15 ECONOMIC ANALYSIS

CHAPTER SUMMARY AND CONCLUSIONS

- The economic impacts of the identified Reference Projects have been assessed using standard CBA techniques. The CBA estimates the net economic impact of each Reference Project relative to the Base Case.
- Findings from the analysis include:
  - no Reference Project returned a positive net benefit to the community under the central case
  - all Reference Projects result in a negative NPV, ranging from -$372.4m for Reference Project 1B to -$565.1m for Reference Project 2A
  - all considered Nullinga Dam solutions return a BCR of approximately 0.1, where every dollar invested would return 10 cents of benefit
- A summary of the CBA findings for the central case scenario are provided below.

REFERENCE PROJECT	1A Standalone 58,000 ML/A	1B Conjunctive 58,000 ML/A	2A Standalone 74,000 ML/A	2B Part. Conjunctive 74,000 ML/A	2C Full. Conjunctive 74,000 ML/A
ECONOMIC COSTS, PRESENT VALUES $M					
Capital costs	$434.1	$412.2	$599.3	$575.7	$563.4
O&M costs	$23.4	$10.8	$29.0	$13.7	$12.1
Total costs	**$457.5**	**$422.9**	**$628.2**	**$589.4**	**$575.5**
ECONOMIC BENEFITS, PRESENT VALUES $M					
Agricultural benefits	$41.9	$41.9	$54.5	$54.5	$54.5
Urban benefits	$0.0	$0.0	$0.0	$0.0	$0.0
Recreational benefits	$8.7	$8.7	$8.7	$8.7	$8.7
Total benefits	**$50.5**	**$50.5**	**$63.2**	**$63.2**	**$63.2**
NPV	-$406.9	-$372.4	-$565.1	-$526.2	-$512.3
BCR	0.11	0.12	0.10	0.11	0.11

- The poor performance of the Reference Projects is primarily due to their high costs relative to the volume of water supplied. For example, the average cost for the Nullinga projects is approaching $10,000 per ML of allocation (after discounting).
- The central case is one of many possible future scenarios and it is highly likely that the Reference Projects could perform better or worse than the suggested by the central case results due to the inherent uncertainty around future water supply and demand.

Uncertainty is accounted for through probabilistic Monte Carlo and sensitivity analysis.

- The Monte Carlo analysis produces 1,000 possible NPVs and BCRs for each Reference Project, which can then be used to calculate expected values and confidence intervals.
- Of the 1,000 simulations, there are no futures where any of the Reference Projects have a BCR greater than one (equivalent to NPV greater than zero). The best possible 99th percentile BCR is 0.39 for the smaller dam in a conjunctive scheme, Reference Project 1B. Noting there is less than 1 per cent chance of a better result.
- Similarly, there are no positive NPVs for any sensitivity analysis for any Reference Projects.

15.1 Purpose

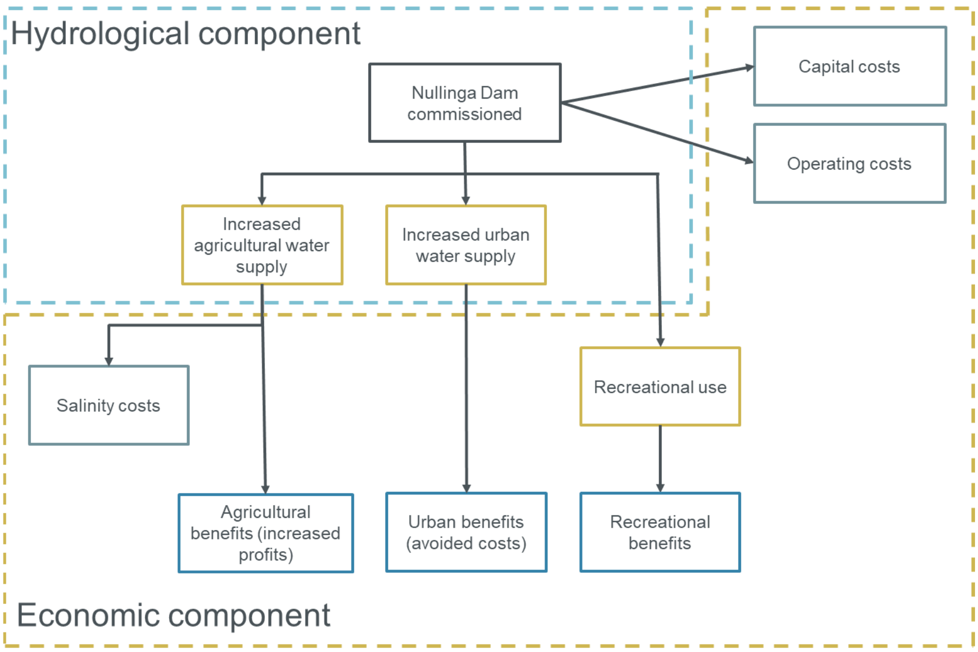
The purpose of this Chapter is to describe the economic analysis undertaken on the identified Reference Projects. The economic impacts have been assessed using standard CBA techniques. This approach estimates the net economic impact of an initiative by comparing all economic benefits that are measurable, material and attributable to the Reference Project with the identified economic costs. The results of an economic CBA demonstrate whether the solution will result in a net economic benefit for the community.

15.2 Approach and assumptions

15.2.1 Identification of costs and benefits

The costs and benefits are illustrated in Figure 15-1 which shows the link between the water supply projects and the benefits and costs via the intermediate impacts. The quantified costs include all required construction and operating expenses. The Reference Projects will increase the supply of water to agricultural users, which would deliver agricultural benefits in the form of increased profits for rural users. The increased supply also has the potential for agricultural costs due to increased salinity (if not appropriately managed).

Figure 15-1 Impacts and quantified costs and benefits



The Reference Projects will increase supply to urban users in Cairns, which may defer the need for planned supply augmentation investments under certain scenarios. Any associated reduction in supply augmentation costs would be an economic benefit. Finally, the development of the NDMIP would generate recreational benefits.

The financial costs captured in the CBA include the capital and operating costs for each Reference Project, while the primary benefits are increased water supply to agricultural and urban users. A structured approach was further used to ensure that all material social and environmental costs and benefits were considered and where possible quantified in the CBA. This involved:

- undertaking a literature review, extensive stakeholder engagement, and analysis of statistical information to identify a **comprehensive longlist** of 27 possible impacts
- completing a **risk and value assessment** to determine the likely materiality of each impact based on likelihood (rare, unlikely, possible, likely, almost certain) and consequence (insignificant, minor, moderate, major, significant)
- setting a 'high' **materiality threshold** to establish a shortlist of social and environmental impacts that have the potential to influence the economic analysis (Table 15-1)
- **further screening** of remaining social and environmental impacts to ensure that they should be included in the economic analysis and not already captured (Table 15-1).

Table 15-1 Social and environmental impacts shortlist

IMPACT	FURTHER SCREENING	DECISION
Employment impacts: ▪ the creation of direct employment ▪ increased indirect employment opportunities for the region ▪ increased agricultural employment opportunities for the region ▪ increased employment and business supply benefits for Aboriginal and Torres Strait Islander persons and businesses.	From an economic perspective, the primary benefits to the community from employment are already captured in the economic analysis in the value of output produced.[107] To include employment benefits again would result in double counting and would be inconsistent with BCDF guidelines.	Employment impacts not included as a separate cost or benefit.
Recreational impacts: ▪ The Nullinga Dam would provide a recreational facility for land and water-based activities, such as fishing, boating, water skiing, hiking, and provide opportunities for tourism development.	The benefits that recreational users would receive from the Nullinga Dam should be captured in the economic analysis. There are likely to be some benefits and costs from tourism development. However, these are unlikely to be as material overall and would be difficult to quantify with the data available.	Recreational impacts quantified.
Displacement impacts: ▪ The direct purchase and acquisition of property to be inundated by water at full supply level will require landholders and their families to relocate from their property. For some landholders, this would represent a major change to their lifestyles and livelihoods.	To the extent that landholders are fully compensated for their losses, the costs to the community from displacement are already captured in land acquisition costs, which are part of capital costs. To include displacement costs again would lead to double counting.	Displacement impacts not included as a separate cost.

107 The income received by workers is a benefit to workers. However, it is also a cost to employers. This washes out in aggregate, unless there is a reason to weigh the gains to workers more or less heavily than the loss to employers.

IMPACT	FURTHER SCREENING	DECISION
Business uncertainty impacts: ▪ Perception of project uncertainty affecting landholders' business viability and long-term investment decisions of landholders in the local study area.	The business uncertainty impacts largely relate to costs, such as displacement, which are already implicitly or explicitly captured in the economic analysis. Hence, the business uncertainty impacts can be seen as another manifestation of those costs rather than an additional cost.	Business uncertainty impacts not included as a separate cost.
Salinity impacts: ▪ The increase in irrigation associated with the Nullinga Dam has the potential to increase water tables and exacerbate salinity, leading to a loss of agricultural profitability.	It is likely that salinity impacts can be largely mitigated through rules around water use. As such the salinity impact are unlikely to be material in the context of the project.	Salinity impacts - excluded in the central case - included in sensitivity analysis.

15.2.2 Quantification of central case costs and benefits

The following section outlines the adopted approach for quantifying the impacts identified in Figure 15-1, under the central case, including model structure and parameter values.

