Water resource assessment for the Victoria catchment

A report from the CSIRO Victoria River Water Resource Assessment for the National Water Grid

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Important disclaimer

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The Assessment was guided by two committees:

i. The Assessment's Governance Committee: CRC for Northern Australia/James Cook University; CSIRO; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Land Council; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; Office of Northern Australia; Queensland Department of Agriculture and Fisheries; Queensland Department of Regional Development, Manufacturing and Water

ii. The Assessment's joint Roper and Victoria River catchments Steering Committee: Amateur Fishermen's Association of the NT; Austrade; Centrefarm; CSIRO; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Land Council; NT Cattlemen's Association; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; NT Farmers; NT Seafood Council; Office of Northern Australia; Parks Australia; Regional Development Australia; Roper Gulf Regional Council Shire; Watertrust

Responsibility for the Assessment's content lies with CSIRO. The Assessment's committees did not have an opportunity to review the Assessment results or outputs prior to their release.

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For further acknowledgements, see page xxv.

Acknowledgement of Country

CSIRO acknowledges the Traditional Owners of the lands, seas and waters of the area that we live and work on across Australia. We acknowledge their continuing connection to their culture and pay our respects to their Elders past and present.

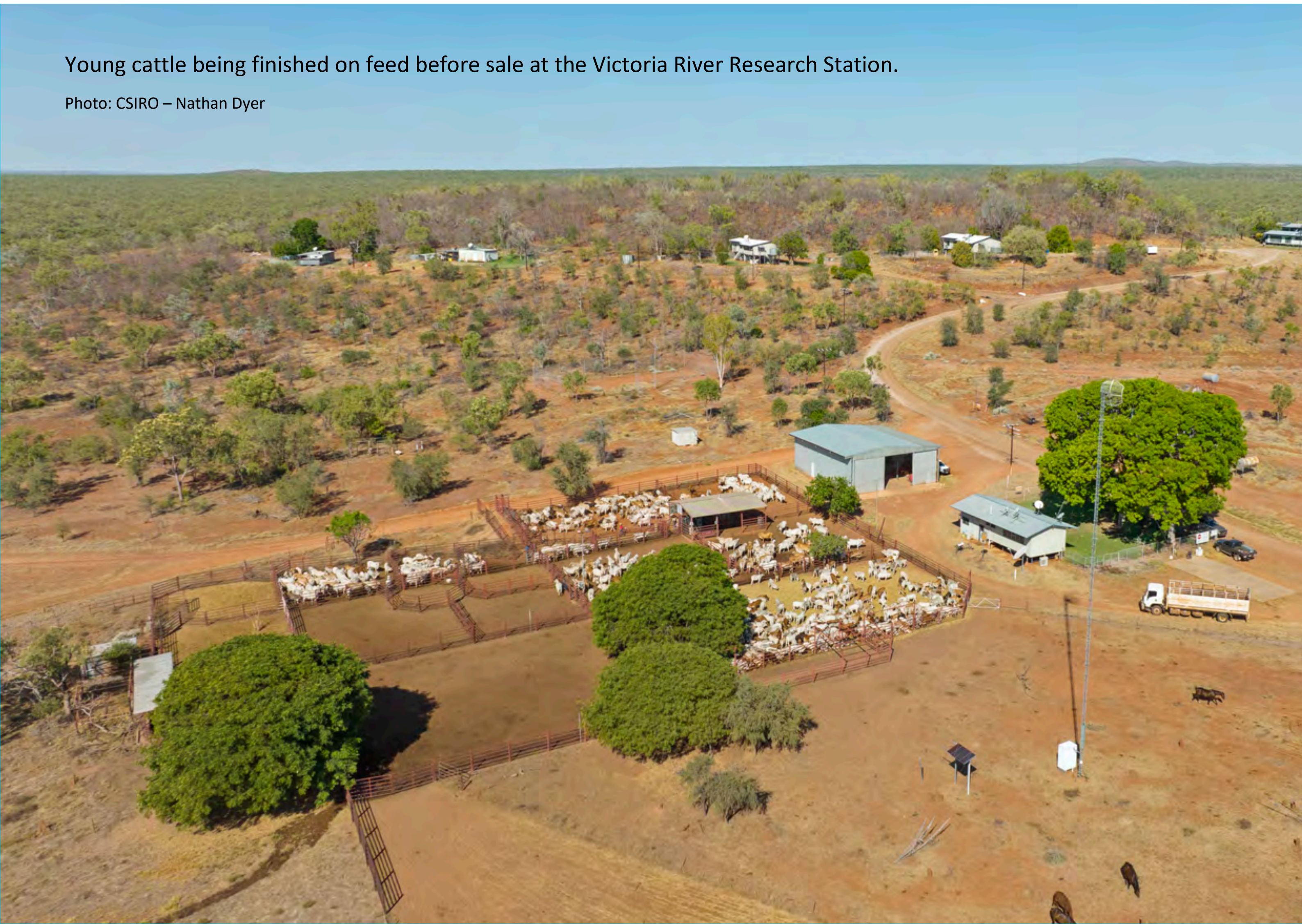
Photo

The Victoria River is the longest singularly named river in the NT with permanent water. Photo: CSIRO – Nathan Dyer

