BUILDING QUEENSLAND

# SUMMARY REPORT

## PARADISE DAM OPTIONS ASSESSMENT

February 2020

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## Overview

Building Queensland was requested by government to undertake an assessment of long-term options for Paradise Dam with the intention of identifying the preferred option(s) for consideration by government (**Options Assessment**). Government further requested that the options be assessed against the primary criteria of meeting dam safety requirements and water security for the long-term future of the region.

The Options Assessment has been produced under the provisions of section 13 of the *Building Queensland Act 2015*—evaluation of proposals about infrastructure. Building Queensland has worked closely with the Department of Natural Resources, Mines and Energy, Queensland Treasury and Sunwater since commencement of the Options Assessment in October 2019.

In parallel, Sunwater has been working with the government on the immediate actions necessary to ensure the safety of communities downstream of Paradise Dam. Sunwater has reduced the dam's capacity to 42 per cent to address safety for the downstream community and to facilitate essential works to lower the dam's wall. Government has also announced plans for Sunwater to undertake the essential works necessary to lower the primary spillway wall by a nominal five metres ahead of the 2020/21 wet season (together referred to as the **Essential Works**). Building Queensland acknowledges that the primary objective of the Essential Works is to address the immediate safety of communities downstream of the dam while maintaining water security requirements for the Bundaberg region into the foreseeable future.

The assessment of long-term options identified that Building Queensland is not in a position to provide a recommendation on long-term option(s) because of the preliminary level of design and other information currently available in relation to the various options. Therefore, Building Queensland has recommended further work be undertaken with Sunwater as a matter of priority to support a firm recommendation to government.

In particular, the independent technical advisor engaged by Building Queensland has identified that further information would be required and suggested further works, including:

- geotechnical assessment of the dam foundations and development of a 3D geological model (which is currently underway),
- the sampling and testing of the primary spillway wall to confirm the validity of the design parameters (which Sunwater has stated must be done during the Essential Works), and
- the refinement of options designs and cost ranges using this updated information and relative to the base case being the final condition (primary spillway level) of the dam after Essential Works.

Building Queensland acknowledges that these further works need to take place in conjunction with the Essential Works to be undertaken by Sunwater in advance of the 2020/21 wet season.

In parallel to the technical work and investigations to be undertaken by Sunwater, and in addition to the Essential Works, Building Queensland will undertake a more targeted demand assessment to build on the service needs, demand estimates and options assessment work and confirm projected demands. This will incorporate comprehensive stakeholder and community consultation processes that were not able to be undertaken as part of the Options Assessment. The further assessment will also give due consideration to the assumptions and findings of the Adept Economics report released in February 2020. In addition, a detailed yield assessment will be arranged by Building Queensland, which will contribute to determining the optimal primary spillway level that prioritises long-term dam safety and future water security.

The outcomes of this further work to be undertaken with Sunwater will allow government to consider and decide upon the preferred long-term option(s) by the end of 2020. This further work will, in turn, inform completion of an accelerated detailed business case by the end of 2021 to recommend a final investment decision to government for the preferred long-term option for Paradise Dam.

## Background / Context

Paradise Dam is a 52m high roller compacted concrete (RCC) dam located approximately 80 kilometres south west of Bundaberg on the Burnett River. The dam was designed and constructed by the Burnett Dam Alliance (which included Burnett Water Pty Ltd, the owner of the dam) and was completed in 2005. Subsequent to its completion, ownership was transferred to Sunwater who now owns, manages and operates the dam, which is a key water supply for irrigation and urban areas around Bundaberg.

In 2013 a flood event resulted in scour downstream of the primary spillway, requiring Sunwater to undertake dam repair and strengthening works. Sunwater completed detailed dam safety reviews, risk assessments, and associated studies which resulted in the development of the Paradise Dam Improvement Project (PDIP).

As part of the PDIP, early stage improvement works were carried out along with improved emergency planning and response measures. Sunwater subsequently completed a preliminary business case for the PDIP in June 2018 and commenced additional investigations to further assess the current condition of the dam and define proposed improvement works. Sunwater also set up a technical review panel in early 2019 to review the outcomes of the investigations, with detailed reports submitted by Sunwater to the technical review panel in August and September 2019. These reports identified, whilst the dam is considered safe under normal conditions, there is an increased risk of dam failure should an extreme flood like the 2013 event occur again.

On 24 September 2019, the Queensland Government announced Sunwater would reduce the water level of Paradise Dam ahead of the 2019-2020 wet season and commence works to reduce dam safety risk, including reducing the dam's capacity to 42 per cent to bring immediate safety for the downstream community and to facilitate work to lower the primary spillway in the short-term by five metres to improve stability and community safety during extreme flood events (the Essential Works). In the same announcement, Government requested that Building Queensland complete a report by February 2020, which assesses long-term options for the dam to ensure water security for the region for future economic growth and to maintain community safety.

## Scope of work

Following the Government's announcement of the Essential Works, the Department of Natural Resources, Mines and Energy (DNRME) engaged Building Queensland to assess the following long-term options for dam improvement works for Paradise Dam to meet the Government's objectives for water security and community safety:

- Option 1: maximum primary spillway height (equivalent to a primary spillway level of RL67.6m[1]).
- Option 2: reduce maximum primary spillway height by 5m (equivalent to a primary spillway level of RL62.6m).
- Option 3: reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m).
- Option 4: reduce maximum primary spillway height by an optimised level (between 5m and 10m) to maintain water security.
- Option 5: decommission the dam.

[1] RL (reduced level) is a technical surveying term that refers to equating elevations of survey points with reference to a common assumed datum. In the context of Paradise Dam, it refers to the height of the top of the primary spillway above a set benchmark point. This is a different measure to the maximum height of the dam above the foundation level, which is identified as 52m.

The base case used for the definition of the options above corresponds to the condition of the Paradise Dam prior to delivery of the Essential Works (that is, a primary spillway level of RL67.6m). The adoption of this base case was required as, at the commencement of the Options Assessment, all technical information available for the review used this base case, including all the designs, costs and dam safety assessments provided by Sunwater.

The scope of the Options Assessment was comprised of two complementary work packages:

1. An independent design, cost and risk review of Sunwater's technical information, led by Aurecon;
2. An independent definition of service needs, assessment of future water demand, and the multi-criteria assessment of the five options, led by Natural Capital Economics.

Building Queensland engaged the abovementioned independent expert advisors in November 2019, to lead the works to complete these two packages. In consultation with DNRME, Building Queensland selected these advisors based on their depth of relevant industry expertise and their independence from recent engagements with Sunwater and from previous work related to Paradise Dam.

Aurecon's review of the design, cost and risk of the nominated five long-term options involved an independent review of technical information supplied by Sunwater, including information on the existing condition of Paradise Dam, available design reports for the options, dam safety assessments, and cost estimates for the five options. Aurecon also reviewed the technical reports released by Sunwater in late November 2019 including the Tatro-Hinds report and the Technical Review Panel report.

Natural Capital Economics' review involved an independent assessment of service needs, the development of projected water demands, the investigation of alternative water supply options, and a multi criteria analysis of the five options using the identified service needs as evaluation criteria. Natural Capital Economics' review was primarily based on information supplied by Sunwater and informed by community consultation, conducted by Natural Capital Economics in December 2019, with a wide range of local stakeholders, current water users and potential water users (a full list is provided in Appendix F of Natural Capital Economics' report which is attached in Appendix B to this report).

## Summary Analysis of Advisor's Findings

### Design-Cost-Risk Review

Aurecon's review found that the designs, costs and risk assessments for each option had been developed in accordance with the relevant ANCOLD guidelines and the processes followed were in accordance with standard industry practice. Aurecon noted the use of design parameters which reflected the level of information available at the time, including some conservative factors (lower bounds of density and shear strength). Aurecon identified further technical investigations (including some already underway and some planned by Sunwater) that could be completed through detailed analysis of the options that would confirm these design parameters.

Aurecon highlighted work underway but not yet completed by Sunwater, including further geotechnical assessment of the dam foundations, development of a 3-D geological model, and the planning for undertaking post tensioned anchoring trials. Aurecon noted that completion of these works will lead to a better understanding of foundation conditions and inform and support the development of strengthening works required to meet the long-term dam safety requirements.

Aurecon recommended further work to undertake core sampling and testing of the RCC within the primary spillway. This work will confirm the condition of the RCC to increase confidence in, and confirm the validity of, the parameters used as the basis for design.

Aurecon's assessment of Option 1 identified that Sunwater had developed different approaches for this option. These were:

- Option 1A: additional risk reduction works on the secondary spillway[2] that may meet the required dam safety assessment criteria
- Option 1B: the use of gates to achieve maximum primary spillway height.

Aurecon noted the operational complexity, high maintenance requirements and general risks associated with using gates, and Sunwater's strong preference against the use of gates. As a result, this option was not recommended for progression in the Options Assessment. Aurecon's review determined that Option 1A's performance in potentially meeting dam safety requirements relies on the outcomes of the dam foundation assessment (currently underway), RCC assessment and anchoring trials (planned by Sunwater).

During their review, Aurecon assessed Options 2, 3 and 4 collectively due to their similar technical scope for lowering the primary spillway level. Aurecon's assessment of these options highlighted that they would all likely achieve a risk position below the ANCOLD life safety limit of tolerability, noting that, like Option 1A above, these three options also rely on foundation assessment and anchoring trials, and the RCC sampling and testing outcomes, to confirm performance against dam safety requirements.

Aurecon's review of the costs for each option identified that while the estimation process followed for developing the costs was reasonable, the design and other supporting information that was originally used to develop the costs had changed as Sunwater's investigations progressed. Aurecon was of the view that the indicative cost ranges supplied by Sunwater for each of the options, were only suitable for an initial comparative assessment. In noting that further detailed engineering design work is required to provide detailed and robust cost estimates, Aurecon cautioned that the current cost range estimates should not be viewed as indicative of the expected project cost and no reliance should be placed on these cost range estimates.

Aurecon's review of the dam safety assessments conducted for each of the options highlighted that the outcomes are a reasonable reflection of the current risks and that the additional investigations underway or planned would further inform the outcomes of the dam safety assessments. Based on the available information, Aurecon found that:

- Option 1 was not below the limit of tolerability (the first key dam safety requirement) whereas Option 1A provided additional risk reduction that may improve this position and potentially reduce the risk below the limit of tolerability. Both of these options are highly dependent on the outcomes of Sunwater's ongoing foundation assessment and anchoring trials and RCC testing of the primary spillway.
- Option 2 may be adequate to reduce the risk position below the limit of tolerability and may be adequate to achieve the ALARP[3] principle (the second key dam safety requirement).
- Option 3 is adequate to reduce the risk position of the existing dam to well below the limit of tolerability (by two orders of magnitude) and would likely meet the ALARP principle as further risk reduction works would likely not be justified.

[2] Option 1A involves demolition and removal of some existing secondary spillway monoliths down to good foundation level, and then reconstruction of these secondary spillway monoliths.

[3] ALARP (As Low As Reasonably Practical) is a term which represents a virtual balance point below the limit of tolerability where the cost effectiveness of further upgrades is considered disproportionate to the risk benefit gained with the assessment to be undertaken in accordance with dam safety guidelines. ALARP should be assessed for an individual dam and also considered across the portfolio of dams owned, with the final position agreed with the dam safety regulator.

- Option 4 would be expected to have a risk position that falls between Options 2 and 3 meaning that it satisfies the limit of tolerability and may be adequate to meet the ALARP principle, as per the findings for Option 2 and Option 3.
- Option 5 eliminates the dam safety risk as the dam is decommissioned

Aurecon's final report, *Paradise Dam Upgrade Options Assessment – Independent Design, Cost and Risk Review* is included in Appendix A.

## Service Needs, Demand Assessment, and Options Assessment

Natural Capital Economics defined a set of service needs, which provided the basis for assessment criteria for the multi-criteria assessment of the five options. In particular, two of the key service needs were classified as threshold criteria for the Options Assessment, that is, criteria against which the options either pass or fail. The identified service needs are:

- Dam safety – considered firstly in determining whether the risk position is below the limit of tolerability based on the outcomes from the design, cost and risk review (used as a threshold criteria), and secondly, in determining the degree to which the option is considered likely to meet the ALARP principle[4] (used as a scoring criteria in the multi-criteria assessment),
- Future water requirements (water security) – considered firstly in determining whether the option is able to meet the water security needs (current and projected future demands to 2050) (used as a threshold criteria) and then secondly, in determining the degree to which the option exceeds the water security threshold requirements (used as a scoring criteria in the multi-criteria assessment),
- Recreational use,
- Environmental risks, and
- Social and cultural risks.

Natural Capital Economics undertook a comprehensive future water demand assessment considering:

- macro factors driving demand for water,
- econometric analysis of historical regional water demands,
- climate change impacts,
- a detailed assessment of current and possible future agricultural production trends and water requirements, and
- the detailed appraisal of urban, commercial and industrial demand trends.

The demand assessment was informed by consultation with key regional industry and community stakeholders throughout December 2019 (a full list of stakeholders is presented in Appendix F of the Natural Capital Economics report which is included in Appendix B to this report).

Natural Capital Economics' findings highlight that long-term projected increases in demands predominantly are expected to result from the gradual conversion of sugar cane farms to higher value crops including macadamia and avocado. This conversion results in a net increase in demand (the water demand for higher value crops minus the original water demands for sugar cane crops). The demand projections were also based on sales of medium and high priority allocations (the right to take water) rather than actual usage, which anecdotally is typically lower than the volume held in allocations. Natural Capital Economics have

[4] The degree to which the option meets ALARP will also include the degree to which the option is under the limit of tolerability

identified that holding allocations larger than required may be used as a supply risk mitigation strategy by growers.