The central case is one of many possible future scenarios and includes a number of conservative assumptions to reduce the likelihood of overestimating the net benefits of the Reference Projects. It is highly likely that the Reference Projects could perform better or worse than suggested by the central case results. To test this, the economic model was run for thousands of alternative future scenarios, from best case to worst case, to test whether the central case results are robust (Section 15.6).

15.2.2.1 General assumptions

The economic model developed for the NDMIP includes a number of general assumptions around project timeframes, appraisal periods, inflation and the discount rate that are relevant for calculating costs and benefits. Table 15-2 provides a summary of the general central case parameters used in the appraisal.

Table 15-2 Parameter assumptions

PARAMETER	ESTIMATE / ASSUMPTION	SOURCE	CONFIDENCE
General Assumptions			
Year construction starts	2020	Sunwater	High
Year operation starts	2031	Sunwater	High
Year first water	2036	Sunwater	Medium
Asset life	100 years	Sunwater	Medium
Appraisal period	2019 to 2060 (30 years of operations)	BCDF guidelines	Medium
Inflation	Consumer price index	Australian Bureau of Statistics	High
Base year	2019	Building Queensland	High
Discount rate	7 per cent real	BCDF guidelines	Medium

All future costs and benefits reported exclude inflation. However, even after considering inflation, a dollar now is worth more than a dollar in the future. To address this, all future costs and benefits are converted to 2019 present values using a 7 per cent real discount rate.

15.2.2.2 Reference Project costs

The Reference Project cost estimates were provided by Sunwater and include all activities outlined below. Unless otherwise stated, all estimates are P90 values[108].

Table 15-3 Activities included in the cost estimates

CONSTRUCTION ACTIVITIES	OPERATING ACTIVITIES
Implementation: ▪ land and cultural heritage ▪ approvals and environment ▪ property impacts ▪ project development ▪ design ▪ construction attendance Construction: ▪ preliminaries and overheads ▪ clearing and earthworks ▪ dam structure and construction ▪ drainage structures and culverts ▪ reinstatement and fishing works ▪ dam improvement works ▪ supply items (pipes, equipment, and so on) ▪ install and construct items ▪ supply pumpstations	Operations: ▪ environment management ▪ electrical, controls and communications ▪ insurance ▪ staffing ▪ periodic maintenance ▪ refurbishment and upgrades It is acknowledged that major refurbishments are recognised as capital expenses under the financial and commercial analysis presented in Chapter 18

15.2.2.3 Agricultural benefits

The agricultural benefits depend on the increase in agricultural water supply and the extent of demand for that water across various agricultural users.

Increased agricultural water supply

All considered Reference Projects will increase the availability of water to agriculture and would support both MP and HP allocations (Table 15-4).

108 The 'P-value' refers to the probability that the specified cost will not be exceeded. For example, the P90 costs are not exceeded in 90 per cent of simulated futures.

Table 15-4 Agricultural water supply assumptions

PROJECT	ESTIMATE/ASSUMPTION	SOURCE	CONFIDENCE
MP allocation			
Reference Project 1 (all sub-options)	36,541 ML	Sunwater	High
Reference Project 2 (all sub-options)	52,541 ML	Sunwater	High
HP allocation			
Reference Project 1 (all sub-options)	1,688 ML	Sunwater	High
Reference Project 2 (all sub-options)	1,688 ML	Sunwater	High

Agricultural water demand

As the major expected benefit of a proposed Nullinga Dam, it is important that the approach to estimating the economic benefits for agricultural users is defensible and robust. At the highest level, the agricultural benefits are driven by the additional volume of water applied to various productive uses and the value of the additional water in production. The value of water in production varies depending on the crop being produced. Given the uncertainties regarding the mix of future agricultural production, the economic appraisal has used multiple lines of evidence to estimate the agricultural benefits by developing three simple agricultural models based on different theoretical approaches:

- stated demand model based on a survey of potential agricultural users
- net margins model based on farm budgets
- water market model based on water market data.

All three modelling approaches have strengths as well as limitations. Instead of selecting a primary model in advance, the model that generated the median agricultural benefit was used for the central case. As shown in Figure 15-2, the appraisal found that stated demand model has the median estimate and therefore has been used to generate the agricultural benefit estimates under the central case.

Figure 15-2 Spectrum of benefits from three agricultural models

The demand for agricultural water has two components:

- quantity – how much water do irrigators want from the water supply projects?
- price – how much are irrigators willing to pay for that water?

The most direct way to obtain this information is to survey irrigators. As detailed in Section 5.3, Building Queensland undertook a market sounding for agricultural demand through a publicly advertised request for information (RFI). To ensure that most current interest was identified, the RFI was held open for three weeks longer than initially considered necessary and further direct engagement was undertaken with some parties who had not responded. In addition to basic demand information, the survey also asked irrigators about their proposed water use. Furthermore, the likelihood of each project eventuating was assessed as likely, possible or unlikely based on the information elicited through the survey and follow up conversations with some respondents on the status of their projects.

The demand for agricultural water can be summarised using demand curves. The demand curves show the volume of allocations from the reference projects demanded at different prices.

Figure 15-3 Likely Ag demand for MP allocations

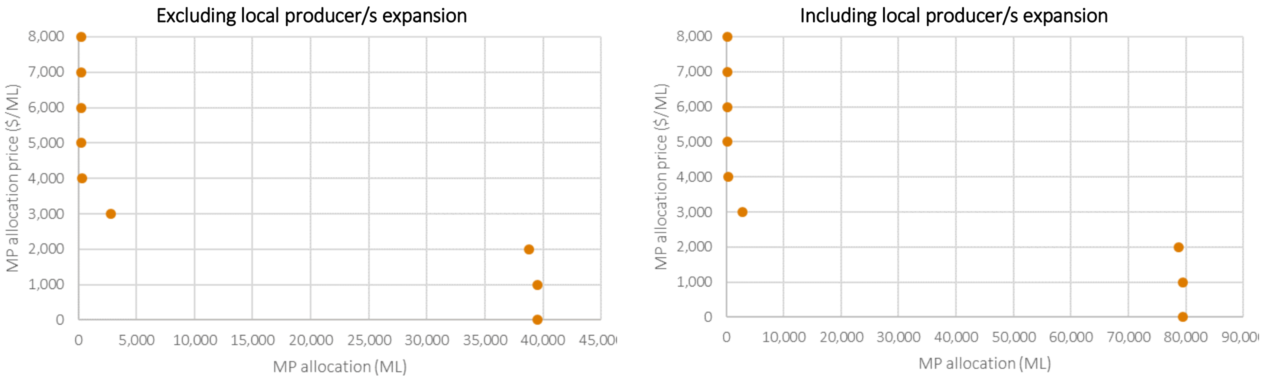


Figure 15-4 Likely Ag demand for HP allocations

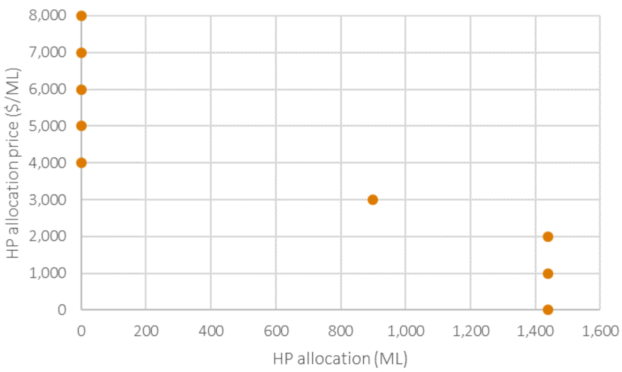


Figure 15-3 indicates that there is minimal demand for MP allocation at or above $3,000 per ML. At or below $2,000 per ML, there approximately 40,000 ML of demand for MP allocation without potential local operator demand, and about 80,000 ML of demand with this potential demand included.

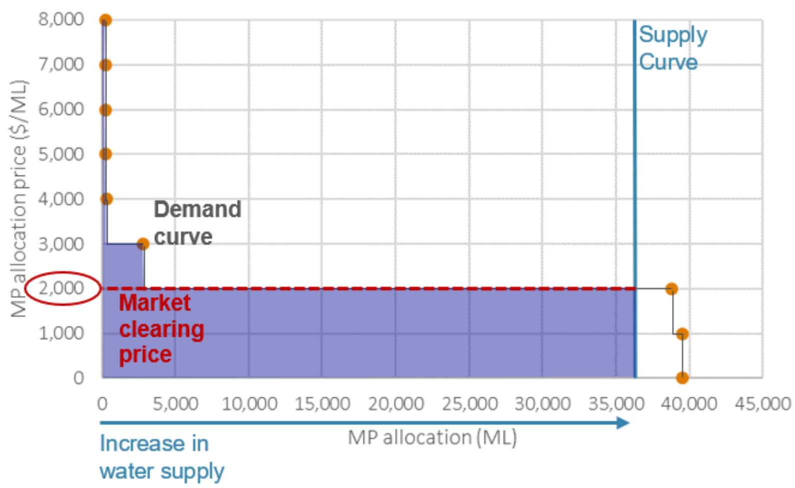
Figure 15-4 suggests little demand for HP allocation.

Calculating the agricultural benefits

The increase in water availability will benefit local agricultural businesses, allowing businesses to expand the area of irrigated production or increase water application rates, improving agricultural yields and profits. These benefits can be calculated using the evidence on supply and demand presented above.

