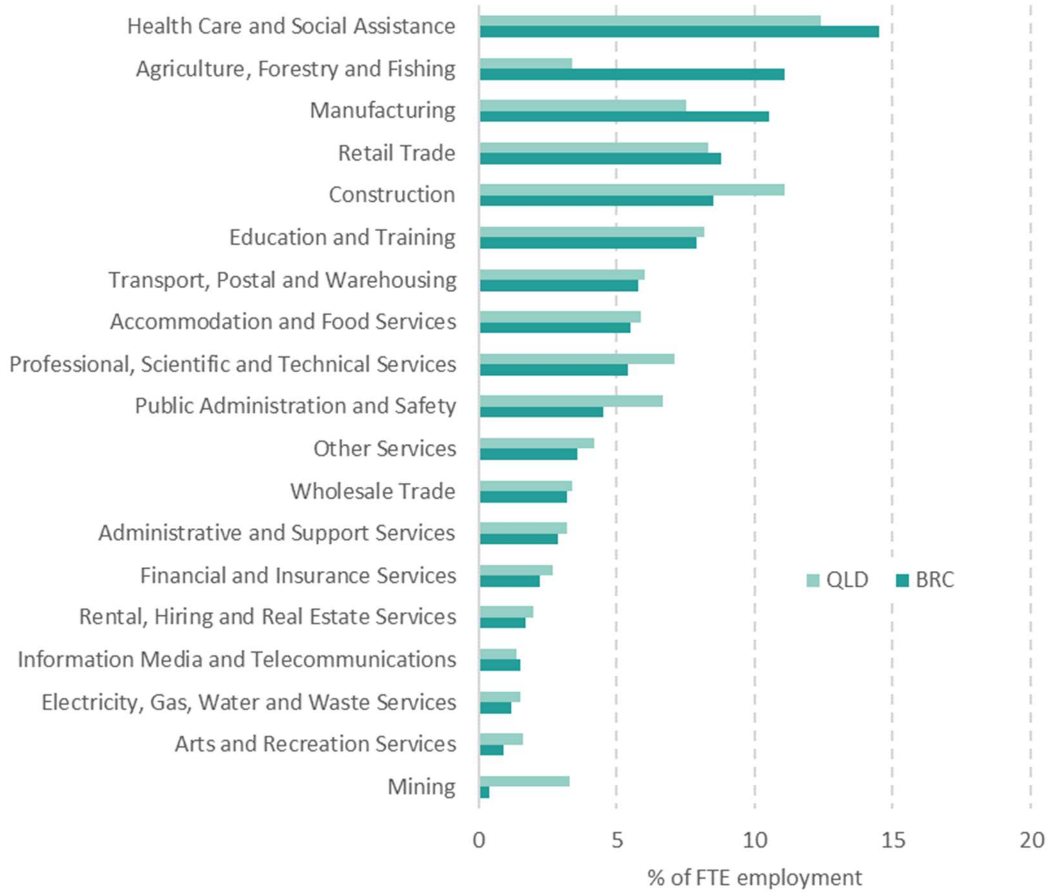

Figure 13. Structure of economy based on employment by industry (BRC vs. Queensland)

Source: National Institute of Economic and Industry Research (NIEIR).

Key point

The local economy is highly reliant on irrigated agriculture for economic prosperity and employment. Population growth is tied to economic prospects in agriculture and associated sectors. Changes in population growth and agricultural sector will drive demand for water.

Changes in key commodity prices

Sugarcane production is the dominant irrigated crop in the region. This has been the case for decades. However, consultation in the region revealed that, unlike other sugar districts (such as the Burdekin) the Bundaberg region has always included a greater proportion of mixed farming. This often includes sugar as the dominant crop, with rotations of broadacre crops (e.g. fodder, peanuts) between the final ratoon and replanting a new sugarcane crop. This has historically also included horticulture crops (e.g. fruit and vegetables).

In more recent years, there has been a trend towards higher value horticulture crops, particularly perennial tree crops (e.g. macadamia and avocado) that provide significantly better returns to farmers.

Figure 14 shows an index of farm gate commodity prices since the completion of Paradise Dam.

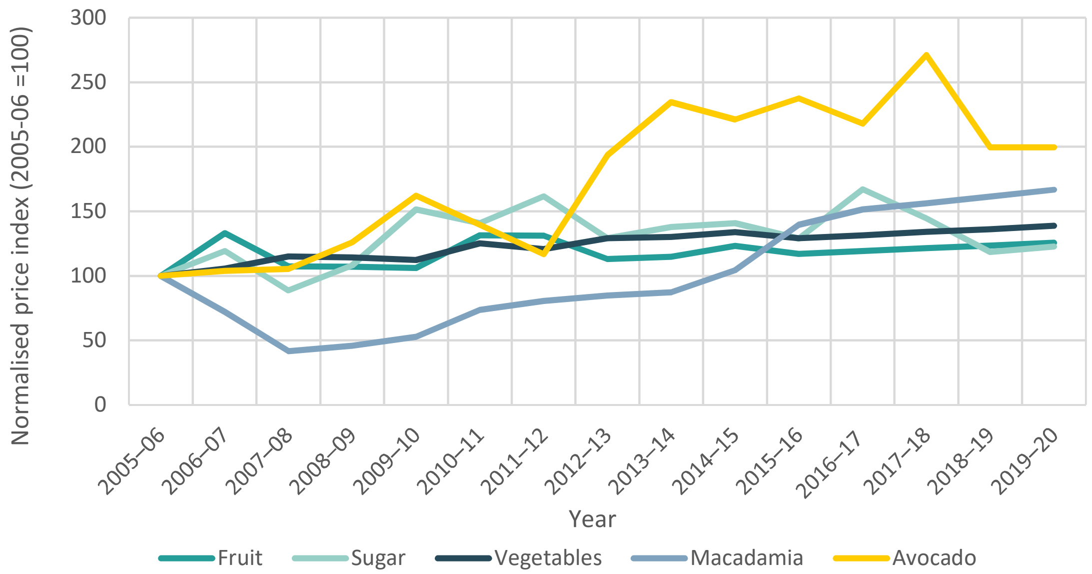

Figure 14. Index of farm gate commodity price index (2005/06 = 100)

Sources: ABARES (2019). Agricultural commodities: September quarter 2019; Australian Macadamia Society (2019). Factsheet. Farm Gate Prices; Avocados Australia. Facts at a Glance for the Australian Avocado Industry 2018/19.

The key points to note relating to key commodities are:

- **Sugar** prices have shown significant variability due to world supply and demand considerations - typical of crops that are 'price takers'. Consultation with industry and available economic analysis suggests that prices have been below the levels required to trigger any expansion of sugarcane production.

- **Fruit and vegetable** prices have demonstrated sustained growth. A majority of the production in the Bundaberg region has a competitive advantage in meeting counter-seasonal demand windows in domestic demand. This is consistent with broader movements in fresh food markets that seek continuity of supply throughout the year to match consumer expectations. For some fruit and vegetable crops, produce from Bundaberg is either exported or sold as an import substitution product. Export markets are expanding (all via Brisbane), but growth is somewhat constrained by the perishable nature of many products, market access, and competition from other producing regions.

- **Avocados** have shown significant growth in production and prices in the past 15 years, and Bundaberg continues to be a beneficiary of this trend. Bundaberg avocados are largely sold onto the domestic market, although some will be exported via the Port of Brisbane. Avocados are one of the few horticultural products in Australia that are demonstrating significant growth rates in per capita consumption. Some of Australia's largest and most vertically integrated horticulture producers (e.g. Costas) have a significant presence in the Bundaberg area. Consultation with industry indicates an expectation for strong growth over the medium to longer term, although the growth rate may slow.

- **Macadamia** have shown significant expansions in both production and prices in the past 10-12 years. While originally for domestic consumption (including import substitution), recent years have seen a strong trend in growth for exported nuts to Asia. Consultation with industry indicate that this trend is expected to continue, although the rate of growth may decline in future years.

Key points

Recent results and market prospects for alternative commodities across the region differ. While the international outlook for sugar is subdued, the outlook for tree crops (avocado and macadamia) are very strong.

Furthermore, the outlook for fruit and vegetables is also relatively strong, as the Bundaberg region continues to exploit counter-seasonal production opportunities to meet consumer preferences for continuity of supply for fruit and vegetables throughout the entire year.

Changes in land use

The nature of irrigated agriculture in the region is changing as the economic viability of some crops are compromised through market pressures, while other opportunities emerge. Consultation in the region indicated that the actual expansion of irrigation areas in recent years has been negligible. Rather, the trend is for existing irrigated sugarcane land within the BWSS to be converted to higher value crops. Using the State's land use mapping layers, the conversion of sugarcane to other crops was mapped for the period 1999 to 2017 (latest data) and is presented in Figure 15.

The mapping shows a transition from sugar to other crops, with significant areas changing to intensive horticulture (e.g. vegetables), perennial tree crops (e.g. macadamias and avocados) and some areas reverting to grazing (i.e. no longer being irrigated at all).

While the data collection and crop categorisation procedures used reduce the robustness of the analysis, the trends evident in the data are consistent with other available data and the results of consultation.

Consultation and field observations undertaken in December 2019 revealed that the land use transition process is continuing and is possibly accelerating. Consultation revealed that some sugarcane farms had been purchased with the intention of conversion to perennial tree crops, but that the rate of conversion process is constrained by a number of factors, including:

- The availability of tree stock is often limited by the slow grafting process, which reduces the rate of conversion.

- Many farmers are deliberately undertaking a gradual conversion to ensure cashflow from annual sugarcane crops is available to offset the 5 – 10 year lags between tree establishment and a full crop from perennial tree crops.

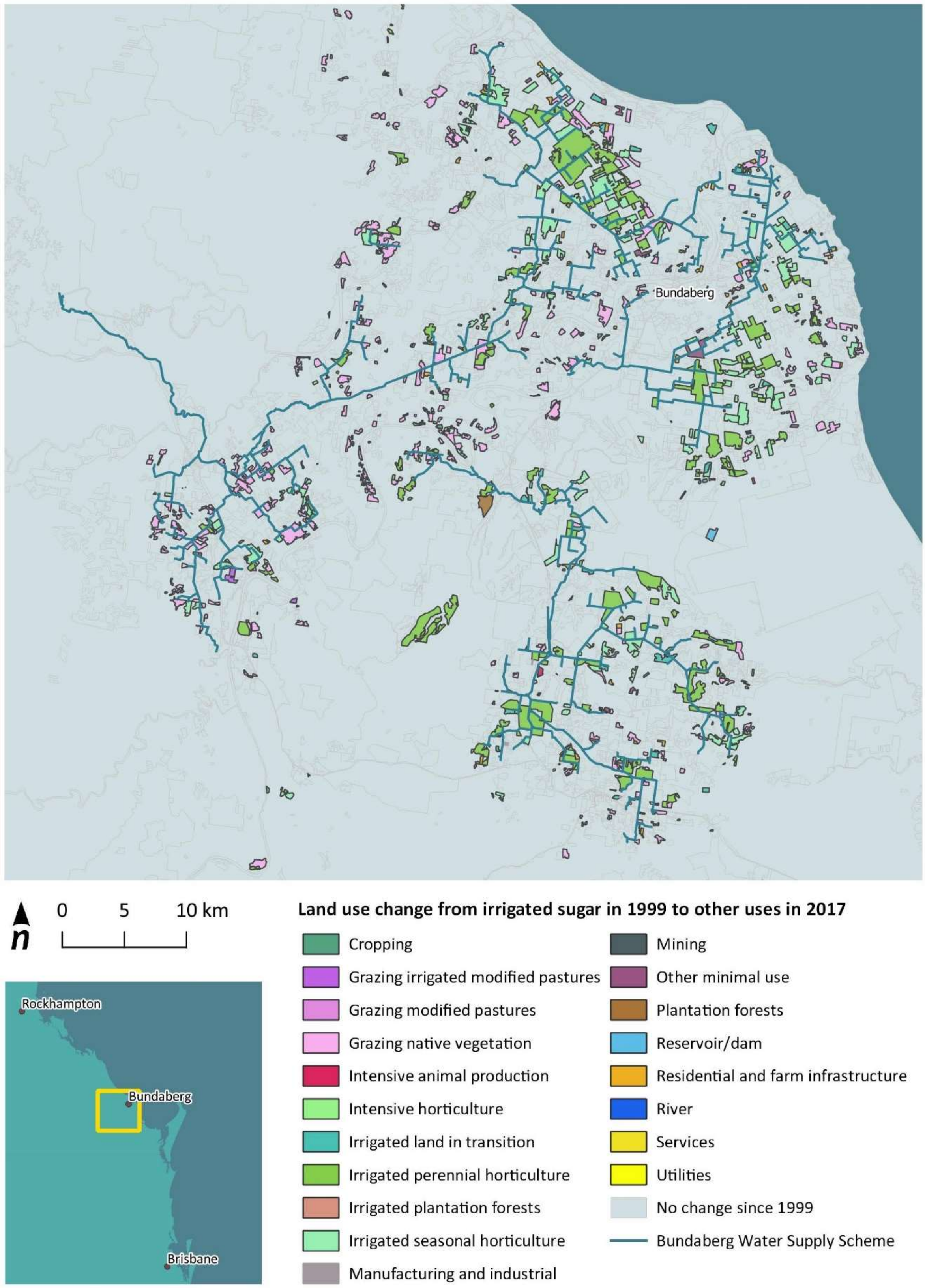

Figure 15. Change in irrigated cropping (sugar to other crops 1999 to 2017)

Source: Queensland Land Use Mapping Program

The relative share of irrigated land use by irrigation activity for the periods 1999, 2009, 2017 and 2019 (estimated) is shown in Figure 16.

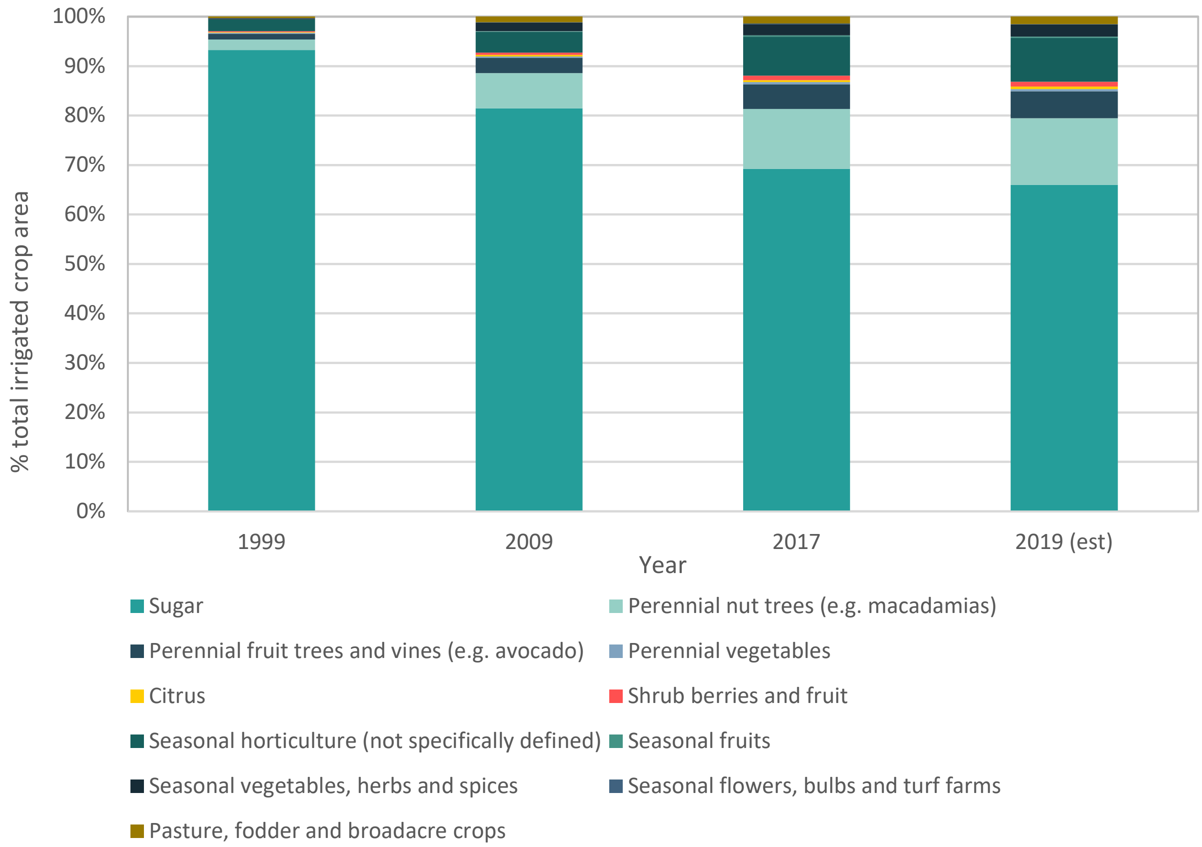

Figure 16. Change in irrigated cropping (share of irrigation land use)

Source: Queensland Land Use Mapping Program

Key points

Estimates of growth in water demand attributable to expanded areas of horticulture crops needs to be calculated as the difference between the water demand for sugarcane irrigation and horticulture irrigation.

If current trends continue, there will be pressure on the viability of the mills in the medium-term unless market conditions for sugarcane farming and milling improve.

Climate and climate change

One of the region's historical advantages for agriculture has been the climate, with reasonable levels of rainfall and temperatures to meet the requirements of multiple agricultural activities (including crops and livestock).

The two main climate parameters of interest are rainfall and temperature. These are outlined overleaf for Bundaberg and Gayndah.

- Bundaberg as a representative climate for the BWSS.
- Gayndah as a representative climate for the western parts of the areas that could draw on Paradise Dam (via the Coulston Lakes pipeline proposal).

Both historic information and information relating to future climate scenarios are presented.

Historical data

Table 15 shows historical rainfall data for Bundaberg and Gayndah. This includes average monthly figures, decile 1 (representative of dry months), and decile 9 (representative of wet months).

Table 15. Historical monthly rainfall (mm)

Metric	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bundaberg													
Decile 1 - dry	45	36	17	14	14	6	3	4	2	13	21	44	680
Average	171	156	113	56	67	50	39	34	35	77	84	127	1,022
Decile 9 - wet	324	313	272	115	123	141	90	70	80	143	159	229	1,490
Gayndah													
Decile 1 - dry	23	17	18	3	3	1	2	2	2	12	22	30	532
Average	113	106	73	38	41	40	38	29	35	66	80	104	762
Decile 9 - wet	218	232	156	86	96	87	87	69	80	122	147	176	1,028

Source: BOM (2019)

Figure 17 shows the historical rainfall data for Bundaberg and Gayndah represented graphically, including the wet and dry deciles.

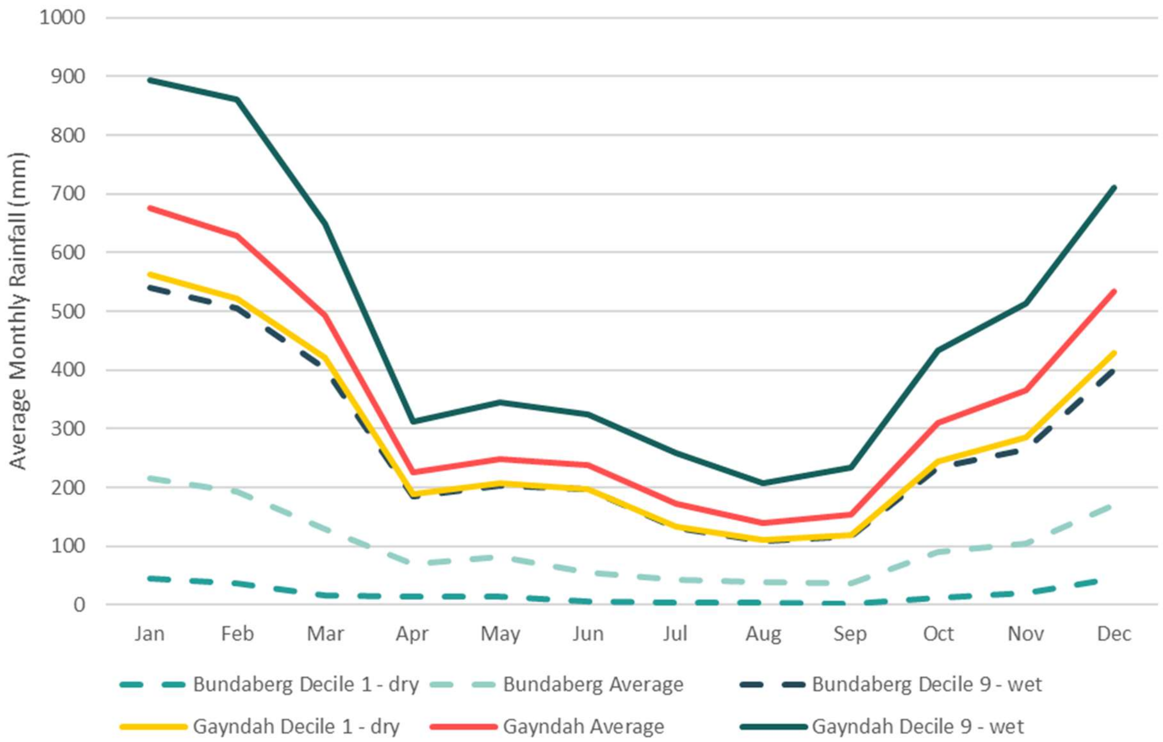

Figure 17. Historical monthly rainfall (mm)

Rainfall in Bundaberg is typical of a summer-dominated rainfall pattern. The data shows annual rainfall in Bundaberg is around 1,020 mm per annum, with significant variation within months and across the year. While total rainfall is lower than some other sugarcane regions (e.g. the Burdekin), the wet season – dry season dynamic is not as pronounced. This can be beneficial for many horticulture crops that require a more consistent application of water over the crop cycle.