Part IV Economics of development and accompanying risks

Chapters 6 and 7 describe economic opportunities for water development in the Victoria catchment, and the associated constraints and risks:

- economic opportunities and constraints (Chapter 6)
- a range of risks to development (Chapter 7).



Young cattle being finished on feed before sale at the Victoria River Research Station.

Photo: CSIRO – Nathan Dyer

6 Overview of economic opportunities and constraints in the Victoria catchment

Authors: Chris Stokes, Shokhrukh Jalilov, Diane Jarvis

Chapter 6 examines the types of opportunities for the development of irrigated agriculture in the catchment of the Victoria River that are most likely to be financially viable. The chapter considers the costs of building the required infrastructure (both within the scheme and beyond), the financial viability of various types of schemes (including lessons learned from past large dam developments in Australia), and the regional economic impacts (the direct and flow-on effects for businesses across the catchment) (Figure 6-1).

The chapter focuses on costs and benefits that are the subject of normal market transactions, but it does not provide a full economic analysis. Commercial factors are likely to be among the most important criteria in deciding between potential development opportunities. Options clearly identifiable at the pre-feasibility stage as not being commercially viable could be deprioritised. More-detailed and Assessment-specific agronomic, ecological, social, cultural and regulatory assessments could then focus on those opportunities identified as showing the most commercial promise. The non-market impacts and risks associated with any financially viable development opportunities, discussed in Chapter 7, must also be considered.