The first step is to estimate how the water from the projects would be allocated. Not all businesses will necessarily be able to purchase water at their indicated price. For example, if a business stated they would purchase water at $1,000 per ML and the price is $1,500 per ML, they would be priced out of the market. The model allocates water based on the assumption that water would be allocated to businesses with the highest willingness to pay through a competitive auction or sale at the price that equates supply and demand or subsequent trade (irrespective of the initial allocation of water).

Figure 15-5 Illustrative example, agricultural benefits to irrigators (Reference Project 1, MP only)



The market clearing price is determined endogenously based on the intersection of supply and demand. All businesses with a willingness to pay above the market clearing price receive water. Some businesses with a willingness to pay equal to the market clearing price receive water. No businesses with a willingness to pay below the market clearing price receive water.

The second step is to estimate the benefits received by those businesses. The model estimates the benefits by multiplying the incremental volume of water assumed to be used by the business by their willingness to pay. The third step is to aggregate the benefits over all local agricultural businesses and both medium and high priority allocations. The final two steps are summarised as follows:

Equation 1 Stated demand model agricultural benefits equation

$$\boldsymbol{Agricultrual\ benefit} = \sum_{ij} \boldsymbol{Willingness\ to\ pay}_{ij} * \boldsymbol{Volume\ recieved}_{ij}$$

where i = businesses and j = MP / HP allocation

This is equivalent to the areas under the demand curves between zero and the volumes made available under each Reference Project. These benefits represent the once-off willingness to pay for a perpetual right to the water associated with an allocation. This is defined at the point in time at which the allocation is sold, assumed to be at first water.

Water traded to agriculture from urban customers

Advice from CRC indicates that they are unlikely to use their allocations from the projects until after planned supply augmentations (refer Section 15.2.2.4) have been completed. This means that the allocations earmarked for urban use would be available for agricultural production for at least 30 to 40 years, until required to support Cairns future water needs.

The volume of excess water traded to agriculture is determined in the urban water component of the model (also discussed below). However, as the volume of excess water varies over time based on supply and demand conditions in Cairns, there is no simple way to convert the excess water into the equivalent of medium priority or high priority allocations, as required by the agricultural water component of the model. To address this, an alternative model component which is based on annual supply volumes (instead of allocations) is used to estimate the benefits of water traded to agriculture.

The benefits of water traded to agriculture are added to the benefits from allocations made directly available to agriculture to estimate the overall agricultural benefits from the Reference Projects.

15.2.2.4 Urban benefits

The urban benefits depend on the increase in water supply to Cairns as well as the extent to which additional water allows Cairns to avoid costs associated with alternative supply augmentations.

Increased urban water supply

CRC has informed Building Queensland that it will purchase a HP allocation from the Nullinga Dam solutions. The urban water component of the model is based on yield, which is defined as the maximum volume that can be supplied while meeting reliability targets. As a result, it is necessary to convert from allocation to yield.

Urban benefits (avoided costs)

The increase in water availability to CRC would allow Cairns to defer alternative supply augmentations. Because a dollar is worth less in the future than now (it is assumed a real discount rate of 7 per cent), postponing alternative supply augmentations has the potential to reduce capital and operating costs in present value terms (that is, after discounting).

The urban water model applies a conventional yield-demand framework to estimate the avoided costs based on the following steps:

- estimate urban water demand over time
- model timing of supply augmentations under the base case and water supply projects
- calculate capital and operating costs over time for supply augmentations under the base case and water supply projects.

The differences in present value costs between the water supply projects and the base case are the avoided costs.

Urban water demand

Urban water demand can be disaggregated into population and average water consumption per person. The population estimates are based on forecasts by the QGSO[109]. Under the medium population growth scenario, used for the central case, the population of Cairns is estimated to increase from about 162,000 in 2016 to about 237,000 in 2041. It is assumed that the annual population growth rate over the last five years of the forecast (1.4 per cent) applies from 2042 to the end of the appraisal period.

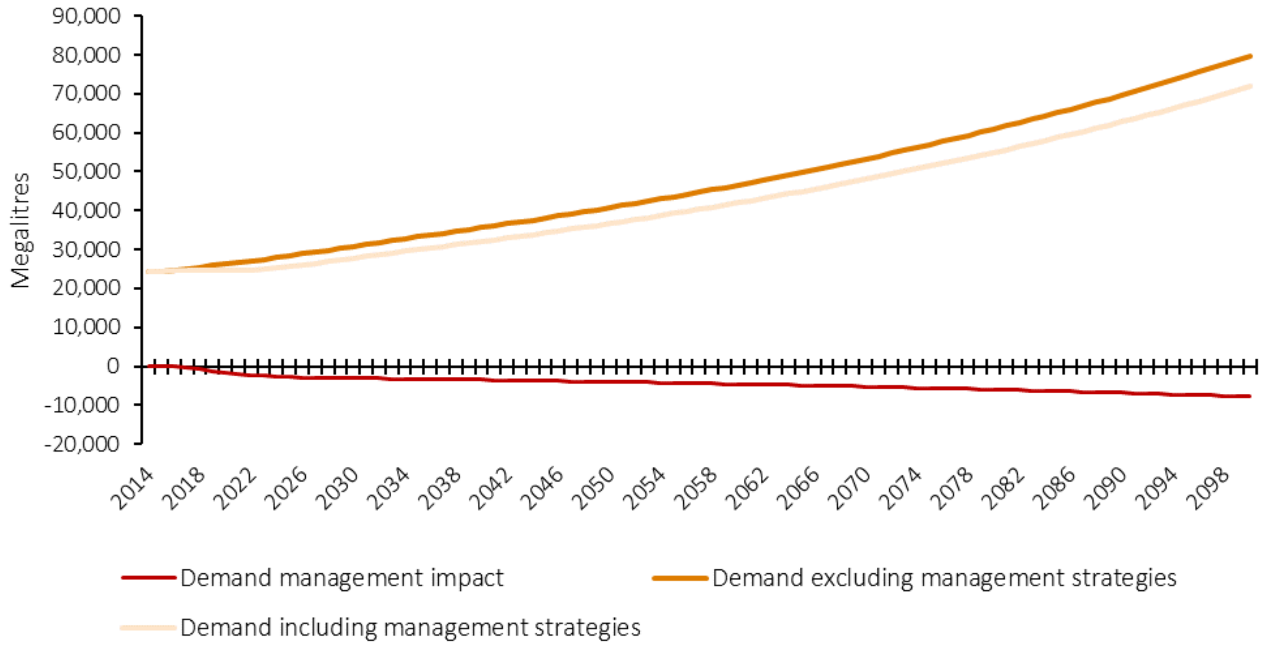
According to CRC[110], average water consumption per person was about 418 litres per day in 2016 (Table 15.5). With planned demand management measures, average water consumption per person is projected to fall about 10 per cent by 2025. The implications of these assumptions for demand are shown in Figure 15-6.

Table 15-5 Urban water demand assumptions

PROJECT	ESTIMATE/ASSUMPTION	SOURCE	Confidence
Initial urban water use	418 per person	CRC	High

Figure 15-6 Projected annual Cairns water demand over time

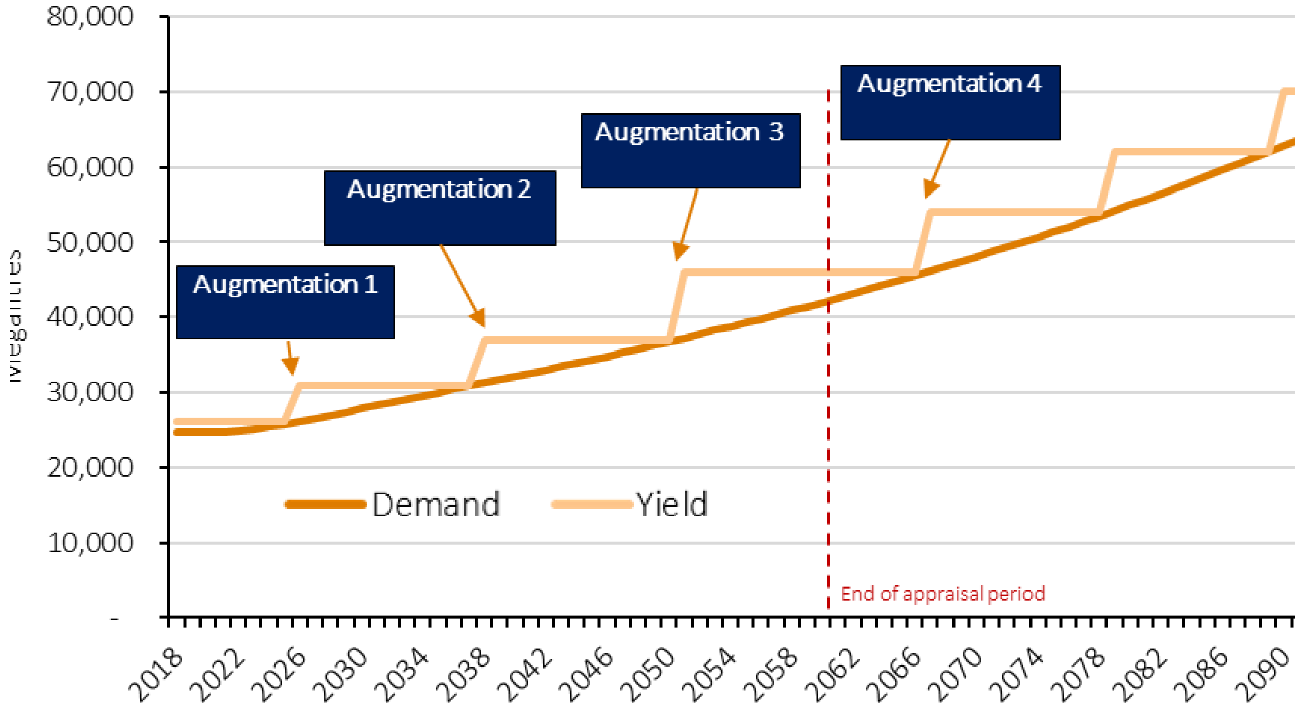
[109] Queensland Government population projections, 2018 edition; Australian Bureau of Statistics, Population by age and sex, regions of Australia, 2016 (Cat no. 3235.0).
[110] Cairns Regional Council (2015), Our Water Security: Cairns Regional Council Water Security Strategy.