Rainfall in Gayndah is generally around 30% lower than in Bundaberg, while the distribution patterns across the year are relatively similar. Therefore, given a similar water requirement for irrigated crops and the use of a deficit irrigation approach, growing crops in the west of the region will require higher application rates than in the eastern parts of the broader region.

Key points

Crop irrigation requirements (ML/ha) are most likely to be higher in western areas of the region than in the BWSS due to differences in rainfall.

Because the wet season – dry season rainfall patterns in the region are less pronounced than some competing regions, this can provide a regional competitive advantage for some crops.

Temperature is also a significant factor for many crops, particularly high temperatures that both increases evapotranspiration and creates heat stress in crops. However, the winter temperatures in the region creates significant opportunities for counter-seasonal horticulture opportunities.

For example, research undertaken by Growcon, University of Queensland and other researchers[10] found:

- The extremes of temperature ranges are typically more important to horticulture crops than mean temperatures.
- Crops such as tomato or capsicum suffer when temperatures exceed 30ºC during the day, significantly impacting on yields.
- Germination for cucurbits (such as pumpkin) significantly declines when temperature exceed 30ºC.
- Tubers such as potatoes are unlikely to set at temperatures above 29ºC and damage to mature vegetables occurs at 32ºC.
- Many crops grown in the region as part of counter-seasonal opportunities (e.g. lettuce, peas) have optimal growing temperatures that are exceeded in the winter months.

For perennial tree crops, the impacts of high temperature can also be profound. For example:

- For macadamias, consultation revealed that vegetative growth, premature nut drop, leaf burn and nut growth and oil accumulation occur from temperatures above around 32ºC and become significantly worse above 35ºC. Trees will require greater irrigation than in cooler climates.
- Avocados are also impacted by warmer temperatures, which can reduce productivity and fruit size.[11]
- Orchards and longer growing crops will need to be carefully considered before planting. Solutions such as sprinklers to cool crops or netting for shade are expensive options and can even be maladaptive over the longer term (Deuter, 2011).

These findings are also consistent with the Queensland Government Adaptation Strategy: Agricultural Sector Plan.[12]

Table 16 shows the historical number of days exceeding 30ºC and 35ºC by month and mean maximum monthly temperatures for both Bundaberg and Gayndah. It shows that even winter temperatures are at or exceeding temperature thresholds for some key crops grown in the region. This is particularly the case in Gayndah where the number of days exceeding 30ºC is twice that of the coastal zone. While the

[10] Putland, Dave & Deuter, Peter. (2011). The effects of high temperatures on vegetable production and the rapid assessment of climate risk in agriculture. HAL (2013) Understanding and managing impacts of climate change and variability on vegetable industry productivity and profits

[11] Howden et al (2005) Climate Change - Risks and Opportunities for the Avocado Industry

[12] Queensland Government (2017) Queensland Government Adaptation Strategy: Agricultural Sector Plan

region has significant opportunities for counter-seasonal production of annual horticulture (summer crops harvested in winter), opportunities are more constrained in the west of the region. This is further exacerbated by constrained water supplies and distances to processing facilities.

Table 16. Historical temperature records (high temperatures)

Metric	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bundaberg													
≥ 30°C	18	16	10	2	0	0	0	0	1	3	6	13	69
≥ 35°C	0	0	0	0	0	0	0	0	0	0	0	0	1
Mean max temp ºC	30	30	29	27	24	22	22	23	25	27	28	30	
Gayndah													
≥ 30°C	25	21	21	9	1	0	0	0	5	13	20	25	140
≥ 35°C	8	5	2	0	0	0	0	0	0	2	5	8	29
Mean max temp ºC	33	32	31	29	25	22	22	24	27	30	32	33	

Source: BOM (2019).

Key points

Temperature thresholds that negatively impact on plant flowering and growth are already being met for some key crops.

Temperature thresholds are most likely to be exceeded in the west of the region, compared to the coastal zone.

Future climate scenarios

Climate change will have an impact on rainfall in the future and subsequent water demand, but the impacts are relatively uncertain. Understanding the impact of climate change on future patterns and separating short-term variability from underlying trends is an extremely complex modelling exercise.

The Climate Futures Tool was used to better understand the range of potential future scenarios for the region's climate. A number of models were used to establish the Climate Futures Tool, and results are typically interpreted as the degree of consensus of impacts across the 67 climate models and the subsequent impacts on rainfall.[13] Because climate change is inextricably linked to greenhouse gas concentrations, scenarios with alternative representative concentration pathways (RCPs) have been developed.[14] The RCP 8.5 is more consistent with current worldwide projections. A summary of rainfall results for the East Coast region for 2050 is shown in Figure 18. The key points include:

- For RCP 4.5, there is moderate consensus across the models that there will be little change in annual rainfall (i.e. -5 to 5% change) and moderate consensus that annual maximum daily temperature will be 0.5 to 1.5 degrees warmer than current temperatures. While the modelling shows that rainfall and temperature could move in either direction (up or down), there is a skewness in the results across all models towards a hotter and dryer climate.

- For RCP 8.5, although still low, the greatest consensus is that it will become hotter (annual maximum daily temperature) and there will be little change in annual rainfall (% change). The skewness of the modelling towards a hotter and dryer climate is more pronounced.

[13] See: https://www.climatechangeinaustralia.gov.au/en/climate-projections/

[14] RCP is a greenhouse gas concentration (not emissions) trajectory adopted by the Intergovernmental Panel on Climate Change.

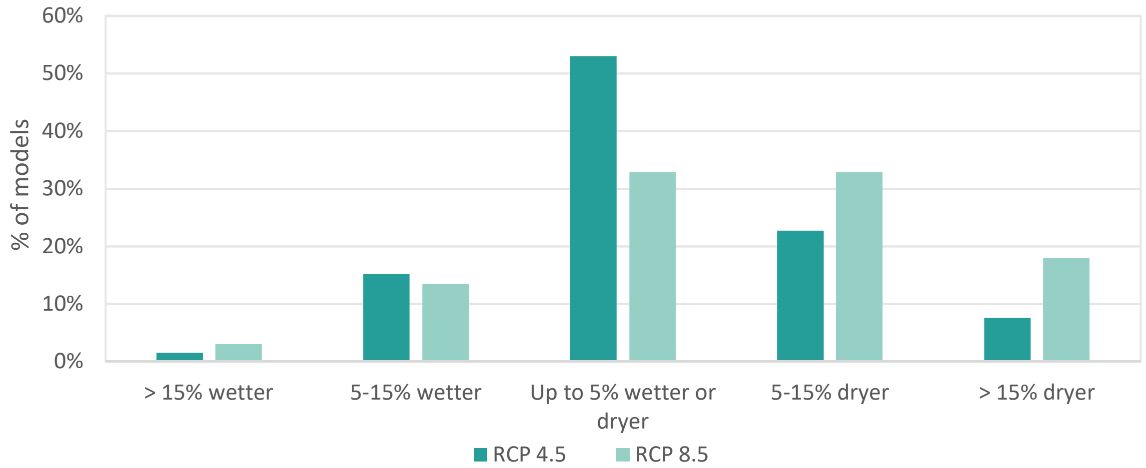

Figure 18. Distribution of climate modelling outcomes for rainfall by 2050

Source: Climate Change in Australia[15]

Most irrigation in the region is deficit irrigation (i.e. irrigation water is applied to make up for a deficit in plant requirements that is not met by rainfall). Based on an annual average rainfall for the region of 1,022 mm, a 10% change in annual average rainfall = approximately 1 ML change in irrigation requirement (holding all other variables constant). Using this assumption and the range of outcomes from the climate models it is possible to develop insight into the impact that climate change may have on irrigation requirements.

The potential impact of permanent changes in annual average rainfall on irrigation requirements is shown in Figure 19. At the extremes, irrigation requirements could be +/- 1.5 ML/ha. However, the weighted average of 67 models for RCP 8.5 is about a 0.3 ML/ha increase in irrigation requirement. The weighted average of 66 models for RCP 4.5 is about 0.2 ML/ha increase in irrigation requirement. The weighted average for RCP 8.5 and the two extremes were used as climate change parameters within the demand modelling for this demand assessment. The impact of short-term rainfall variability and actual irrigation rates is analysed in Section 3 of this report.

[15] Climate Futures Tool Online: https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/projections/ Accessed 06/12/19.

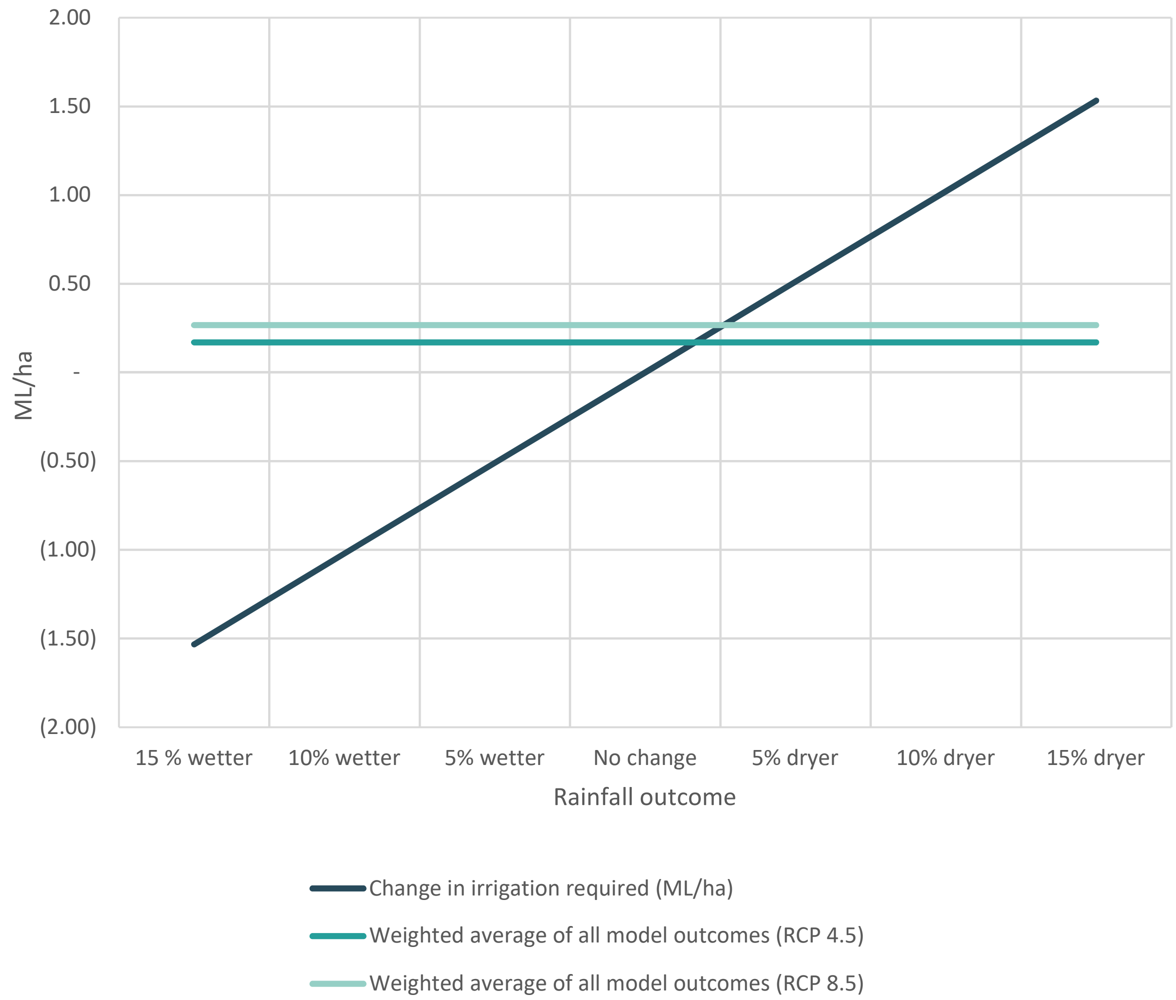

Figure 19. Impact of permanent changes in annual average rainfall on irrigation requirements

Source: Climate Futures Tool[16]

Key points

In the longer-term, climate change will have an impact on the region's competitive advantages, productivity and irrigation requirements.

By 2050, expected peak temperatures will have a detrimental impact on the productivity and viability of some crops, while irrigation rates will likely need to increase to compensate for declines in long-term rainfall expectations.

Changes in irrigation requirements have been incorporated into our demand assessments.

B3. Historical Medium Priority use

This section briefly outlines the analysis of MP allocations in the BWSS. Data used in this analysis was provided by SunWater.

[16] Climate Futures Tool. Online: https://www.climatechangeinaustralia.gov.au/ and NCEconomics estimates

Historical patterns of use

An assessment of historical MP water usage from Paradise Dam was undertaken based on data supplied by SunWater for years 2009 to 2019. The seven zones included in the analysis were the Burnett Zones CA, CB, and GZ as well as the Kolan Zones AA, AB, AC and AD as per SunWater (2019).[17]

Quarterly historical data was provided for five variables: water usage, water allocation entitlements (WAE), announced allocations (AA), temporary trade (TT) and carry over (CO). Figure 20 shows the trends in usage, WAE, AA, TT and CO.

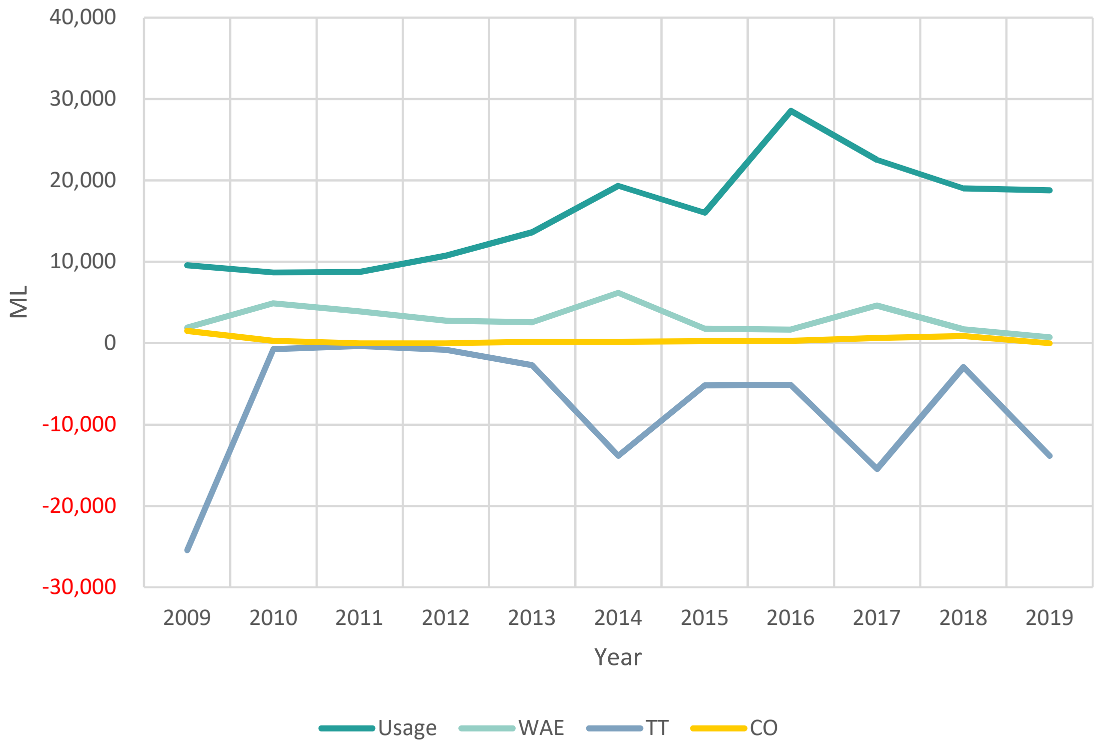

Figure 20. Trends in medium priority usage, allocation entitlements, temporary trade and carryover water (ML) in the relevant BWSS.

Across all the seven zones covered in this analysis, water usage increased from around 9,600ML per annum to 19,361ML per annum between 2009 and 2014. Usage peaked at 28,545ML in 2016 before dropping to 19,011ML in 2018. Additional WAE purchases across the seven zones have been variable but averaged 2,980ML per annum, whereas carry-over water averaged 384ML per annum for the 2009-2019 period.

Figure 21 shows historical MP water usage by zone over 11 years from 2009. Zone CA has used the most water up to 2018 and then more recently Zone CB is drawing more MP water. Overall, there has been an increase in usage from 9,594ML in 2009 to 28,545ML in 2016. After 2016 usage dropped to 19,011ML by 2018.

[17] Paradise Dam has 124,000ML of MP water allocation which there has been a 24,186 uptake (SunWater, 2019)

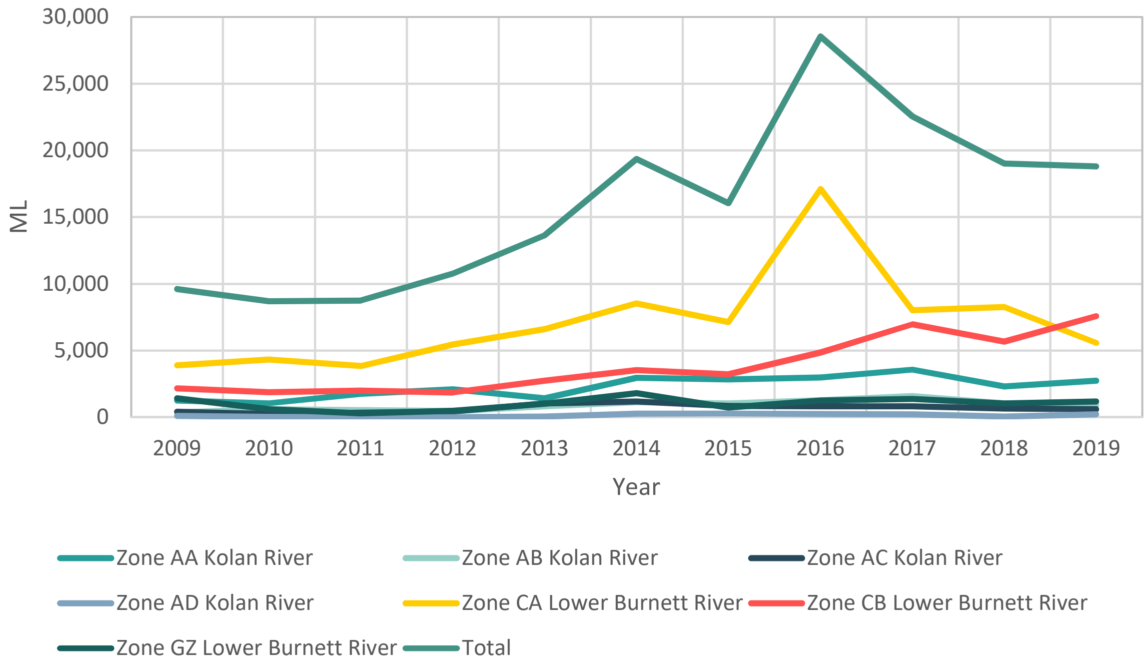

Figure 21. Trends in medium priority water usage (ML) for all seven zones from 2009 to 2019

Usage of MP water for irrigation purposes is influenced by the amount and timing of rainfall as well as crop water requirements. Thus, it is expected that during periods of low rainfall farmers will use more MP water to meet crop water requirements.

Monthly rainfall data was sourced from the Bureau of Meteorology (BoM, 2019).[18] While climate varies significantly, Figure 22 shows there has been a decrease in annual rainfall across the seven zones between 2009 and 2019 (the period for this analysis).

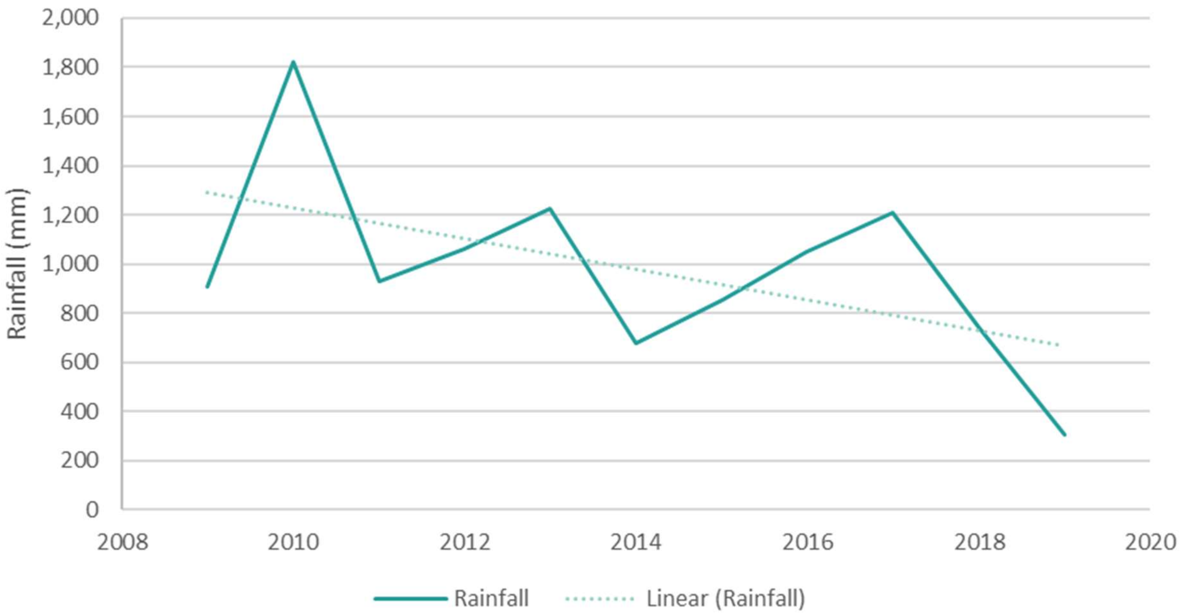

Figure 22. Trends in annual rainfall from 2009 to 2019

[18] BoM (2019) Climate Data Online, Bundaberg Aero, Station No. 39128, Bureau of Meteorology, Australian Government, access November 2019 via http://www.bom.gov.au/climate/data/

Econometric analysis

An econometric analysis was undertaken to investigate the relationship between rainfall and MP water usage. The relationship was investigated using an ordinary least squares regression analysis. The purpose of the regression analysis was to establish how changes in rainfall affects MP water usage across the seven zones supplied by the Paradise Dam. Because of the way the data was provided by SunWater, the analysis was undertaken at a whole-of-system level (i.e. usage information was the total water used in all seven zones, and analysis of individual irrigator changes to shifts in annual rainfall was not possible). A customer level assessment would have been more robust as customer usage patterns will better reflect their specific crop water requirements given both availability of accessible MP water and rainfall. Thus, the results from this econometric assessment should be used with caution and as a general guide at the system level only.