Natural Capital Economics also reviewed scenarios whereby alternative water supply options could assist the five options meet water security requirements. Concurrently with the Options Assessment, Sunwater are developing a Burnett Basin Blueprint which identifies and defines alternative water supply options in the region. For the purposes of Natural Capital Economics' review, Sunwater provided a short list of these options, including the likely storage capacity available and indicative costs for each option.

Natural Capital Economics assessed the ability of the five options to meet the projected demands, with the threshold criteria used to eliminate Option 3 and Option 5, as they cannot meet future water requirements to the year 2050 (with Option 5 assessed as also being unable to meet current demands). The remaining options were benchmarked, at a high level, against the projected demands out to the year 2050.

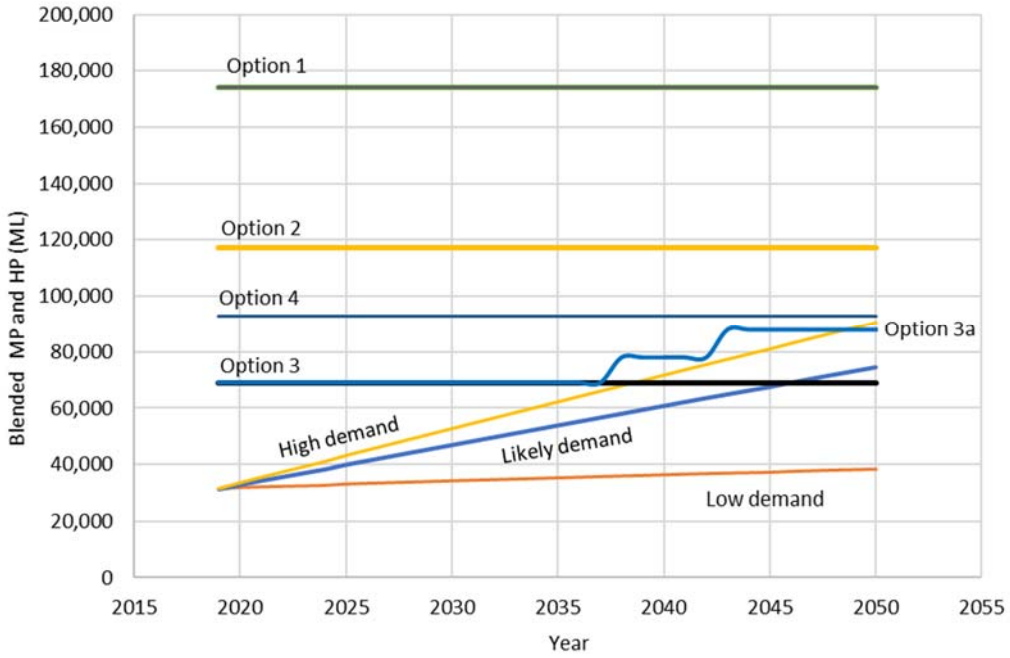
Natural Capital Economics' review of the existing medium and high priority water allocations available from Paradise Dam, identified that a large proportion of the high priority allocations are currently unsold, with current expectations (based on recent sales and consultation with customers) anticipating that they would likely remain unsold in the near future. Natural Capital Economics investigated a scenario to convert some of the unsold high priority allocations to medium priority allocations. The investigation found that this had the effect of making a greater volume of water available to underpin irrigation growth in the shorter term, with a negligible risk of demand for high priority allocations being constrained.

Natural Capital Economics identified that the conversion of high priority to medium priority allocations, providing a greater volume of available water, had the effect of allowing Option 3 to meet projected demands to a point much further in the future. However, the option does not provide an equivalent level of water security to the other options over the full time period investigated. Option 3A was therefore introduced as a sub-option, which included alternative water supply options to assist in meeting projected water demands to 2050.

Natural Capital Economics' projected water demand scenarios are illustrated in Figure 1, which shows the capacity of the options assessed (noting the priority conversion stated above) and the timeframe for the demand projections. Three demand scenarios are identified in Figure 1, a high demand (represented as a P95[5] demand), a low demand (represented as a P5 demand) and the likely demand (represented as a P50 demand).

[5] A P95 demand is a representation that there is a 95% chance of actual demand being lower than this value (and a corresponding 5% chance of being exceeded). In the same manner, the P5 demand has only a 5% chance that actual demands are lower than this value and the P50 demand represents a virtual mid-point, that is, the actual demand is 50% likely to be higher or lower.

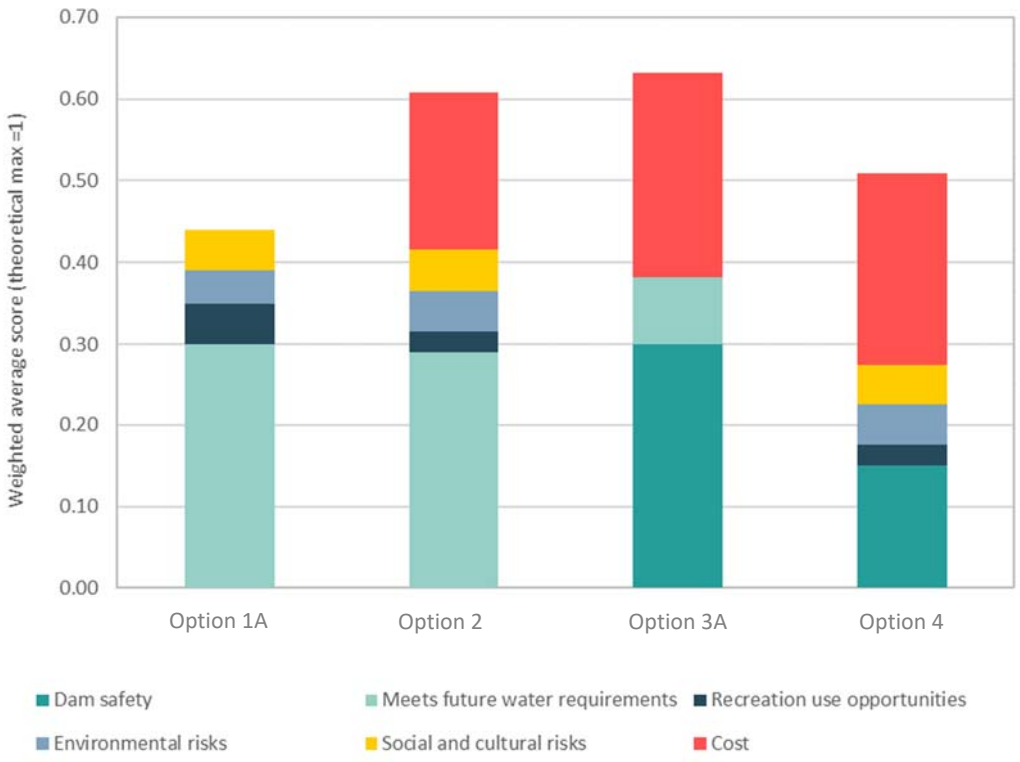
Figure 1 Assessment of Options Against a Range of Demand Scenarios




Natural Capital Economics assessed the four remaining options using multi-criteria analysis at an options assessment workshop attended by representatives of DNRME, Treasury and the dam safety regulator. The defined service needs were used as assessment criteria and weightings were assigned to the criteria (with the weightings agreed by workshop participants) focussing on the key criteria of dam safety, meeting future water requirements (water security) and the indicative cost of the options.

The outcomes of the multi-criteria analysis are presented in Figure 2.

Figure 2 Weighted Assessment Scores for Each Option



Natural Capital Economics conducted sensitivity analyses on the outcomes of the multi-criteria analysis however this analysis resulted in no changes to the ranking of options.

Natural Capital Economics' multi-criteria analysis identified several options suitable for progression to a detailed business case, these were:

- Option 2: reduce maximum primary spillway height by 5m (equivalent to a primary spillway level of RL62.6m).
- Option 3A: reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m), supplemented by alternative water supply options to maintain water security for the region.
- Option 4: reduce maximum primary spillway height by an optimised level (between 5m and 10m) to balance water security and dam safety and supplemented by alternative water supply options.

Option 1A was not recommended for progression by Natural Capital Economics due to the option's low score in the multi-criteria analysis. This low score was predominantly due to the high indicative cost of the option and comparative performance in meeting dam safety requirements and the very low probability that projected demand would warrant the additional yield.

Natural Capital Economics also identified that their use of the conversion of unsold high priority allocations to medium priority allocations requires further work to implement, including detailed modelling to determine the volume of high priority water which could be converted, detailed stakeholder and community consultation to confirm approval processes, and work to ensure that any potential impacts to supply and drought resilience are identified and managed.

Natural Capital Economics' final report, *Paradise Dam Improvement Project: service needs, demand estimates and options assessment* is included in Appendix B.

Natural Capital Economics undertook a high-level review of the Adept Economics report entitled *Economic Costs of Inaction on Paradise Dam*, which was released on 24 February 2020[6]. The review highlighted some potential limitations due to key estimates used, the robustness of the analysis, the credibility of findings and application to a defensible cost-benefit analysis. The estimates presented should be used with extreme caution, as a number of assumptions and input parameters are not yet certain and would require further testing as part of a detailed business case. It is observed, however, that the nature of the analysis contained in the report does not preclude the validity of the demand assessment undertaken.

Natural Capital Economics' high level review report, *High level review of the Economic Costs of Inaction on Paradise Dam – Approach, findings and implications for Building Queensland*, is included in Appendix C.

## Impact of announced Essential Works

Following the announcement of the Essential Works on 24 September 2019, an amendment to the *Water Supply (Safety and Reliability) Act 2008* was introduced on 4 February 2020 by the Minister for Natural Resources, Mines and Energy to enable Sunwater to lower the primary spillway level to reduce dam safety risk. The accompanying Ministerial media announcement stated that the legislation *ensures that spillway modification work can occur without delay* in the 2020 dry season. The legislation was passed by Parliament on 13 February 2020.

Building Queensland notes that the Essential Works announced by the Government in September 2019 to reduce dam safety risk in the short-term (which will include an immediate nominal 5 metre lowering of the

[6] Note the report was downloaded by Natural Capital Economics from links included in a news article on the Bundaberg Now website - https://www.bundabergnow.com/2020/02/24/2-4-billion-cost-to-economy-if-paradise-dam-not-fixed/. No correspondence including the report was sent to Building Queensland.

primary spillway level), will result in a change to the base case used for any further assessment of the options. Building Queensland further notes that the announced Essential Works are not inconsistent with any of the long-term options recommended for further consideration. The impact of the new base case on each of the options will be fully considered in the next stages of work.

Consequently, the base case for the future assessment of long-term options for Paradise Dam, as part of the next stage of detailed business case analysis, will be a primary spillway level of RL62.6m. Whereas a primary spillway level of RL67.6m was assumed as the base case for the purposes of the Options Assessment, given the information available and supplied by Sunwater.

It should be further noted that Sunwater has advised that due to the construction method required to undertake the Essential Works, the primary spillway level at the completion of the Essential Works may be slightly, but not materially, different to the previously announced lowering of five metres. The base case used in the next stage of assessment for the detailed business case will therefore need to take account of the expected actual primary spillway level at the completion of the Essential Works.

This change in base case will impact the following components of work, which are required to achieve the recommended long-term primary spillway height, as identified by the independent advisors:

- option designs and construction methodology (indicated by Aurecon),
- option costs, including the relative costs of options (indicated by Aurecon and Natural Capital Economics), and
- option risks, including the interim risk positions associated with construction (indicated by Aurecon).

The following investigations performed as part of the Options Assessment will not be affected by the change in base case:

- the service needs identified for the dam, and
- the demand assessment for the region.

The impact of the new base case on each of the options will be fully considered in the recommended further work for progression of the detailed business case.

## Consolidated recommendations and next steps

The key recommendations arising from the independent advisors' (Aurecon and Natural Capital Economics) reviews as part of the Options Assessment and Building Queensland's analysis and summary report are outlined in the following points:

### Recommendations from Aurecon

- Complete the current geotechnical assessment of the foundations of the dam including development of a 3D geological model.
- Undertake core sampling and testing of the RCC in the primary spillway (noting that this would need to be done at the same time as the Essential Works)
- Undertake Anchoring trials to confirm foundation capacity.
- Complete further development of preliminary designs and cost estimates for the options using the new base case (the primary spillway level at the completion of the Essential Works).

### Recommendations from Natural Capital Economics

- The options costs are based on design information which must be updated to the new base case. Once updated the comparative cost position of each option can be reassessed.
- 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 detailed business case, a more detailed approach is recommended that builds on and complements the current assessment through detailed consultation and market sounding, a detailed econometric analysis, assessing the influence of prices on demand, consideration of distribution system constraints, sub-regional demand estimates, and crop specific economic thresholds and modelling to assess impacts on demands.
- Assessment of the impacts of changes to current water sources in the region including groundwater and the role Paradise Dam has in meeting regional water security with the current sources.
- Potential actions to better match availability and demand should be considered, including the potential to convert excess High Priority allocations to Medium Priority allocation, and the potential development of a new product that better matches the needs and risk profile for perennial tree crops. However further work is required including government approvals, stakeholder engagement, assessment of impacts on drought resilience, and assessment of the impacts on other water supplies including groundwater.
- On the basis of the Options Assessment, the independent advisor recommended that the following options progress through to investigation in the next stage of the detailed business case:
  - Option 2: reduce maximum primary spillway height by 5m (equivalent to a primary spillway level of RL62.6m).
  - Option 3A: reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m) supplemented by alternative water supply options which would meet projected demands and provide water security for the region.
  - Option 4: reduce maximum primary spillway height by an optimised level (between 5m and 10m) to balance water security and dam safety and supplemented by alternative water supply options as required.
- Further, Natural Capital Economics' high-level review of the Adept Economics Report (refer **Appendix C**) highlighted the need for further analysis in the detailed business case to test the assumptions around greenfield and brownfield development of high value crops and their impact on water demands. Natural Capital Economics' review also identified other issues which are relevant to the further work recommended by this Summary Report and will need to be considered in the development of the detailed business case.