Timing of supply augmentations

The timing of supply augmentations for Cairns is estimated under the base case and reference projects. Supply augmentations are undertaken as required to ensure that yield exceeds demand and service standards are achieved. Hence, various supply augmentations will be required over time to meet projected demand growth (for example, see Figure 15-7).

Figure 15-7 Illustrative supply augmentation schedule for Cairns



The list and order of these supply augmentations is determined outside the model based on strategy commitments. Specifically, CRC has advised that under the base case (in the absence of the Nulling projects) they intend to undertake the following sequence of supply augmentations:

- **First action:** Mulgrave River Stage 1 and associated Draper Road water treatment plant (WTP) Stage 2
- **Second action:** Barron River Stage 1 and associated Kamerunga WTP Stage 1
- **Third action:** Mulgrave River Stage 2[111] and associated Draper Road WTP Stage 3
- **All subsequent actions:** Desalination plants.

The additional yields associated with the planned supply augmentations vary from 5,000 ML for Mulgrave River Stage 1 to 9,000 ML for Barron River Stage 1 (Table 15-6).

Table 15-6 Supply augmentation yield assumptions

PROJECT	ESTIMATE/ASSUMPTION	SOURCE	Confidence
Base	26,000 ML	ODHydrology	Medium
Mulgrave River Stage 1	5,000 ML (incremental)	ODHydrology	Medium
Barron River Stage 1	9,000 ML (incremental)	ODHydrology	Medium
Mulgrave River Stage 2	6,000 ML (incremental)	ODHydrology	Medium
Desalination plants	8,000 ML (incremental)	Sunwater	Medium

As discussed in Chapter 5, CRC would purchase an allocation of HP water from 2036, though this water would not be used for urban use until after Mulgrave River Stage 2 has been completed, and when it is required (anticipated to be 2063). It is assumed that this water is subsequently traded for agricultural uses during this period.

It is acknowledged that delivery of the Reference Projects could help defer future CRC planned augmentation works, in particular the desalination plant, though this falls outside the current appraisal period.

Capital and operating costs

The capital and operating costs for the supply augmentations and associated water treatment plants were primarily sourced from CRC[112]. The capital and operating costs for the desalination plants were the exception and were estimated from confidential data based on similar plants in other Australian jurisdictions. All costs were updated to 2019 dollars. The capital costs of the supply augmentations range from about $60 million to about $170 million, with the desalination plant anticipated to have the higher capital and operating costs (Table 15-7).

Table 15-7 Supply augmentation cost assumptions

PROJECT	ESTIMATE	SOURCE	CONFIDENCE
CAPITAL COSTS			
Mulgrave River Stage 1	$58.9m	CRC	Medium

111 Further research is required to confirm the feasibility of Mulgrave River Stage 2.
112 Cairns Regional Council (2015), Our Water Security: Cairns Regional Council Water Security Strategy.

PROJECT	ESTIMATE	SOURCE	CONFIDENCE
Barron River Stage 1	$165.7m	CRC	Medium
Mulgrave River Stage 2	$85.3m	CRC	Medium
Desalination plants	$169.7m	Sunwater	Low
OPERATING COSTS			
Mulgrave River Stage 1	$1.1m	CRC	Medium
Barron River Stage 1	$1.6m	CRC	Medium
Mulgrave River Stage 2	$1.8m	CRC	Medium
Desalination plants	$5.8m	Sunwater	Low

As discussed above, the urban water component of the model tracks the timing of supply augmentations under the base case and water supply projects. The capital and operating costs are then recorded for the appraisal period and converted to present values. The difference between the present value costs under the base case and water supply projects gives the avoided costs.

Water treatment costs

The costs to CRC associated with treating water from a proposed Nullinga Dam are also material. Water treatment would likely require the construction and operation of Kamerunga WTP Stage 2, which has estimated capital costs of about $50 million and annual operating costs of about $1 million (Table 15-8). The present value of these costs is subtracted from the avoided costs to calculate net urban benefits.

Table 15-8 Project water treatment costs assumptions

COMPONENT	ESTIMATE	SOURCE	CONFIDENCE
Capital costs	$53.7m	CRC	Medium
Annual operating costs	$1.2m	CRC	Medium

15.2.2.5 Recreational benefits

Dams can provide important recreational benefits to local communities and tourists alike. For example, some estimates suggest that Tinaroo Falls Dam could currently have around 500,000 visitors per year (Table 15-9).[113] It is reasonably anticipated that there are recreational benefits that can be captured with the delivery of a Nullinga Dam.

Based on previous studies and input from DBC contributors, it has been assumed that the annual number of recreational visitors to Nullinga Dam would be about 10 per cent of Tinaroo (or 50,000 per year). A number of non-market valuation studies were reviewed to estimate the recreational value per visit. The most directly applicable study was undertaken by the Central Queensland University (CQU). The study uses the travel cost method to estimate the value of recreational fishing for three freshwater dams in Queensland.[114] The smallest estimate was for the Bjelke-Petersen Dam, which had an estimated value of $78 per visit. To be conservative, it was assumed that the recreational value per visit is $39; half the estimate from the CQU

[113] Carmody and Prideaux (2010)
[114] Rolfe and Prayaga (2007)

study.[115] This estimate is also conservative when compared to the broader literature on recreational values. For example, an international review of about 160 studies estimated median values for several recreational activities. The lowest was about $23 per visit for general recreational areas whereas the highest was about $126 per visit for biking (converted to 2019 dollars).[116]

There are likely to be costs associated with providing the facilities necessary to realise the recreational benefits at Nullinga Dam. Sunwater estimates the capital costs are likely to be about $5.7 million while the annual operating costs are likely to be about $25,000. The costs associated with providing the facilities are subtracted from the recreational benefits to calculate the net effect over the appraisal period. This is then converted to a present value.

Table 15-9 Recreational benefit assumptions

COMPONENT / METRIC	ESTIMATE	SOURCE	CONFIDENCE
Visitors to Tinaroo	500,000 per year	Carmody and Prideaux (2010)	Low
Visitors to Nullinga	10 per cent of Tinaroo (50,000 per year)	Ayala Consulting	Low
Average recreational value	$39 per visit	Informed by Rolfe and Prayaga (2007)	Low
COSTS			
Capital costs	$5.7m	Sunwater	Medium
Annual operating costs	$25,000	Sunwater	Medium

[115] Some of the visitors to Nullinga would have otherwise visited Tinaroo or other dams. However, as long as (i) the estimated demand for Nullinga is accurate, (ii) there is no change in congestion at Tinaroo, and (iii) there is no change in the price of accessing Tinaroo, any reduction in surplus from Tinaroo should be ignored (see Boardman et al. 2000). With respect to accuracy, the estimated demand for Nullinga does implicitly capture substitutes, including other dams and other recreational activities more generally. In this case, it reflects the substitutes available for the Bjelke-Petersen Dam, the original source of the estimate.

[116] Reported in ACIL Tasman (2006), The value of recreation at Logue Brook Dam, Report prepared for the Department of Water.

15.3 Summary of central case results

The economic model was run for each of the Reference Projects to estimate the benefits and costs relative to the base case (Table 15-10). None of the Reference Projects examined returned a positive net benefit to the community under the central case. Reference Project 1B would return the highest BCR of 0.12. However, it is noted that this is not statistically different from the results of all considered Reference Projects, which means that for every dollar invested in a Nullinga Dam solution, only 10 cents of benefits are returned.

The Reference Projects all deliver negative NPVs, ranging from -$370m to -$565m.

Table 15-10 Summary CBA results ($2019)

REFERENCE PROJECT	1A Standalone 58,000 ML/a	1B Conjunctive 58,000 ML/a	2A Standalone 74,000 ML/a	2B Part. Conjunctive 74,000 ML/a	2C Full. Conjunctive 74,000 ML/a
Economic Costs, Present Values $M					
Capital costs	$434.1	$412.2	$599.3	$575.7	$563.4
O&M costs	$23.4	$10.8	$29.0	$13.7	$12.1
Total costs	**$457.5**	**$422.9**	**$628.2**	**$589.4**	**$575.5**
Economic Benefits, Present Values $M					
Agricultural	$41.9	$41.9	$54.5	$54.5	$54.5
Urban	-	-	-	-	-
Recreational	$8.7	$8.7	$8.7	$8.7	$8.7
Total benefits	**$50.5**	**$50.5**	**$63.2**	**$63.2**	**$63.2**
NPV	**-$406.9**	**-$372.4**	**-$565.1**	**-$526.2**	**-$512.3**
BCR	**0.11**	**0.12**	**0.10**	**0.11**	**0.11**

The poor estimated performance of the Reference Projects is primarily due to their high costs, coupled with low yields. The average cost for the Reference Projects is approaching $10,000 per ML of allocation (after discounting).