Data and approach

The econometric analysis was undertaken by regressing water usage on rainfall, WAE, AA, TT and CO water. Our hypothesis was that, as rainfall amounts reduce, more MP water will be required to meet crop water demand. An initial assessment of rainfall and MP water usage indicated on average less MP water was used as rainfall increased. Figure 23 shows that this relationship has a wider 95% confidence interval during low and higher rainfall amounts.

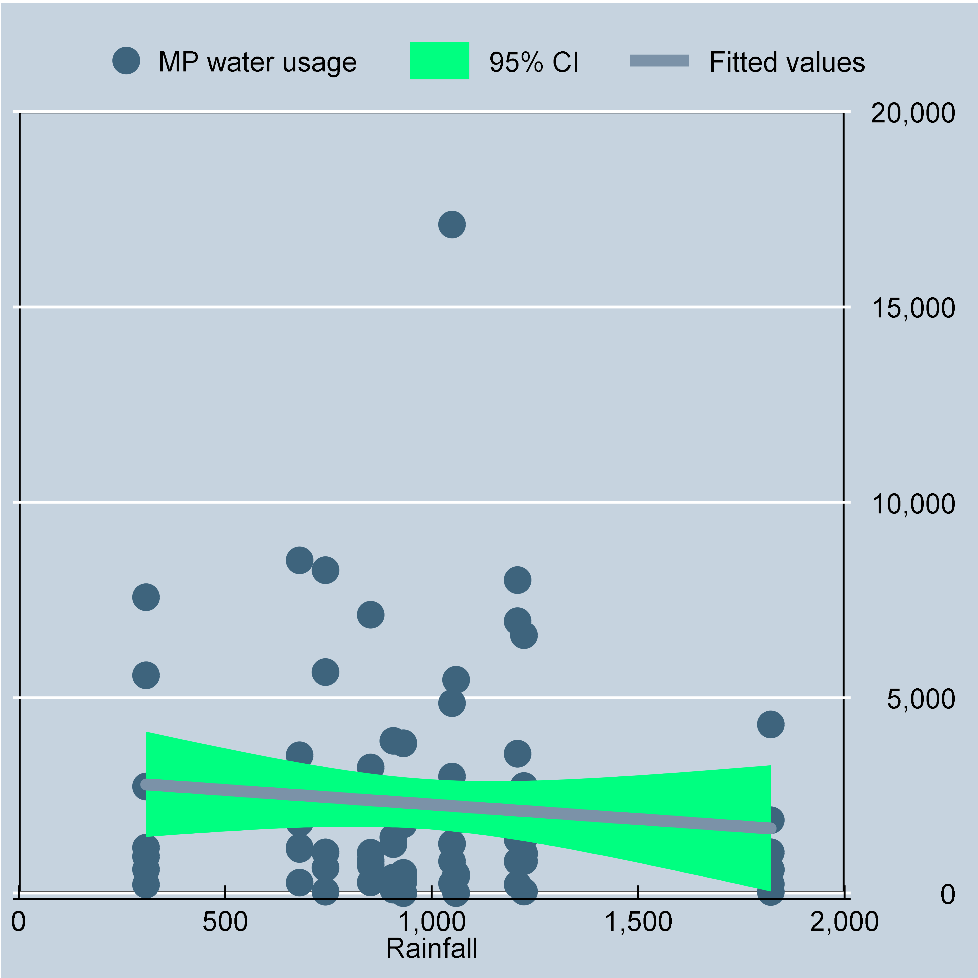

Figure 23. Scatter plot between MP water use and annual rainfall

Table 17 provides summary statistics used in the regression analysis. There were 77 observations from the seven zones.

Table 17. Key inputs and assumptions incorporated into model

Variable	Observations	Mean	Std. Dev.	Min	Max
Usage (ML)	77	2,282	2,811	1	17,109
Rainfall (mm)	77	980	366	308	1,821
Water Allocation Entitlements (ML)	77	426	651	-68	3,276
Announced Allocations (ML)	77	23,480	29,349	0	124,203
Temporary Trade (ML)	77	-1,122	2,968	-19,676	1,694
Carry over (ML)	77	55	115	-3	633

Results

Preliminary modelling suggested that there was a lag in the response of MP water use to annual rainfall. Therefore, the dependent variable (water usage) was lagged by one period. This implies that low rainfall in the current period will result in increased usage in the following period. A log-linear model was used for the estimation as follows:

$$\log(usage\_1) = \beta_0 + \sum \beta_1\, rainfall + \sum \beta_2\, WAE + \sum \beta_3\, AA + \sum \beta_3\, TT + \sum \beta_3\, CO + \varepsilon$$

Where:

Usage_1 is the MP 1 water usage in ML (dependent variable lagged by 1 period)
Rainfall is rainfall in 100mm
WAE is water allocation entitlement in ML
AA is announced allocation in ML
TT is temporary trade in ML
CO is carry-over water in ML
ε is the error term

Regression results are presented in Table 18.

These results indicate that a 100mm decrease (increase) in rainfall[19] is associated with an 8.39% increase (decrease) in MP water usage. Therefore, if a farmer uses an average of 6 ML/ha under average rainfall conditions (1,022 mm/annum), and rainfall is 10% (100 mm) lower, the farmer would apply an additional 0.5ML/ha (i.e. 6 ML* 8.39% = 0.5 ML).

The regression model had an adjusted R^2 of 33%. This indicates that 33% of the variation in MP water usage is explained by the independent variables included in the model.

Table 18. Regression results (n=77)

Variable	Coefficient	Robust Std. error	p-Value	95% Confidence interval		Average marginal impact
Rainfall (100mm)	-0.08760	0.04154	0.039	-0.17043	-0.00476	-8.39%
WAE	0.00053	0.00025	0.040	0.00002	0.00103	0.05%

[19] A 100mm change in rainfall is the equivalent to 1 ML over 1 ha.

Variable	Coefficient	Robust Std. error	p-Value	95% Confidence interval		Average marginal impact
AA (ML)	0.00001	0.00000	0.003	0.00000	0.00002	0.001%
TT (ML)	-0.00003	0.00006	0.622	-0.00015	0.00009	-
CO (ML)	0.00567	0.00138	0.000	0.00292	0.00841	0.57%
Constant	6.98071	0.44214	0.000	6.09912	7.86231	n/a

Dependent variable: Log(usage), n=77, Adjust R^2=33%

Implications for MP allocation demand assessments

The results from the regression analysis indicates that across the seven zones, a decrease of 100mm or 1ML/ha in annual rainfall does not necessarily lead to a 1ML/ha increase in MP water usage. The modelling also suggests that the response to decrease in rainfall amounts is not immediate but delayed. This implies that after a period of limited rainfall, farmers will irrigate more to achieve the soil and crop water requirements. Additionally, the availability of water allocations (through AA) only stimulates limited increases in usage – suggesting that there are constraints on demand increases. Such constraints may include: limited opportunities to increase the area under irrigation, market access for extra produce, commodity prices, energy costs, limited water distribution infrastructure for areas that may require more water, among others.

Key points

The regression analysis suggests that across the seven zones, a decrease of 100mm or 1ML/ha in annual rainfall does not necessarily lead to a 1ML/ha increase in MP water usage.

The results suggest that there is a delay between a reduction in rainfall and farmers' decisions to increase irrigation rates.

The results also suggest that an increase in the availability of water allocations (AA) stimulates limited increase in water demand.

B4. Irrigated sugar

Approximately 95% of sugar produced in Australia is grown in Queensland, and Bundaberg is one of five primary sugarcane growing regions in the state (DoA, 2019; QEAS, 2019). According to a recent report by QEAS (2019), the whole sugar value chain in Bundaberg and Burnett generates around 1,800 FTE jobs (or nearly 7% of all jobs in the Bundaberg SA3 region). This supports approximately $440 million of local economic activity (QEAS, 2019).

Current situation and water use

Historically sugar milling and processing has been the most significant commercial/industrial water using activities in the region. Among the main regional water users are the three local sugar mills: Millaquin, Bingera and Isis. Figure 24 depicts a short timeseries of tonnes of crushed sugarcane and the world indicator sugar price (in US$/lb).[20] The quantity of crushed sugarcane at each of the three mills appears to generally follow the world indicator sugar price. This suggests that when the world sugar price is trending 'higher', farmers are incentivised tom plant more crop, and more sugar is

[20] Sugarcane producers are price-takers, meaning that they are sellers in a competitive market and therefore have no control over the price of the product.

crushed in the region, and when price is 'lower' less sugar is crushed. Since 2016 the world price for sugar has declined and for a 'vast majority of world producers' this price is below production costs (FAO, 2019). This has also coincided with a more positive market environment for other crops that is resulting in changes in land use, and a general decline in the area under sugar.

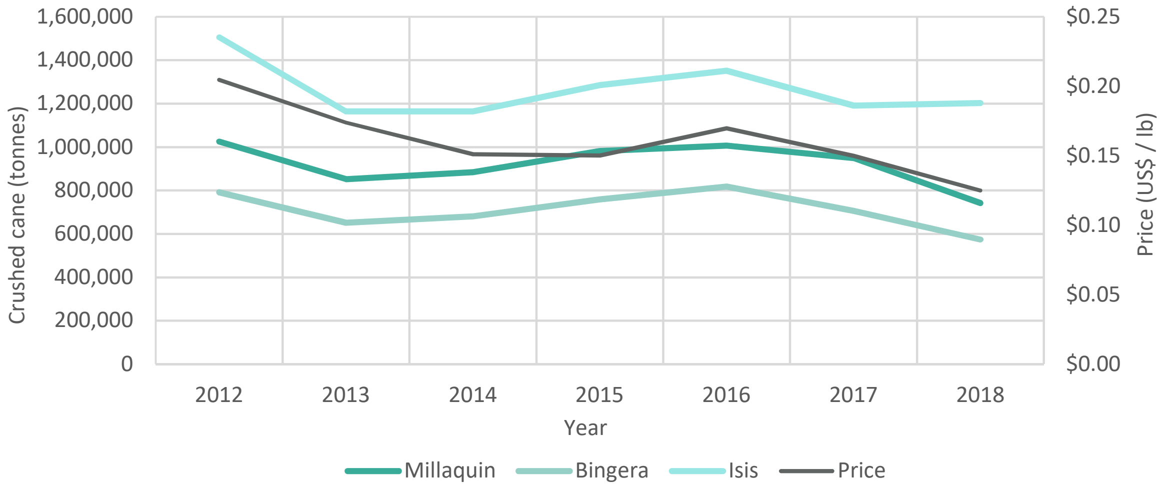

Figure 24. Tonnes of crushed sugarcane and world indicator sugar price

Source: Canegrowers (2013 – 2019); ABARES (2019)

Based on the State's land use mapping, the annual average rate of conversions (i.e. converted sugarcane land for higher value crops) is around 589 ha per annum. This is consistent with the views within industry, although more accurate industry data is not available at this time.

Irrigation watering requirements range from 5.8 ML/ha through to 6.8 ML/ha for less efficient watering systems on some soil types, with consensus that around 6.3 ML/ha is preferable. The choice of irrigation application technique is determined by factors including the reliability and cost of water allocations, SunWater water service delivery charges, electricity charges and labour costs.

Demand drivers and market opportunities

ABARES (2019) indicates that worldwide consumption of sugar is forecast to exceed production for the first time in two years, placing some upward pressure on prices in the short-term. However, high carry-over stocks will provide a substantial buffer against any material rise in prices (ABARES, 2019). In 2027, the OECD-FAO (2018) predicts that the price of sugar is likely to decrease (in real terms). This forecast gives producers less reason to grow sugar when they could be farming higher value crops. Due to this expectation, there is considered to be a lower likelihood that greenfield sugarcane land will be developed in the (short-medium) future. Yet, if the industry were to recover, then the this could lead to sugarcane being re-established within areas of the irrigation scheme that have become dormant in recent years. Consultation also revealed that a sustained recovery in sugar production was contingent on both improving market conditions and an ability to reduce costs (particularly energy and to a lesser extent water)

Key assumptions underpinning estimates

Table 19 summarises the key parameters and assumptions used for the demand analysis of irrigated sugar.

Table 19. Key inputs and assumptions incorporated into model

Parameter	Range of parameters			Comments
	Low	Medium	High	
Market outlook (impact on rate of change)	-	-	-	Sugarcane land is presently being converted to higher value crops, which means that residual loss is equivalent to gains elsewhere.
Trend in annual change in land use (ha)	-359	-589	-846	Average annual conversion from sugarcane land is estimated at 589 ha. This would see existing loss patterns continue. Yet, pace of loss is still unknown given the uncertainty of future growth of other (higher value) crops that convert sugarcane land.
Annual irrigation requirements (ML / ha)	5.8	6.3	6.8	Advised by industry.
Reliability. Is it important? Impact on allocations held vs. average water used	-	-	-	Primarily an annual crop that makes use of MP allocations. There is limited incentive to hold additional water to offset reliability of allocation risk (because holding costs exceed the benefits of risk mitigation). Water users won't pay for having greater reliability.
Impact of climate change (RCP 8.5) on water use ML/ha by 2050	-1.5	0.3	1.5	Based on outputs of climate modelling. These form the range of parameters for the climate change sensitivity analysis.

B5. Irrigated horticulture

Irrigated horticulture has seen significant changes in the past 10 years, as some sugarcane land transitions to higher value horticulture crops. Because of the superior reliability of water from the BWSS, local industry is seeking to concentrate much of the future development of high-value horticulture in areas currently serviced by Paradise Dam water and the Bundaberg Water Supply distribution system.

Macadamias

Current situation and water use

The harvest season for macadamia in Bundaberg is primarily February to July, around one moth ahead of the Northern Rivers area of NSW which is the other major production areas in Australia. Consultation in the region and State land use mapping both indicate that macadamia development is almost exclusively occurring on existing sugarcane farms. Based on the State's land use mapping, the annual average rate of conversions is around 337 ha per annum. This is consistent with the views of industry, although detailed industry data are not available at this time. Existing sugarcane farms generally sell for $25-$35/ha, a significant premium on their worth for sugarcane production, but still significantly lower than the cost to purchase and establish greenfield irrigated macadamia farms. Conversion to perennial tree crops such as macadamias can cost in excess of $70,000 per ha.

Irrigation watering requirements range from 5.2 ML/ha for micro-sprinklers through to 11.9 ML/ha for less efficient watering systems on some soil types, with general consensus that around 10 ML/ha was preferable (Anon, 2004). The choice of irrigation application technique is determined by factors, including the reliability and cost of water allocations, SunWater water service delivery charges, electricity charges and labour costs. Consultation with a number of growers indicated that more efficient irrigation techniques required more labour inputs (e.g. maintaining sprinkler systems) and did not provide moisture to plant leaves, which is important to avoid leaf burn. Therefore, the growers tend to consider the superior commercial outcome is to use more water.

Consultation with SunWater relating to the recent sales of allocation indicate that the water was sold to irrigators with the BWSS. There are two drivers for this:

- Crop requirements for macadamia are higher than sugar (around 10 ML/ha vs. around 6 ML/ha).
- The downside risks of lower announced allocations are much greater for perennial tree crops due to the higher costs of crop establishment and the significant lags between crop establishment and revenue generation. Therefore, some producers are purchasing and holding additional MP allocation as substitute for any perceived deficiencies in the reliability of MP allocations.

Demand drivers and market opportunities

Macadamias have shown a significant rate of growth in recent years and Bundaberg is now one of the two major production areas within Australia along with the north coast of NSW. The focus of sales is progressively moving to export opportunities in China, Vietnam and Hong Kong that collectively account for around 10% of exports (Horticulture Innovation Australia, 2018).

Overall, there has been a general upward trend in Australian macadamia production and net exports. Figure 25 shows that there has been a general increase in macadamia production. An estimated 45,000 tonnes were produced in 2014/15 and this increased to over 49,000 tonnes in year 2017/18. Similarly, net exports have increased from 17,000 tonnes to over 21,000 between 2014 and 2018. The value of exported macadamia increased from $215 million in 2014/15 to $297 million by 2017/18. Macadamia imports have been relatively small compared to the production and export volumes. In 2017/18, only 111 tonnes of macadamia were imported into Australia. The volume of fresh supply of macadamia to retail and food services outlets has increased from about 3,000 tonnes to over 3,700 tonnes between 2015 and 2018. Thus, macadamia profitability is driven by both international and domestic demand.

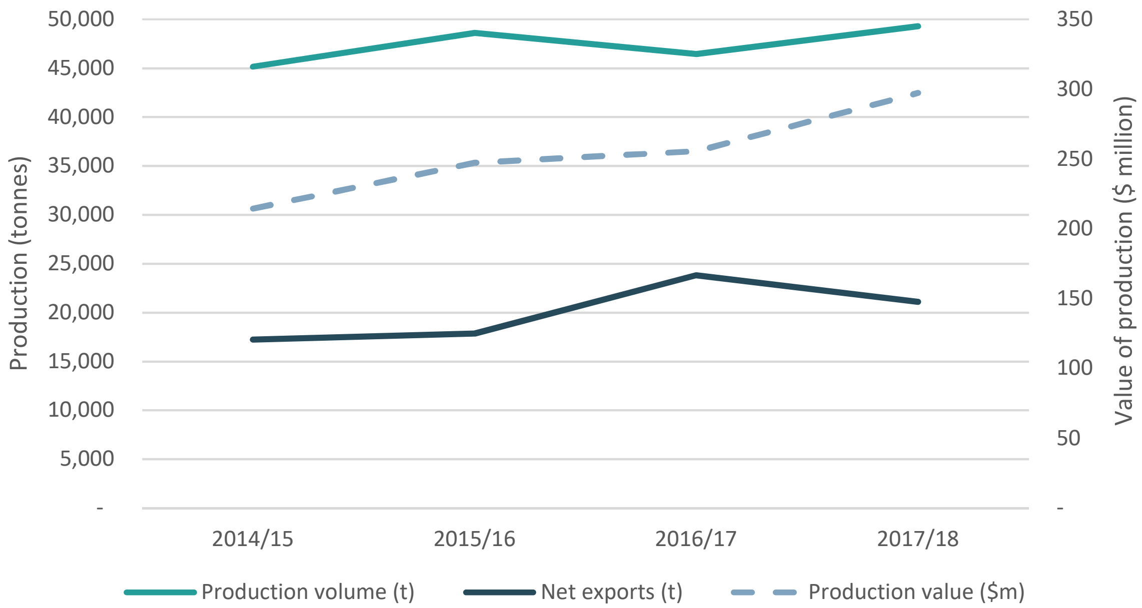

Figure 25. Australia macadamia production and trade

Source: Horticulture Australia (2015, 2016, 2017, 2018, 2019)

Bundaberg region is a relatively low cost and high productivity environment. A few larger Australian businesses have entered the regional market and are very active. Consultation and research suggest growth prospects largely relate to exploiting emerging export opportunities (e.g. China) via Port of

Brisbane. The larger businesses are driving much of these market outcomes through the establishment of direct export markets.

Expansions in processing capacity have / are occurring by larger producers to achieve a degree of vertical integration and to capture value-adding opportunities. These plants have additional capacity to act as regional hubs for processing of crops from smaller producers.

Water availability and relatively cheap conversions of irrigated sugarcane land to macadamia is the key driver of demand. Constraints on growth are the limitations of available grafted trees, and the lag between establishment and full production (7 - 10 years) that creates a need for substantial working capital. To offset this risk, many producers are undertaking a process of incremental change from sugarcane to macadamia, where sugarcane continues to provide cashflow in the interim.

Key assumptions underpinning estimates

Table 20 summarises the key input parameters and assumptions used for the demand analysis.