### Recommendations from Building Queensland

1. Based on the independent advisors' reports, Building Queensland notes that the following further work is required as part of the next stage of the detailed business case:
   a. Completion of Sunwater's geotechnical investigations of the dam foundations, including a 3D geological model to inform the understanding of the dam foundations, and commencement of Sunwater's planned anchoring trials to confirm the capacity of the dam foundations. Building Queensland acknowledges that this work needs to take place in conjunction with the Essential Works to be undertaken by Sunwater ahead of the 2020/21 wet season.

b. Sunwater to arrange for core sampling and testing of the RCC in the primary spillway (Sunwater has advised this must be undertaken during the Essential Works) to confirm key design parameters.

c. In parallel to the Sunwater led work identified in points 1a. and 1b. above, Building Queensland will arrange for an additional detailed demand assessment that builds on and complements the existing work including detailed community and stakeholder consultation and market sounding, a detailed econometric analysis, assessing the influence of prices on demand, consideration of distribution system constraints, sub-regional demand estimates, and crop specific economic thresholds and modelling to assess impacts on demands. The further assessment will also give due consideration to the assumptions and findings of the Adept Economics report released in February 2020, as identified in the high-level review by Natural Capital Economics (Appendix C).

d. Noting a detailed yield assessment has not yet been undertaken, and again in parallel with the works described above, Building Queensland will arrange for investigations into the yield required to meet water security expectations, including assessment of an optimised primary spillway level, and assessment of alternative water supply options. These investigations will inform the refinement of options.

e. Sunwater to continue refinement of options designs and cost estimates (using the base case determined by the outcome of the Essential Works), including design of alternative water supply options.

Building Queensland will implement a governance process to ensure appropriate independent oversight and review of the outcomes of these works, including peer review.

2. Based on the outcomes of the further work recommended in points 1) a. to 1) e. above, Building Queensland will undertake a detailed re-assessment of the recommended options (Option 2, Option 3A, and Option 4). Building Queensland will also include Option 1A in this assessment to ensure it is fully considered in light of the outcomes of the further work recommended above. The analysis will be undertaken in accordance with the Building Queensland Business Case Development Framework and Queensland Treasury's Project Assessment Framework. This includes assessment of the options against service need, including the updated demand assessment outcomes, and more detailed economic analysis, including cost effectiveness and cost benefit analysis.

3. The outcomes of the recommended further work in points 1a. to 1e. and the detailed re-assessment of the recommended options outlined above, will be progressed immediately with Sunwater and in parallel to the Essential Works and presented to government for further consideration and decisions regarding the final recommended option(s). Subject to government approval, Building Queensland and Sunwater will agree on an accelerated schedule for completion of a detailed business case by late 2021, which confirms long-term dam safety and water security requirements.

Subject to the outcomes of the recommended further work set out above, it is anticipated that the final stage of the detailed business case will assess the following options, which are described below relative to the new base case (the condition of the dam at the completion of the Essential Works, which will have a spillway level equivalent to Option 2), noting that strengthening work will be required for each option:

- Option to maintain the primary spillway height at the level of the base case;
- Option to raise the primary spillway height to an optimal level (bounded by the level of Option 1A, RL67.6m) that balances dam safety and water security requirements with alternative water supply options included as required; and,

- Option to lower the primary spillway height to an optimal level (bounded by the level of Option 3A, RL57.6m) that balances dam safety and water security requirements, with alternative water supply options included as required.

Building Queensland and Sunwater will work closely to ensure that the recommended further works, and subsequent detailed business case can be completed within the following indicative timeframes:

- Additional Sunwater-led investigations plus designs for options refinement by the end of 2020,
- Building Queensland-led investigations (demand and yield assessments) for detailed options re-assessment by the end of 2020,
- Submission of outcomes of further detailed analysis to Government by the end of 2020, and
- Completion of a final detailed business case by the end 2021.

# 1 BACKGROUND / CONTEXT

## 1.1 Paradise Dam Improvement Project and Essential Works

Paradise Dam is a 52m high roller compacted concrete (RCC) dam located approximately 80 kilometres south west of Bundaberg on the Burnett River. The dam was designed and constructed by the Burnett Dam Alliance (which included Burnett Water Pty Ltd, the owner of the dam) and was completed in 2005. Subsequent to its completion, ownership was transferred to Sunwater who now owns, manages and operates the dam, which holds a total capacity of over 300,000 megalitres and is a key water supply for irrigation and urban areas around Bundaberg.

In 2013 a flood event resulted in scour downstream of the primary spillway, requiring Sunwater to undertake dam repair and strengthening works. Sunwater completed flood repair works in 2013, and undertook detailed dam safety reviews, risk assessment investigations, and associated studies which resulted in the development of the Paradise Dam Improvement Project (PDIP) to mitigate the risk of instability of the dam. Sunwater's 2017 Portfolio Risk Assessment (revision 6) identified the Paradise Dam Primary Spillway Improvement Project and the Paradise Dam Secondary Spillway Improvement Project as high priority for completion to retire risk in its portfolio. Both the Primary and Secondary Spillway Improvement Projects formed part of the PDIP.

As part of the overall improvement strategy, Sunwater also carried out early stage dam improvement works from 2015 to 2017 to strengthen the base of primary spillway monoliths and reviewed and implemented improved emergency planning and response measures from 2015 to 2018 (and ongoing).

Sunwater completed a preliminary business case for the remaining improvement works under the PDIP in June 2018. This short-listed two options for further development in the detailed business case, including necessary improvement works to reduce risks and retain the dam at the existing full supply level, and an option to lower the primary spillway crest level by 10m (or more) and associated improvement works for reduced cost with reduced supply capacity.

Sunwater commenced planning and design activities and initial engagement with Building Queensland for the next phase in late 2018. As the total value of the PDIP exceeds $100 million, Building Queensland is responsible for the development of a detailed business case as per section 14 of the *Building Queensland Act 2015*.

Building Queensland, Sunwater and key stakeholders commenced work in early 2019 to define the requirements for a detailed business case. Through this process, Sunwater commissioned further geotechnical investigations, a revised dam stability assessment, and peer review by national and international experts. These investigations identified, whilst the dam is considered safe under normal conditions, there is an increased risk of dam failure should an extreme flood like the 2013 event occur again. This was considering, in particular, the revised risk of shear or sliding failure through the roller compacted lift joint layers during flood events, in addition to other key risks including scouring and undermining of the dam wall, and failure through the foundation below the secondary spillway.

On 24 September 2019 the Queensland Government announced Sunwater would reduce the water level of Paradise Dam to improve stability during extreme flood events and commence essential works to reduce dam safety risk including lowering the primary spillway by five metres (the Essential Works). In the same announcement, Government requested that Building Queensland complete a report by February 2020, which assessed long-term options for the dam to provide water security for the region, enable future economic growth, and maintain community safety.

## 1.2 Ministerial Statements

The Minister for Natural Resources, Mines and Energy has made several public statements in relation to the Paradise Dam Improvement Project and the scope of this Options Assessment:

- 24 September 2019: Minister Lynham tasked Building Queensland with "*assessing and reporting by February 2020 on options to ensure water security for the region for future economic growth and to maintain community safety*". This statement formed the basis for undertaking this Options Assessment.
- 29 November 2019 and 06 December 2019: The Minister announced the formation and commencement of an Independent Commission of Inquiry to conduct a thorough investigation to determine the root cause of structural and stability issues identified in the engineering and technical studies into the Paradise Dam. Specifically, Minister Lynham stated that all investigations related to the dam continued in parallel with the Commission of Inquiry.
- 05 February 2020: The Minister announced an amendment to the *Water Supply (Safety and Reliability) Act 2008* that "*… ensures that spillway modification work can occur without delay"*. This amendment allows for the Essential Works program to commence in the 2020 dry season while the statement indicates that "*The long-term options for the dam are still being looked at by Building Queensland*".

## 1.3 Parallel Works

This project, the Paradise Dam Options Assessment (henceforth the Options Assessment) was undertaken alongside several other investigations by various parties into issues relevant to Paradise Dam and the surrounding region. Where the timing and/or scope correlates with the Options Assessment, the outcomes of these parallel works have been incorporated into this report.

### 1.3.1 Sunwater Burnett Blueprint

The purpose of Sunwater's Burnett and Kolan Regional Blueprint process is to:

- Analyse long-term risks and opportunities for the Burnett and Kolan basins (including local supply constraints and global demand drivers, such as outlook for commodity prices)
- Identify and assess (early stage) responses for different long-term scenarios for Sunwater water supply schemes
- Identify areas of opportunity for Sunwater corporate strategy

The Blueprint process was conducted concurrently with the Options Assessment, with stakeholder investigations undertaken by Sunwater in December 2019, supply options identified in January 2020 and the completion of the process expected in April 2020.

The Options Assessment and Blueprint process coordinated regional stakeholder engagement activities in December 2019 to streamline the capture of information and engagement with the community. Additionally, the Blueprint's assessment of regional water supply options (including the long list (30) and short list (12) of options) has been incorporated into the Options Assessment process as alternative water supply options.

### 1.3.2 Paradise Dam Technical Reports

Sunwater released several technical reports relating to the dam on 29 November 2019. These reports included:

- Technical Review Panel Report

  - Summary of findings of the Sunwater Technical Review Panel Workshops held in May and August 2019 including discussion on a wide range of technical aspects of the dam including geology, dam stability, design of options and risk mitigation approaches.
- Summaries of Stability Assessment and Shear Strength Review performed by GHD.
- Tatro-Hinds Report on Shear Strength Evaluation
  - Report commissioned to provide independent review and comment on the RCC lift joint shear strength assessment and approach including reference to risks, alternate approaches, impact of drilling and suitability of test methods employed.

These reports have been considered and findings incorporated into the Design, Cost and Risk review.

### 1.3.3 Other parallel works

There are several other ongoing works pertaining to the Paradise Dam which, due to either the scope of the work or the timing of the works, cannot be considered as inputs to the Options Assessment.

#### 1.3.3.1 North and South Burnett Feasibility Study

The North Burnett Regional Council and South Burnett Regional Council, with support from DNRME, will undertake a Feasibility Study to identify water supply options for the North and South Burnett region. The project includes identification of options, assessment of demand within the region and stakeholder engagement. The project will culminate with the delivery of a Preliminary Business Case by the end of June 2020.

It is anticipated that the work done in the Options Assessment on alternative water supply options will assist in the development of preferred options for this study.

#### 1.3.3.2 Inspector-General Emergency Management – Emergency Preparedness

The Inspector-General Emergency Management reviewed the current condition of the dam and the emergency preparedness of both Sunwater and the local communities relating to the safety of the dam. This report was completed in December 2019.

The information generated under the scope of this review around emergency preparedness was focussed on the short-term requirement for community safety whereas the Options Assessment is focussed on the long-term options for water security and community safety.

#### 1.3.3.3 Community Reference Group

A community reference group was established by Sunwater in October 2019 to facilitate effective two-way exchange of information between Sunwater and communities in the Bundaberg-Burnett region. The terms of reference for the group are to ensure that information and decisions on the essential works are fully explained to community members and that community concerns and questions about the Paradise Dam Essential Works and Dam Improvement Program can be addressed by Sunwater. The reference group has met monthly from October 2019 and is expected to continue to do so until October 2020.

#### 1.3.3.4 Bundaberg Regional Council Economic Assessment

The Bundaberg Regional Council (coordinating on behalf of a range of industry and community stakeholders[7]) engaged Adept Economics and Rowland Communications to undertake an economic

[7] Wide Bay Burnett Regional Organisation of Councils, Regional Development Australia Wide Bay, Bundaberg Fruit and Vegetable Growers, Isis Canegrowers, Bundaberg Canegrowers, Macadamia Society of Australia and other local agricultural representatives

assessment of the value of irrigation water from Paradise Dam through engagement with regional councils and stakeholders. The assessment included an investigation of:

- Economic cost (development foregone) of not reinstating full supply level.
- Value of irrigation water ($/ML) to regional economy.
- Advocate for return to original capacity.

The Adept Economics report, entitled *Economic Costs of Inaction on Paradise Dam*, was released on 24 February 2020 after the final Summary Report had been submitted to the Building Queensland Board for consideration. Notwithstanding, Building Queensland instructed Natural Capital Economics to undertake a high-level review of the Adept Economics report to identify key issues that would have most relevance to Building Queensland's Summary Report. Natural Capital Economics' high level report is included in **Appendix C** to this Summary Report.

The high-level review by Natural Capital Economics highlighted some potential limitations in the Adept Report due to key estimates used, the robustness of the analysis, the credibility of findings and application to a defensible cost-benefit analysis. Natural Capital Economics found that a number of assumptions and input parameters are somewhat unclear and questionable and therefore cautioned against using the estimates presented in the Adept Economics Report. Natural Capital Economics observed, however, that the nature of the analysis contained in the Adept Economics Report does not preclude the validity of the demand assessment undertaken by Natural Capital Economics for Building Queensland.

The key issues highlighted by Natural Capital Economics in their supplementary report are:

- **Future changes in land use.** Adept's assumed growth rates of high value crops are relatively similar to those developed by Natural Capital Economics and consistent with market trends. However, Adept's simple assumption that future development is primarily greenfield is inconsistent with historical data and trends, current trends revelled through consultation, and statements in Adept's own report. This assumption has a profound impact on water demand and could result in demand outstripping FSL yields in as little as 20 years. The assumption of greenfield development is highly questionable and should be robustly tested in the DBC.
- **Economic cost estimation.** Adept's estimates of the cost of Government inaction are effectively the benefits foregone attributable BQ's Option 3. The estimates should be treated with extreme caution. There are a number of assumptions and input parameters within the analysis that are somewhat unclear and/or questionable. Where assumptions and input parameters were clear, Natural Capital Economics was unable to accurately replicate the estimates. Generally, the cost estimates appear to be high due to several assumptions and input parameters used.