In terms of benefits, there is sufficient demand in the sense that most of the water made available through the Reference Projects is likely to be purchased and used, where the stated prices of $2,000 per ML for MP and $3,000 per ML for HP is adopted. However, the average benefit is estimated to be less than $1,000 per ML of allocation (after discounting).

The agricultural benefits are attenuated by the assumption that benefits are only received for 30 years after project completion. Additionally, there are no urban benefits under the central case evaluation period. This is because CRC has indicated that it will not seek water from a Nullinga Dam until after their planned alternative supply augmentations. Since these supply augmentations should be sufficient to meet demand growth until after the appraisal period, Cairns is unlikely to use water from the considered Reference Projects within the appraisal period. Hence, there is no urban benefit.

The economic analysis reveals that the present value of the economic costs significantly outweigh the economic benefits for the investment. This provides insights into the likely net productivity benefits of the proposed investment which considers the sum of the following impacts:

- the investment adds to the Queensland capital stock (measured by the capital cost – could be called capital deepening) and this produces, relative to the base case, a direct increase in output (measured by the economic benefits):
  - the cost is substantially greater than the benefits as measured by the very low BCR of approximately 0.1
  - the investment will have very low capital productivity and this is likely to be substantially below the average for the existing Queensland capital stock.
- the investment also needs to be funded which has a negative economic deadweight opportunity cost (perhaps between 20% to 30% of capital expenditure) – this offsets the economic benefits
- in effect, the investment reduces the Queensland average capital stock productivity and therefore reduces overall measured multi-factor productivity.

It is noted that if salinity damage impact is included, as a result of increased irrigation associated with the Nullinga Dam which leads to higher groundwater levels at Cattle Creek. This could bring saline groundwater to the surface and is assumed to make 1,000 hectares of irrigated land unsuitable for agriculture in 2041. The value of lost agricultural returns per hectare can be approximated by the land price. A scan of commercial real estate shows that current values for sugarcane properties in northern Queensland are about $12,300 per hectare. Applying the discount rate, the estimated present value of salinity damage is about $2 million (in NPV terms). As discussed previously, to the extent that the problem can be managed through water use rules, there may not be any salinity damage costs.

Sections 15.4 and 15.5 present the estimated costs and benefits for the central case in greater detail. Several important assumptions underpinning the central case results are uncertain. Section 15.6. rigorously tests the implications of these assumptions for the results using probabilistic and sensitivity analysis.

15.4 Central case cost results

This section outlines the economic costs under the central case. All costs are presented on an undiscounted basis (that is, not accounting for the time value of money). Table 15-11 recaps the economic costs included within the central case model.

Table 15-11 Recap of economic costs under the central case

ECONOMIC COST	DESCRIPTION	APPROACH
Capital costs	Costs incurred in the development of the reference case projects	Estimates provided by Sunwater
Operating costs	Costs incurred in the operation and maintenance of the reference case projects	Estimates provided by Sunwater

Table 15-12 presents a summary of the real capital and operating costs, as of 2018/19. Reference Project 1B has the lowest capital cost, approximately $713.7m and Reference Project 2A has the highest capital cost requirement of approximately $1.1bn.

Comparing these undiscounted costs to the discounted values presented in Section 15.5 shows the large impact of the discount rate. For example, the estimated capital cost of the Reference Project 2A is $1.1 billion in undiscounted terms compared with $600 million when discounted. This effect is accentuated when applied to longer-run impacts, such as some benefits under the Reference Projects (see Section 15.5).

Table 15-12 Undiscounted capital and operating costs

No.	Reference Project	Upfront Capital Cost $M 2018-19	Average annual OPEX* $M 2018-19
1A	Standalone Dam (58,000ML/a)	755.8	4.1
1B	Conjunctive Dam (58,000ML/a)	713.7	2.0
2A	Standalone Dam (74,000ML/a)	1068.0	5.1
2B	Partial Conjunctive Dam (74,000ML/a)	1022.8	2.5
2C	Full Conjunctive Dam (74,000ML/a)	999.1	2.2

The capital expenditure occurs over an 11-year period. The expenditure schedule varies over this period, with at least 60 per cent of capital expenditure occurring in the final 3 years for all considered solutions.

The annual average operating costs for the Reference Projects, presented in Table 15-12, shows Reference Project 2A has the highest estimated ongoing cost, at $5.1m per annum. It should be noted that each project's operating expenditure schedule is lumpy and is included as such within the CBA model, noting this includes major refurbishment costs, which are treated as capital under the financial analysis.

15.5 Central case benefit results

This section outlines the quantified economic benefits for each reference project under the central case. These estimates are presented in undiscounted terms (e.g. ignoring the time value of money). Table 15-13 provides an explanation of the methodologies used in estimating the economic benefits.

Table 15-13 Recap of economic benefits under the central case

ECONOMIC BENEFIT	DESCRIPTION	APPROACH
Agricultural benefits	Increased profits of agricultural producers due to increased water availability made possible by the reference projects	Supply and demand modelling, with demand being primarily based on survey responses of potential water users.
Urban benefits	Avoided costs of investment in water supply augmentations for urban users in Cairns	Yield-demand modelling to determine the extent to which water supply augmentations are deferred by the reference projects, and the associated cost savings.
Recreational benefits	Recreational benefits facilitated through creation of dam	Number of users multiplied by willingness-to-pay, sourced from academic research.

15.5.1 Agricultural benefits

Table 15-14 presents the undiscounted agricultural benefits for each Reference Project. This is broken down into the direct benefit (e.g. water that is directly acquired by farmers) and the traded water benefit (e.g. water that is acquired through the purchase of excess water from Cairns). The benefits sum to the total agricultural benefits.

Reference Project 1A and 1B generate a total agricultural benefit of $265 million, with the majority (77 per cent) being direct benefit. As a result of the additional water, Reference Projects 2A, 2B and 2C generate about $345 million of total agricultural benefit, again with most (82 per cent) being direct benefit.

The impact of discounting is apparent when comparing the undiscounted agricultural benefits above with the discounted benefits in Section 15.3. For example, the small Nullinga Dam solutions (1A and 1B) discounted benefits are over 80 per cent lower than the undiscounted benefits.

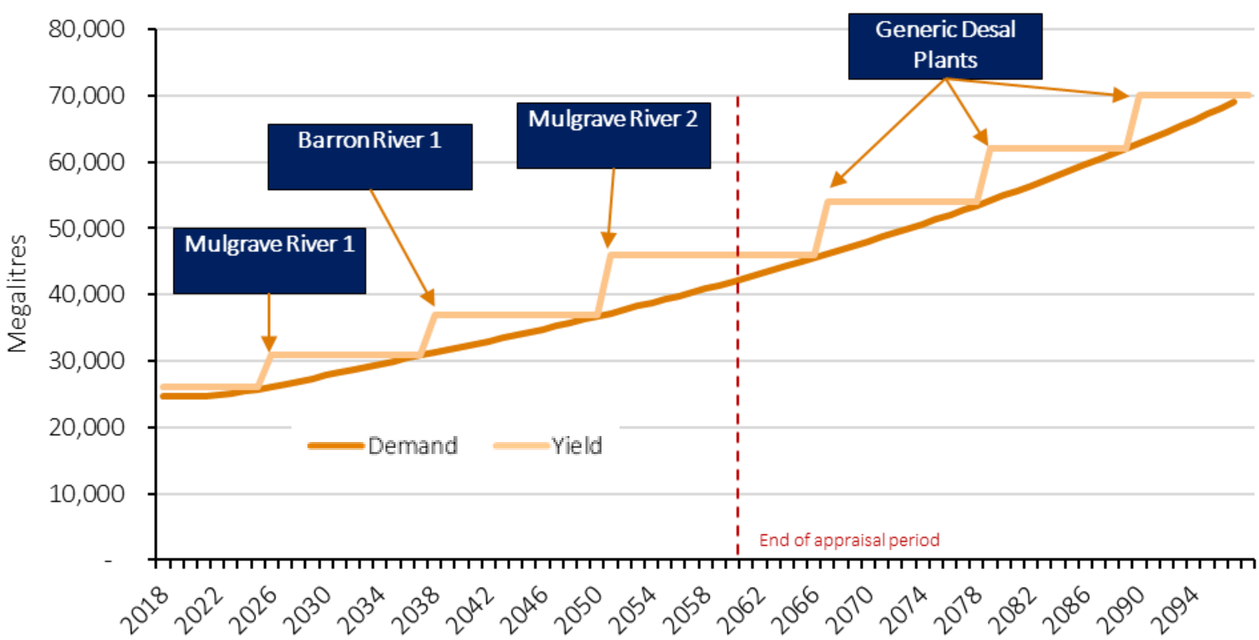
Table 15-14 Undiscounted agricultural benefits

REFERENCE PROJECT	DIRECT BENEFIT $M	TRADED WATER BENEIFT $M	TOTAL AGRICULTURAL BENEFIT $M
1A and 1B	$203.564	$61.503	**$265.067**
2A, 2B and 2C	$283.564	$61.503	**$345.067**