Table 20. Macadamia demand model inputs and assumptions

	Range of parameters			
Parameter	Low	Medium	High	Comments
Market outlook (impact on rate of change)	70%	100%	130%	All scenarios would see growth continue. The medium parameter would see current rates of growth continue.
Trend in annual change in land use (ha)	236	337	438	This would see existing growth patterns continue, but consultation revealed there is significant uncertainty on the pace of future growth (decelerating/accelerating).
Annual irrigation requirements (ML / ha)	5.2	10.0	11.9	Lower application rates are for micro-sprinklers on clay soils. Industry consultation indicates target requirement closer to 10 ML/ha as less efficient sprinklers are being used to offset higher labour costs associated with micro-sprinklers).
Reliability. Is it important? Impact on allocations held vs. average water used	-	-	-	Reliability is very important due to downside risk of losing trees, or not being able to water at critical points of season. This is the key driver for irrigators purchasing excess MP allocations to offset risk.
Impact of climate change (RCP 8.5) on water use ML/ha by 2050	-1.5	0.3	1.5	Based on outputs of climate modelling. These form the range of parameters for the climate change sensitivity analysis.

Avocados

Current situation and water use

Avocados have seen a rapid expansion in production areas in the Bundaberg region in recent years. Based on the State's land use mapping program, annual average increases in planted trees are around 120-130 ha, a figure that is consistent with advice from industry in the region.

Avocado production has increased from about 55,000 tonnes in 2012/13 to 77,000 tonnes in 2017/18. While Australia does export some avocadoes, Australia is a significant net importer of avocados, peaking at around 20,000 tonnes in 2016/17. The bulk of imports are from New Zealand that is able to export at particularly competitive prices. Figure 26 shows the trend in in production and trade volumes for years ending June 2012 and June 2018.

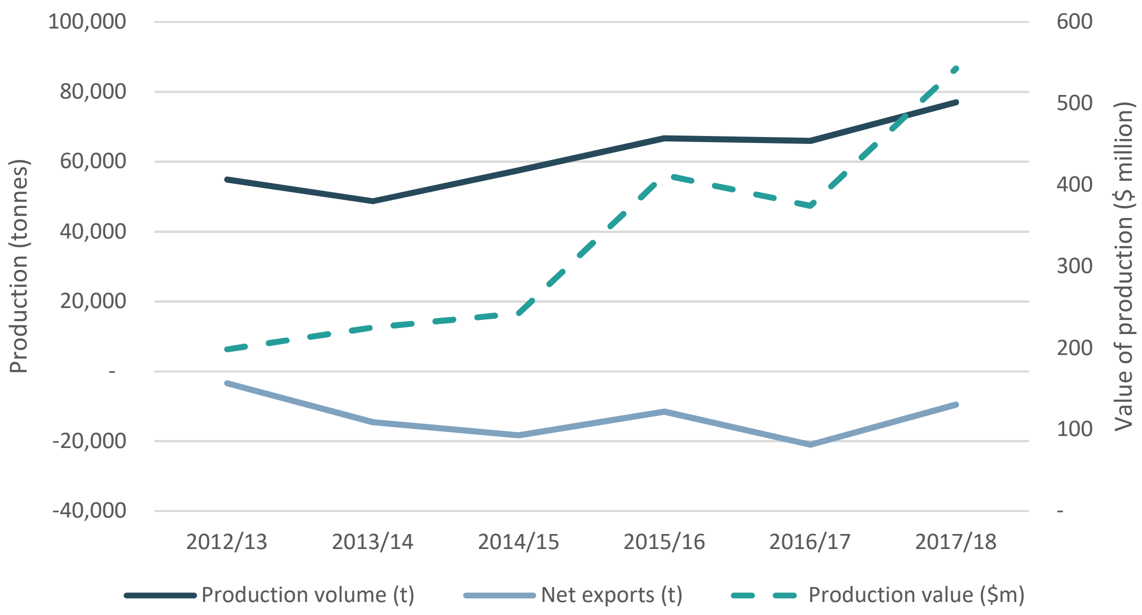

Figure 26. Australia avocado production and trade

Source: Horticulture Innovation Australia (2014, 2015, 2016, 2017, 2018, 2019)

Water use is typically between 7.2 and 9.7 ML/ha depending on the application technique and dominant soil type (Anon, 2004). Tree establishment in areas with a clay-loam soils are often preferred by growers as this enhances soil moisture retention, while the ultimate tree structure is often shorter which enables more efficient harvest practices.

Major production areas include the Atherton tablelands, Bundaberg/Childers, northern NSW, Sunraysia (NSW) and Pemberton (WA). The height of availability of Queensland avocadoes is typically March to June, with lower levels of harvest extending to September. The March to June period provides an almost perfect counter-seasonal harvest opportunity to the southern states.

Demand drivers and market opportunities

Consultation and previous economic analysis has shown that margins are much higher for avocados than for sugarcane and other broadacre crops, often in excess of $10,000 ha for mature trees, providing a commercial incentive for change. This is not expected to change materially in the medium to long-term.

Avocados are predominantly grown for domestic consumption (including significant import substitution), with some limited export (Horticulture Innovation Australia, 2018). Consultation and research suggest that growth for domestic demand is growing slightly faster than population, and export opportunities depend on market conditions. Export of avocados is more complex than other high value tree crops grown in the Bundaberg region (e.g. macadamias) due to biosecurity requirements and the more perishable nature of the product.

Bundaberg region is a relatively low cost and high productivity environment and already holds a significant proportion of Australia's production. Water availability and cheap conversions of irrigated sugarcane land to trees is a key driver. Consultation and previous economic analysis indicate that margins are much higher than for sugarcane and other broadacre crops, providing a commercial incentive for change. This is not expected to change materially in the medium to long-term.

A few larger Australian businesses have entered the regional market (e.g. Costas) and are very active. Constraints on growth are that the local industry is competing with relatively cheap imports, particularly from New Zealand where production significantly outstrips local demand, production expansion opportunities are significant, and costs can be kept in check. Furthermore, the lag between establishment costs and full production (7 - 10 years) creates a need for substantial working capital. To offset this risk, many producers are undertaking a process of incremental change from sugarcane to trees, where sugarcane continues to provide cashflow in the interim.

Key assumptions underpinning estimates

Table 21 summarises the key input parameters and assumptions used for the demand analysis.

Table 21. Avocado demand model inputs and assumptions

	Range of parameters			
Parameter	**Low**	**Medium**	**High**	**Comments**
Market outlook (impact on rate of change)	25%	50%	100%	All scenarios would see growth continue. The medium parameter would see growth rates lower than the last few years in response to a slowing of price growth.
Trend in annual change in land use (ha)	31	62	124	This would see existing growth patterns continue, but consultation revealed the growth rate is decelerating from very high recent trends.
Annual irrigation requirements (ML / ha)	7.2	8.5	9.7	Lower application rates are for micro-sprinklers on clay loam soils. Application requirements are as high as 9.7 ML/ha for sandy non-structured soils.
Reliability. Is it important? Impact on allocations held vs. average water used	-	-	-	Reliability is very important due to downside risk of losing trees, or not being able to water at critical points of season. This is the key driver for irrigators purchasing excess MP allocations to offset risk.
Impact of climate change on water use ML/ha by 2050 (RCP 8.5)	-1.5	0.3	1.5	Based on outputs of climate modelling. These form the range of parameters for the climate change sensitivity analysis.

Citrus

Current situation and water use

Queensland land use mapping data indicates that the current area under citrus is around 260 ha, but annual growth has been negligible in recent years (e.g. <10 ha per annum). ABS data indicates that lemons and mandarin account for around 85% of the value of production for citrus in the Bundaberg region. The remainder of production is spread across limes, grapefruit and oranges. Citrus growth has been subdued in recent years due to a number of production challenges (e.g. disease) and a subdued market. Consultation in the region indicated that citrus is a low order priority for future development.

Irrigation application rates range from 6.6 ML/ha (micro-sprinklers) through to 9.3 ML/ha for sandy non-structured soils (Anon, 2004).

Demand drivers and market opportunities

While the Australian market is growing for both lemons and mandarin, the growth is broadly aligned with population growth and export opportunities for citrus are relatively limited, accounting for 5-10% of Australia's production. Given that other crops such as macadamia have higher returns, investment in citrus is largely being crowded out. Furthermore, the lag between establishment costs and full production creates a need for substantial working capital. To offset this risk, producers typically undertake a process of incremental change from sugarcane to trees, where sugarcane continues to provide cashflow in the interim.

Key assumptions underpinning estimates

Table 22 summarises the key input parameters and assumptions used for the demand analysis.

Table 22. Citrus demand model inputs and assumptions

	Range of parameters			
Parameter	**Low**	**Medium**	**High**	**Comments**
Market outlook (impact on rate of change)	10%	75%	100%	All scenarios would see growth continue, but absolute growth is negligible.
Trend in annual change in land use (ha)	1	7	9	This would see existing growth patterns continue, but overall impact on water demand is negligible.
Annual irrigation requirements (ML / ha)	6.6	8.0	9.3	Low application rates are for trickle tape while other estimates are for micro-sprinklers. Application requirements are as high as 9.3 ML/ha for sandy non-structured soils.
Reliability. Is it important? Impact on allocations held vs. average water used	-	-	-	Reliability is very important due to downside risk of losing trees, or not being able to access water at critical points of season. This is the key driver for irrigators purchasing excess MP allocations to offset risk.
Impact of climate change on water use ML/ha by 2050 (RCP 8.5)	-1.5	0.3	1.5	Based on outputs of climate modelling. These form the range of parameters for the climate change sensitivity analysis.

Other fruit

Current situation and water use

Avocado (modelled separately) is the major fruit crop in the area, accounting for two thirds of the total value of fruit production. Other major fruit crops include mango, blueberry, strawberry and pineapple. Analysis of the State's land use mapping indicates historical annual growth in the area of other fruit production is around 160 ha.[21] Water use estimates range from 4.6 ML/ha (trickle tape) to 9.4 ML/ha (low pressure spray).

Demand drivers and market opportunities

Industry data shows a significant upswing in production and value adding for blueberries in recent years and this has sparked considerable investment along the Queensland Coast. However, the domestic market is nearing saturation after a doubling of production between 2016 and 2018 (Horticulture Innovation Australia, 2018). Wholesale prices have fallen dramatically, and growers are entering a period of a cost/price squeeze. Australia is still a net importer of fresh blueberries as domestic producers struggle to compete with competitively priced imports. Therefore, growth is expected to slow.

For strawberries, Queensland producers on the Sunshine Coast and around Bundaberg have a significant counter-seasonal production window for supplying the domestic market during winter. This market is relatively mature and growth is aligned with population growth. Export opportunities for fresh strawberries are growing, but only at a rate of 1% of Australia's total production per annum (Horticulture Innovation Australia, 2018).

For mango, supply has been steadily increasing in recent years creating downward pressure on prices. Export volumes have been relatively steady in recent years (Horticulture Innovation Australia, 2018).

[21] It should be noted that this includes 50% of the growth in land use for 'Horticulture not otherwise classified' measure. The balance of horticulture not otherwise classified has been allocated to vegetables. Note. The impact of this allocation will not have a material impact on water demand estimates as the crop requirements are relatively similar.

Pineapple production and sales are almost entirely for the domestic market and the market has shown no material growth in recent years.

There is also some melon and banana production recorded for the region. These markets are also primarily for the domestic market and market growth is subdued (Horticulture Innovation Australia, 2018).

Consultation indicated that while margins may be diminishing for many fruit products, they are still typically much higher than for sugarcane and other broadacre crops, providing a commercial incentive for change. This is not expected to change materially in the medium to long-term. However, domestic market growth will constrain demand and the risk of oversupply and falling prices is real in the absence of more detailed market information.

There is a trend towards vertical integration across the broader fruit sector. Consultation indicated this was already occurring with crops such as tomatoes where glasshouse tomatoes are now dominating growth in production due to better continuity in production and quality control (e.g. Costas Tomatoes in Guyra). Climate change (extreme temperatures) will negatively impact on fruit production, quality and risks to quality in the longer-term.

Key assumptions underpinning estimates

Table 23 summarises the key input parameters and assumptions used in the demand analysis.

Table 23. Other fruit demand model inputs and assumptions

	Range of parameters			
Parameter	**Low**	**Medium**	**High**	**Comments**
Market outlook (impact on rate of change)	25%	50%	75%	All scenarios would see growth continue, but absolute growth is negligible.
Trend in annual change in land use (ha)	40	80	120	This would see existing growth patterns continue, but overall impact on water demand is negligible.
Annual irrigation requirements (ML / ha)	4.6	7.0	9.4	Low end is trickle tape irrigation. High end is low pressure spray.
Reliability. Is it important? Impact on allocations held vs. average water used	-	-	-	Primarily annual crops and use of MP allocations. Limited incentive to hold additional water to offset reliability of allocation risk (holding costs exceed the benefits of risk mitigation).
Impact of climate change on water use ML/ha by 2050 (RCP 8.5)	-1.5	0.3	1.5	Based on outputs of climate modelling. These form the range of parameters for the climate change sensitivity analysis.

Vegetables

Current situation and water use

Bundaberg is a major vegetable production region and the majority of production is for domestic fresh markets. Dominant crops by value of production include tomatoes, capsicum, melons, sweet potatoes and beans (Horticulture Innovation Australia, 2018). Bundaberg is already a major seasonal production hub for most of these crops.

While there are small areas of production of very high value crops (e.g. lettuce), the scale of these markets does not require significant areas of production. Furthermore, much of the very high value crops production is moving to greenhouse production where greater control over the production process and quality control is possible.

Analysis of the State's land use mapping indicates historical annual growth in the area of vegetable production is around 170 ha.[22]

Water use estimates range from 3.0 ML/ha (trickle tape) to 6.0 ML/ha (low pressure spray) (Anon, 2004).

Demand drivers and market opportunities

Consumer sales of fresh vegetables are dominated through the major supermarket chains, and retailers are increasingly responding to consumer preferences for continuity of supply for vegetables year-round. Bundaberg offers significant counter-seasonal production windows to match key demand windows across many vegetable crops, but growth of these markets will ultimately be constrained by growth in aggregate domestic demand. Export opportunities are highly constrained for many of the current crops grown in Bundaberg.

Consultation indicated that while margins may be diminishing for many vegetables, they are still typically much higher than for sugarcane and other broadacre crops, providing a commercial incentive for change. This is not expected to change materially in the medium to long-term. However, domestic market growth will constrain demand and the risk of oversupply and falling prices is very real in the absence of good market information.

Climate change (peak temperatures) may also create a risk to the region's competitive advantage in the longer-term as counter-seasonal production windows change and potentially shorten.

Key assumptions underpinning estimates

Table 24 summarises the key input parameters and assumptions used for the demand analysis.

Table 24. Vegetable demand model inputs and assumptions

	Range of parameters			
Parameter	**Low**	**Medium**	**High**	**Comments**
Market outlook (impact on rate of change)	25%	50%	75%	All scenarios would see growth continue, but absolute growth is slowing.
Trend in annual change in land use (ha)	43	86	129	This would see existing growth patterns continue, but at a slower rate than recent history.
Annual irrigation requirements (ML / ha)	3.0	4.0	6.0	Parameters encompass a range of crops and irrigation types, ranging from trickle tap to overhead sprayers.
Reliability. Is it important? Impact on allocations held vs. average water used	-	-	-	Primarily annual crops and use of MP allocations. No incentive to hold additional water to offset reliability of allocation risk (holding costs exceed the benefits of risk mitigation).
Impact of climate change on water use ML/ha by 2050 (RCP 8.5)	-1.5	0.3	1.5	Based on outputs of climate modelling. These form the range of parameters for the climate change sensitivity analysis.

[22] It should be noted that this includes 50% of the growth in land use for 'Horticulture not otherwise classified' measure. The balance of horticulture not otherwise classified has been allocated to other fruit. Note. The impact of this allocation will not have a material impact on water demand estimates as the crop requirements are relatively similar.

Pasture, fodder and broadacre crops

Current situation and water use

Broadacre crops are used in two ways in the region. Firstly, as a rotation crop between the last ratoon for sugarcane and the sugarcane replanting. In effect, these crops are used as part of a crop rotation regime to maintain soil health. Secondly, these crops are used as a cash crop where the choice is dependent on market conditions and water availability, with these crops often becoming attractive in constrained water availability years. These crops can be highly profitable under the right circumstances as establishment costs are very low.

Water use for these crops is relatively low per ha, ranging from 2 to 5 ML/ha depending on crop choice (Anon, 2004). As long-term growth trends in these crops increase, aggregate demand for water will decline because these crops require less irrigation than other crops.

Demand drivers and market opportunities

Annual demand for these crops fluctuates widely depending on short-term market conditions, climate, and the need for rotation crops within the broader sugarcane industry. This is likely to continue.

Key assumptions underpinning estimates

Table 25 summarises the key input parameters and assumptions used for our demand analysis.

Table 25. Pasture, fodder and broadacre crop demand model inputs and assumptions

	Range of parameters			
Parameter	**Low**	**Medium**	**High**	**Comments**
Market outlook (impact on rate of change).	50%	100%	150%	All scenarios would see growth continue, but absolute growth is negligible.
Trend in annual change in land use (ha)	9	17	26	This would see existing growth patterns continue, but at a slower rate than recent history.
Annual irrigation requirements (ML / ha)	2.0	3.0	5.0	Range across a range of pulses, maize, sorghum and peanut requirements.
Reliability. Is it important? Impact on allocations held vs. average water used				Primarily annual crops and use of MP allocations. Limited incentive to hold additional water to offset reliability of allocation risk (holding costs exceed the benefits of risk mitigation).
Impact of climate change on water use ML/ha by 2050 (RCP 8.5)	-1.5	0.3	1.5	Based on outputs of climate modelling. These form the range of parameters for the climate change sensitivity analysis.

B6. Residential and commercial/ industrial (High Priority demand)

Current situation and water use

This section briefly addresses residential and commercial/industrial uses. Water demand by residential/commercial users is met by high priority (HP) allocations. Much of the residential and commercial/industrial usage is delivered through the BRC water distribution network.

The HP demand profile is serviced from multiple sources (Paradise Dam, Fred Haigh Dam and groundwater). BRC holds a groundwater allocation of 6,430 ML and 9,588 ML in surface water allocations (from Paradise and Fred Haigh Dams).

BRC's strong preference is to utilise groundwater whenever possible as this source is more cost effective to treat to potable standards (pers. comm. Tom McLaughlin, BRC). Allocations from Fred Haigh face supply and reliability constraints and high costs to use within the BRC serviced network. Therefore, it is most likely that future HP needs would be met through Paradise Dam allocations.

Figure 27 highlights the relationship between population growth, residential use and commercial/industrial water demand – as population increases, water demand increases.

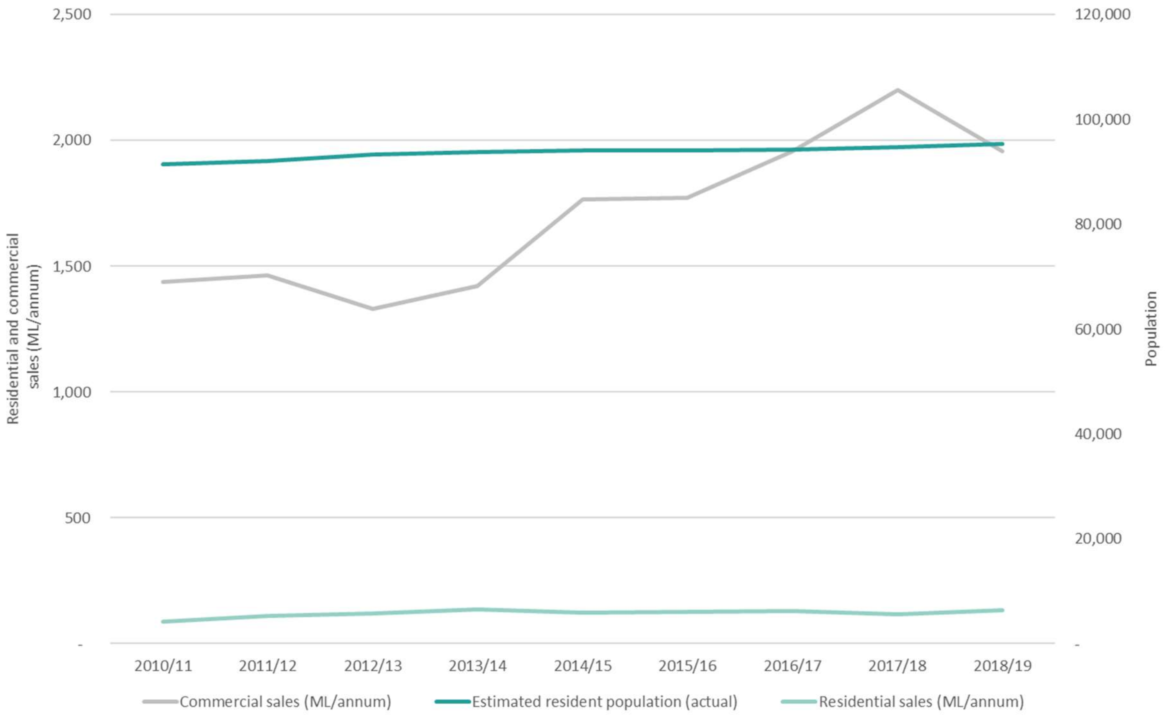

Figure 27. Relationship between population growth and HP water demand

Note: Because of the conjunctive nature of supply options and insufficient data on the sources of HP water consumed, it is assumed that future growth in demand for HP water would be sourced from Paradise Dam (if available), while the current sales of HP allocation from Paradise Dam is used as the starting point for the demand assessment.

Residential

Residential water use varies between seasons and year-on-year. Therefore, to improve analysis, SunWater supplied residential sales from water and sewer connections per year from 2010/11 to 2018/19. Drawing on this data, coupled with population, consumption per person per day was estimated. The 'most likely' estimate is 174 litres/person/day (l/p/d) with a range of 158 l/p/d to 190 l/p/d.