Natural Capital Economics' review highlighted the need for further analysis in the detailed business case process to test the assumptions around greenfield and brownfield development of high value crops and their impact on water demands. Natural Capital Economics' review has identified additional issues which have relevance to the further work recommended by this Summary Report, and will therefore be considered further in the development of the detailed business case.

#### 1.3.3.5 Bundaberg Fruit and Vegetable Growers Technical Review

The Bundaberg Fruit and Vegetable Growers engaged the US-based dam engineering firm Rizzo International to investigate alternate options for Paradise Dam including repair, along with a review of the publicly released technical reports by GHD and Tatro-Hinds. The reports are expected to be presented to the State Government and Sunwater prior to further decision-making regarding Paradise Dam. DNRME are managing contact with the group. On 5 February 2020, the Minister announced that outcomes of the investigation

would be sent to Sunwater in March 2020 for consideration in the context of their current and previous work and the Options Assessment.

#### 1.3.3.6 Sunwater Essential Works

The Queensland Government announced, on 24 September 2019, the commencement of Essential Works to reduce the flooding risk of Paradise Dam by lowering the water level in the dam and subsequently lowering the primary spillway by five metres. Following this announcement, an amendment to the *Water Supply (Safety and Reliability) Act 2008* was introduced by the Minister for Natural Resources, Mines and Energy to enable Sunwater to lower the primary spillway level to reduce dam safety risk on 4 February 2020. The accompanying media announcement states that the legislation *ensures that spillway modification work can occur without delay* in the 2020 dry season. The legislation was passed on 13 February 2020.

The Options Assessment has proceeded independently of the Essential Works which is focussed on short term actions, however the impact of these works will inform future stages of work, including the development of the base case for the detailed business case.

#### 1.3.3.7 Commission of Inquiry

A commission of inquiry into the structural and stability issues affecting the dam was announced by the Queensland Government on 29 November and commenced on 6 December 2019. The scope of the inquiry was to investigate the following matters:

- the root cause of structural and stability issues identified in engineering and technical studies conducted on the Paradise Dam between 30 January 2013 and 30 November 2019.
- where the root cause is attributable, or attributable in part, to the design, construction and/or commissioning stages of the Paradise Dam, the facts and circumstances that contributed to the structural and stability issues having regard to issues of governance, effectiveness of processes and systems, approval processes, reporting obligations, any remedial measures taken up to commissioning stage, and other relevant items

The commission is due to deliver its report in April 2020. While this timing does not correspond to the timing of the Design-Cost-Risk Review package of work (to which the findings of the inquiry would be most relevant), the findings and conclusion will inform future work when made available. This inquiry is predominantly a backward-looking process whilst the Options Assessment is predominantly forward-looking.

# 2 SCOPE OF WORK

## 2.1 Overview

In October 2019, DNRME engaged Building Queensland to assess and report on options to ensure water security for the region for future economic growth and to maintain community safety. The Options Assessment was to be finalised by February 2020.

In response to this request and in accordance with section 13 of the *Building Queensland Act 2015* a scope for comparative analysis of selected options to inform Government decisions regarding the future of Paradise Dam was developed in conjunction with DNRME and Queensland Treasury.

The scope of engagement identified the five options to be assessed:

- **Option 1:** retain maximum primary spillway height (equivalent to a primary spillway level of RL67.6m).
- **Option 2:** reduce maximum primary spillway height by 5m (equivalent to a primary spillway level of RL62.6m).
- **Option 3:** reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m).
- **Option 4:** reduce maximum primary spillway height by an optimised level (between 5m and 10m) to maintain water supply security.
- **Option 5:** decommission the dam.

The base case used in the Options Assessment corresponds to the condition of the Paradise Dam prior to completion of the Essential Works (that is, a primary spillway level of RL67.6m). The adoption of this base case was required as all technical information (designs, costs and dam safety assessments) available for review (as developed by Sunwater) used this base case.

The scope of the Options Assessment was broken into two work packages, delivered by independent expert advisors, selected based on their depth of relevant industry expertise and independence from Sunwater and previous studies on Paradise Dam:

1. Design, cost and risk review work package
    a. Review of options' designs in relation to dam safety assessments, assumed design factors and the scoping of options
    b. Review of options' costs and risks to cost assumptions (rates and factors) and risk / contingency allowances
2. Service needs and options assessment work package
    a. Define Service needs – dam safety, water security, environmental impacts, recreation amenity, social impacts and flood mitigation. For water security this includes:
        i. Demand assessment – engagement with key stakeholders, organisations and individual customers to determine the total demand for water in the medium to long-term
        ii. Alternative water supply options – include a high-level analysis of alternative supply options that may meet water supply requirements in conjunction with Paradise Dam.
    b. Options assessment – undertake an assessment of the five short list options against the service need criteria identified above.

## 2.2 Design, Cost and Risk Review Package

### 2.2.1 Overview of Works

The delivery of the design, cost and risk review package of works involved the completion of the following elements:

- **Planning:** Liaison with key stakeholders including Queensland Government agencies including DNRME, Queensland Treasury and Sunwater to confirm scope and methodology.
- **Design Review – Dam Safety:** Undertake independent review of Sunwater's dam safety modelling processes and outputs on Paradise Dam.
- **Design Review – Options Design:** Undertake independent review of the design and scope of works of the options developed by Sunwater, including assumptions, design criteria and potential alternative approaches.
- **Cost Review:** Assess the cost estimates developed for each option to establish the confidence that can be placed in the developed estimates for options assessment purposes.
- **Risk Review:** Examine the risks accounted for in the design of each of the options, the mitigation measures included in the design, and the impact the risks and mitigation measures have had on the design scope and cost for the option.
- **Report:** Communicate the outcomes of the review in a summary report (refer **Appendix A**).

**Aurecon** was selected to lead the design, cost and risk review.

### 2.2.2 Clarifications / Limitations

The provision of advice through the design, risk and cost review is subject to the following clarifications:

- The review provides high-level commentary upon assumptions, information, processes and judgement used to develop technical information.
- Due to the nature of the information available, the base case for the review will be the original dam condition rather than the dam's condition upon completion of the Essential Works. Where possible, the impact of the Essential Works (which had not fully commenced prior to completion of the Options Assessment) has been commented upon.
- The works are based on review of Sunwater's technical information, including design reports, dam safety assessments (including the dam safety modelling process) and cost estimates, but in the time available, did not involve any independent modelling, analyses or computations to verify work by others. Aurecon also reviewed the technical reports released by Sunwater in December 2019 including the Tatro-Hinds report and the Technical Review Panel report.
- Information was not available, at the commencement of the review, on option 2 to reduce the maximum spillway height by 5m (equivalent to a primary spillway level of RL62.6m). Sunwater started developing a concept level design and costs for this option in November 2019 and undertook a dam safety assessment. This information was provided for review in mid-January 2020.
- The works have a different scope to the Commission of Inquiry as set out in 1.3.3.7.
- Review was undertaken concurrently with further development of options by Sunwater and GHD and several reports and documents were at draft stage at the time of review.

## 2.3 Service Needs and Options Assessment Package

### 2.3.1 Overview of Works

The delivery of the service needs and options assessment work package involved the completion of the following elements:

- **Planning:** Liaison with key government stakeholders to confirm scope and methodology and develop a framework for the assessment of options.
- **Stakeholder Engagement:** Engage with appropriate community and local government stakeholders to inform the Options Assessment.
- **Service Needs:** Assess service needs that are to be addressed by the Paradise Dam Improvement Project.
- **Agricultural Demand Assessment:** Assess the current and potential future demand for water from agriculture and related businesses in the region.
- **Urban Water Demand Assessment:** Asses the current and potential future demand for water from urban areas in the region.
- **Alternative Supply Options:** Undertake a high-level review of potential alternative water supply options that could be used to support the five options to provide water security.
- **Options Assessment:** Undertake a comparative options assessment for the considered options against the service need and benefits sought and identified.
- **Report:** Present the findings of the investigation in a report (refer **Appendix B**).

**Natural Capital Economics** was selected to lead the service needs and options assessment package.

### 2.3.2 Clarifications

These assessments were based on information supplied by Sunwater and was informed by consultation, conducted by Natural Capital Economics in December 2019, with a wide range of local stakeholders, water users and potential users (a full list of stakeholders is included in Appendix F of the Natural Capital Economics report presented in **Appendix B**).

# 3 ANALYSIS OF FINDINGS AND RECOMMENDATIONS

## 3.1 Service Needs

Definition of the service needs to be met by the Paradise Dam Improvement Project is necessary to determine the assessment criteria to be used by the Options Assessment. The determination of service needs for the Options Assessment builds on the service needs identified in the Preliminary Business Case. A detailed review of the service needs is included in section 2 of the Natural Capital Economics report contained in **Appendix B**, with the findings summarised in Table 1.

**Table 1: Service Needs for Paradise Dam as Defined by Natural Capital Economics**

| 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 considered firstly a threshold test that must be met and secondly a scoring criteria representing the degree to which the option is considered likely to meet ALARP. |
| 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 (medium priority (MP), high priority (HP) and aggregate normalized estimates (e.g. all MP equivalent) for all key water use categories over the forward period. All measures in ML/annum.<br>Benchmarking service needs estimates against yields from the five options assessed.<br>This is considered firstly in determining whether the option is able to meet the water security needs (current and projected future demands to 2050) (used as a threshold criteria) and secondly, in determining the degree to which the option meets the water security requirements (used as a scoring criteria in the multi-criteria assessment) |
| **Secondary service needs and considerations** | | | |
| Dam safety risk could constrain recreational opportunities at the site.<br>Different options will impact on recreational actions. | A safe dam site will ensure recreational opportunities can continue. | Recreational use opportunities. | The scope of recreational opportunities at the dam site from the five options assessed are not materially different from current opportunities. |
| Failure of existing dam creates environmental risks. | PDIP will mitigate dam failure risks and subsequent environmental risks of a failure. | Environmental risks. | Environmental risks are not materially different from current levels. |
| There are environmental risks inherent to each of the five options. | PDIP will address environmental risks associated with construction and future operations. | | |

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

The options assessment process determines and scores the performance of the options in meeting these identified service needs for Paradise Dam.

## 3.2 Review of Design, Cost and Risk Information

### 3.2.1 Purpose

The technical information (including designs, cost estimates and risk assessments), used as the basis for the options to be evaluated, was provided from investigations performed by Sunwater and engineering consultant GHD in 2018 and 2019. The review of the technical information was performed by Aurecon as part of the Options Assessment to establish a level of confidence in the information developed by Sunwater and GHD (including cost and risk assessments). The review included assessment of:

- The appropriateness and execution of processes used to develop the information;
- The application of levels of uncertainty to ensure a consistent basis for evaluation is available;
- The level of testing and condition information available; and
- The assumptions made where direct testing or condition information is not available.

The review will ensure that appropriate context and uncertainty is incorporated into the assessment of options and provides technical commentary that may assist the future works at the dam. The completed Design-Cost-Risk review report can be found in Appendix A, with the key findings summarised below.

### 3.2.2 Context

To fully understand, review and comment on the engineering designs, costs estimates and risk assessment of the options, the engineering and technical characteristics of Paradise Dam in its current state (that is, prior to the commencement of Essential Works) must be established. Therefore, the Design-Cost-Risk review established an initial understanding of the following aspects:

- Geological and geotechnical model
- The dam wall materials and construction method
- The dam wall design

As previously noted, the technical review used a base case corresponding to the condition of the dam prior to the Essential Works. Where appropriate, comment has been made on the potential impact of the Essential Works, with further work required in future to align design, cost and risk information to the new base case.

The key findings in relation to the current state of the dam were:

- The current assessment of failure modes utilised by the Dam's owner is considered thorough with evidence-based justifications provided and sound engineering judgement used to determine the modes of failure.
- The roller compacted concrete (RCC) properties used as inputs to the design process may be considered generally appropriate subject to clarification regarding the following:
  - The level of bonding of lift joints assumed;
  - The use of joint cohesion as a component of lift joint shear strength;
  - The density of RCC assumed;
  - The tensile strength assumed in areas where there is no evidence of bedding mix;
  - The potential impact of 'honeycombing' in the upper layer;
  - The composition of the RCC mix used in construction (noting that it differs from the composition of RCC mix used for pre-construction trials); and
  - The sample testing regime undertaken by Sunwater (both selection of cores and tests performed on the selected samples) used as a basis for the assumption regarding the shear strength of the RCC.
- The number and location of RCC core samples tested reflected the sites that were accessible for sampling. For the primary spillway, the shape of the spillway crest did not allow sampling access, although some inclined cores were taken through the primary spillway from the base of the dam. Further testing of the primary spillway can occur once the Essential Works are underway.
- The dam foundation properties and the geological /geotechnical model developed followed a logical sequence consistent with ANCOLD guidelines. The level and the reliability of information available is considered suitable for an options assessment process, but further investigations are required for future design stages. Additional sampling and testing will provide a greater level of reliability to the results and clarify the following uncertainties:
  - Original foundation design and excavation depths
  - The presence of any additional fault zones not yet identified due to limited sampling and testing. This is considered likely due to the complex fault zones already identified
  - The inclusion of kinematic systems, the parameters used to reflect foundation rock defects, and the modelling of deep-seated sliding mechanisms in considering hydraulic uplift and defect orientations
- The concerns over the dam foundation properties and the current model lead to uncertainty in the current reliability of the anchor designs, which is a critical component of the options under assessment. Additional sampling and testing will provide a greater level of certainty regarding the robustness of the design of options that include anchoring.
- The combination of the RCC mix used, lift joint issues, and the design and cross section of the upstream and downstream faces of the dam may all contribute to an increased risk of instability in the dam.