15.5.2 Urban benefits

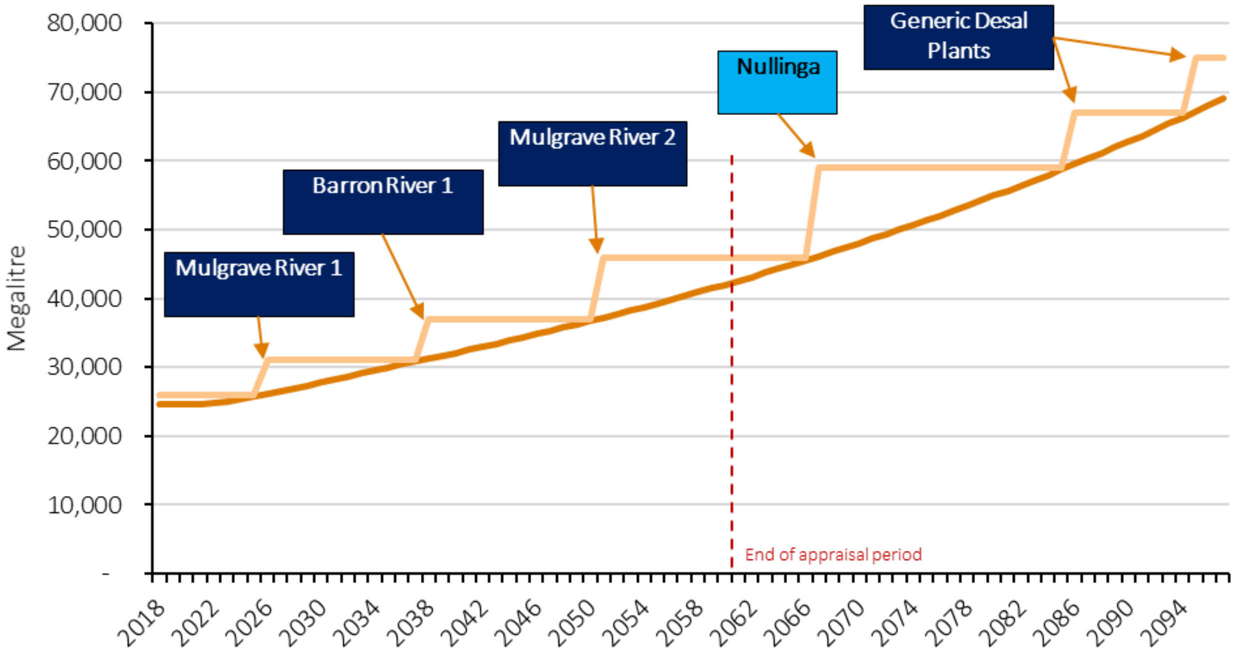
Figure 15-8 presents the estimated supply augmentation schedule under the base case. The demand management strategy is sufficient to provide a temporary buffer between yield and demand. However, the Mulgrave River Stage 1 augmentation is required by 2026. This provides yield in excess of modelled demand until 2038. At this point, the Barron River Stage 1 augmentation is constructed. The yield of water exceeds demand until 2051, wherein the Mulgrave River Stage 2 is constructed. This provides sufficient yield until past the end of the appraisal periods (2055 and 2060). Several desalination plants are required after the appraisal periods.

Figure 15-8 Supply augmentation schedule for Cairns – Base Case



The Nullinga projects contribute to yield. However, as discussed above, this water will not be used until after Mulgrave River Stage 2, even when the water is available sooner. Figure 15-9 presents the supply augmentation schedule under all considered Reference Projects.

Figure 15-9 Supply augmentation schedule for Cairns, with Nullinga Dam



These are identical since all Reference Projects supply the same yield to Cairns at the same time. Cairns' water supply is augmented by the Nullinga Dam in 2067, which delays investment in the desalination plants. However, these delays fall outside of the appraisal period and as such the model does not capture these urban user benefits. Hence, the estimated benefits are zero.

15.5.3 Recreational benefits

A new Nullinga Dam is estimated to attract around 50,000 recreational visitors per year, with each visitor receiving $39 per visit of benefits on average. Over the appraisal period this corresponds to an undiscounted benefit of about $52.3m ($2019), after accounting for the costs of the recreational facilities. The discounted recreational benefit over 80 per cent lower than then undiscounted benefit, further highlighting the large impact discounting has on the modelling results.

15.6 Uncertainty

This CBA is inherently uncertain due to its forward-looking nature. The Reference Projects are subject to generic uncertainties such as the appropriate discount rate, economic appraisal period, and so on. However, there also exist project-specific uncertainties. These include climate change impacts on water supply, the extent of demand missing from the survey, whether local operators expand existing production, and so on.

It is therefore critical to account for uncertainty in the modelling approach. A comprehensive and rigorous CBA will address this uncertainty using objective and evidence-based methodologies. For this DBC, uncertainty has been addressed through development of a probabilistic Monte Carlo model as well as conventional sensitivity analyses.

- Monte Carlo analysis

  Involves specifying probability distributions for uncertain parameters. In each simulation, the model draws a value from each probability distribution, runs the model, and records the NPVs and BCRs. This is repeated many times to estimate the probability distributions of the results and the probabilistic modelling is further used to calculate the associated confidence intervals.

- **Sensitivity analysis**

  Analyses the impacts of varying key parameters by defined amounts on the NPV and BCRs. Unlike Monte Carlo analysis, sensitivity analysis does not specify the probability associated with different events.

The assumptions and results of these approaches are outlined below. Additional scenarios have also been considered and the results presented in Section 0.

15.6.1 Monte Carlo analysis

Monte Carlo analysis can be used to rigorously explore the performance of the Reference Projects over many possible futures. This involves applying stochastic processes to key parameters, which allows them to vary each time the model generates results. This allows the model to quickly assess the impact of thousands of potential future scenarios.

For the NDMIP 1,000 model simulations have been run to consider the implications of potential scenarios. For every model simulation, the variable is generated based on its probability distribution. This produces a set of 1,000 possible NPVs and BCRs, which can then be used to calculate expected values and develop confidence intervals.

The average NPVs across the 1,000 model simulations are presented, along with the 10th and 90th percentile results to demonstrate the potential tail end risks.

15.6.1.1 Monte Carlo methodology

The model parameters were assumed to vary based on either a uniform distribution or discrete distribution. A uniform distribution allows a parameter to vary between an upper and lower bound with equal probability. Table 15-15 outlines the 19 parameters that are vary based on a uniform distribution as part of the Monte Carlo analysis.

Table 15-15 Uniform probability distribution parameters

UNIFORM PROBABILITY DISTRIBUTION PARAMETERS	10th Percentile	90th Percentile	COMMENT
General			
Discount rate	4.6%	9.4%	Varies applied discount rate
Urban component			
Urban water use	385 l per day	451 l per day	Varies urban water use per household
Agriculture component			
Price scale factor	0.8	1.2	Varies factor to account for bias in reported willingness to pay
Volume scale factor	1.2	2.4	Varies factor to account for missing demand in reported volume
MDWSS MP price	$3,174 $/ML	$3,726 $/ML	Varies MDWSS medium priority price
MP Price elasticity	-1.3	-2.5	Varies MDWSS medium priority elasticity
MDWSS HP price	$5,796 $/ML	$8,004 $/ML	Varies MDWSS high priority price
HP Price elasticity	-1.3	-2.5	Varies MDWSS high priority elasticity

UNIFORM PROBABILITY DISTRIBUTION PARAMETERS	10th Percentile	90th Percentile	COMMENT
Water utilisation rate	74%	86%	Varies utilisation rate in agriculture model
Net margin scale factor	0.8	1.2	Varies factor to account for bias in net margins (net margins model only)
Recreational benefit			
Number of visitors Tinaroo	300,000	700,000	Varies visitor numbers to Tinaroo
Visitors Nullinga	6%	14%	Varies percentage of visitors to Nullinga
Average WTP of visitors	$24	$55	Varies WTP of visitors

Table 15-16 outlines the three parameters that are vary based on a discrete probability distribution.

Table 15-16 Discrete probability distribution parameters

DISCRETE (BINARY) PROBABILITY DITRIBUTION PARAMETERS	OUTCOME ONE	OUTCOME TWO	COMMENT
Urban component			
Mulgrave stage 2 proceeds	Mulgrave 2 does not proceed (20%)	Mulgrave proceeds (80%)	Binary of whether Mulgrave proceeds
Agriculture component			
Long term demand	Demand not realised (20%)	Demand realised (80%)	Binary of long-term demand realisation
Expansion of local commercial operations	No expansion (25%)	Expansion (75%)	Binary of expansion included

In addition, there are a number of more complex probability distributions in which there are more than two possible outcomes, potentially with unequal probabilities. The parameters governed by these distributions are outlined in Table 15-17.

Table 15-17 Additional probability distribution parameters

ADDITIONAL PROBABILITY DISTRIBUTION PARAMETERS	COMMENT
General	
Climate change	Selects the climate change scenario for water supply in the urban and agricultural components (net margins model only)
Costs	
Capital expenditure	Selects the capital expenditure scenario (P10, P50, P90)
Urban component	
Urban population	Selects the urban population growth scenario (low, mid, high)
Agricultural component	
Agricultural model	Selects the agricultural model used (central, market model, net margins model) – discussed further below

RFI respondents included	Selects which groups of RFI respondents are included in the analysis based on likelihood (likely only, likely and possible, all)

15.6.1.2 Monte Carlo results

The results of the Monte Carlo analysis across the Reference Projects are presented in Table 15-18. The table shows the mean value, 10th percentile value, and 90th percentile value for the present value costs, present value benefits, and NPV.