A study undertaken by Beal & Stewart (2011) in South East Queensland indicated that the four biggest end-uses within the household are: shower, tap, clothes washer and toilet. Gan & Redhead (2013) provide a breakdown of household water usage in summer and winter months (see Figure 28).[23]

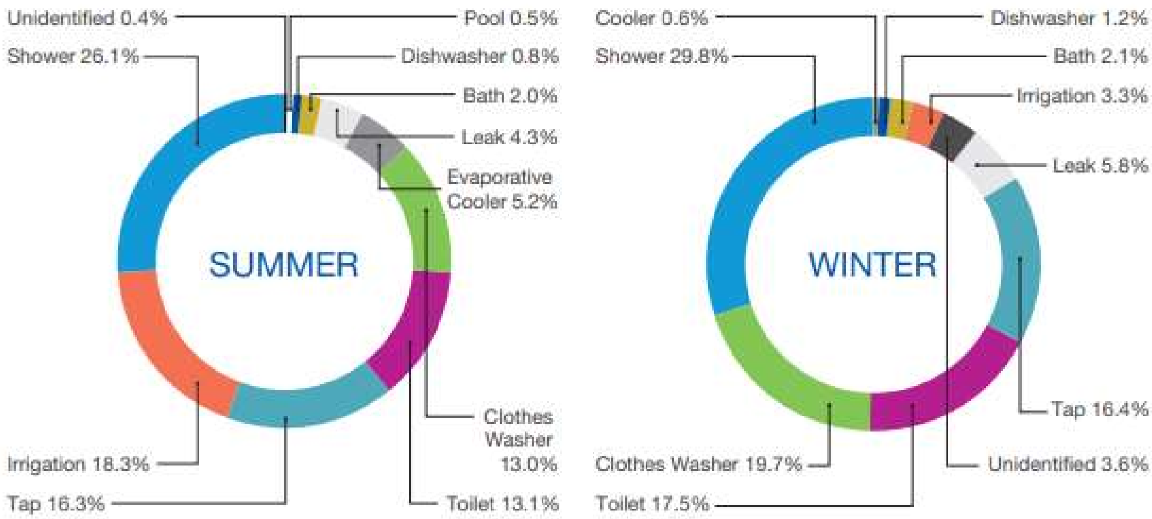

Figure 28. Residential water use (end use percentage shares by volume)

Source: Gan & Redhead (2013)

Historically, residential demand broadly has followed population growth. BRC has a current population of around 94,000 (ABS, 2016). Queensland Treasury (2018) provided historical and forecasted population data (in low, most likely, high estimates) from 2006 to 2041 in 5-yearly increments.[24] With this information it was possible to estimate annual population growth.[25]

Commercial and industrial

Based on available economic data for BRC, the total economic value-added in 2017-18 was approximately $3.5 billion (NIEIR, 2019).[26] The four largest local industries by value-add are agriculture (13.8%), health care and social assistance (12.3%), manufacturing (9.6%) and construction (8.5%). Together these total approximately 44% of the region's total economic value-add and much of the demand for these industries is population-driven.

Similar to residential water demand, SunWater supplied commercial/industrial water sales data over nine years. Estimated population growth rates were also used to estimate future commercial/industrial water demand.

Demand drivers and market opportunities

Residential demand has historically grown in line with population (with short-term variability around the mean growth rate). It is assumed this general relationship and applied it to the future population projection to establish a range of estimates for residential use. Regression analysis of commercial usage also showed a strong relationship with population growth.

Consultation undertaken as part of the analysis indicated that there are no major commercial/industrial projects in the future that would cause a step-change in water demand.[27]

[23] The study is based in Melbourne, where typically the summer is dry and the winter is wet. Although Melbourne has a different climate to Bundaberg residential uses are likely to be similar, particularly within the house.
[24] Population forecasts were extended to 2051 by reviewing the 5-yearly trend.
[25] To improve robustness of the prediction Monte-Carlo simulations (sensitivity analysis) was performed on these estimates.
[26] 'Value-add' is a measure of the value generated by business activity.
[27] The Bundaberg Beverages soft drink factory is not predicted to cause a step-change.

Therefore, it has been assumed that commercial/industrial water demand growth will continue to grow at the same rate as population.

Therefore, in developing HP future estimates, existing up take of HP allocations from Paradise Dam (2,849 ML), and growth estimates for the whole HP demand curve (i.e. Paradise Dam meeting all growth in HP demand) are then applied to the existing uptake.

Key assumptions underpinning estimates

Table 26 summarises the key input parameters and assumptions used for the demand analysis for residential and commercial uses.

Table 26. Residential and commercial demand model inputs and assumptions

	Range of parameters			
Parameter	**Low**	**Medium**	**High**	**Comments**
Residential demand (L / person / day)	158	174	190	Low estimate corresponds to the lowest average water sales per person per day over the past nine years (data via SunWater). High estimate corresponds to highest average water sales per person per day over the same time period. The medium estimate is the average of the low and high estimates.
Estimated annual population growth	0.2%	0.8%	1.3%	Estimated by examining historical and projected population data supplied by Bundaberg Regional Council.
Estimated annual commercial growth	0.2%	0.8%	1.3%	Assumed to grow in line with population growth.
Reliability. Is it important? Impact on allocations held vs. average water used	-	-	-	Residential water delivery must be completely reliable under all conditions.
Impact of climate change (RCP 8.5) on water use ML/ha by 2050	-	-	-	Residential water demand assumed to remain unchanged under future climate change conditions.[28]

B7. Aggregate estimates

This section briefly summarises the aggregate estimates of demand for allocations out to the year 2050. Current sales of water from Paradise Dam as at the end of 2019 are used as a starting point (i.e. 24,186 ML MP and 2,849 ML HP).

The parameters used in the modelling are outlined in Section 3 and in detail earlier in this Appendix.

Medium Priority allocations

The aggregate MP allocation estimates are based on the net change associated with the change in crop mix within the BWSS. In effect, this is the net effect of growth in high value crops (predominantly trees), offset by the reduction in water use attributable to the scaling down of sugarcane production. The full range of estimates out to 2050 against yields for each of the PDIP options (the horizontal lines) are outlined in Figure 29. The green demand line shows the mid-point of our estimates. The yellow and grey lines show high and low demand estimates from the sensitivity analysis.. The extremes are significantly impacted by the wide range of possible outcomes in current climate modelling, and the broad range of future development scenarios.

[28] Even though the change has not been estimated we recognise that the assumption might change with further investigation.

The high demand estimate is significantly influenced by the high irrigation requirements for macadamia and avocados. These high requirements represent the emerging practice of spray irrigation compared to more efficient drip irrigation (see macadamia and avocado section of this Appendix - Section B5).

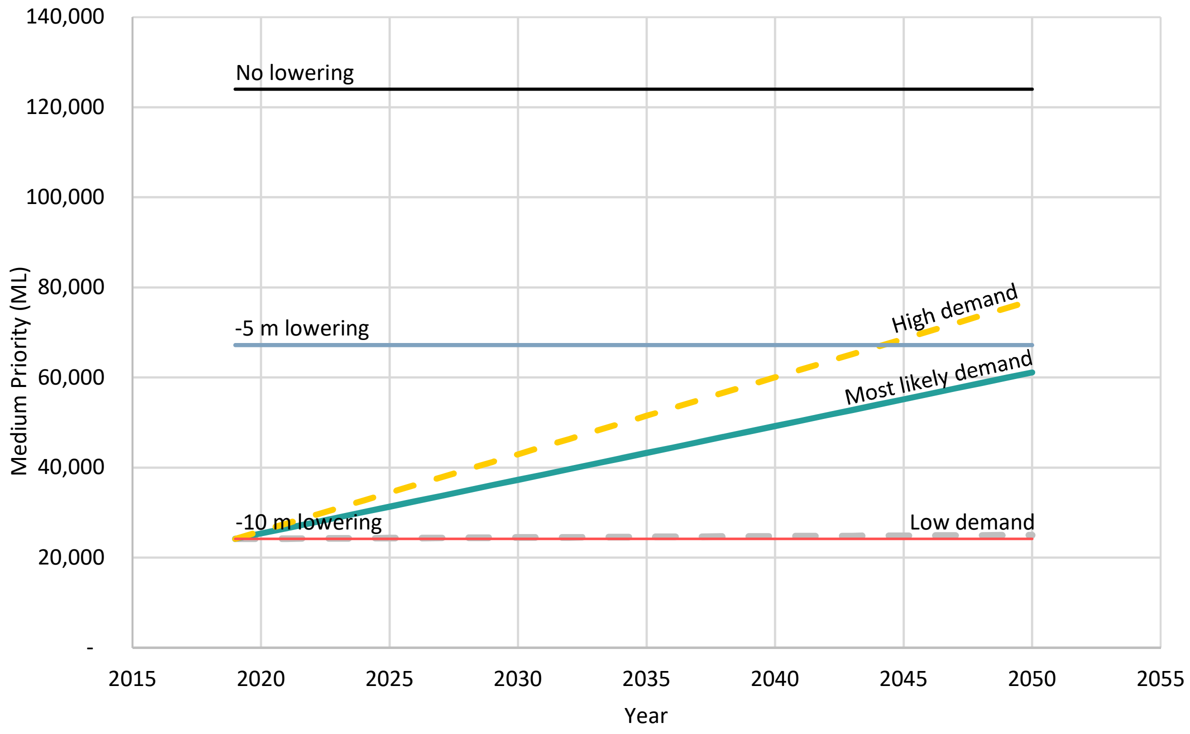

Figure 29. Estimated medium priority (MP) demand vs options yield (ML/year)

Key points

- A **10 m lowering** does not provide an opportunity for growth in sales of MP allocations. Any future growth of crops would require greater utilisation of existing allocations (e.g. facilitated by trade), or would require the development of one or more of the alternative supply options currently under consideration by SunWater.
- A **5 m lowering** would be sufficient to meet the mid-point demand estimates out to 2050. However, the high demand estimate would exceed yield around the year 2045. The high demand estimate could be lowered significantly through more efficient pricing of water service charges and / or the establishment of a new form of allocation that reflected the reliability requirements of perennial tree crops.
- **Current full supply level (FSL)** vastly exceeds all possible growth scenarios.

Sensitivity analysis

Figure 30 shows the outcomes from the Monte Carlo simulations for MP demand for allocations in 2050. The key points to note are that the mid-point is around 53,000 ML (well within the yield for the 5 m lowering), while the 90% confidence interval is between 25,000 and 78,000 ML.

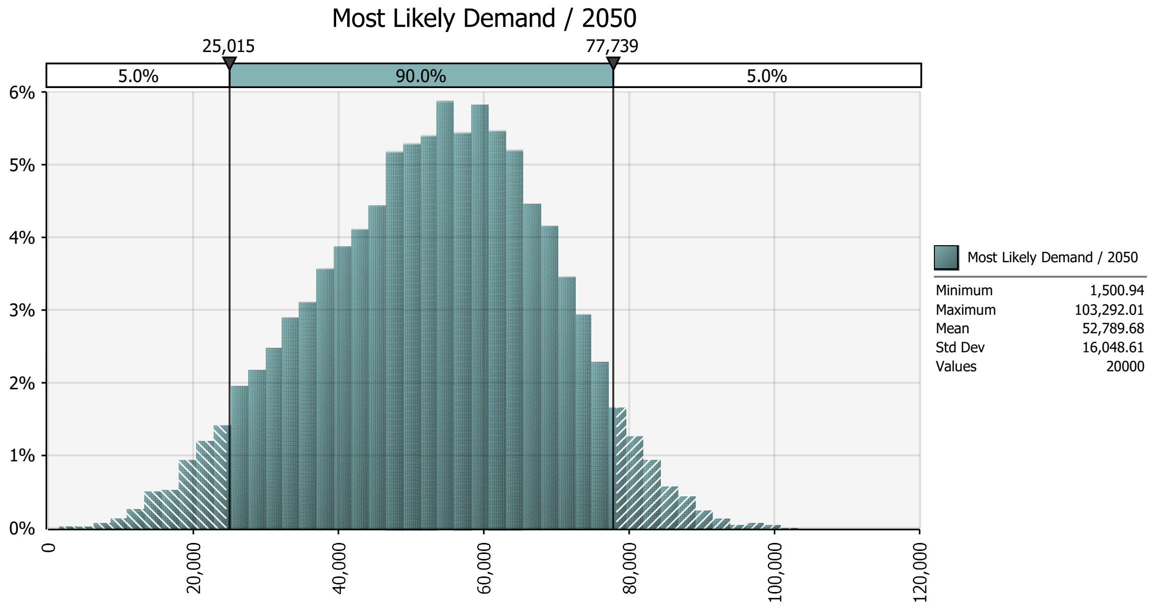

Figure 30. Medium priority estimated 2050 demand sensitivity analysis results

The distribution is skewed for two primary reasons. Firstly, the distribution of the range for demand for some individual crops is skewed towards higher requirements (particularly macadamias). Secondly, some growth assumptions are also skewed towards a faster growth rate around the mid-point.

Figure 31 shows the input variables that explain the bulk of the variation in the estimates. The key point to note is that it is the wide range of water requirements for macadamias that explain most of the range of estimates. Importantly, it is the high end of the range for macadamias that is the key driver for demand exceeding yield.

Key points

Given there are significant water use efficiency opportunities to meet crop requirements (and bring requirements well below the 10 ML/ha assumed as the mid-point of requirements), these should be pursued before any consideration of maintaining the current yields is considered.

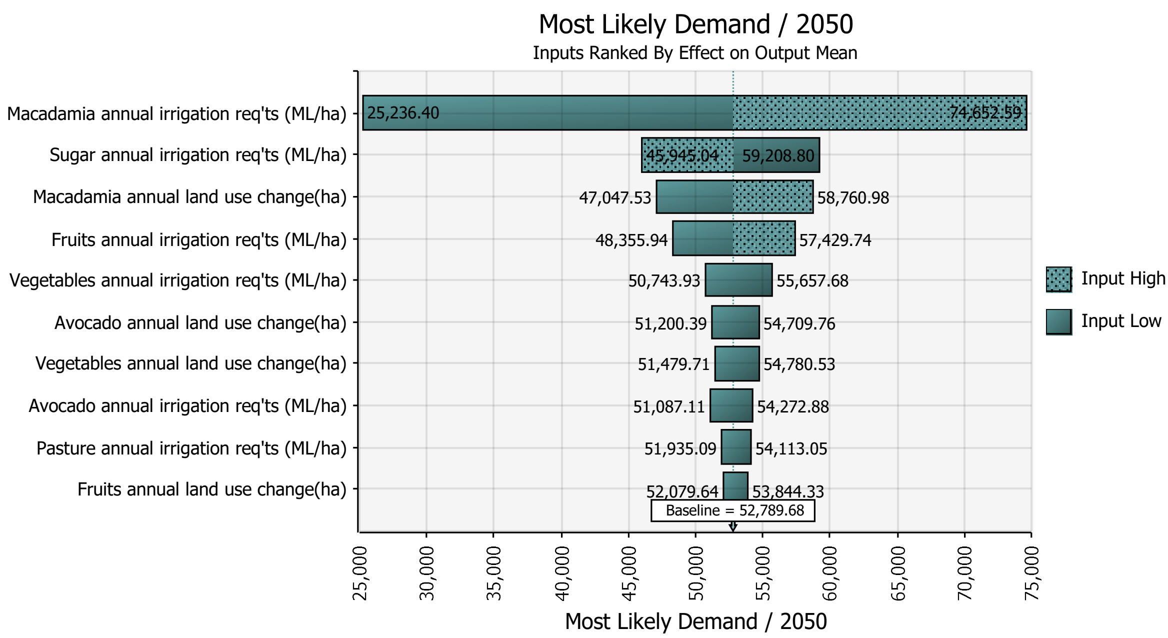

Figure 31. Inputs ranked by their effect on estimated medium priority demand in 2050

A summary of the estimated MP demand over the next 30 years is presented in Table 27. Our modelling indicates that by 2050 the 'most likely' MP demand is estimated at about 61,140 ML. This estimated 2050 demand has a range of about 24,751 ML to 78,178 ML. This range is influenced by assumptions on future irrigation crop mixes and irrigation water usages.

Table 27. Estimated MP demand (ML) as at 2019 and at 5-year intervals beginning 2020*

Year	2019	2020	2025	2030	2035	2040	2045	2050
Low (p5)	24,186	24,204	24,295	24,386	24,478	24,569	24,660	24,751
Most likely	24,186	25,378	31,339	37,299	43,259	49,220	55,180	61,141
High (p95)	24,186	25,928	34,636	43,345	52,053	60,761	69,470	78,178

*Where:

- Low demand - This is the low estimate we've used in our assessment of demand and supply. There is only a 5% probability that demand will be lower than this (or a 95% probability demand will be higher).
- Most likely - This is our most likely estimate based on the modelling. This is the demand growth we expect.
- High demand - There is a 95% probability that demand will be lower than this (or a 5% probability demand will be higher).

High priority allocations

Aggregate HP allocations estimates are based on the parameters outlined in the *Residential and commercial/industrial* section above. The full range of estimates (out to the year 2050) against yields for each of the PDIP options (the horizontal lines) are outlined in Figure 32. It shows that even with a 10m lowering (the black horizontal line) there is a significant excess of HP yield.

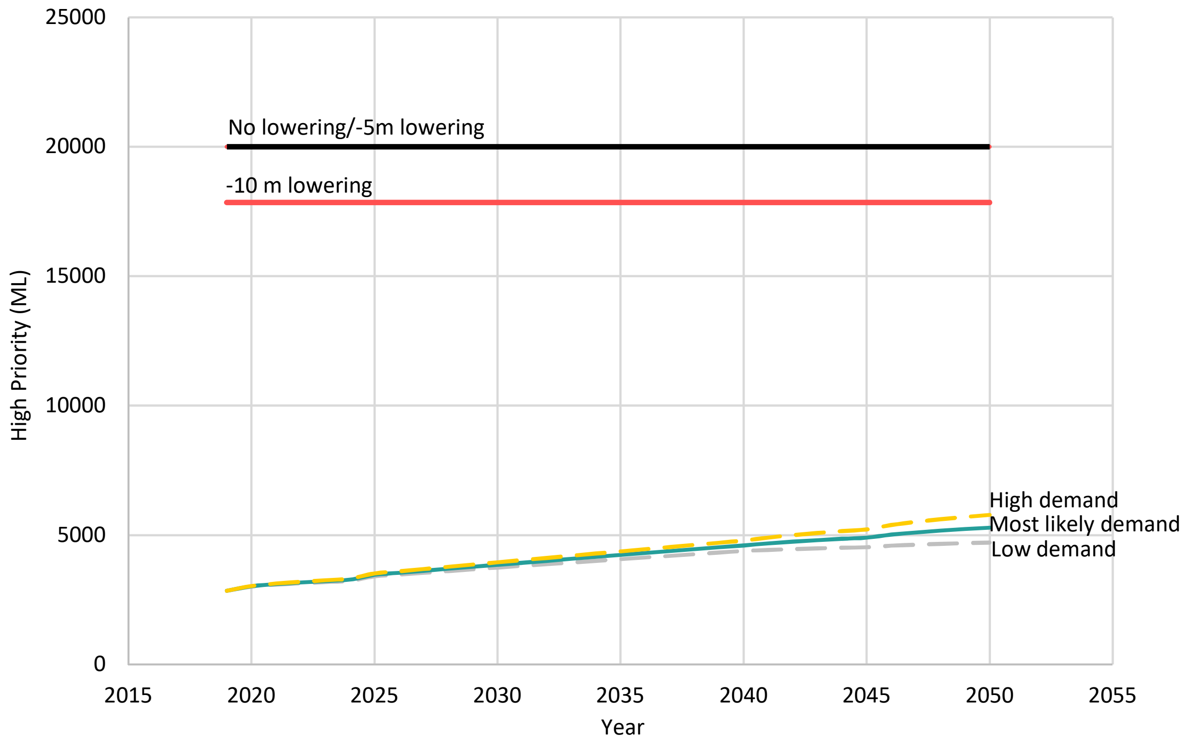

Figure 32. Estimated high priority (HP) demand vs options yield (ML/year)

Sensitivity analysis

Figure 33 shows the outcomes from the Monte Carlo simulations for HP demand for allocations in 2050. The key points to note are that the mid-point is around 5,200 ML (well within the yield for the 10 m lowering), while the 90% confidence interval is between 4,700 and 5,800 ML.

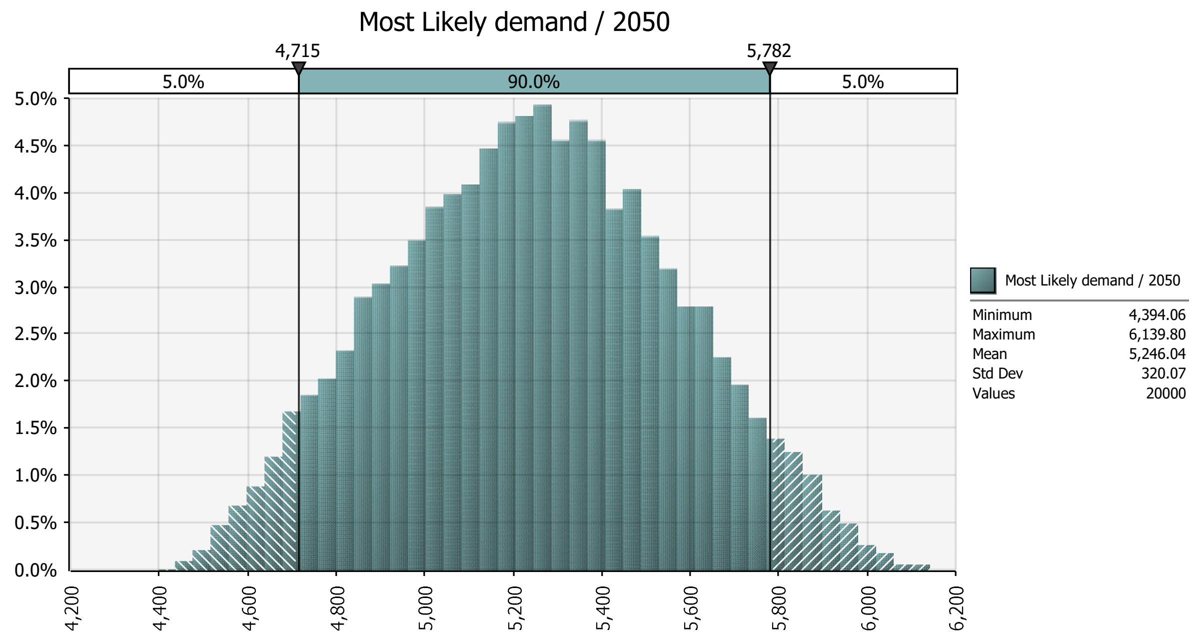

Figure 33. High priority demand sensitivity analysis results

Figure 34 shows that the majority of the variation in the estimates is explained by the range of population forecasts.