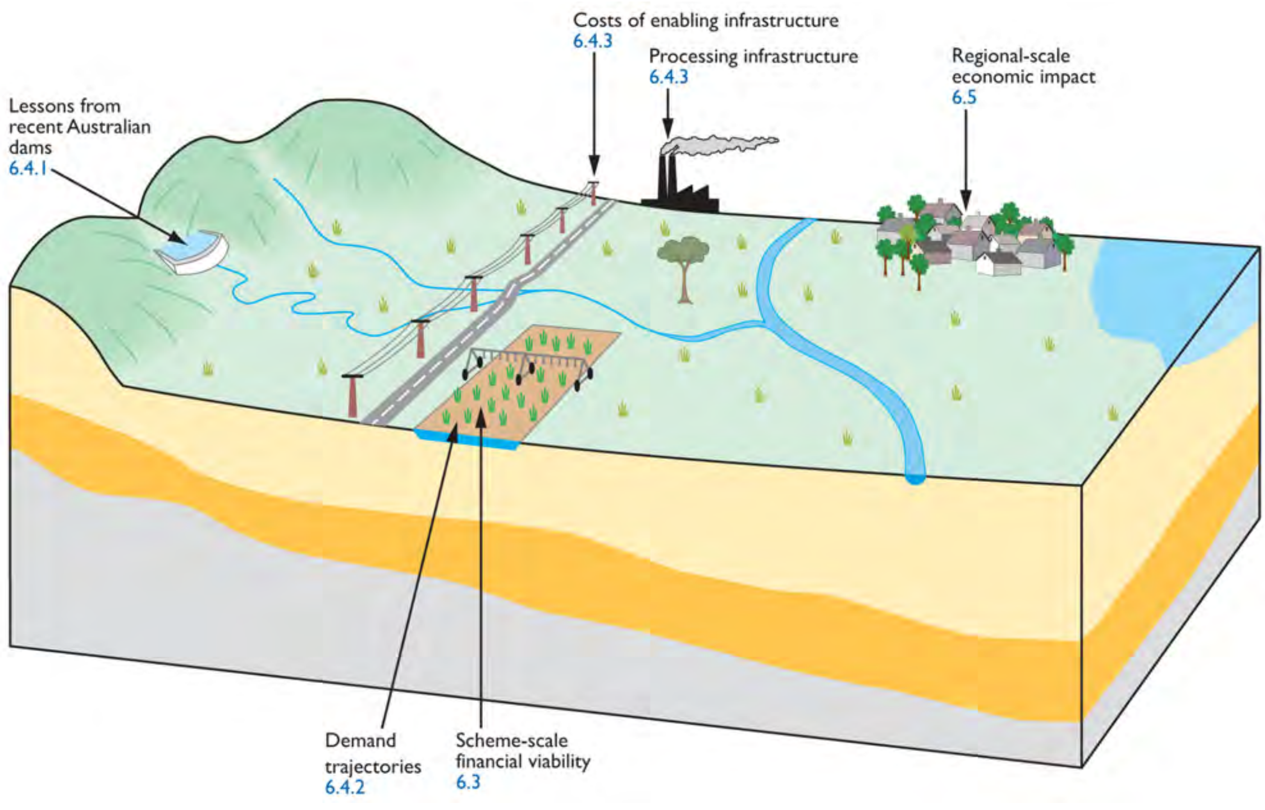


Figure 6-1 Schematic diagram of key components affecting the commercial viability of a potential greenfield irrigation development

6.1 Summary

6.1.1 Key findings

Scheme-scale financial viability

New investment in irrigation development in the Victoria catchment would depend on finding viable combinations of low-cost water sources, low-cost farming development opportunities, and high-productivity farms; finding opportunities for reducing cropping costs and attracting price premiums for produce; and managing a wide range of risks.

Financial analyses have indicated that large dams in the Victoria catchment are unlikely to be viable if public investors target full cost recovery at a 7% internal rate of return (IRR) and do not provide assistance, which would make water from the most cost-effective dam sites too expensive for irrigators. However, large dams could be marginally viable if public investors accepted a 3% IRR. On-farm water sources provide better prospects than large dams: where sufficiently cheap water development opportunities can be found, they could support viable broadacre farms and horticulture with low development costs. Horticulture with high development costs (e.g. fruit orchards) in the Victoria catchment would be more challenging unless farm financial performance could be boosted by (i) finding niche opportunities for premium produce prices, (ii) making savings in production and marketing costs, and/or (iii) obtaining high yields.

Farm performance can be affected by a number of risks, including water reliability, climate variability, price fluctuations, and the need to adapt farming practices to new locations. Setbacks that occur soon after an irrigation scheme has been established have the largest effect on scheme viability. There is a strong incentive for choosing well-proven crops and technologies when starting any new irrigation development, and for being thoroughly prepared for those agronomic risks of establishing new farmland that can be anticipated. Risks that cannot be avoided must be managed, mitigated where possible, and accounted for when determining the realistic returns that may be expected from a scheme and the capital buffers that would be required.

Cost–benefit analysis of large public dams

A review of recent large public dams built in Australia has highlighted some areas where cost–benefit analyses (CBAs) for water infrastructure projects could be improved upon, particularly the need for more-realistic forecasting of the demand for water. This chapter provides information for benchmarking a number of the processes commonly used in such CBAs, including demand forecasting. These processes can then act as a check when proposals for new dams are being unrealistically optimistic (or pessimistic).

Regional economic impacts

Any new irrigated agriculture development and its supporting infrastructure will have knock-on benefits to the regional economy beyond direct economic growth from the new farms and construction. The initial construction phase of a new irrigation development in the Victoria catchment could provide an additional (approximately) $1.1 million of indirect regional benefits, over and above the direct benefits, for each million dollars spent on construction within the local region. The ongoing production phase of a new irrigation development could provide an additional (approximately) $0.46 to $1.82 million of indirect regional benefits for each million dollars of direct benefits from the increased agricultural activity (gross revenue), depending on the type of agricultural industry. The indirect regional benefits would be reduced if some of the extra expenditure generated by a new development was leaked to outside the catchment. Each $100 million increase in agricultural activity could create approximately 100 to 852 jobs.