### 3.2.3 Key findings

#### 3.2.3.1 Dam Safety Assessments

The process undertaken by Sunwater to establish a model for the safety of Paradise Dam was found to be generally in line with contemporary practices recommended by ANCOLD and DNRME. Based on the outcomes of the Dam Safety Assessment, evaluation of the options in relation to dam safety is considered to

be reliable, subject to the outcomes of the recommended further investigations to improve the understanding of the current condition of the dam.

#### 3.2.3.2 Options Design

The design review investigated the current designs available for each option to determine:

- Whether the design fits the brief of the option to which it corresponds
- The appropriateness of the basis of design for each option, including the appropriateness of design assumptions, design and acceptance criteria and design methodology
- Performance of the design against the safety criteria
- Any alternative designs that may be considered

Several general findings were produced that applied to Options 1 through 4, relating to the basis of design used to develop each option:

The information available for review on the designs for the long-term options is outlined in *Appendix A Data Screening* of the Aurecon Design, Cost and Risk Review report which is included in Appendix A to this report. Several general findings were produced that applied to Options 1 through 4, relating to the basis of design used to develop each option:

- The state of completeness of designs was not consistent across the options with no information available on the optimal solution (as it has not been determined) or Option 5 decommissioning, and the design of Option 2 (lowering by 5m) was still progressing while the Design, Cost and Risk review was being finalised. In addition, Option 3 was produced close to preliminary design level whereas the designs for Option 1 were part way in between the concept and preliminary stages.
- Some sub-options were also identified after completion of the draft report including Option 1A and Option 1B as outlined below. These options have not been fully reviewed.
- The design assumptions applied are considered reasonable, noting recommendations for further sampling and testing prior to further design that will reduce uncertainty in these assumptions.
- The design and acceptance criteria applied are considered in accordance with latest ANCOLD and industry practices.
- Methodologies used to perform design are considered in accordance with latest ANCOLD and industry practices.
- Aurecon noted the use of design parameters which reflected the level of information available at the time, including some conservative factors (lower bounds of density and shear strength).

Aurecon note that the designs for Options 1-4 were based on some assumptions relating to the condition of RCC and dam foundation. As outlined above, these conditions should be further investigated through sampling and testing to inform the more detailed design stages. It is also noted that the condition of the dam upon completion of the Essential Works will impact the design and construction methodology chosen to develop the long-term options for the dam. These impacts should be investigated once the scope of the Essential Works is finalised.

Aurecon also reviewed the scenario where further lowering works are required after completion of the Essential Works and found that, on the basis of the available information, there is no technical impediment to this occurring. Therefore, it is considered feasible to continue the investigation of alternative primary spillway levels (to the final level on completion of the Essential Works) as long-term options for Paradise Dam.

### Option 1: Retain maximum primary spillway height (equivalent to a primary spillway level of RL67.6m).

Sunwater and GHD developed three potential approaches to strengthen and improve the condition of the dam, while retaining the current maximum primary spillway height. The three approaches considered are:

- Option 1: Primary approach provided by Sunwater to retain maximum primary spillway height
- Option 1A: The primary approach and rebuild monoliths R-W in the secondary spillway
- Option 1B: Gated solution to retain maximum primary spillway height

Information analysed by the reviewers relating to Option 1, with Options 1A and 1B provided at a high level to augment the primary approach. It is noted that Option 1 alone does not achieve the desired risk position below the ANCOLD life safety limit of tolerability, necessitating further works (such as Options 1A and 1B) to allow this option to meet dam safety guidelines. Aurecon noted the operational complexity, high maintenance requirements and general risks associated with using gates, and Sunwater's strong preference against the use of gates.

Based on a review of the methodology, the scope of works for the proposed risk reduction measures addresses the dam safety deficiencies that dominate the current risk position of the dam. This is subject to clarification on the following outstanding issues:

- Protection of the left abutment downstream toe against overtopping flows at flood levels above the left abutment crest.
- Potential for erosion downstream of extended apron due to geology could necessitate the provision of additional protection.
- Potential for overtopping of secondary spillway return channel to lead to undermining and failure of right abutment apron and foundation.
- Further development of 3D modelling to better understand the behaviour of the monoliths on the bend in the secondary spillway.

The execution of the primary methodology, including the installation of anchors, is considered viable, although further core sampling and testing is advised to provide additional confidence in the viability of the anchoring solution. It is noted that access to the primary spillway for the purposes of core sampling, would be difficult but achievable.

Aurecon noted that there are alternative methodologies that may allow the maximum primary spillway height of the dam to be retained, including:

- The use of a downstream RCC buttress to increase the cross section and protect the downstream rock at both the primary and secondary spillway.
- A combination of anchoring and buttressing.
- Further protection of the spillway apron through extended buttress or change from stepped spillway with apron to a smooth spillway with roller bucket or flip bucket.

Detailed information regarding potential alternatives have not been considered as part of this review as this information has not yet been developed. These alternatives may be investigated further at more detailed stages of design.

### Option 2, 3 and 4: Options involving the lowering below maximum height of the primary spillway

Due to the similarities in considerations for design, the options involving the lowering of the primary spillway to five metres, ten metres or an optimised amount below maximum height have been considered together.

The works to deliver Options 2 and 3 are summarised below, with works to deliver an optimised option (Option 4) considered to represent an interpolation of the other options. As with the maximum primary spillway height option, the impact of the base case (at the completion of the Essential Works) must be considered in the future development of these options.

The options considered in this section are:

- Option 2: Reduce maximum primary spillway height by 5m (equivalent to a primary spillway level of RL62.6m).
- Option 3: Reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m)
- Option 4: Reduce maximum primary spillway height by an optimised level (between 5 and 10m)

Based on the scope of works above, the options would achieve risk positions below the ANCOLD life safety limit of tolerability. It is considered that the scope of works for the proposed risk reduction measures addresses the dam safety deficiencies in terms of the potential failure modes that dominate the current risk position of the dam. This is subject to clarification on the following outstanding issues:

- Potential for erosion downstream of extended apron due to geology could necessitate the provision of additional protection.
- Further development of 3D modelling to better understand the behaviour of the monoliths on the bend in the secondary spillway.

The execution of the options, including the installation of anchors, is considered viable, although subject to similar comments as Option 1 regarding further testing to provide additional confidence in the viability of the anchoring solution. It is noted that demolition of the spillway would be difficult and time consuming, but achievable, with residual risks to be managed through detailed design process.

A suitable alternative to lowering the spillway crest level while maintaining the lowered crest level flood capacity include the use of spillway gates or a fuse plug embankment at a suitable location. These alternatives may be considered further at a more detailed level of design.

Option 5: Decommissioning

Decommissioning of the dam (as described in the preliminary business case) is considered viable from a technical perspective, while noting that alternative methodologies for the decommissioning process may be available. It is noted that detailed design for decommissioning has yet to be undertaken.

#### 3.2.3.3 Options Costs

The costs developed for each option were evaluated to determine whether an appropriate level of contingency was applied in the options assessment process, based on the robustness and level of development present in each estimate. The following aspects of all available estimates were investigated:

- The level of cost estimations;
- Proposed work methods and assumptions;
- Quantities and certainty about estimates;
- Indirect cost assumptions and indices;
- Level of contingencies; and
- Benchmarking against recent cost estimates for comparable dam projects.

The review of costs identified that while the estimation process followed for developing the costs was reasonable, the design and other supporting information that was used to develop the costs had changed as investigations had progressed. Based on the information available for each option, the level of sensitivity to varying assumptions and rates have been analysed using Monte Carlo simulation as part of the Options Assessment. With appropriate consideration of these sensitivities, the cost estimates are considered appropriate to compare directly as part of the assessment.

It is noted that the relative costs of each option will change once the state of the dam upon completion of the Essential Works is established, with further design work required to quantify this change.

Aurecon noted that the current cost ranges should not be viewed as indicative of the expected project costs, noting that further design work is required to provide more detailed cost estimates that can be reviewed in the detailed business case.

#### 3.2.3.4 Options Risks

The Design, Cost and Risk review investigated the processes and judgement used to develop the risk information that was considered as part of the Options Assessment.

The potential failure modes and risk assessment provided are considered a reasonable reflection of the current risks of the dam in its present state, noting that there is generally some level of variability in assessment due to the incorporation of subjective failure probabilities. Similarly, the risk identification, assessment and mitigation process used are in accordance with ANCOLD guidelines and considered robust.

The review considered the risk positions presented by each of the proposed options against both the ANCOLD limit of tolerability and the ALARP position. The risk positions of the options highlighted from the review include:

- Option 1 was not below the limit of tolerability (the first key dam safety requirement) whereas Option 1A provided additional risk reduction that may improve this position and potentially reduce the risk below this limit. Both of these options are highly dependent on the outcomes of Sunwater's ongoing foundation assessment and anchoring trials and RCC testing of the primary spillway.
- Option 2 may be adequate to reduce the risk position below the limit of tolerability and may be adequate to achieve the ALARP principle (the second key dam safety requirement)
- Option 3 is adequate to reduce the risk position of the existing dam to well below the limit of tolerability (by two orders of magnitude) and would likely meet the ALARP principle as further risk reduction works would likely not be justified.
- Option 4 would be expected to have a risk position that falls between Options 2 and 3 meaning that it satisfies the limit of tolerability and may be adequate to meet the ALARP principle, as per the findings for Option 2 and Option 3.
- Option 5 eliminates the dam safety risk as the dam is decommissioned

The risk positions as outlined above have been incorporated into the options assessment process.

### 3.2.4 Recommendations

The recommendations of the design, cost and risk review undertaken are as follows:

- While noting that assumptions have been made where information has yet to be developed, the design, cost and risk information developed by Sunwater and GHD are sufficiently robust to be compared through an options assessment process with appropriate sensitivities applied to account for remaining uncertainties.

- The number and location of RCC core samples tested reflected the sites that were accessible for sampling at the time. Further testing of the primary spillway can occur once the Essential Works are underway and will increase confidence as a basis for further design.
- The recommended work should:
  - Complete the current geotechnical assessment of the foundations of the dam including development of a geological model.
  - Undertake core sampling and testing of the RCC in the primary spillway.
  - Undertake anchoring trials to confirm foundation capacity.
  - Complete further development of preliminary designs and cost estimates for the options using the new base case (final primary spillway level at the completion of the Essential Works).

## 3.3 Demand Assessment

### 3.3.1 Purpose

An assessment of likely demand was performed to assess the ability of the options to provide for the future water requirements of the region. The purpose of this assessment was to provide a probabilistic model for future demand, to be compared to the projected yield for each project option as part of the options assessment process.

The comprehensive and detailed demand assessment included the following:

- 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 (Medium Priority (MP) allocations including: 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 High Priority (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 (processors, supermarket chains).

The detailed demand assessment performed by Natural Capital Economics can be found in Appendix B, with the key findings summarised below.

### 3.3.2 Context

Paradise Dam was built to support future growth in the agricultural industry in the Burnett River catchment and also meet the high priority urban water needs of Bundaberg. 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).

The development of the demand assessment involved consultation and consideration of trends that are likely to impact water demand for key users in the region. This includes consideration of:

- **Demographics and economic factors:** The projected growth in Bundaberg's population is considered to be closely tied to economic prospects in agriculture and associated industries in the surrounding region. The degree to which the projected growth materialises will impact the region's demand for water.
- **Trends in key commodity prices:** Recent results and market prospects for alternative commodities across the region differ. While the 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. The underlying trends in commodity prices over the past 10 years have been found to be consistent with changes in land use and subsequent changes in irrigation water demand.
- **Changes in land use:** Consultation with local stakeholders indicates that there has been a recent trend for irrigated sugarcane land in the region to be converted to higher value crops (including perennial tree crops), rather than a net expansion in area under irrigation. This trend is in response to the changing relative economic viability of the crops, but limited by the financial factors governing the establishment of large tree crops and physical constraints in the availability of tree stock. Therefore, estimates of growth in water demand for horticulture products will be somewhat offset by the corresponding reduction in water demand for sugarcane.
- **Climate Change:** Climate has been a traditional advantage of the region, with the combination of rainfall and temperature conditions allowing the development of a wide range of agricultural activities and enabling the region's producers to explore opportunities for counter-seasonal production. 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.

The demand projections were based on sales of medium and high priority allocations (the right to take water) rather than actual usage, which anecdotally is typically lower than the volume held in allocations. In part, holding allocations larger than required is used as a supply risk mitigation strategy by growers.

### 3.3.3 Key findings

#### 3.3.3.1 Demand for medium priority allocations

The demand for medium priority allocations has been based on analysis and modelling of key regional crops to account for identified trends and prospects by commodity. For each commodity, the following has been considered:

- The current situation and water use;
- Demand drivers and market opportunities; and
- 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.