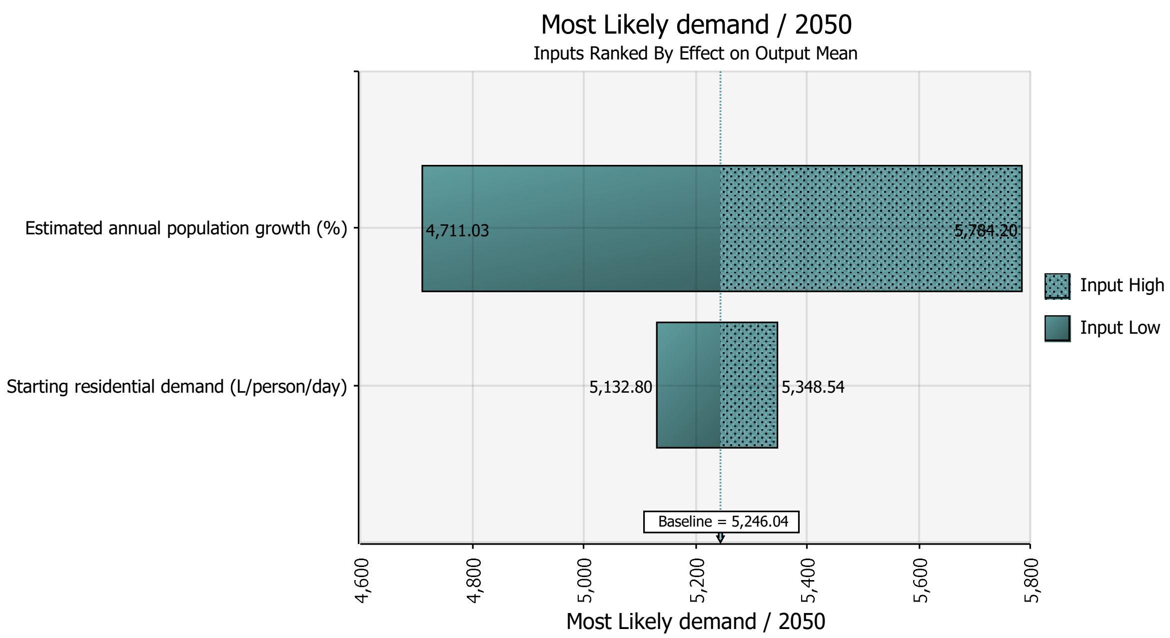

Figure 34. Inputs ranked by their effect on estimated high priority demand

A summary of the estimated HP demand over the next 30 years is presented in Table 28 Our modelling indicates that by 2050 the most likely MP demand is estimated at about 5,290 ML. This estimated 2050 demand has a range of about 4,713 ML to 5,780 ML. This range is influenced by assumptions on future irrigation crop mixes and irrigation water usages.

Table 28. Estimated HP demand (ML) as at 2019 and at 5-year intervals beginning 2020

Year	2019	2020	2025	2030	2035	2040	2045	2050
Low (p5)	2,849	3,010	3,405	3,747	4,073	4,388	4,534	4,713
Most likely	2,849	3,023	3,466	3,857	4,233	4,602	4,901	5,286
High (p95)	2,849	3,035	3,517	3,950	4,372	4,789	5,220	5,780

Implications for the options assessment

The analysis to date has a number of implications for the options assessment, particularly with respect to the outlying probability that demand for MP allocations could exceed the yield from a 5 m lowering. There are two options to address this risk:

- **Portfolio of options.** Consider a potentially more cost-effective portfolio of options to meet demand. This could include the option to lower Paradise Dam by 10 m, with the cost reductions used to establish a more cost-effective supply augmentation.

- **Conversion of excess HP to MP allocations**. Under this option, HP allocations that won't be required could be converted to MP allocations at a later date if the higher end of the demand estimates materialise. Under the Burnett Basin Resource Operations Plan, the rate of conversion of HP to MP is a factor of 2.5:1.[29] Figure 35 shows the findings of an analytical exercise where all allocations were converted to MP equivalents. It shows the aggregated MP + HP demand and yields in MP equivalents (ML/year). The 5 m lowering option would meet the high demand scenario if conversions were undertaken. The 10m lowering option would meet the high demand scenario to 2033 and the most likely demand estimates to 2045.

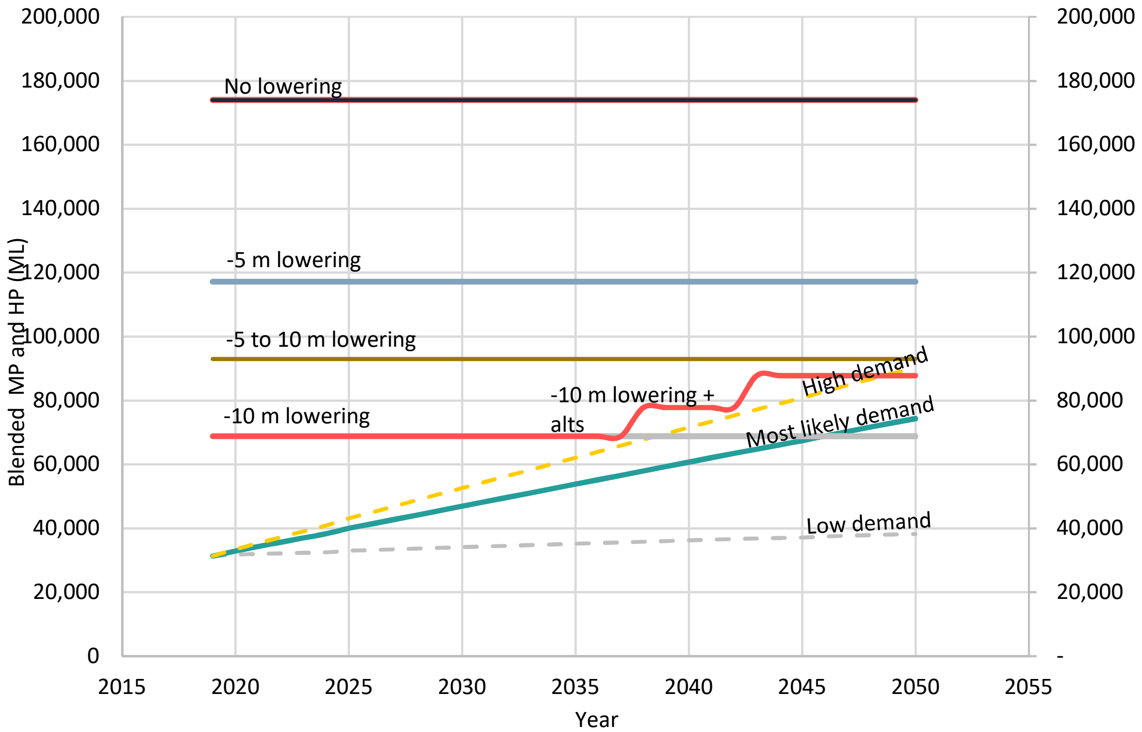

Figure 35. Aggregated MP + HP demand and yields all in MP equivalents (ML/year)

[29] SunWater provided NCEconomics with a conversion factor of 2.32:1 from a current but not yet published study. While we chose to settle for the published conversion factor of 2.5:1, we ran some scenarios to test the impact of this on estimated aggregated demand and found the lower ratio to have no material impact on the results.

A summary of the estimated aggregated MP+HP demand over the next 30 years is presented in Table 29. Our modelling indicates that by the year 2050 the most likely MP demand is estimated at about 74,360 ML. This estimated 2050 demand has a range of about 37,966 ML to 91,393 ML. This range is influenced by assumptions on future irrigation crop mixes and irrigation water usages.

Table 29. Estimated aggregated MP+HP demand (ML) at 5-year intervals

Year	2020	2025	2030	2035	2040	2045	2050
Low (p5)	31,761	32,960	34,028	35,061	36,073	36,912	37,966
Most likely	32,935	40,003	46,941	53,843	60,724	67,433	74,356
High (p95)	33,485	43,301	52,987	62,636	72,266	81,722	91,393

Key points

It is considered that a portfolio of options should be included within the PDIP Options Assessment (e.g. a 10m lowering plus an alternative option/s), and the use of allocation conversions in conjunction with a 5m lowering.

B8. References

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APPENDIX C: ALTERNATIVE SUPPLY OPTIONS

Meeting future water security requirements was identified as one of the primary service needs for the PDIP. As some of the options to be assessed are not expected to meet these requirements up to the year 2050, demand could be supplemented by alternative supply options. A shortlist of feasible options was provided by SunWater (SunWater, 2019), involving projects of varying costs and sizes. Consistent with contemporary water supply planning, cost-effectiveness should be a primary decision tool to ensure an efficient use of funds. The following analysis outlines how the most cost-effective options were identified and how they can be incorporated into the options for assessment.

Key point

It is important to meet any excess demand in the most cost-effective way, which can be achieved through careful consideration and selection of the alternative supply options.

C1. Methodology

Using the costs and the estimated yields of each project provided by SunWater, a cost per ML was calculated for each project. This allowed the projects to be sorted by cost-effectiveness. This information combined with the yields revealed which projects could be selected to meet a specific level of excess demand. Sensitivity analysis was also conducted. This involved using Monte Carlo simulations to determine p5 (low) and p95 (high) estimates of the costs.

In the selection and implementation of alternative supply projects, location and timing are two other important considerations suggested beyond cost-effectiveness. It is important to note that some projects are upstream of Paradise Dam and some are downstream. This may influence their effectiveness in supplying the future demand, particularly given that almost all growth in demand is expected to occur within the BWSS. Furthermore, the supply deficit for a given option may not arise immediately, so it may not be necessary to undertake certain projects until the demand materialises.

C2. Results

Using the above methodology, the feasible alternative supply options were sorted and plotted to indicate the cost-effectiveness of each option (see Figure 36). Once the yield deficit is known, the figure can be used to optimise selection of a given option (or options) to meet excess demand. For example, if excess demand is 5,000ML/annum then selecting *Jones Weir – raising 1.4m* would provide the most cost-effective solution (of the options presented). If 30,000ML/annum was required then a number of options working from left to right would provide the most cost-effective solution (e.g. *Jones Weir, Claude Wharton Weir* and *Bucca Weir Raising*). The p5 and p95 cost estimates are displayed for each option by the error bars.

Although cost-effectiveness is an important driver, other considerations (e.g. environmental, social/cultural) will also need to be factored into decision-making (if this alternative supply option approach is preferred).

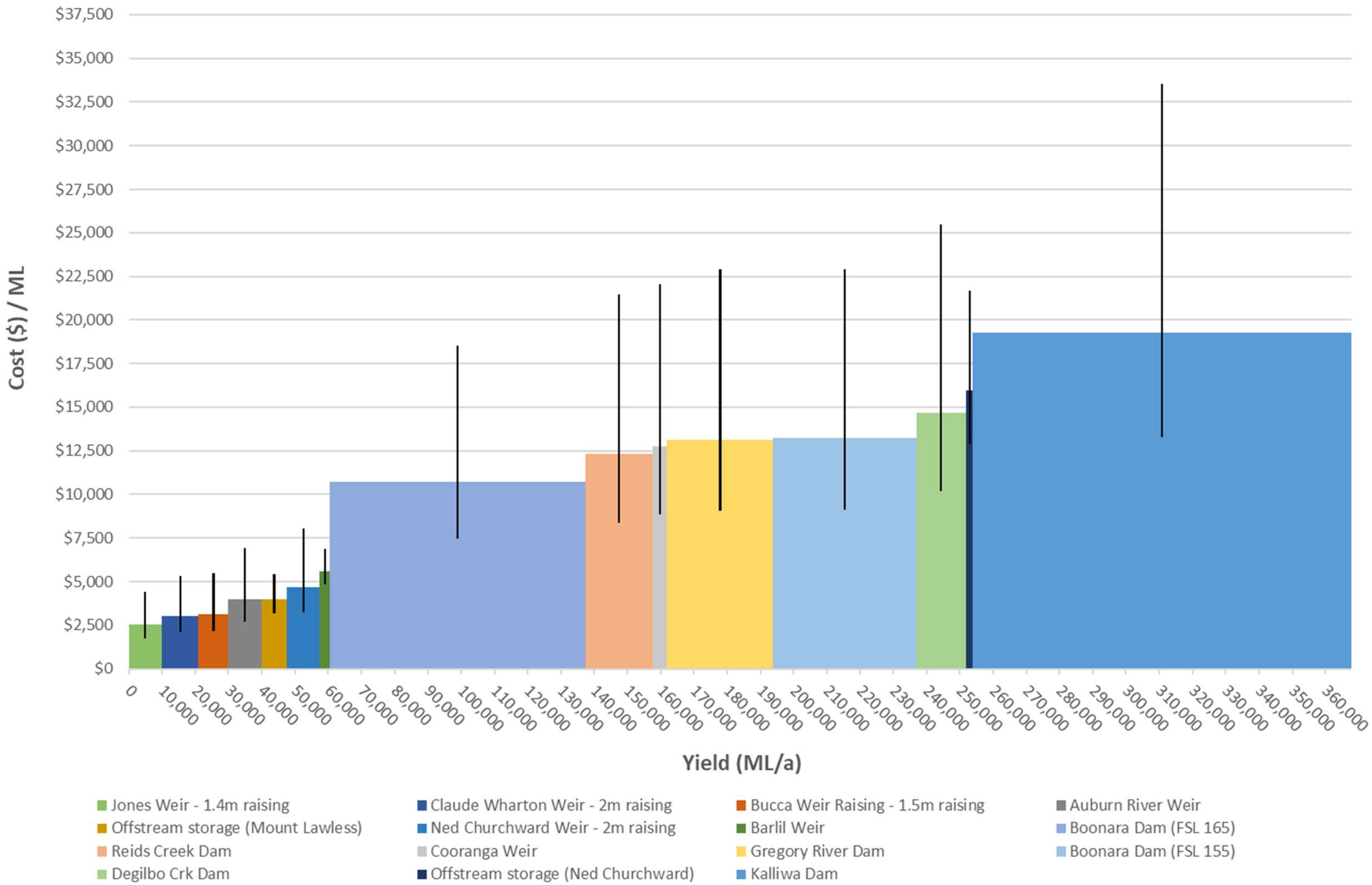

Figure 36. Alternative supply options ordered by cost-effectiveness (including p5 and p95 error bars)

Source: NCEconomics modelling based on Burnett Basin Alternative Storage Options (SunWater, 2019)

It should also be noted that only Bucca Weir, Ned Churchward Weir and Offstream storage (Ned Churchward) are downstream of the Dam. Where a project is downstream of the Dam it may warrant further analysis (even if not the most cost-effective) as it may have the added benefit of alleviating distribution capacity constraints in the current system.

Key point

An efficient and cost-effective suite of alternative water supply options have been used in establishing Option 3a for the Options Assessment.

C3. References

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APPENDIX D: OPTIONS ASSESSMENT

D1. Approach

This section briefly outlines the approach used for the options assessment of the PDIP shown in Table 30.

Table 30. Overview of options

Option	Yield (in MP equivalent)	Description
Option 1a- Full upgrade without lowering the spillway	174,000 ML	Post tension anchoring: • Primary Spillway 98 No. 91 Strand PT anchors. • Secondary Spillway monos L-R 24 No. 82 strand PT anchors. Monos S-W 10 No. 55 strand anchors. • Left Abutment 10 No. 73 Strand PT anchors. 60m stilling basin. New gravity training walls. Secondary spillway side channel and gravity wall. Outlet works modifications. Left abutment and basalt pimple erosion protection. Temporary coffer dam upstream of secondary spillway Demolition of Monoliths R-W Removal of 5-8m of poor foundation material Rebuild Monoliths R-W
Option 2 – Lowering of spillway crest level by 5m and other strengthening works	117,186 ML	Primary spillway lowering by 5m. Raising of the secondary spillway by 5m. Post tension anchoring: • Primary Spillway 84 No. 91 Strand PT anchors. • Secondary Spillway monos L-S 57 No. 55 strand PT anchors. Monos R-W 73 No. 27 strand anchors. 55m stilling basin. Capping of the secondary spillway channel. New gravity training walls Lowering of Intake tower and fishway. Remediation of reservoir rim. Outlet works modifications. Left abutment and Basalt pimple erosion protection.
Option 3 – Lowering of spillway crest level by 10m and other strengthening works	68,809 ML	Primary spillway lowering by 10m. Post tension anchoring: • Primary Spillway 35 No. 91 Strand PT anchors. • Secondary Spillway monos L-R 30 No. 82 strand PT anchors. Monos S-W 10 No. 24 strand anchors. 50m stilling basin. New gravity training walls. Lowering of Intake tower and fishway. Remediation of reservoir rim. Outlet works modifications. Left abutment and Basalt pimple erosion protection.

Option	Yield (in MP equivalent)	Description
Option 3a plus alternative supplies	87,809 ML	Option 3 plus in-scheme alternative water supplies to match demand forecasts. These alternative storages have been identified and undergone a preliminary analysis under SunWater's Blueprint process.
Option 4 – Optimal lowering of spillway crest level by between 5 and 10m, and other strengthening works	92,997 ML	No detailed description developed to date. However, this option will lie somewhere between options 2 and 3.
Option 5 – Full decommissioning	0 ML	Dewatering of the reservoir. Removal of the dam structure, outlet works and associated facilities. Removal/treatment of sediments which have accumulated in the reservoir. Rehabilitation and revegetation of the reservoir area.

Source: Provided directly by SunWater. Craig Hillier pers. Comms.

The decision to use alternative supply options should consider the incremental cost of selecting a more expensive PDIP option compared to the cost of the alternative water supply option/s. In this way, the analysis is consistent with best-practice water supply planning (i.e. meet water demands at the lowest cost).

Key point

The options assessment analysed all PDIP options and alternative supply options as identified and scoped by SunWater.

Objectives of options assessment

The objective of the options assessment was to utilise a robust, transparent, repeatable, defendable approach to assess and compare each of the PDIP options. Where required, the alternative water supply options were assessed to identify the projects that should be considered for inclusion in the detailed DBC. In effect, the options assessment provides a means to reduce the longer list of options to three options for detailed assessment. The options assessment approach used to assess the different types of data and information for each PDIP options relies on a consistent and common framework.

Key point

The objective of the options assessment is to assess each PDIP option and reduce the longer list to fewer options for detailed assessment.

Threshold analysis

Threshold analysis was employed to eliminate unacceptable options. The thresholds that were applied were:

- Ability to meet dam safety requirements.
- Ability to meet current and future demands.

The remaining options were assessed further through a multi-criteria analysis (MCA).

Broad framework: multi-criteria analysis

Consistent with common practice, MCA was used to underpin the options assessment. MCA is a decision support tool that was developed as an approach for use in operations research, where decision makers attempt to assess multiple options across a range of decision factors (reasons or considerations) that may have different and inconsistent assessment measures, including non-monetary valuation.

MCA has been widely adopted in the fields of water and environmental management as it is valuable in assessing unique elements of a project that do not include financial components.

When applied with care and transparency, an MCA can provide a structured and an easy-to-use framework for comparing options. Within the business case, it can be an important contribution to the analysis, as it can provide a means of incorporating the relative impact (positive or negative) of different options in achieving service need outcomes.

Figure 37 provides an overview of the MCA structure used for the Options Assessment, including alignment with the PDIP service needs.