6.2 Introduction

Large new infrastructure projects in Australia are expected to be increasingly more accountable and transparent. This trend extends to the planning and building of new water infrastructure, and the way water resources are managed and priced (e.g. Infrastructure Australia, 2021a, 2021b; NWGA, 2022, 2023), and includes greater scrutiny of the costs and benefits of potential large new public dams. The difficulty in accurately estimating costs and the chance of incurring unanticipated expenses during construction, or of not meeting the projected water demands or achieving revenue trajectories when completed, put the viability of developments at risk if they are not thoroughly planned and assessed. For example, in a global review of dam-based megaprojects, Ansar et al. (2014) found that the forecast costs were systematically biased downwards, with three-quarters of projects running over budget and the mean of the actual costs being almost double the initial estimates. This is typical for most types of large infrastructure projects, not just dams (see review in Section 6.4.1).

Ultimately, economic factors are likely to be among the most important criteria in deciding the scale and types of potential development opportunities in the Victoria catchment. An assessment of 13 agricultural developments in northern Australia found that, while the natural environments were challenging for agriculture, the most important factors determining the viability of developments were management, planning and finances (Ash et al., 2014). At the pre-feasibility stage, options that can be clearly identified as not being financially viable could be deprioritised. The expensive, more-detailed and project-specific agronomic, ecological, social, cultural and regulatory assessments could then focus on the more promising opportunities. This chapter aims to assist future planning and evaluation of investments in new irrigated agriculture developments by highlighting the types of projects that are more likely to be viable, and quantifying the costs, benefits and risks involved. It provides a generic information resource that is broadly applicable to a variety of irrigated agriculture development opportunities but does not examine any specific options in detail. The results are presented in a way that allows readers to identify the costs, risks, and farm productivity values specific to the project opportunities in which they are interested, to evaluate their likely financial viability. The information also provides a set of benchmarks for establishing realistic assumptions and the thresholds of financial performance required for water and farm developments, individually and in combination, to be financially viable.

This chapter builds on earlier material in Chapter 4 (assessing the viability of new irrigated agriculture opportunities in the Victoria catchment at the enterprise level) and in Chapter 5 (assessing the opportunities for developing water sources to support those farms). Section 6.3 provides information, within a financial analysis framework, for determining whether those farming options and water sources can be paired into viable developments. It presents the financial criteria that would have to be met for new farms to be able to cover the development costs. Section 6.3 highlights some key considerations for evaluating the costs and benefits of new publicly funded dams, including lessons learned from recent large dam projects in Australia.

Section 6.4 also provides indicative costs for some of the additional enabling infrastructure required (typically additional to the costs included in project CBAs). Finally, Section 6.5 explores the knock-on effects of any new irrigated development in the Victoria catchment, quantifying the regional economic impacts using regional input–output (I–O) analysis.

Rather than analysing the cost–benefit of specific irrigation scheme proposals, this chapter presents generic tables for evaluating multiple alternative development configurations, providing the threshold farm gross margins and water costs and pricing that would be required in order to cover infrastructure costs. These tables serve as tools that allow users to answer their own questions about agricultural land and water development. Examples of the questions that can be asked, and which tables provide the answers, are given in Table 6-1.

Table 6-1 Types of questions that users can answer using the tools in this chapter

For each question, the relevant table number is given, together with an example answer for a specific development scenario. More questions can be answered with each tool by swapping around the factors that are known and the factor being estimated. (All initial estimates assume farm performance is 100% in all years, i.e. before accounting for risks. See Table 6-3 for the supporting generalised assumptions.)