The following crops were investigated:

- Sugarcane
- Avocado
- Macadamia

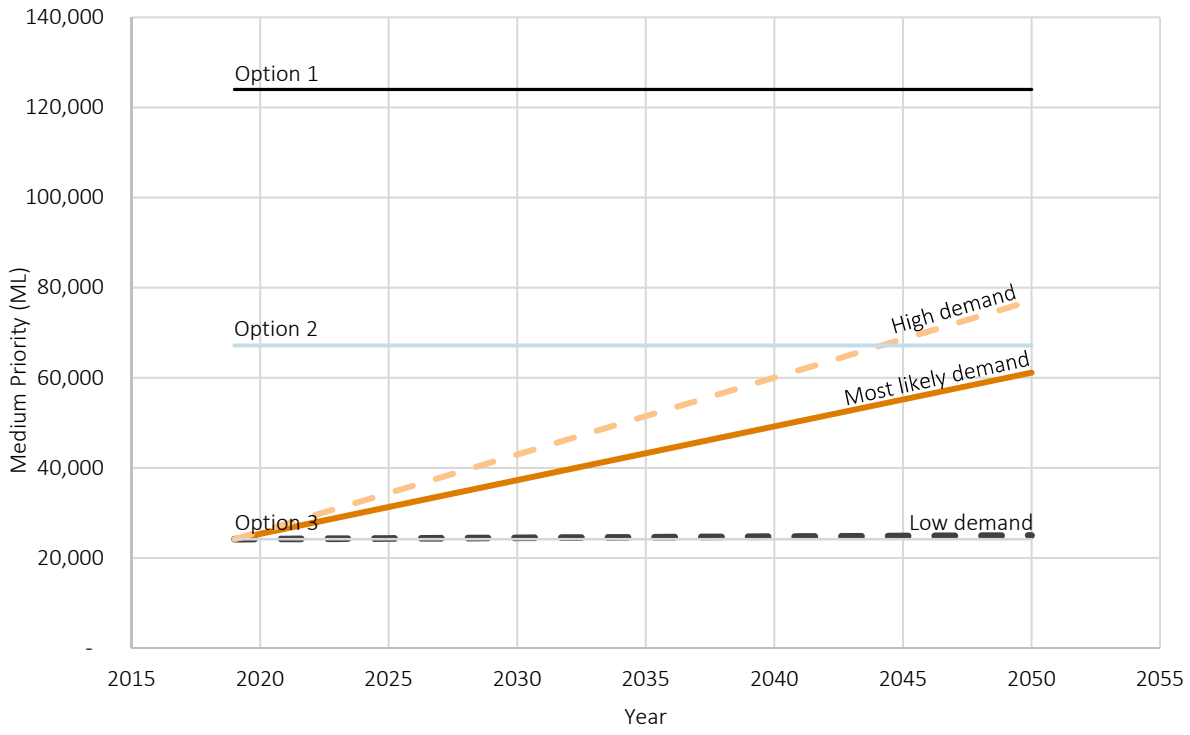
- Citrus
- Other Fruit
- Vegetables
- Broadacre and fodder

In addition, the following behaviours have been reported to impact the demand into the future:

- Development of high value crops almost exclusively on existing sugarcane farms, meaning that any growth in horticulture irrigation must be considered net of previous irrigation requirements for sugarcane on the equivalent land.
- Perennial tree crops have a significantly greater downside risk of very low announced allocations, resulting in irrigators often holding more allocations than they would use in a typical year. Effectively, holding additional allocations is a risk management strategy. This behaviour is projected to continue to impact demand into the future.

Based on the analysis outlined above, demand for MP allocations have been modelled to 2050. Due to the range of data and assumptions used to compile the model, a Monte Carlo simulation is used to develop a probabilistic range of estimates with key scenarios (p5 demand, most likely demand and p95 demand) presented in Figure 3. Figure 3 also shows the yield of the Paradise Dam at the various spillway heights described by the options, allowing comparison to demand projections.

Figure 3 Demand Assessment for Medium Priority Allocations




### 3.3.3.2 Demand for high priority allocations

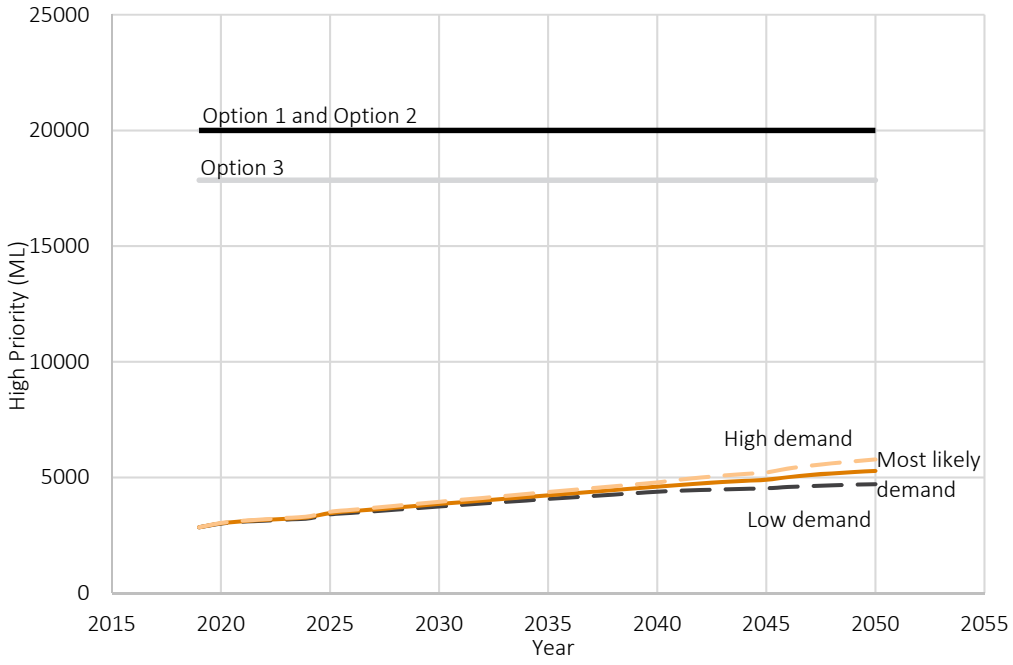
The HP demand profile is serviced from multiple sources (Paradise Dam, Fred Haigh Dam and groundwater). Bundaberg Regional Council (BRC) holds a groundwater allocation of 6,430 ML and 9,588 ML in surface water allocations (from Paradise and Fred Haigh dams). BRC's strong preference is to utilise groundwater

whenever possible as this source is relatively more cost-effective to treat to potable water standards compared to dam water. 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. There are currently no planned industrial or commercial developments identified that would result in a step change to HP allocation requirements, and so HP allocation is assumed to be aligned to population growth in the region.

The demand review identified that a large proportion of the high priority allocations are currently unsold, with current expectations (based on recent sales and consultation with customers) anticipating that they would likely remain unsold in the near future.

Monte Carlo simulation was used to provide a probabilistic range of estimates for HP water demand and compare to the yield of Paradise Dam under the various options. The key demand scenarios are shown in Figure 4:

Figure 4 Demand Assessment for High Priority Allocations



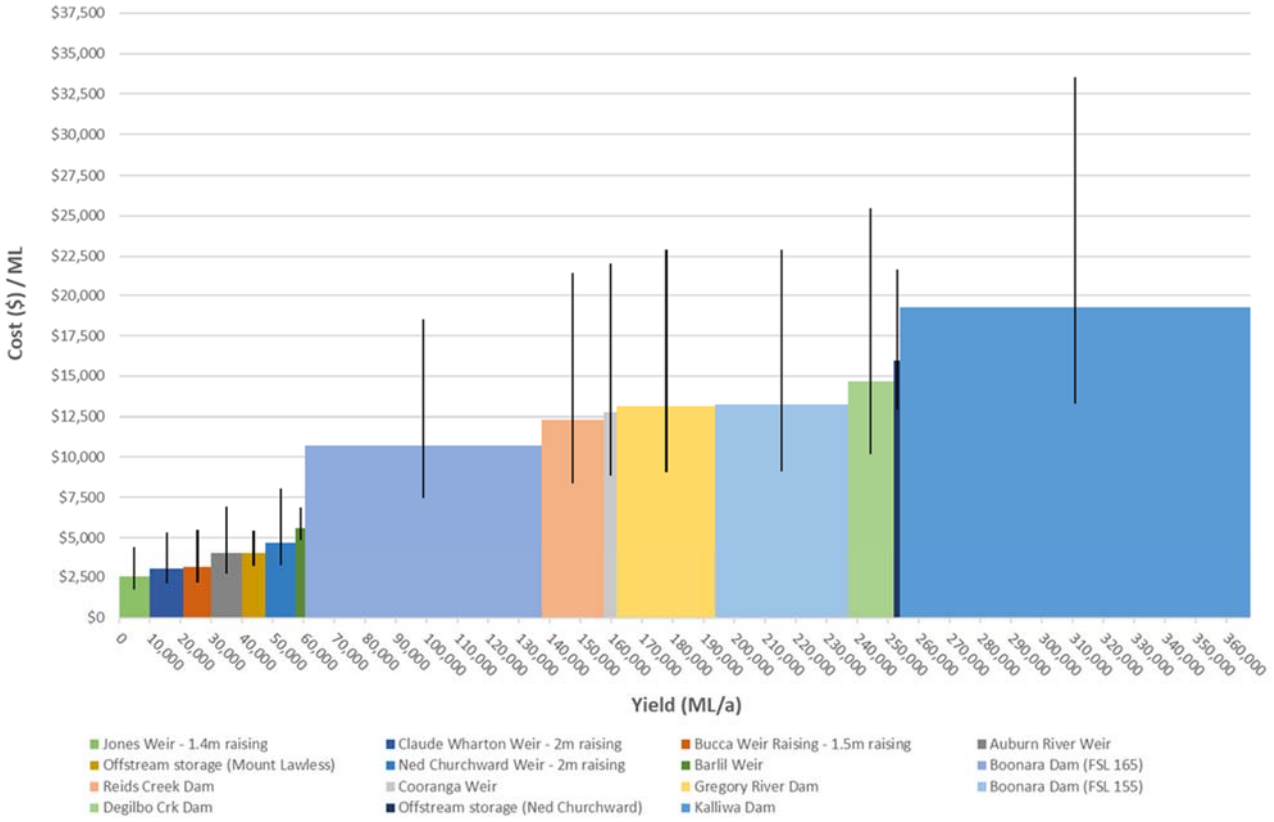

### 3.3.3.3 Alternative water supply options

In addition to Paradise Dam, several potential alternative water supply options may help to meet the region's demand for water. These options should be considered alongside dam works to reach a consolidated option that best delivers water to meet the regional demand, including consideration of yield, cost, location, timing and reliability of supply. A shortlist of feasible options has been provided by Sunwater from the Burnett Blueprint process, with these options evaluated by cost-effectiveness and feasibility of execution incorporating relevant sensitivities.

The yields and costs for each of the alternative water supply options have been determined at a high level only and further work is required to confirm these figures.

A graphical representation of the costs and yields associated with the short-listed options is shown in Figure 5.

Figure 5 Alternative Water Storage Options (Cost and Yield)




Based on the information available, an efficient and cost-effective portfolio of alternative water supply options have been incorporated into the options for assessment where appropriate. These options are likely to involve less complex planning and approvals processes (given they are typically smaller, offstream, or extensions of existing infrastructure) with some of the options also having previously been investigated. The alternative water supply options included in the analysis were the Bucca Weir raising, the Ned Churchwood Weir raising and the Ned Churchwood Offstream Storage.

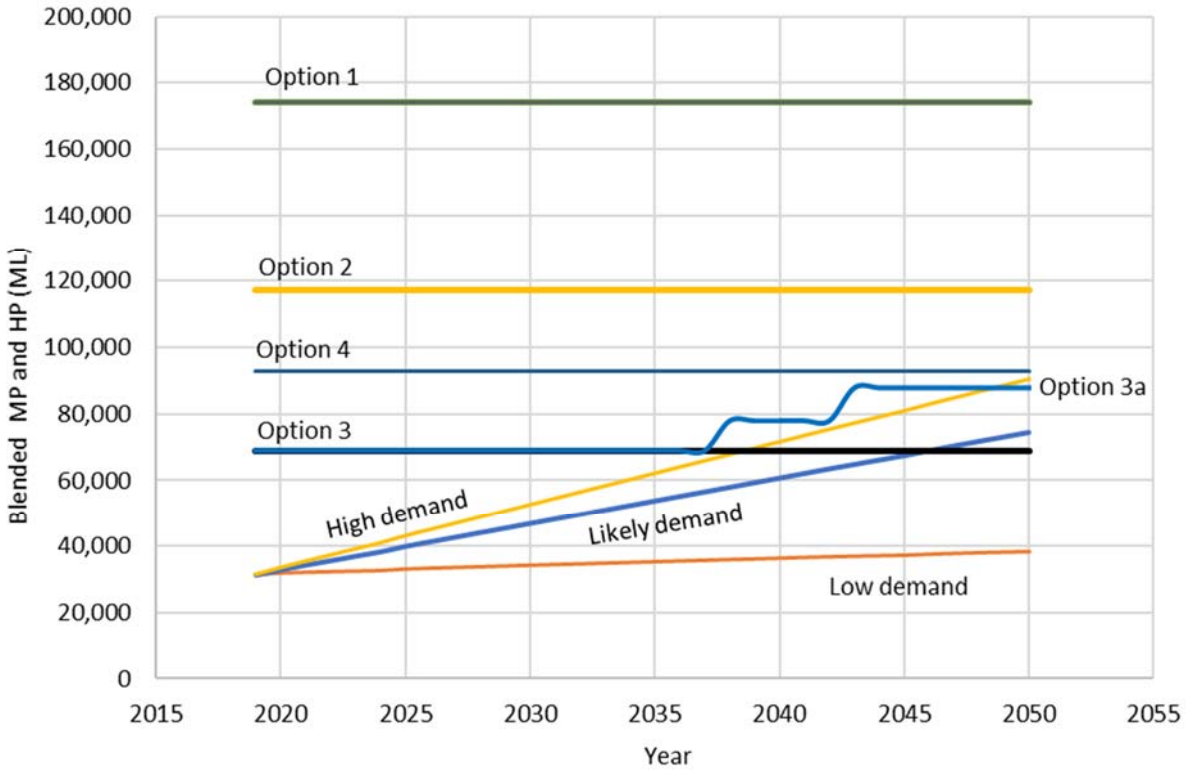
It is noted that further analysis of each alternative supply option, including the impacts of installing infrastructure upstream and downstream of the Paradise Dam, environmental, social and cultural concerns, should be undertaken if these options are further developed. The timeframes for planning and delivery of the alternative water supply options should also be taken into account when considering their ability to meet the needs identified by the demand assessment.