Examining the mean values first, the net present values associated with all of the Reference Projects are negative. This is similar to the central case, although the projects are less negative than under the central case. For example, using the probabilistic model the estimated NPV of Reference Project 2A is -$506m instead of -$565m. This implies that the consideration of probabilistic factors, on average, improves the model results.

The improvement reflects a combination of lower costs and higher benefits. The costs are lower primarily because the probabilistic model samples from P10, P50 and P90 capital cost schedules, unlike the central case which only uses P90 capital costs. The benefits are mainly higher because there are some futures where urban water demand growth is high and Mulgrave River Stage 2 is not feasible. In these cases, there can be substantial urban benefits from the Reference Projects under the probabilistic model, since desalination plants would otherwise be required within the construction period. By contrast, the urban benefits are zero under the central case.

As expected, the 10th percentile results are less favourable than the mean results whereas the 90th percentile results are more favourable. The percentiles can be used to construct confidence intervals. For example, based on the assumptions outlined above, there is an 80 per cent probability that the NPV of for Reference Project 2A is between -$597m and -$425m.

Table 15-18 Results of Monte Carlo analysis – NPV[117]

COMPONENT	MEAN	10TH PERCENTILE	90TH PERCENTILE
Reference Project 1A			
Economic costs, PV $M	$425.7	$344.9	$518.9
Economic benefits, PV $M	$65.7	$28.2	$119.2
NPV	**-$360.0**	**-$421.7**	**-$306.8**
Reference Project 1B			
Economic costs, PV $M	$393.9	$317.4	$477.8
Economic benefits, PV $M	$67.5	$29.1	$118.3
NPV	**-$326.3**	**-$381.4**	**-$279.3**
Reference Project 2A			
Economic costs, PV $M	$586.6	$469.9	$719.8
Economic benefits, PV $M	$80.2	$35.0	$142.8
NPV	**-$506.4**	**-$596.9**	**-$425.2**

[117] NB. Care should be taken in comparing the results for the 10th and 90th percentiles across rows due to the probabilistic nature of the analysis. For example, present value benefits less the present value costs will generally not equal the net present values except at the mean.

COMPONENT	MEAN	10TH PERCENTILE	90TH PERCENTILE
Reference Project 2B			
Economic costs, PV $M	$547.8	$446.2	$664.8
Economic benefits, PV $M	$79.7	$34.4	$142.2
NPV	-$468.1	-$549.0	-$399.7
Reference Project 2C			
Economic costs, PV $M	$536.7	$433.6	$647.4
Economic benefits, PV $M	$81.8	$34.8	$145.5
NPV	-$454.9	-$528.3	-$388.1

To illustrate the estimates over the 1,000 simulations, the distributions of benefit-cost ratios are represented in histograms for the Reference Projects (Figure 15-10 to Figure 15-14). The bars of the histograms show the proportion of simulations in each bin. As a hypothetical example, if the bar associated with the BCR bin 0.20 has a height of 0.08, this means that the estimated BCR was close to 0.20 in approximately 80 simulations.

The histograms further confirm the negative results. Of the 1,000 simulations, there are no futures where any of the reference projects have a BCR greater than one (equivalent to NPV above zero).

Examining the shape of the distributions, the histograms for the Nullinga projects tend to skew leftwards. This means that extremely low BCRs are quite likely, but there is a small probability obtaining of BCRs about 0.3 or above.