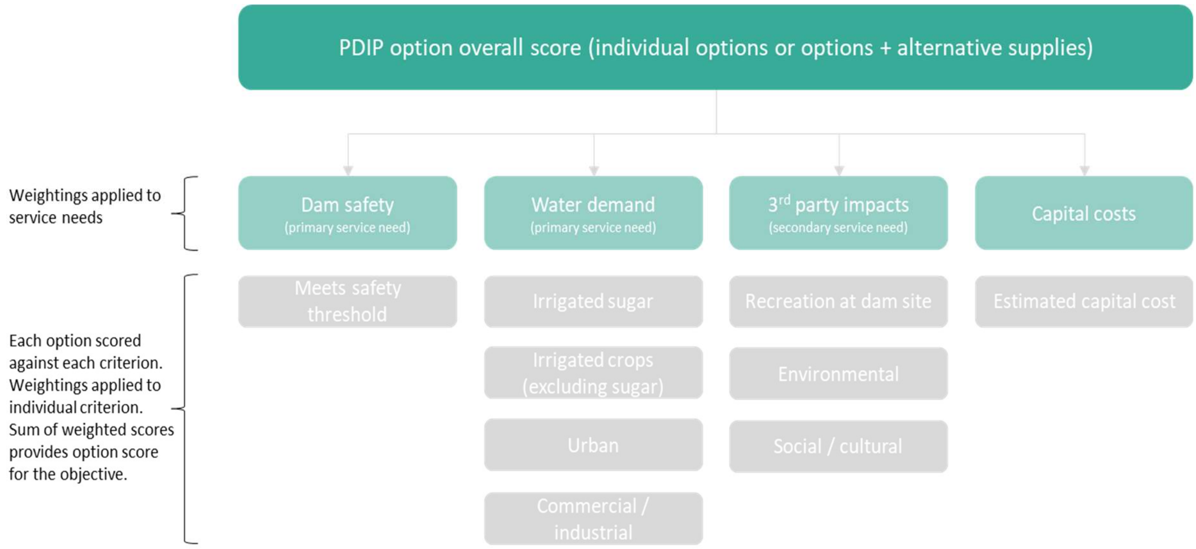

Figure 37. Structure of the MCA underpinning the Options Assessment

An initial assessment was undertaken by the project team. This assessment was subsequently reviewed through an options assessment workshop with the Project Steering Group and Project Working Group. This included amending the scoring of individual options and specifying the range of key parameters underpinning the sensitivity analysis.

Key points to note are:

- Each PDIP option that was not excluded by the threshold analysis (including alternative supply options) was assessed discretely within the MCA.

- The outputs of the MCA for each PDIP assessed were then compared to identify which option was most likely to be superior in meeting the service needs and should therefore be a shortlisted option for the DBC.

- Each option was assessed against a suite of discrete objectives based on the service needs criteria. In addition to the service needs, the range of estimated capital costs were also used as the service needs should be met at the lowest cost to the community. It is also important to assess the trade-offs between costs and achieving the other service needs. It should be noted that these costs were provided directly by SunWater and should be treated as indicative only.

- Weightings are commonly applied to each of the categories of service needs to reflect their relative importance to decision-makers. Under each service need, there are typically a number of relevant criteria, against which each project is assessed. These criteria were also weighted within the objective to reflect their relative importance.
- Using the measures developed for each of the service needs as a basis, each PDIP was scored against the discrete criteria (e.g. meets dam safety requirements, recreation at the dam site).
- Where more than one criterion was used to assess a service need (e.g. the four water demand types), each of those criteria was also weighted.
- Because each criterion was measured in a different way (e.g. ML, $), a process of normalisation (sometimes called standardisation) was used to enable comparability across measures of different types.

MCA is most effective when there is a very clear basis for scoring project options against criteria and where this evaluation framework is agreed and documented before the analysis has commenced. However, MCA ultimately involves subjective judgements on values. In addition, it does not tell the decision-maker whether individual proposals are of net social benefit (i.e. whether anything at all should be chosen), or the optimal scale of any particular proposal.

Key point

A thresholds analysis followed by a multicriteria-analysis (MCA) was used to underpin the options assessment.

D2. Assessment

This section summarises the application of the framework to the PDIP options.

Threshold assessment and shortlisting options

Three options were initially ruled out during the threshold assessment. This included Option 1 (Full Supply Level), Option 3 (10m Lowering) and Option 5 (Decommission). Option 1, despite involving significant works to strengthen the dam, would not be expected to satisfy the *Limit of Tolerability* for dam safety and is therefore not considered acceptable. Options 3 and 5 did not meet future water security requirements. Option 3 can supply a p95 high demand scenario until around 2038 and most likely demand estimates until 2045, but not 2050, while Option 5 immediately results in a large regional supply deficit. Given this, both options were not considered acceptable.

A version of Option 1, henceforth called Option 1a, was subsequently developed and costed by SunWater which is expected to satisfy the *Limit of Tolerability*, but at an additional cost.

Furthermore, alternative supply options could be used to address the potential supply deficits mentioned above. With this in mind, Options 3a and 5a were included. These options involve a 10m lowering and decommission, respectively; however, they include the additional supply projects required to meet demand. The additional supply projects are outlined in more detail in Appendix C and were selected from the SunWater shortlist of alternative supply options based on cost-effectiveness ($/ML), location (preferences for within scheme) and greenfield or brownfield projects (preferences for brownfield to mitigate environmental and social costs and to increase the likelihood of achieving regulatory approvals).

Table 31 shows the proposed alternative supply projects that would have to be undertaken in parallel with the primary projects to meet demand.

Table 31. Alternative supply options – project bundles*

	Option 3a	Option 5a
Primary projects	10m Lowering	Decommission
Alternative supply Projects	**Bucca Weir Raising - 1.5m raising** **Ned Churchward Weir - 2m raising** **Offstream storage (Ned Churchward)** Jones Weir - 1.4m raising	**Bucca Weir Raising - 1.5m raising** **Ned Churchward Weir - 2m raising** **Offstream storage (Ned Churchward)** Jones Weir - 1.4m raising Claude Wharton Weir - 2m raising Auburn River Weir Offstream storage (Mount Lawless) Barlil Weir Boonara Dam (FSL 165)

*In-scheme options in bold

Of the three alternative options, only Options 1b and 3a were carried forward. Option 5a was not progressed due to its significantly higher expected cost and its need for a large number of additional supply projects that would not be in-scheme.[30]

Steps for applying multi-criteria analysis

The MCA involved a systematic analysis of each option including:

- Establishment of weights for each of the six criteria.
- Assignment of scores for each of the options.
- Normalisation of assigned scores.
- Estimating weighted average scores for each of the options.
- Sensitivity analysis (outlined in Section D3).

Weightings

Weightings were applied across service needs and costs to reflect the relative importance of each criteria. The established weightings were determined based on SunWater's weightings (from the PBC) and were informed by consultation with the stakeholders (BQ Project Working Group) at an Options Assessment Workshop on 22nd January 2020. Broadly, dam safety and water supply were considered to be primary needs, followed by cost, while recreation, environmental risk and social risk were considered secondary needs.

Table 32 shows the MCA criteria weightings and the rationale for the assigned weights.

Table 32. MCA criteria weightings

Criteria/Service Need	Weightings	Rationale
Dam Safety	30%	This is a major service need for the PDIP.
Meets future water requirements	30%	This is a major service need for the PDIP.
Recreation use opportunities	5%	This is largely a secondary (subsidiary) issue.

[30] Current customers with supply agreements would expect to be compensated for contract breaches by SunWater if decommission was to occur.

Criteria/Service Need	Weightings	Rationale
Environmental risks	5%	This is largely a secondary (subsidiary) issue.
Social and cultural risks	5%	This is largely a secondary (subsidiary) issue.
Cost	25%	Costs are a major consideration, particularly the opportunity cost of recommending an option that has very high costs, but over delivers on meeting future water requirements.

Feedback from the Options Assessment workshop included the need to test a scenario with a higher weighting on cost and lower weightings on the secondary issues. This is considered in the sensitivity analysis section below.

Scoring

Some of the assessments were quantitative, such as capital costs and water demand, and others were qualitative, such as the assessment of social and cultural needs. The qualitative assessments were converted into quantitative assessment using a Likert scale.

Table 33 shows an illustrative Likert scale commonly used to convert qualitative assessments into quantitative assessments for use within an MCA.

Table 33. Illustrative Likert scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Description	Extreme negative impact	Major negative impact	Moderate negative impact	Minor negative impact	Slight negative impact	No impact	Slight positive impact	Minor positive impact	Moderate positive impact	Major positive impact	Extreme positive impact

Table 34 shows the scoring methods used for each of the objectives in the MCA.

Table 34. MCA scoring methods

Objective/Service Need	Scoring Method
Dam Safety	Bespoke Likert scale where: 5 = ALARP; 4 = comfortable meets Limits of Tolerability, and; 3 or below is a fail on dam safety (captured previously through threshold analysis).
Meets future water requirements	Ratio of yield to highest estimated aggregate demand (all MP equivalent). Where options had yield higher than the maximum estimated aggregate demand, their score was capped at the ratio of the maximum estimated aggregate demand to the estimated aggregate demand. This was done to ensure that significant excesses of unused water would not be counted as a benefit.
Recreation use opportunities	Likert scale (-5 to +5)
Environmental risks	Likert scale (-5 to +5)
Social and cultural risks	Likert scale (-5 to +5)
Cost	Estimated capital cost ($)

Key point

Both quantitative and qualitative criteria were used, based on the assessment of service needs.

Like the weightings, the scores were discussed at the BQ Project Working Group workshop on 22nd January 2020 to confirm agreement on the relative values.

The final scores for each option against each criterion and explanatory comments are shown in Table 35 to Table 38 on the following pages. Table 33 shows the scoring for Option 1a (Full Supply Level) and considerations for each objective.

Table 35. Option 1a (Full Supply Level) assigned raw scores

Criteria	Raw scores			Comments
	Worst	Most likely	Best	
Dam safety	3.75	4.0	4.25	Dam safety review indicates Limit of Tolerability met, but maybe not ALARP
Meets future water requirements	1.3	1.6	3.1	All volumes have been converted to MP equivalents (ratio of 2.5:1). Most likely shows the ratio of yield to most likely demand estimate. Low shows ratio with p95 demand estimated and high shows ratio with p5 demand estimate. Numbers less than 1 show supply deficit.
Recreation use opportunities	-1	0	1	Dam of the same scale should deliver similar outcomes.
Environmental risks	0	0	1	Dam of the same scale should deliver similar outcomes, but improvement to fish ladder design etc. may be incorporated into new dam.
Social and cultural risks	0	0	0	Impact is likely to be neutral.
Cost (rounded to nearest million dollars)	-$1,381m	-$800m	-$555m	Cost estimates were provided by SunWater. Worst and best scores use p95 and p5 estimates of cost from Monte Carlo simulations.

Table 36 shows the scoring for Option 2 and considerations for each objective.

Table 36. Option 2 (5 metre lowering) assigned raw scores

Criteria	Raw scores			Comments
	Worst	Most likely	Best	
Dam safety	3.75	4.0	4.25	Dam safety review indicates Limit of Tolerability met, but maybe not ALARP
Meets future water requirements	1.3	1.6	3.1	All volumes have been converted to MP equivalents (ratio of 2.5:1). Most likely shows the ratio of yield to most likely demand estimate. Low shows ratio with p95 demand estimated and high shows ratio with p5 demand estimate. Numbers less than 1 show supply deficit.
Recreation use opportunities	-2	-1	0	While the type of assets and opportunities don't change, the area available for water-skiing near the boat ramp will be smaller. This will be partially offset by an increase in grassed are adjacent to the water.
Environmental risks	0	1	1	Lower spillway will reduce storage and allow for frequent overtopping that better reflects natural variability. Possible improvements in fish ladder redesign and operations.
Social and cultural risks	-1	0	1	Impact is likely to be neutral but could vary +/- depending on construction and management.

Criteria	Raw scores			Comments
	Worst	Most likely	Best	
Cost (rounded to nearest million dollars)	-$770m	-$597m	-$524m	Cost estimates were provided by SunWater. Worst and best scores use p95 and p5 estimates of cost from Monte Carlo simulations.

Table 37 shows the scoring for Option 3a (10m lowering + alternatives) and considerations for each objective.

Table 37. Option 3a (10 metre lowering + alternatives) assigned raw scores

Criteria	Raw scores			Comments
	Worst	Most likely	Best	
Dam safety	4.25	4.5	4.75	Dam safety review indicates Limit of Tolerability met (as will new structures), but maybe not ALARP across the portfolio of assets.
Meets future water requirements	1.1	1.3	2.6	All volumes have been converted to MP equivalents (ratio of 2.5:1). Most likely shows the ratio of yield to most likely demand estimate. Low shows ratio with p95 demand estimated and high shows ratio with p5 demand estimate. Numbers less than 1 show supply deficit. Deficit occurs around 2038 on p95 demand estimates and around 2045 for most likely demand estimates. P95 demand requirements met by Bucca Weir 1.5m raising by 2038, Ned Churchwood Weir 2m raising by 2042, Ned Churchwood Offstream Storage by around 2048 (the three options that are below Paradise Dam with the options occurring in order of cost-effectiveness) and Jones Weir 1.4m raising by around 2049 (the most cost-effective of the remaining options).
Recreation use opportunities	-3	-2	-1	While the type of assets and opportunities don't change, the area available for water-skiing near the boat ramp will be smaller. This will be partially offset by an increase in grassed are adjacent to the water. Potential for new recreational values anticipated at new storages. These were adjusted downwards in the 22nd January workshop as the new recreational values from other storages are likely to be minimal.
Environmental risks	-5	-4	-3	Lower spillway will reduce storage and allow for frequent overtopping that better reflects natural variability. Possible improvements in fish ladder redesign and operations. These were adjusted downwards in the 22nd January workshop due to expected additional environmental impacts at alternative sites (site dependent).
Social and cultural risks	-3	-2	0	Impact at Paradise Dam is likely to be neutral but could vary +/- depending on construction and management. These were adjusted downwards in the 22nd January workshop due to expected additional impacts at new sites (site dependent).
Cost (rounded to nearest	-$704m	-$537m	-$467m	Present values of the included supply projects were added to the cost estimates provided by SunWater for 10m

Criteria	Raw scores			Comments
	Worst	Most likely	Best	
million dollars)				lowering. Worst and best scores use p95 and p5 estimates of cost from Monte Carlo simulations.

Table 38 shows the scoring for Option 4 and considerations for each objective.

Table 38. Option 4 (optimised 5 to 10 metre lowering) assigned raw scores

Criteria	Raw scores			Comments
	Worst	Most likely	Best	
Dam safety	4.0	4.25	4.5	Dam safety review indicates Limit of Tolerability met, but maybe not ALARP.
Meets future water requirements	1.0	1.3	2.4	All volumes have been converted to MP equivalents (ratio of 2.5:1). Most likely shows the ratio of yield to most likely demand estimate. Low shows ratio with p95 demand estimated and high shows ratio with p5 demand estimate. Numbers less than 1 show supply deficit.
Recreation use opportunities	-2	-1	0	While the type of assets and opportunities don't change, the area available for water-skiing near the boat ramp will be smaller. This will be partially offset by an increase in grassed are adjacent to the water.
Environmental risks	0	1	1	Lower spillway will reduce storage and allow for frequent overtopping that better reflects natural variability. Possible improvements in fish ladder redesign and operations.
Social and cultural risks	-1	0	1	Impact is likely to be neutral but could vary +/- depending on construction and management.
Cost (rounded to nearest million dollars)	-$714m	-$554m	-$486m	Cost estimates based on linear interpolation of the costs provided by SunWater for the 10m lowering and the 5m lowering. Worst and best scores use p95 and p5 estimates of cost from Monte Carlo simulations.

Normalisation process

Given the assessment criteria were measured in different units (in this case determined from the service needs assessments), the results were transformed to a normalised scale. There are a number of ways to do this. For example, normalisation can be done by dividing each criterion score by the sum of all scores for that criterion, or scores can be assessed relative to the minimum or maximum (min/max method) score for that criterion (depending on what measure is the most desirable).

The min/max method was used for all scores in the MCA. This involved subtracting the minimum value for a criterion over all options from an option's individual score and dividing that by the difference between the maximum and the minimum (see formula below).

$$Normalised\ Score = \frac{Score - min}{max - min}$$

For example, if an option was scored as 3 for dam safety, the worst dam safety score was 0, and the best was 5, the normalised score would be 0.6 (see formula below).

$$Normalised\ Score = \frac{3-0}{5-0} = 0.6$$

Normalisation ensures that all scores are on a scale of 0 to 1, where 1 signifies that the option received the best score for that criterion and 0 signifies that the option received the worst score.

Key point

Raw scores were normalised using the min/max method to enable aggregation within the MCA.

Results

After scoring, normalising and weighting, the MCA provided comparable scores and rankings for the 4 assessed options. A total weighted score of 1 would mean that the option is ranked the best (or equal best) for every criteria and a total weighted score of 0 would indicate that an option is ranked the worst (or equal worst) for every criteria. Table 39 shows that the total weighted scores are all close to 0.5. Option 3a has the best total weighted score (0.632) for the most likely scenario followed by Option 2 (0.609), Option 4 (0.510) and Option 1a (0.440). The scores are not significantly different from each other and no option is clearly superior.

Table 39 shows the most likely scores of each assessed option and their respective rankings.

Table 39. Scores and rankings summary

	Option 1a Full Supply Level	Option 2 Less 5 m	Option 3a Less 10m + in-scheme alternatives	Option 4 Less 5 to 10 m
Weighted average scores				
Dam safety	0.000	0.000	0.300	0.150
Meets future water requirements	0.300	0.290	0.082	0.000
Recreation use opportunities	0.050	0.025	0.000	0.025
Environmental risks	0.040	0.050	0.000	0.050
Social and cultural risks	0.050	0.050	0.000	0.050
Cost	0.000	0.193	0.250	0.235
Total (maximum = 1)	0.440	0.609	0.632	0.510
Ranking	**4**	**2**	**1**	**3**

Figure 38 shows the weighted score results for each of the assessed options with the contributions of each objective shown.

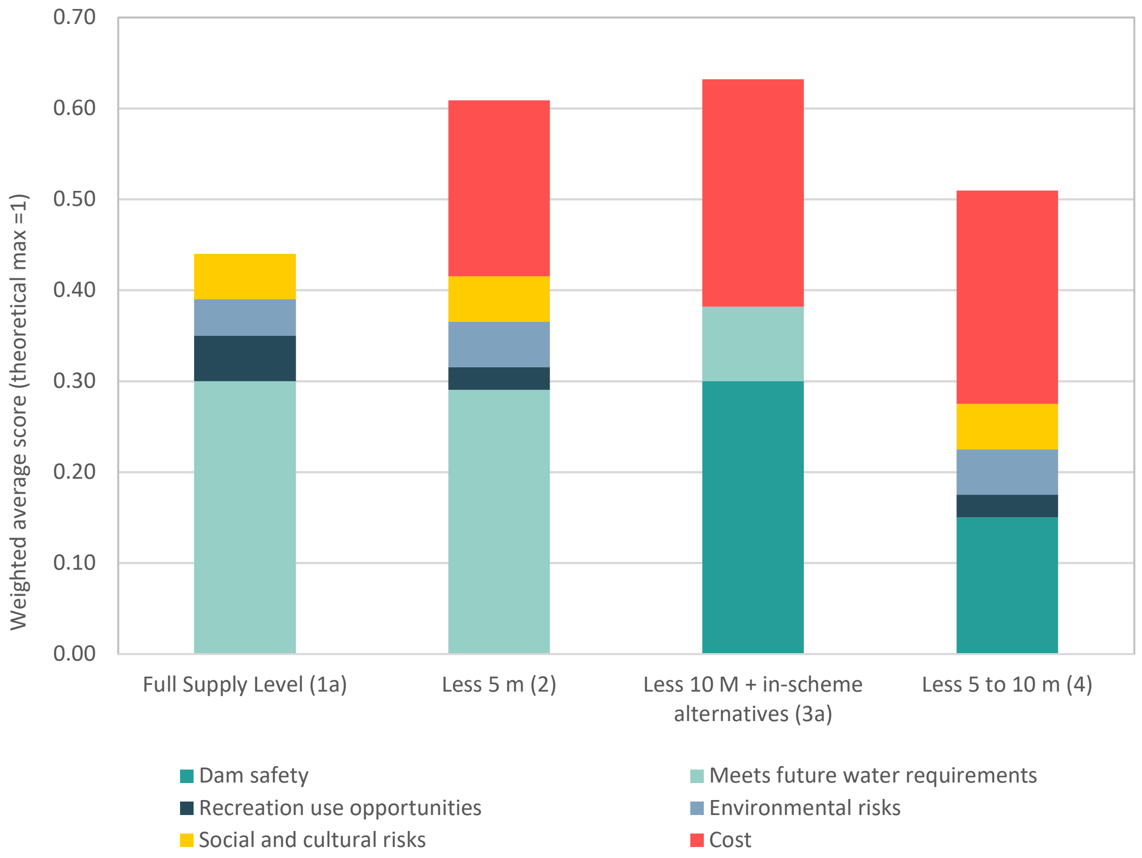

Figure 38. Weighted score results breakdown (most likely results)

Key point

The initial assessment using the MCA indicates that Option 3a is superior. However, there is little difference between the weighted scores across the options assessed. Option 1a was ranked last under this assessment.

D3. Sensitivity analysis

Sensitivity analysis was undertaken across a number of parameters in the MCA to determine how sensitive the superior scored option was to changes in input data, specifically:

- The weightings to the individual objectives (alternative weightings were tested).
- The assigned scores for each option against each objective (a range of scores was used either side of the most likely value as the basis for this sensitivity test).
- The normalisation method used (a linear sum method tested as a comparison to the max-min method).
- Alternative ratios for the conversion of HP to MP allocations (reflecting the ratio used in the Resource Operations Plan and recent work by SunWater).

Weightings

At the BQ Project Working Group (Options Assessment) Workshop cost was weighted at 30% and the secondary issues weighted at 3.33% rather than 5%. Table 40 shows the weighted score results for each of the assessed options with higher cost (30%) and lower secondary issue (3.33%) weightings.

Key issues to note:

- The revised weightings resulted in slight changes in the overall weighted score; however, the ranking of the options did not change.
- Option 1a performed relatively worse because its weighted average score is more influenced by secondary objectives and it does not benefit from the increased weighting on cost.
- Option 3a performed relatively better because its weighted average score is heavily influenced by cost and it isn't affected by the decreased weightings on secondary objectives.
- There were not significant changes in the weighted average scores for Options 2 and 4 because they are influenced by both cost and secondary objectives, so the effects are balanced out.
- This scenario resulted in a larger spread of the scores at 0.29 compared to 0.19 in the base scenario.