### 3.3.4 Recommendations

Based on the findings of the demand assessment process, the following recommendations are made:

- Potential actions to better match availability and demand for allocations be considered, including the potential to convert excess HP allocations to MP to meet demand as growth materialises. The potential capacity for each option under such a scheme is shown in Figure 6 below, with the potential to utilise conversion in the future to be considered by the options assessment process. The impact to stakeholders and regional drought resilience of undertaking conversion should also be considered. The investigation found that this had the effect of making a greater volume of water available to underpin irrigation growth in the shorter term, with a negligible risk of demand for high priority allocations being constrained.

Figure 6 Blended HP and MP Capacity of Options




## 3.4 Options Assessment

### 3.4.1 Purpose

The original five options identified in the Options Assessment scope and additional options identified through the Option Assessment process are to be assessed comparatively to provide the basis for a recommendation for future actions to progress the Paradise Dam Improvement Project. A detailed summary of the options assessment performed by Natural Capital Economics can be found section 4 of the Natural Capital Economics report contained in Appendix B, with the outcomes summarised below.

### 3.4.2 Context

In order to perform the comparative analysis, a consolidated list of options was developed. The consolidated list included options developed through the technical assessment and consultation with stakeholders, alongside options included in the project's initial scope. The options were subjected to the following evaluation methodology:

1. A threshold approach to eliminate any options that did not meet the critical service needs, being dam safety and water security requirements.
2. A multi-criteria analysis (MCA) of all remaining options to identify the recommended options for consideration in the DBC.

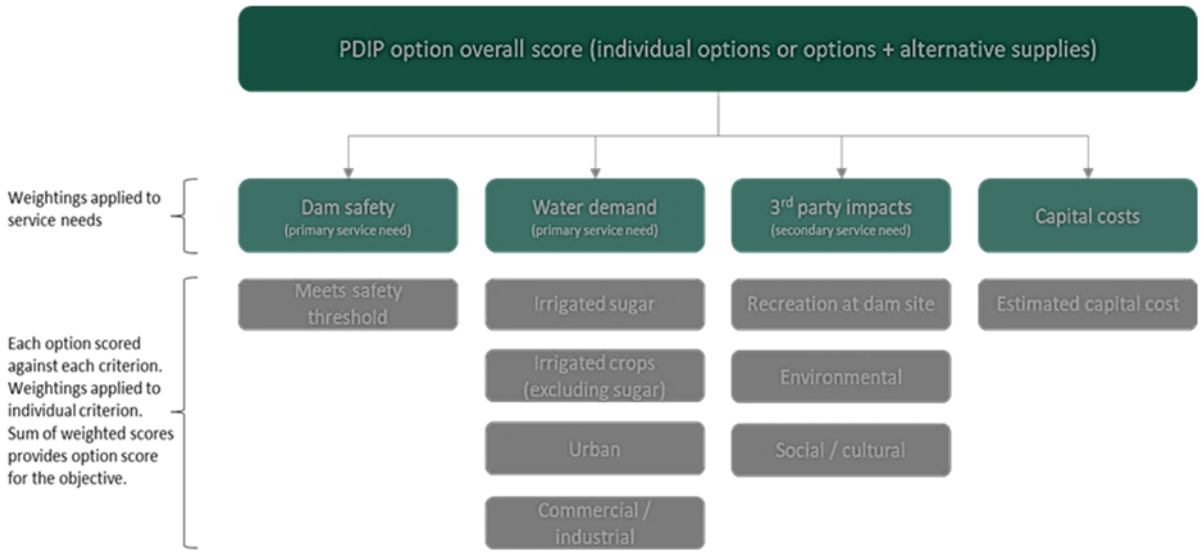
The threshold analysis is applied to options that do not meet the minimum requirements of the primary service needs, with unacceptable options eliminated on this basis.

Consistent with common practice, MCA is used to underpin the options assessment process. 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. An MCA is

considered appropriate for this assessment due to the short timeframe and high-level nature of detail available for the analysis, with a cost-benefit analysis to be used in later stages of the PDIP to support an investment decision.

An overview of the methodology employed through the MCA is shown in the figure below. Each criterion (corresponding to a service need) was assigned a weighting based on its importance to the PDIP.

Figure 7 Methodology for Multi-Criteria Analysis of Options




The options were subjected to the following analysis:

- Assignment of scores for each of the options against each criterion;
- Normalisation of assigned scores;
- Estimated weighted average scores for each option; and
- Sensitivity analysis.

Weighting of criteria and scoring of each option was undertaken by a group selected to represent key stakeholders from the project's governance structure. The criteria and weightings assigned are summarised in the table below.

**Table 2: Weighting of Criteria for Options Assessment**

| 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. |
| 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. |

The options assessment analysis was performed in an options assessment workshop, with agreement sought from all attendees including representatives of Natural Capital Economics, Building Queensland, Queensland Treasury and DNRME.

To compare qualitative and quantitative criteria, a Likert [8]scale was used to evaluate qualitative information numerically. Following scoring, the raw scores were normalised to enable aggregation within the MCA criteria. 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.

### 3.4.3 Key findings

#### 3.4.3.1 Consolidated list of options for assessment

The list of options for consideration through the options assessment process are shown in the table below. Where differing approaches have been identified to deliver an option as identified in the project's scope, each approach is treated as a distinct option with the option numbered to reflect its relationship with a parent option.

**Table 3: Consolidated List of Options**

| Option | Approx. Yield as MP equiv | Description of Works |
|---|---|---|
| **Option 1:** Retain maximum primary spillway height (equivalent to a primary spillway level of RL67.6m) | 174,000 ML | ▪ Primary spillway returned to original height<br>▪ Post tension anchoring<br>– Primary spillway: 98 No. 91 Strand PT anchors<br>– Secondary spillway: Mono L-R 24 No. 82 Strand PT anchors; Mono S-W 10 No. 55 Strand anchors<br>– Left abutment: 10 No. 73 Strand PT anchors<br>▪ 60m long stilling basin<br>▪ New gravity training walls<br>▪ Secondary spillway side channel and gravity wall<br>▪ Outlet works modifications<br>▪ Left abutment and basalt pimple erosion protection |
| **Option 1A:** Retain maximum primary spillway height (equivalent to a primary spillway level of RL67.6m) and rebuild monoliths R-W in the secondary spillway | 174,000ML | Works for Option 1 plus additional risk reduction works on the secondary spillway:<br>▪ Temporary coffer dam upstream of secondary spillway<br>▪ Demolition of Monoliths R-W<br>▪ Removal of 5-8m of poor foundation material<br>▪ Rebuild Monoliths R-W |
| **Option 1B:** Gated solution for retaining maximum primary spillway height (equivalent to a primary spillway level of RL67.6m) | 174,000ML | **Stage 1:** Demolition of top 10 m primary spillway crest from original height to provide short term risk improvement.<br>**Stage 2:**<br>▪ Construct 55 m long stilling basin<br>▪ New gravity training walls<br>▪ Post tension anchoring:<br>– Primary Spillway: 84 No. 91 Strand PT anchors<br>– Secondary Spillway: Mono L-S 57 No. 55 strand PT anchors; Mono R W 73 No. 27 strand anchors<br>▪ Re-construct ogee crest to primary spillway incorporating gallery for maintenance of post tensioned anchors<br>▪ Installation of 5 m high x 15 m wide Hydraulic Flap Gates<br>▪ Raise Secondary Spillway by 5 m |

[8] A Likert scale allows the conversion of qualitative scoring (descriptive statements) into quantitative scoring (a numerical value). For example, a descriptive statement "moderate negative impact" can be quantified as a score of -3 while a "moderate positive impact" can be quantified as a score of +3 compared to "no impact" which would score zero.

| Option | Approx. Yield as MP equiv | Description of Works |
|---|---|---|
| | | ▪ Secondary Spillway channel capping<br>▪ Outlet works modifications<br>▪ Left abutment and basalt pimple erosion protection |
| **Option 2:** Reduce maximum primary spillway height by 5m (equivalent to a primary spillway level of RL62.6m) | 117,000 ML | ▪ Level of primary spillway maintained at 5m below original height<br>▪ Raising of the Secondary Spillway by 5 m<br>▪ Post tension anchoring:<br>– Primary Spillway: 84 No. 91 Strand PT anchors<br>– Secondary Spillway: Mono L-S 57 No. 55 strand PT anchors; Mono R W 73 No. 27 strand anchors<br>▪ 55 m long stilling basin<br>▪ Capping of the Secondary Spillway channel<br>▪ New gravity training Walls<br>▪ Lowering of intake tower and fishway<br>▪ Remediation of reservoir rim<br>▪ Outlet works modifications<br>▪ Left abutment and basalt pimple erosion protection |
| **Option 3:** Reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m) | 69,000ML | ▪ Level of primary spillway lowered to 10m below original height<br>▪ Post tension anchoring:<br>– Primary Spillway: 35 No. 91 Strand PT anchors<br>– Secondary Spillway: Mono L-R 30 No. 82 strand PT anchors; Mono S W 10 No. 24 strand anchors<br>▪ 50 m long stilling basin<br>▪ New gravity training walls<br>▪ Lowering of intake tower and fishway<br>▪ Remediation of reservoir rim<br>▪ Outlet works modifications<br>▪ Left abutment and basalt pimple erosion protection |
| **Option 3A:** Reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m) supplemented by alternative water supply options which would meet projected demands and maintain water security for the region. | 88,000ML (combined) (19,000 ML from alternative supplies) | Works as per Option 3, plus in-scheme alternative water supplies to match demand forecasts. These alternative storages have been identified and undergone preliminary analysis through Sunwater's Burnett Blueprint process. |
| **Option 4:** Reduce maximum primary spillway height by an optimized level (between 5m and 10m) to balance dam safety and water supply security supplemented by alternative water supply options as required. | 93,000ML (estimated) | No detailed description of works provided for this Option, but they are assumed to lie between Option 2 and Option 3. |
| **Option 5:** Decommission the dam | 0ML | ▪ Dewatering of the reservoir.<br>▪ Removal of the dam structure, outlet works and associated facilities.<br>▪ Removal/treatment of sediments which have accumulated in the reservoir.<br>▪ Rehabilitation and revegetation of the reservoir area. |

### 3.4.3.2 Options assessment

The options assessment process was conducted as per the methodology outlined above.

Option 1B (full supply level through gated solution) was not formally scored as part of the process due to the reservations from the Sunwater regarding the operational complexity and general risks of gated solutions. The following options were eliminated from the assessment using the threshold evaluation.

**Table 4: Threshold Criteria Evaluation**

| Option | Rationale for Elimination |
|---|---|
| **Option 1** | The primary approach to Option 1, even after significant works to strengthen the dam, is not expected to satisfy the Limit of Tolerability for dam safety and therefore cannot be considered as a viable choice. |
| **Option 3** | Option 3 can supply a p95 high demand scenario until 2038 and meet a 'more likely' demand estimate until 2045, but not 2050. |
| **Option 5** | Option 5 immediately results in a large supply deficit in the BWSS. |

The ability of options to meet projected demand assumes the conversion of currently un-allocated high priority water into medium priority allocations. However, the viability of the options assessed is not dependent on this conversion. The conversion provides some additional time to meet demands before alternative water supply options are required. Further work including stakeholder engagement and approval would be required to facilitate this conversion. A full water resources assessment of the options considered, particularly the alternative water supply options, is required to confirm long-term yields.

The remaining options were analysed through the MCA. The estimated establishment costs for each option used in the assessment, incorporating sensitivities identified in the technical review, are shown in Table 5.

The cost ranges shown in Table 5 were supplied by Sunwater and are suitable only for comparative purposes. They are not budget estimates for the options and further design work is required to establish the full options costs. In addition, the costs have been developed using the original condition of the dam as the base case. The condition of the dam at the completion of the Essential Works will form the new base case and will affect the cost ranges identified below.