Figure 15-10 Histogram of BCR results – Reference Project 1A

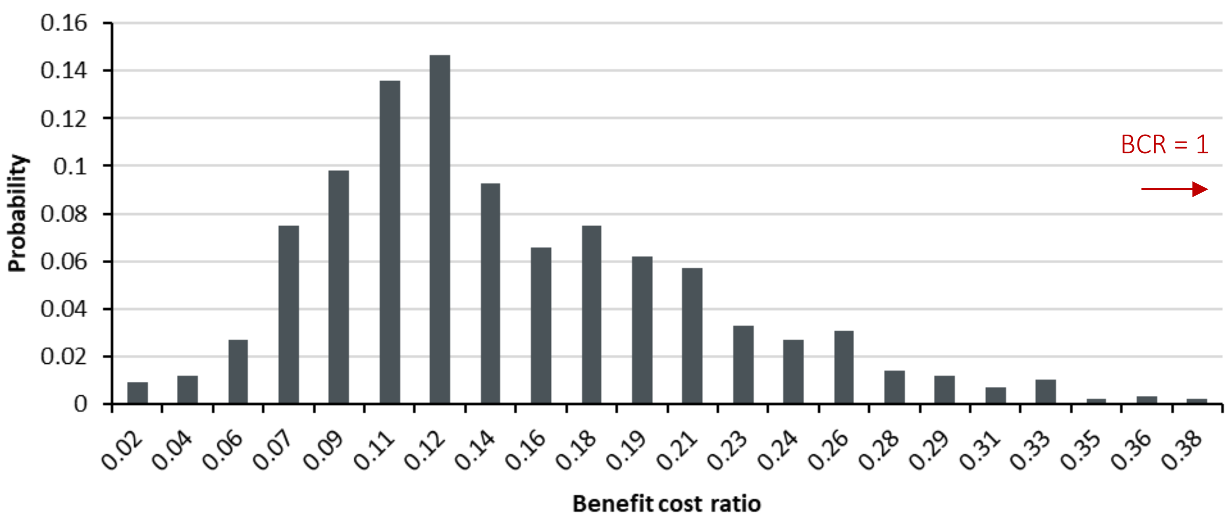


Figure 15-11 Histogram of BCR results – Reference Project 1B

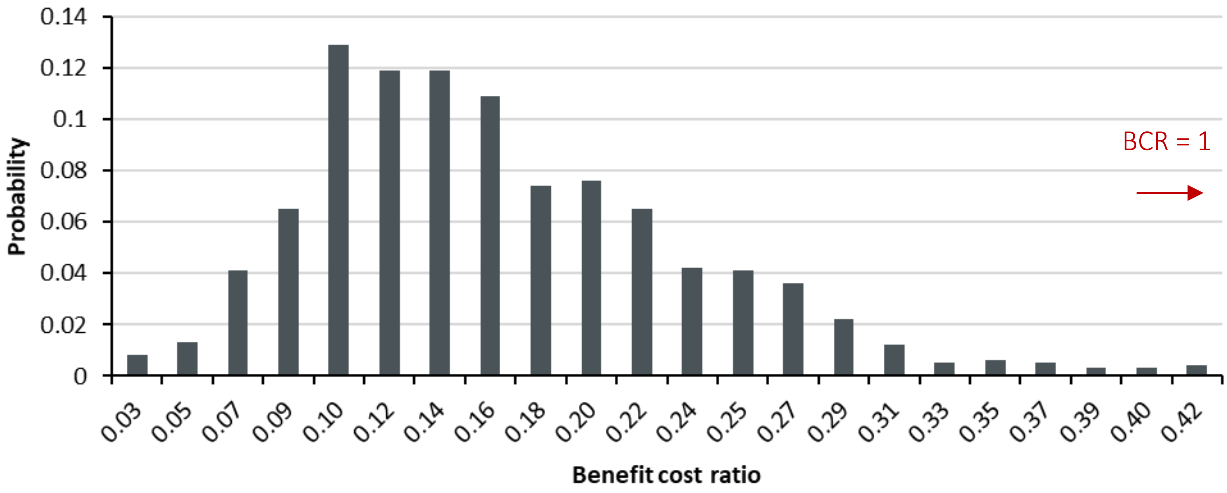


Figure 15-12 Histogram of BCR results – Reference Project 2A

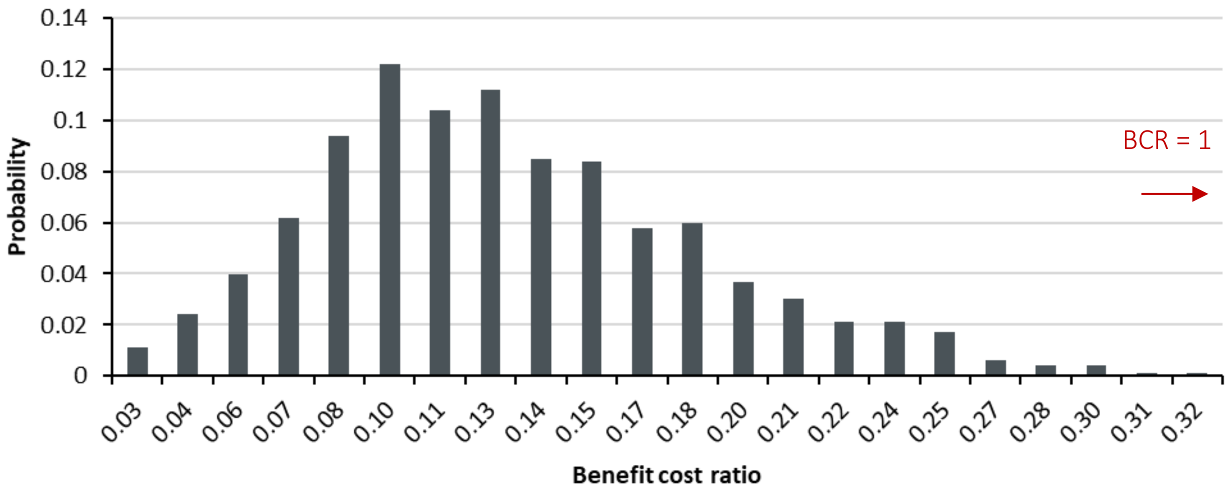


Figure 15-13 Histogram of BCR results – Reference Project 2B

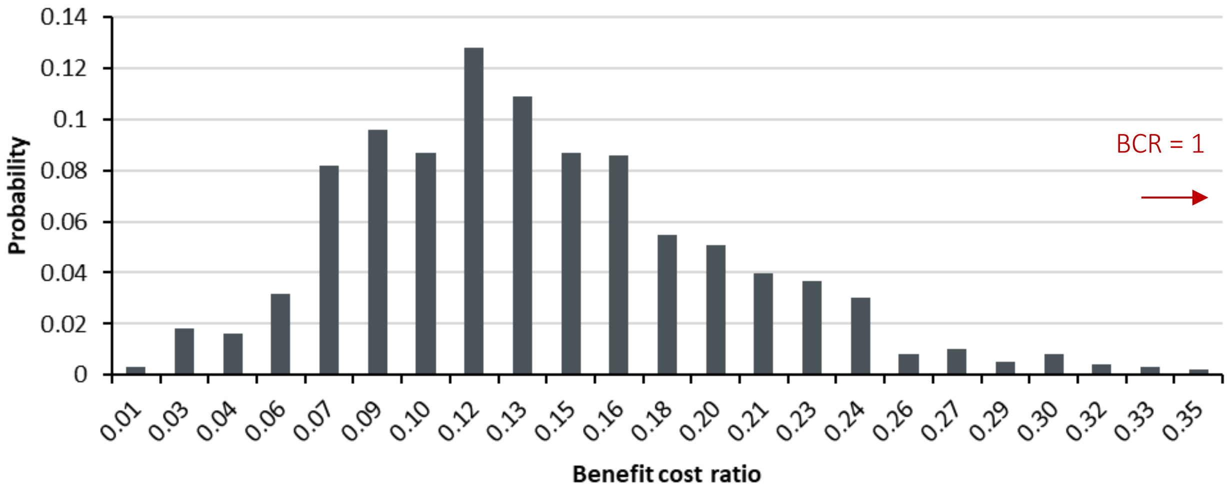
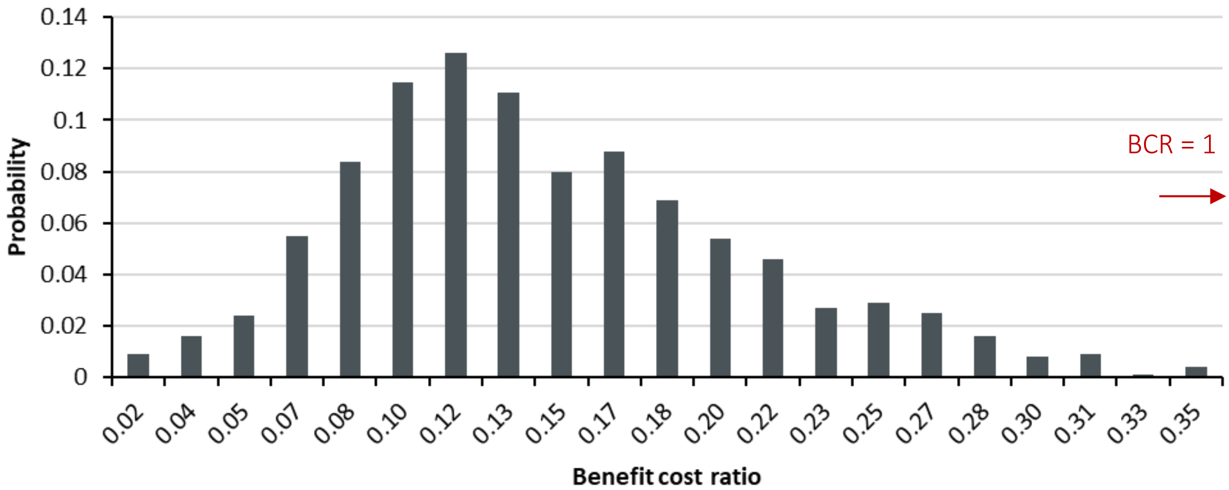


Figure 15-14 Histogram of BCR results – Reference Project 2C



15.6.2 Sensitivity analysis

Sensitivity analysis have been performed on the central case assumptions and key data inputs to provide further insight on the potential impact of movements in key variables on the NPV results of the Reference Projects. Table 15-9 summarises the assumptions that have been adjusted for the purposes of completing the sensitivity analysis on the NPV of the Reference Project.

Table 15-19 Reference Projects Sensitivities

ASSUMPTION/KEY DATA INPUTS	DESCRIPTION
Capital expenditure	Percentage variations ± 10/20%
Operations and maintenance costs	Percentage variations ± 10/20%
Discount rate	4% and 10%
Project timing	Start construction 2026

As is expected, the Reference Project NPVs are more sensitive to movements in capital costs, than movements in operation and maintenance expenditure.

Reducing the discount rate to 4 per cent results in a decrease in NPV. This is because the lower discount rate increases the present value costs more than it increases the present value benefits, for the considered Reference Projects. This reflects the fact that the costs are substantial relative to the benefits and incurred over an extended period. The pattern for is reversed when applying a discount rate of 10 per cent. That is, the NPVs increase under the higher discount rate.

The sensitivity under which the Reference Projects are deferred by six years exhibits the most favourable results for the considered sensitivities. Reference Project 2B, for example, sees an increase of approximately $180 million in NPV terms. This is primarily due to the impact of the discount rate on present value costs outweighing the impact on present value benefits. As such, there is minimal change in the BCRs, and further deferring the Reference Projects will never make them favourable. However, there is a small benefit for the Nullinga projects from deferral as it lengthens the appraisal period sufficiently to capture some of the benefits to urban water users.

Table 15-20 Sensitivity analysis results

REFERENCE PROJECT	1A Standalone 58,000 ML/a	1B Conjunctive 58,000 ML/a	2A Standalone 74,000 ML/a	2B Part. Conjunctive 74,000 ML/a	2C Full. Conjunctive 74,000 ML/a
Central Case	**-$406.9**	**-$372.4**	**-$565.1**	**-$526.2**	**-$512.3**
Capital costs					
+20 per cent	-$493.7	-$454.8	-$684.9	-$641.4	-$625.0
+10 per cent	-$450.3	-$413.6	-$625.0	-$583.8	-$568.7
-10 per cent	-$363.5	-$331.2	-$505.1	-$468.6	-$456.0
-20 per cent	-$320.1	-$290.0	-$445.2	-$411.1	-$399.7
O&M costs					
+20 per cent	-$411.6	-$374.5	-$570.9	-$528.9	-$514.8
+10 per cent	-$409.3	-$373.5	-$568.0	-$527.6	-$513.5
-10 per cent	-$404.6	-$371.3	-$562.2	-$524.9	-$511.1
-20 per cent	-$402.2	-$370.2	-$559.3	-$523.5	-$509.9
Discount rate					
4%	-$490.6	-$437.0	-$692.1	-$631.1	-$611.7
10%	-$332.3	-$308.7	-$456.0	-$429.7	-$419.5
Project deferral					
Project deferral	-$266.3	-$243.3	-$371.7	-$345.8	-$336.6
Different Ag Model					
Net margin model	-$414.4	-$379.8	-$573.0	-$534.1	-$520.2
Water market model	-$387.6	-$353.1	-$539.4	-$500.5	-$486.7

15.6.3 Scenario analysis

Several alternative scenarios to the central case assumptions were modelled, including:

- P50 results
- No expansion of local commercial operations
- 50-year (operations) evaluation period

Table 15-21 Summary CBA results, central case v scenarios

REFERENCE PROJECT	1A Standalone 58,000 ML/a	1B Conjunctive 58,000 ML/a	2A Standalone 74,000 ML/a	2B Part. Conjunctive 74,000 ML/a	2C Full. Conjunctive 74,000 ML/a
CBA Results for P90 costs and benefits (central case)					
NPV $M	-$406.9	-$372.4	-$565.1	-$526.2	-$512.3
BCR	0.11	0.12	0.10	0.11	0.11
CBA Results for P50 costs and benefits					
NPV $M	-$354.2	-$321.1	-$499.9	-$462.3	-$446.6
BCR	0.14	0.15	0.12	0.13	0.14
CBA Results for no expansion of local commercial operations					
NPV $M	-$406.9	-$372.4	-$575.3	-$536.4	-$522.6
BCR	0.11	0.12	0.08	0.09	0.09
CBA Results for longer evaluation period (including 50 years of operations v 30 years under central case)					
NPV $M	-$392.2	-$356.2	-$548.8	-$508.3	-$494.2
BCR	0.15	0.16	0.13	0.14	0.14

The findings from the scenario analysis include:

- all Reference Projects result in negative NPVs under all scenarios
- economic results improve under a P50 scenario, as the costs are incurred earlier than benefits
- there is no net change to the NPVs or BCRs for Reference Project 1A and 1B with the removal of local operator demand, as the smaller dam solution cannot cater for this demand even under the central case
- a longer evaluation period marginally improves the NPVs of all Reference Projects.