To further test the sensitivity of the results to the weightings, revisions were made in the opposite direction. Lowering the weightings on dam safety, water supply and cost by 5% each from the base weightings while raising the secondary issue weightings by 5% changed the rankings. With these changes, Option 2 was found to perform best, with Option 3a dropping down to fourth. This scenario reduced the spread of scores to 0.13 from 0.19, relative to the base scenario.

Table 40 shows the weighted score results for each of the assessed options with lower dam safety, water supply and cost weightings (25%, 25% and 20% respectively) and higher secondary issue weightings (10%).

While different weightings may have an effect on the results, this does not significantly change the weighted average score for the assessed options. It is important to note that Options 2 and 4 are affected far less by the changes than the other two options as they receive score contributions from almost all objectives.

Table 40. Sensitivity results from high costs and secondary issue weighting

		Full Supply Level (1a)	Less 5 m (2)	Less 10 M + in-scheme alternatives (3a)	Less 5 to 10 m (4)
Base results	Total score	0.440	0.609	0.632	0.510
	Ranking	4	2	1	3
Increased cost weighting	Total score	0.393	0.606	0.682	0.515
	Ranking	4	2	1	3
Increased secondary issue weighting (10%)	Total score	0.530	0.647	0.518	0.563
	Ranking	3	1	4	2

Key finding

With large alterations, weightings were found to effect rankings; however, for the feasible values discussed in the Options Assessment workshop, the effect was minimal. Option 1a consistently ranked last under this sensitivity analysis.

Scores

The scores are another source of uncertainty and this was dealt with by using worst-case and best-case scenarios where each option was given worst- and best-case scores for each objective. Best-case scores involved increasing the base score by a specified factor while the worst-case score involved decreasing that score by the same amount.[31] The scores for water supply and costs used p5 and p95 estimates.

Table 41 shows the comparison of the worst-case, best-case and most likely scenario rankings.

Table 41. Scenario rankings comparison

Ranking	Option 1a (Full Supply Level)	Option 2 (less 5 m)	Option 3a (less 10m + in-scheme alternatives)	Option 4 (less 5 to 10m)
Worst assessment	4	2	1	3
Most likely assessment	4	2	1	3
Best assessment	4	2	1	3

The rankings do not change across the scenarios. Option 3a consistently receives the highest rank across the three scenarios; however, the scores are not significantly different in any case.

It is important to note that due to their higher weightings, any changes to the scores for dam safety, water supply and cost have a greater effect on the results than equivalent changes to the scores for the secondary objectives.

Key findings

Worst-case and best-case scores did not have an effect on the final rankings; however, in general, the scores of objectives with higher weightings (dam safety, water supply and cost) have greater effects on total weighted scores than those with lower weightings. In the scheme of things, these effects are minimal.

Option 1a consistently ranked last under this sensitivity analysis.

Normalisation

To see if the method of normalisation was affecting the outcome, two other methods were tested, the linear sum method and the proportion of max method. The linear sum method involves dividing the raw score by the sum of the options' scores for a given criterion. The proportion of max method involves dividing the raw score by the maximum score out of all the options for a given criterion. The max-min method was preferred due to its interpretation of 0 and 1 being the worst and best; however, the other methods still provide outputs suitable to an MCA.

Table 42 shows the effect of the different normalisation methods on the rankings.

[31] An exception to this is the environmental risk category for Options 3a and 4 where it was assumed that the best-case score would not be any better than the most likely score.

Table 42. Comparison of rankings with different normalisation methods

Rankings	Option 1b	Option 2	Option 3a	Option 4	Average Weighted Score	Spread of Weighted Scores
Max-Min	4	2	1	3	0.55	0.19
Proportion of Max	3	1	4	2	0.74	0.08
Linear Sum	3	1	4	2	0.25	0.02

While the different normalisation methods do change the rankings the two alternative methods do not provide enough separation of the options to say anything meaningful. This is seen in the different spreads of the weighted scores. In effect, the max-min approach provides a greater degree of separation for the Options Assessment.

Key finding

The normalisation method did not significantly influence the MCA results. The max-min approach is preferred as it provides a greater degree of separation between results.

Alternative HP:MP ratios

All yield and demand estimates were converted to MP equivalents for the MCA. A ratio of 2.5MP:1HP (from the Burnett Region Resource Operations Plan) was used; however, the most recent and initial results[32] from SunWater's modelling suggested a ratio of 2.32MP:1HP may be more appropriate. The analysis was repeated using this ratio to determine its impact on the findings. This ratio was found to affect both the yield and demand calculations so much of the effect is cancelled out.

The biggest impact of the ratio is on the logistical aspect of certain options.[33] Options 1b and 2 would still be expected to cover demand to 2050; however, for the other two options some changes would have to be made. The reduced ratio would require the implementation of alternative supply projects to be brought forward by 1-3 years for Option 3a. While no additional projects would be required, this would increase the present value of the cost estimates. Option 4 would require an additional supply project, to be implemented in 2049, in order to meet demand in 2050.

In regard to the MCA, the scores for Options 1b and 2 are similar to before, while the scores for Options 3a and 4 in the water supply and cost objectives are slightly altered. This makes 3a drop below 2 for the worst-case and most likely scenarios; however, it moves back to the top in the best-case scenario. This is due to an increased absolute variation in cost for Options 3a and 4 (bringing forward additional supply projects). Overall, the scores are still not significantly different from one another with a lower MP:HP ratio, with a spread of 0.15.

Table 43 shows the option rankings using alternative MP:HP ratios.

Table 43. Comparison of rankings with different MP:HP ratios

Ranking	2.5MP:1HP				2.32MP:1HP			
	Option 1b	Option 2	Option 3a	Option 4	Option 1b	Option 2	Option 3a	Option 4
Worst assessment	4	2	1	3	4	1	2	3
Most likely assessment	4	2	1	3	4	1	2	3
Best assessment	4	2	1	3	4	3	1	2

[32] These results are initial findings that have not yet been published but were provided to inform the sensitivity analysis.
[33] The logistical aspect refers to both changes in the timing of projects and the addition of further supply projects.

Key finding

A change in the MP:HP ratio does not have a significant impact on the MCA results; however, it results in some changes in the timing of alternative supply projects for Options 3a and 4.

Option 1a consistently ranked last under this sensitivity analysis.

Should a full supply level option really be considered in the DBC?

It can be seen in the core results and in the various sensitivity analyses that, while there are some cases where other options' rankings vary, Option 1a is consistently ranked poorly. This is largely driven by its high cost and relatively lower dam safety score, especially as these criteria are heavily weighted. Another weighting sensitivity test was done to determine whether much weightings would need to be before Option 1a is a viable option. This involved changing the rankings to play to its strengths. Even with extreme weightings of 7.5% for cost and dam safety, 40% for water supply and 15% for each of the secondary issues, Option 1a does not score the highest.[34] It is dominated by Option 2 for any reasonable set of weightings.

Figure 39 shows how Option 1a performs when the weightings are selected to its advantage.

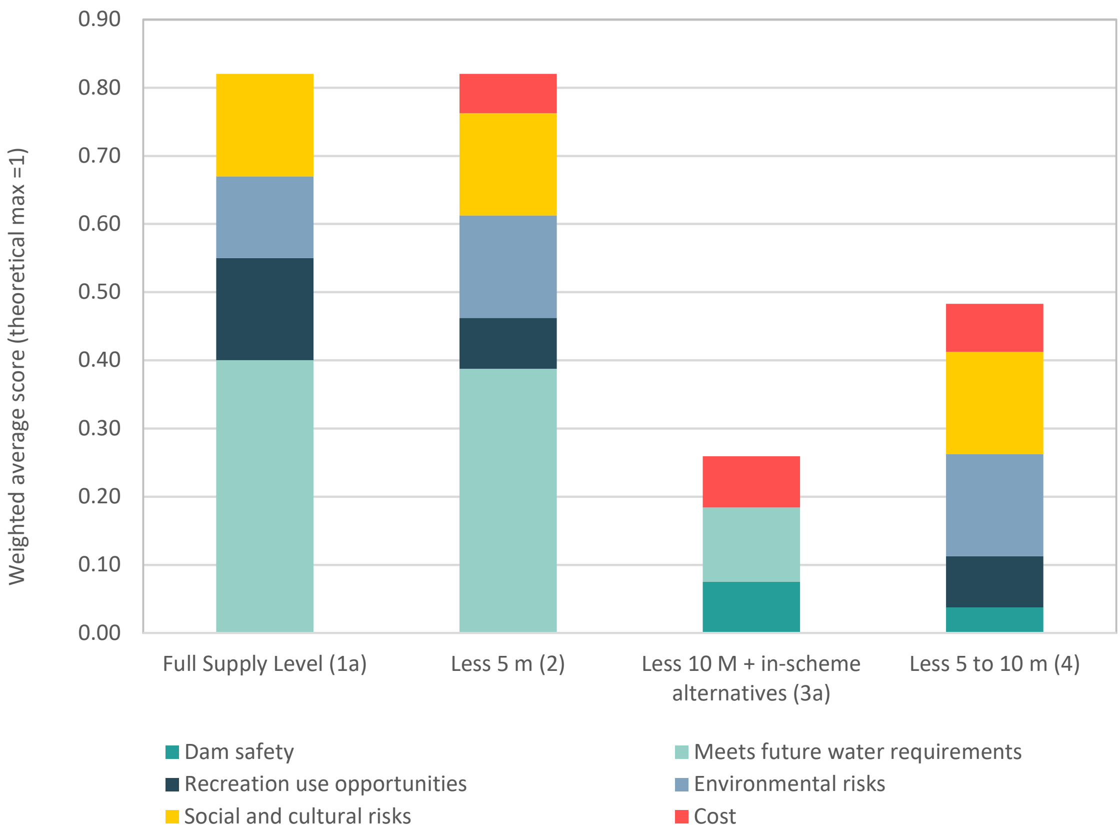

Figure 39. Score breakdown for favourable weightings for Option 1a (most likely results)

[34] Option 1a has a score of 0.8200 versus Option 2's score of 0.8203.

Key finding

While Option 1a might not always be the worst of the assessed options, it is highly unlikely to be the best with any reasonable set of weightings. Therefore, it is not recommended for assessment under the DBC.

D4. Findings and recommendations

The Options Assessment, through a multi-step process including a threshold analysis, multi-criteria analysis and various consultations, was used to create a shortlist of three options.

Option 3a is highly ranked across most scenarios, including those with increased weighting on cost, best-case and worst-case scores. Option 2 was ranked highly with increased weighting on secondary issues and with a lower MP:HP ratio. Option 4 was mostly ranked second or third while Option 1a consistently ranked poorly under all sensitivity tests conducted. The scores are not significantly different across the other options. It is therefore recommended that Options 2, 3a and 4 be taken forward to the DBC.

Key recommendation

The Options Assessment found that Options 2, 3a and 4 are not sufficiently different to choose only one at this stage. Therefore, each of these options are recommended for consideration in the DBC.

It is further recommended that Option 2 (5m Lowering) be used as the base case and compared against Option 3a (10m Lowering + Alternatives) for the DBC. Option 4 (5-10m Lowering) may require more analysis; however, the potential for optimisation of the height could make it another attractive option.

APPENDIX E: NON-BUSINESS CASE OPTIONS

The selection of options for business case consideration were based on their ability to meet demand rather than to have yields equivalent to the current Paradise Dam yields.[35] As outlined in Appendix B, even the highest demand estimates are lower than the current full supply yield. While this report recommends meeting demand estimates, it does not advocate options that would immediately provide the equivalent to the current FSL yield. The rational for this is simply that much of the yield available would likely not be presently used (potentially, even in the longer term) and it would significantly add to the establishment cost. It is unlikely that it would constitute an efficient investment or an effective use of public funds.

It is instructive to consider the incremental costs between meeting demand estimates (the service need) and configuration of supply augmentation that would provide an equivalent yield to the current FSL immediately.

Additional options assessed are:

- *Option 2a* – 5m lowering plus alternative options to meet current Paradise Dam full supply yield.
- *Option 3b* – 10m lowering plus alternative options to meet current Paradise Dam full supply yield.
- *Option 5b* – Paradise Dam decommission plus alternative options to meet current Paradise Dam full supply yield.

Our cost estimates are based on the costs and uncertainty ranges provided by SunWater for the PDIP options and SunWater (alternative supply options – see Appendix C). All of the non-business case options still incur capital cost estimates for lowering the spillway crest level or decommissioning, and then the cost of investing in the options located in-scheme (i.e. direct substitutes for yields lost), then followed by the most cost-effective alternative options across the whole region to provide an equivalent yield to the Paradise Dam full supply yield. SunWater (2019) provides a list of the shortlisted alternative supply options that could be funded to achieve the current Paradise Dam Full supply yield.[36] These alternative supply options are:

- Bucca Weir Raising - 1.5m raising
- Ned Churchward Weir - 2m raising
- Offstream storage (Ned Churchward)
- Jones Weir - 1.4m raising
- Claude Wharton Weir - 2m raising
- Auburn River Weir
- Offstream storage (Mount Lawless)
- Barlil Weir
- Boonara Dam (FSL 165)
- Reids Creek Dam
- Cooranga Weir
- Gregory River Dam
- Boonara Dam (FSL 155)
- Degilbo Crk Dam
- Kalliwa Dam

Figure 40 shows the estimated total capital expenditure for each of the three non-business case options. The estimated total capital expenditure for lowering the Dam by 5m and investing in alternative supply options to meet current Paradise Dam full supply yield is $832 million (with a range of $647 million to $1.2 billion). A 10m lowering and investment in alternative supply options to meet current full supply yield is $1.6 billion (with a range of $1.2 to $2.6 billion). Decommissioning the Dam

[35] Current full supply yields are not being used as the demand has been historically lower than the supply.
[36] Please see Appendix C for more details.

and then investing in alternative options to meet current full supply yield has an estimated cost of $2.4 billion (with a range of $1.7 to $3.9 billion).

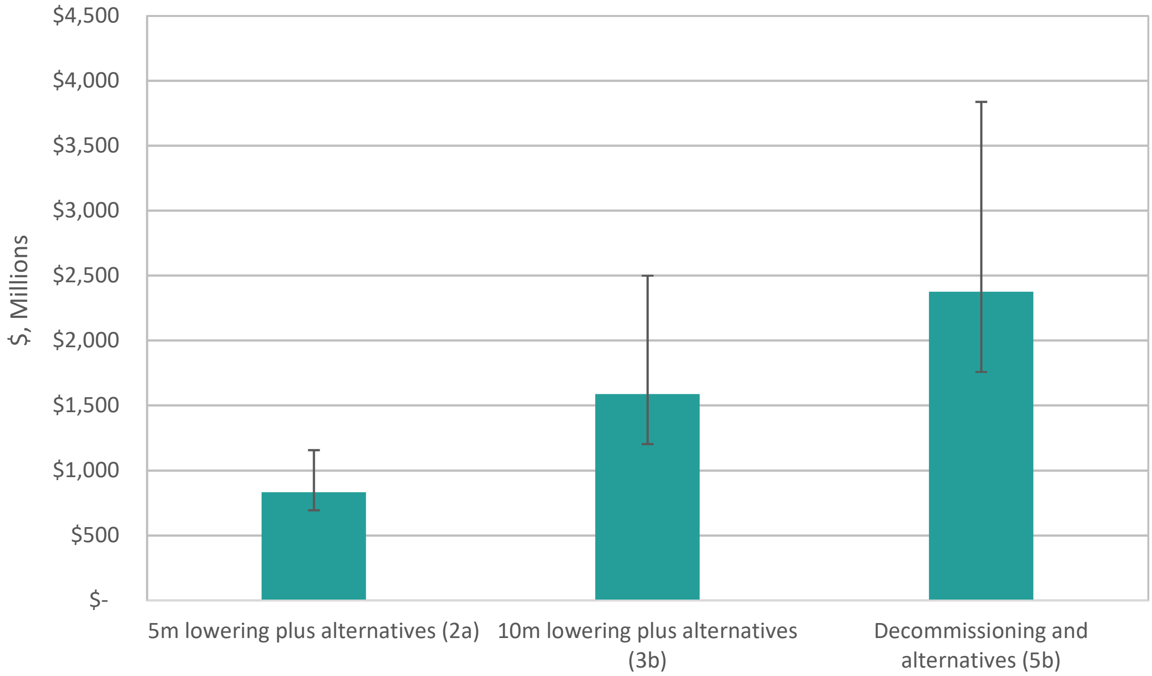

Figure 40. Total capital expenditure to meet equivalent yield to Paradise Dam full supply yield

It is instructive to consider the estimated incremental cost between implementing a preferred option that meets demand forecasts compared to options that provide yield equivalent (via alternative supply options) to the Paradise Dam FSL. This is shown in the Table 44 (most likely cost estimates only).

Table 44. Incremental cost of meeting p95 demand vs. FSL yield (range)

Measure	Option 2a	Option 3b	Option 5b
Comparison Option to deliver yield to meet demand	Option 2	Option 3a	Option 5a
Comparison Option estimated establishment cost[37]	$524M - $770M	$467M - $704M	$853M - $1,582M
Establishment cost to meet FSL yield	$694M - $1,156M	$1,203M - $2,500M	$1,759M - $3,838M
Incremental (additional) cost to meet FSL yield over demand estimate	$170M - $386M	$736M - $1,796M	$906M - $2,256M

Key point

The incremental (additional) cost of immediately meeting FSL yield compared to an efficient pathway to meet p95 demand requirements is estimated to be between $170M and $2,256M.

[37] These are present values as we would recommend alternative supplies are established to meet demand as it emerges.

APPENDIX F: CONSULTATION

Consultation was undertaken throughput the project to elicit information, data and insight relating to several key issues. This was a mix of face-to-face meetings, phone conversations, participation in workshops and email exchanges providing key data and information. To expedite consultation, wherever possible, available data was sourced and rapidly analysed[38] to enable more targeted consultation to both: a) verify or seek feedback on available data, and b) fill information gaps.

Given the sensitivity of some information, including commercial insights, confidentiality was offered and afforded to interviewees when appropriate.

There was general consensus across the parties consulted that presentations of findings would prove beneficial to the CRG and broader community. It was requested that these presentations should be made post the release of the BQ report.

Table 45. Consultation summary

Organisation	Consultation approach	Focal areas
SunWater	Meetings, exchange of data, phone calls, field visits (dam site, distribution channels).	Previous technical analysis of dam safety risks, previous options assessed, water sales and use, alternative water supply projects.
BQ and State Government agencies	Meetings, phone calls, workshops (including PSC and PWG).	Overarching project process, reporting on progress and approach (including feedback), options identification and assessment, reporting and feedback.
Bundaberg Regional Council	Phone and email exchange of data.	Historical water use (volumes, sources and preferences for groundwater), water demand drivers, population forecasts, major economic drivers and opportunities, pipeline of major industrial and commercial projects, risks to regional economy of changes in farming mix (e.g. mill viability).
North Burnett Regional Council	Phone calls and emails.	Status and background information relating to broader development opportunities (e.g. Coalstoun Lakes), recreational attributes and use of Dam site.
Paradise Dam Community Reference Group	Participation in 2 meetings followed up by one-on-one calls and discussions with different members.	Dam safety vs. yield tradeoffs, potential economic impact of development opportunities foregone, general changes in land use and industry prospects, need for presentations and further consultation post BQ report release and prior to commencement of DBC.
Bundaberg Regional Irrigators Group	Phone calls and face-to-face discussion.	Current trend of land conversion, crop patterns (including ratoons and other broadacre crops), crop requirements (optimal and actual use), impediments to investment (infrastructure, input costs, market conditions), distribution system bottlenecks, energy prices, alternative water products.

[38] It should be noted that the data available to undertake much of the analysis for this report was readily available, of a reasonable quality, and was reasonably recent.

Canegrowers / Horticulture Innovation Australia	Phone calls and access to industry statistics and information.	Historical land use and water us data, commodity price trends and expectations, key cost drivers, processing/value adding capacity and viability, trade data and information, relevant research.
Bundaberg Fruit and vegetable	Phone and email exchange of information.	Trends for changes in land use/land conversion, availability of industry data and challenges in generating reliable data (project currently underway, but won't be finished until later in 2020), industry prospects and trends (macadamias, avocados, citrus, annual fruits, annual vegetables), water demand and climate change, the need for broadening water products on offer, impediments to growth from distribution system bottlenecks, review of ranges of crop requirements, focal areas for demand assessment in DBC (including market sounding), future consultation required post release of BQ report.
Major retailers (supermarkets)	Confidential phone conversations.	Market demand trends (volumes, incremental vs. step-wise demand growth, continuity of supply), supply risks and diversification, competition from imports.
Macadamia producers	Confidential phone conversations and some face-to-face discussions in situ.	Key competitor regions, indicative investment requirements, lags between investment and cashflow generation, physical and market opportunities and impediments to growth, export vs. domestic focus, irrigation practices (and rates), potential climate risks.
Avocado producers	Confidential phone conversations and some face-to-face discussions in situ.	Indicative investment requirements, lags between investment and cashflow generation, physical and market opportunities and impediments to growth, focus on import substitution, competition from other Australian regions and New Zealand, irrigation practices (and rates), potential climate risks.
Large multi-site annual horticulture producer	Confidential phone conversation.	Investment and location decisions, diversification of production risk, general market prospects and competition, market access, range of water requirements per ha.
Various	Participation in SunWater Blueprint workshop.	Identification and scoping of broader regional issues.