**Table 5: High-level Option Cost Ranges**

| Option | Low | More likely | High |
|---|---|---|---|
| **Option 1A** | $555,000,000 | $800,000,000 | $1,381,000,000 |
| **Option 2** | $524,000,000 | $597,000,000 | $770,000,000 |
| **Option 3A** | $431,000,000 | $527,000,000 | $744,000,000 |
| **Option 4** | $486,000,000 | $554,000,000 | $714,000,000 |

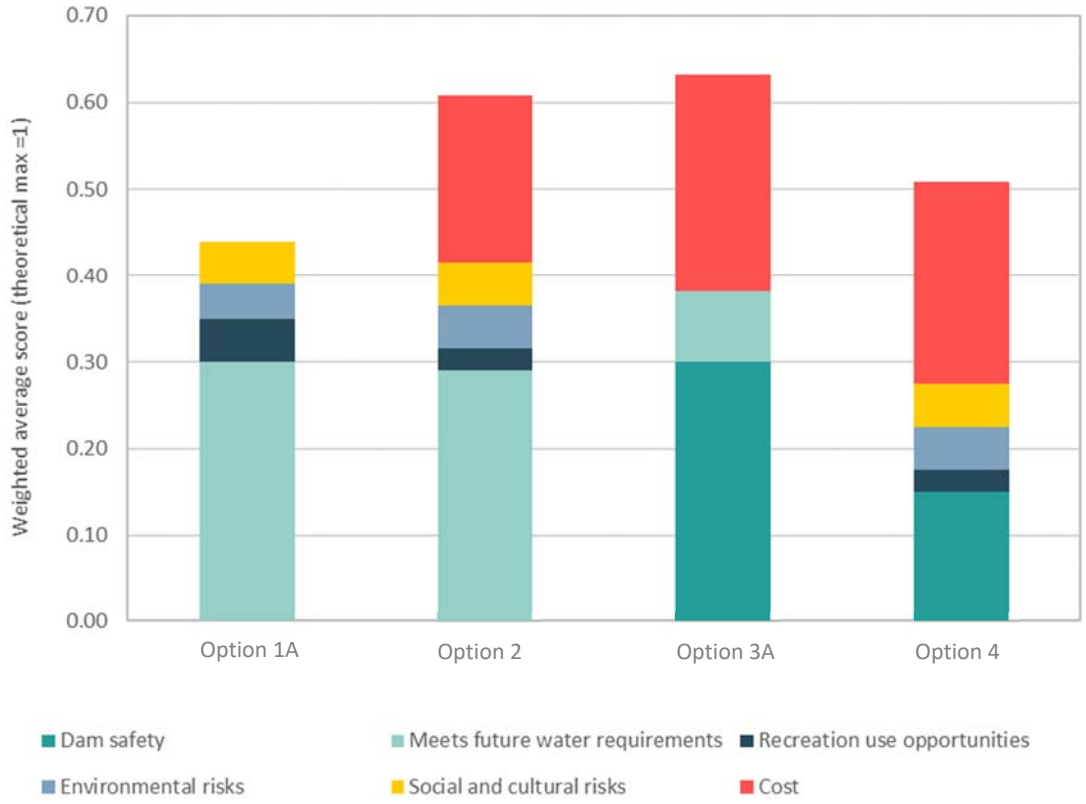
This analysis is based on the initial cost estimates developed by Sunwater and their advisors. There are some inconsistencies in the scope and robustness of these preliminary costings, including the ranges of cost estimates modelled and the selection of base case. These will need to be addressed in the DBC.

The normalised scores and rankings for each option obtained at the conclusion of the options assessment workshop are shown in Table 6 and Figure 8. The scoring values used in the graph are based on the 'most likely' scoring scenario applied to each category and option.

Table 6: Multi-Criteria Analysis Summary

| | Option 1A | Option 2 | Option 3A | Option 4 |
|---|---|---|---|---|
| **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 8 Multi-Criteria Analysis Summary




Sensitivity analysis analysed the impact of both uncertainty in weightings, normalisation and scoring, with no significant effects or changes in ranking observed on that basis.

### 3.4.3.3 Other issues for further consideration

Several other issues have arisen during this project that warrant detailed consideration within the DBC, or concurrently to the DBC. These include:

- *Consistent approach to options costing.* This analysis is based on the initial cost estimates provided by Sunwater. 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'[9] 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.
- *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 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.
- *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 detailed business case, a more detailed approach is recommended that builds on and complements the current assessment through detailed consultation and market sounding, a detailed econometric analysis, assessing the influence of prices on demand, consideration of distribution system constraints, sub-regional demand estimates, and crop specific economic thresholds and modelling to assess impacts on demands.
- *Implication of groundwater water resource for Bundaberg Regional Council (BRC).* BRC currently has 6,430 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 through undertaking a groundwater risks assessment and assessing the value of a strategic reserve of high priority allocations.
- *Assessing the incremental value of flood risk mitigation.* The cost benefit analysis 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.
- *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.

[9] 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.

### 3.4.4 Recommendations

The key findings and recommendations of the options assessment process are summarised below:

- The findings of the assessment for each option are summarised below:
  - Option 1 does not meet the threshold level for dam safety and is excluded from consideration.
  - Option 3 and Option 5 do not meet the threshold level for water security and are excluded from consideration.
  - Options 1A, 2, 3A and 4 were assessed using MCA, with the outcome summarised in the table and graph in the above section.
- On the basis of the options assessment process, the independent advisor recommended that the following options progress to investigation through a detailed business case:
  - Option 2: reduce maximum primary spillway height by 5m (equivalent to a primary spillway level of RL62.6m).
  - Option 3A: reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m) supplemented by alternative water supply options which would meet projected demands and maintain water security for the region.
  - Option 4: reduce maximum primary spillway height by an optimised level (between 5m and 10m) to maintain water supply security supplemented by alternative water supply options which would meet projected demands and maintain water security for the region.
- In addition, Natural Capital Economics have provided a list of issues for further consideration prior to or within the detailed business case (refer section 3.4.3.3). These include:
  - Consistent approach to options costing
  - Assessment of alternative supply options and associated distribution scheme efficiency benefits
  - Expanding the scope and depth of the demand assessment
  - Assessing groundwater failure scenarios and implications for Bundaberg Regional Council
  - Identifying alternative water products between medium and high priority allocations
  - Assessing the incremental value of flood risk including the effects of the proposed flood levy on the Burnett River east bank in Bundaberg
  - Assessing sugar mill viability risks of conversions from sugar cane to higher value crops

# 4 IMPACT OF THE GOVERNMENT DECISION REGARDING ESSENTIAL WORKS

Following the announcement of the Essential Works on 24 September 2019, an amendment to the *Water Supply (Safety and Reliability) Act 2008* was introduced on 4 February 2020 by the Minister for Natural Resources, Mines and Energy to enable Sunwater to lower the primary spillway level to reduce dam safety risk. The accompanying Ministerial media announcement stated that the legislation *ensures that spillway modification work can occur without delay* in the 2020 dry season. The legislation was passed by Parliament on 13 February 2020.

Building Queensland notes that the Essential Works announced by the Government in September 2019 to reduce dam safety risk in the short-term (which will include an immediate, nominal 5 metre lowering of the primary spillway level), will result in a change to the base case used for any further assessment of the options. Building Queensland further notes that the announced Essential Works are not inconsistent with any of the long-term options recommended for further consideration. The impact of the new base case on each of the options will be fully considered in the next stages of work.

Consequently, the base case for the future assessment of long-term options for Paradise Dam, as part of the next stage of detailed business case analysis, will be a primary spillway level of RL62.6m. Whereas a primary spillway level of RL67.6m was assumed as the base case for the purposes of this Options Assessment, given the information available and supplied by Sunwater.

It should be further noted that Sunwater has advised that due to the construction method required to undertake the Essential Works, the primary spillway level at the completion of the Essential Works may be slightly, but not materially, different to the previously announced lowering of five metres. The base case used in the next stage of assessment for the detailed business case will therefore need to take account of the expected actual primary spillway level at the completion of the Essential Works.

This change in base case will impact the following components of work, which are required to achieve the recommended long-term primary spillway height, as identified by the independent advisors:

- option designs and construction methodology (indicated by Aurecon),
- option costs, including the relative costs of options (indicated by Aurecon and Natural Capital Economics), and
- option risks, including the interim risk positions associated with construction (indicated by Aurecon).

The following investigations performed as part of the Options Assessment are not affected by the change in base case:

- The service needs identified for the dam, and
- The demand assessment for the region.

The impact of the new base case on each of the options will be fully considered in the recommended further work for progression of the detailed business case.

# 5 CONSOLIDATED RECOMMENDATIONS AND NEXT STEPS

The key recommendations arising from the independent advisors' (Aurecon and Natural Capital Economics) reviews as part of the Options Assessment and from Building Queensland's analysis and Summary Report are outlined in the following points:

### Recommendations from Aurecon

The recommendations of the design, cost and risk review undertaken are as follows:

- Complete the current geotechnical assessment of the foundations of the dam including development of a 3D geological model.
- Undertake core sampling and testing of the RCC in the primary spillway (noting that this would need to be done at the same time as the essential works)
- Undertake Anchoring trials to confirm foundation capacity.
- Complete further development of preliminary designs and cost estimates for the options using the new base case (the primary spillway level at the completion of the Essential Works).

### Recommendations from Natural Capital Economics

- The options costs are based on design information which must be updated to the new base case. Once updated the comparative cost position of each option can be reassessed.
- 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 detailed business case, a more detailed approach is recommended that builds on and complements the current assessment through detailed consultation and market sounding, a detailed econometric analysis, assessing the influence of prices on demand, consideration of distribution system constraints, sub-regional demand estimates, and crop specific economic thresholds and modelling to assess impacts on demands.
- Assessment of the impacts of changes to current water sources in the region including groundwater and the role Paradise Dam has in meeting regional water security with the current sources.
- Potential actions to better match availability and demand should be considered, including the potential to convert excess High Priority allocations to Medium Priority allocation, and the potential development of a new produce that better matches the needs and risk profile for perennial tree crops. However further work is required including government approvals, stakeholder engagement, assessment of impacts on drought resilience, and assessment of the impacts on other water supplies including groundwater.
- On the basis of the options assessment process, the independent advisor recommended that the following options progress through to investigation in the next stage of the detailed business case:
  - Option 2: reduce maximum primary spillway height by 5m (equivalent to a primary spillway level of RL62.6m).
  - Option 3A: reduce maximum primary spillway height by 10m (equivalent to a primary spillway level of RL57.6m) supplemented by alternative water supply options which would meet projected demands and provide water security for the region.
  - Option 4: reduce maximum primary spillway height by an optimised level (between 5m and 10m) to balance water security and dam safety and supplemented by alternative water supply options as required

- Further, Natural Capital Economics' high-level review of the Adept Economics Report (in **Appendix C**) highlighted the need for further analysis in the detailed business case to test the assumptions around greenfield and brownfield development of high value crops and their impact on water demands. Natural Capital Economics' review also identified other issues which are relevant to the further work recommended by this Summary Report and will need to be considered in the development of the detailed business case.

### Recommendations from Building Queensland

1. Based on the independent advisors' reports, Building Queensland notes that the following further work is required as part of this first stage of the detailed business case:
    a. Completion of Sunwater's geotechnical investigations of the dam foundations, development of a 3D geological model to inform the understanding of the dam foundations, and commencement of Sunwater's planned anchoring trials to confirm the capacity of the foundations. Building Queensland acknowledges that this work needs to take place in conjunction with the Essential Works to be undertaken by Sunwater during 2020.
    b. Sunwater to arrange for core sampling and testing of the RCC in the primary spillway (Sunwater has advised that this must be undertaken during the Essential Works) to confirm key design parameters.
    c. In parallel to the Sunwater led work identified in points 1a. and 1b. above, Building Queensland will arrange for a more detailed demand assessment that builds on and complements the existing work including detailed community and stakeholder consultation and market sounding, a detailed econometric analysis, assessing the influence of prices on demand, consideration of distribution system constraints, sub-regional demand estimates, and crop specific economic thresholds and modelling to assess impacts on demands. The further assessment will also give due consideration to the assumptions and findings of the Adept Economics report released in February 2020, as identified in the high-level review by Natural Capital Economics (**Appendix C**).
    d. Noting a detailed yield assessment has not yet been undertaken, and at the same time as the works in point 1c. above, Building Queensland will arrange for investigations into the yield required to meet water security expectations, including assessment of Paradise Dam and an optimised primary spillway level, and assessment of alternative water supply options. These investigations will inform the refinement of options.
    e. Sunwater to continue refinement of options designs and cost estimates (using the base case determined by the outcome of the Essential Works), including design of alternative water supply options.

    Building Queensland will implement a governance process to ensure appropriate independent oversight and review of the outcomes of these works, including peer review.
2. Based on the outcomes of the further work recommended in points 1) a. to 1) e. above, Building Queensland will undertake a detailed re-assessment of the recommended options (Option 2, Option 3A, and Option 4). Building Queensland will also include Option 1A in this assessment to ensure it is fully considered in light of the outcomes of the further work recommended above. The analysis will be undertaken in accordance with the Building Queensland Business Case Development Framework and Treasury Project Assessment Framework. This includes assessment of the options against service need, including the updated demand assessment outcomes, and more detailed economic analysis, including cost effectiveness and cost benefit analysis.

3. The outcomes of the recommended further work in points 1a. to 1e. above and the detailed re-assessment of the recommended options outlined above, , will be progressed immediately with Sunwater and in parallel to the Essential Works and presented to government for further consideration and decisions regarding the final recommended option(s). Subject to government approval, Building Queensland and Sunwater will agree on an accelerated schedule for completion of a detailed business case by late 2021, which confirms long-term dam safety and water security requirements. .

Subject to the outcomes of the recommended further work above, it is anticipated that the detailed business case will assess the following options, which are described below relative to the new base case (the condition of the dam at the completion of the Essential Works, which will have a spillway level equivalent to Option 2), noting that extensive strengthening work will be required for each option:

- Option to maintain the primary spillway height at the level of the base case.
- Option to raise the primary spillway height to an optimal level (bounded by the level of Option 1A, RL67.6m) that balances dam safety and water security requirements with alternative water supply options included as required; and
- Option to lower the primary spillway height to an optimal level (bounded by the level of Option 3A, RL57.6m) that balances dam safety and water security requirements, with alternative water supply options included as required.

Building Queensland and Sunwater will work closely to ensure that the recommended further works, and subsequent detailed business case can be completed within the following indicative timeframes:

- Additional Sunwater-led investigations plus designs for options refinement by the end of 2020,
- Building Queensland-led investigations (demand and yield assessments) for detailed options re-assessment by the end of 2020,
- Submission of outcomes of further analysis to Government by the end of 2020, and
- Completion of a final detailed business case by the end of 2021.

# APPENDIX A INDEPENDENT DESIGN, COST, AND RISK REVIEW REPORT – AURECON

# APPENDIX B INDEPENDENT SERVICE NEEDS, DEMAND ESTIMATES AND OPTIONS ASSESSMENT REPORT – NATURAL CAPITAL ECONOMICS

# APPENDIX C INDEPENDENT HIGH-LEVEL REVIEW OF ADEPT ECONOMICS REPORT: *ECONOMIC COSTS OF INACTION ON PARADISE DAM* – NATURAL CAPITAL ECONOMICS

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