QUESTION (WITH EXAMPLE ANSWER)	RELEVANT TABLE
1) How much can various types of farms afford to pay per ML of water they use?	Table 6-4
A broadacre farm with a gross margin (GM) of $4000/ha and water consumption of 8 ML/ha could afford to pay $135/ML while achieving a 10% internal rate of return (IRR).	
2) How much would the operator of a large off-farm dam have to charge for water?	Table 6-6
If off-farm water infrastructure had a capital cost of $5000 for each ML/y supply capacity (yield) at the dam wall, the (public) water supplier would have to charge $537 for each ML to cover its costs (at a 7% target IRR).	
3) For an on-farm dam with a known development cost, what is the equivalent $/ML price of water?	Table 6-8
If a farm dam had a capital development cost of $1500 for each ML/y supply capacity (yield), water could be purchasable at a cost of $190 for each ML (at a 10% target IRR).	
4) (a) What farm GM would be required to fully cover the costs of an off-farm dam? **(b) What proportion of the costs of off-farm water infrastructure could farms cover?**	Table 6-5
If off-farm infrastructure had a capital cost of $50,000/ha to build, broadacre farms would need to generate a GM of $5701/ha in order to fully cover the water supplier costs (while meeting a target 7% IRR for the water supplier (public investor) and a 10% IRR for the irrigator (private investor)). With the same target IRRs, a broadacre farm with a GM of $4000/ha could contribute the equivalent of $20,000 to $30,000 per ha towards the capital costs of building the same $50,000/ha dam (~50% of the full costs of building and operating that infrastructure).	
5) What GM would be required in order to cover the costs of developing a new farm, including a dam or bores?	Table 6-7
A horticultural farm with low overheads ($1500/ha) that cost $40,000/ha to develop (e.g. $30,000/ha to establish the farm and $10,000/ha to build the on-farm water supply for irrigating it) would require a GM of $6702/ha to attain a 10% IRR.	
6) How would risks associated with water reliability affect the farm GMs above?	Table 6-9
If an on-farm dam could fully irrigate the farm in 70% of years and could irrigate 50% of the farm in the remaining years, all farm GMs in the answers above would need to be multiplied by 1.18 (i.e. would be 18% higher), and the price irrigators could afford to pay for water would need to be divided by 1.18. For example, in Q4, the GM required in order to cover the costs of the farm development would increase from $5825/ha to $6874/ha after accounting for the risks of water reliability.	

QUESTION (WITH EXAMPLE ANSWER)	RELEVANT TABLE
7) How would the risks associated with 'learning' (initial farm underperformance) affect estimates?	Table 6-11
If a farm with a 10% target IRR achieved a GM that was 50% of its full potential in the first year, and gradually improved to achieve its full potential over 10 years, then the GMs above would need to be multiplied by a factor of 1.26 (i.e. would be 26% higher). For example, in Q6, the required farm GM would increase to $8661/ha after accounting for the risks of both water reliability and learning (a combined 49% higher than the value before accounting for risks).	

6.3 Balancing scheme-scale costs and benefits

Designing a new irrigation development in the Victoria catchment would require balancing three key determinants of irrigation scheme financial performance to find combinations that might collectively constitute a viable investment. The determinants are:

- farm financial performance (relative to development costs and water use) (Chapter 4)
- capital cost of development, for both water resources and farms (Chapter 5 and Section 6.3.1)
- risks (and the associated required level of investment return) (Section 6.3.5).

The determinants considered have been limited to those with greater certainty and/or lower sensitivity, so that the results can be applied to a wide range of potential developments.

A key finding of the irrigation scheme financial analyses is that no single factor within the above list is likely to be able to provide a silver bullet for meeting the substantial challenge of designing a commercially viable new irrigation scheme. Balancing the benefits to meet costs in order to identify viable investments would likely require contributions from each of the above factors and careful selection to piece together a workable combination. This section provides background information on the analysis approach used, to help readers understand how these factors influence irrigation scheme financial performance.

6.3.1 Approach and terminology

Scheme financial evaluations use a discounted cashflow framework to evaluate the commercial viability of irrigation developments. The framework, detailed in the companion technical report on agricultural viability and socio-economics (Webster et al., 2024), is intended to provide a purely financial evaluation of the conditions required to produce an acceptable return from an investor's perspective. It is not a full economic evaluation of the costs and benefits to other industries, nor does it consider 'unpriced' impacts that are not the subject of normal market transactions, or the equity of how costs and benefits are distributed. For the discussion that follows, the costs and benefits of an irrigation scheme were taken to include all those from the development of the land and water resources to the point of sale for farm produce.

This section explains the terminology and standard assumptions used.

A 'discounted cashflow analysis' considers the lifetime of costs and benefits following capital investment in a new project. Costs and benefits that occur at various times are expressed in constant real dollars (December 2023 Australian dollars), with a discount rate being applied to streams of costs and benefits.

The ‘discount rate’ is the percentage by which future costs and benefits are discounted each year (compounded) to convert them to their equivalent present value.

For an entire project, the ‘net present value’ (NPV) can be calculated by subtracting the present value of the stream of all costs from the present value of the stream of all benefits. The ‘benefit to cost ratio’ (BCR) of a project is the present value of all the benefits of a project divided by the present value of all the costs involved in achieving those benefits. To be commercially viable (at the nominated discount rate), a project would require an NPV that is greater than zero (in which case the BCR would be greater than one).

The IRR is the discount rate at which the NPV is zero (and the BCR is one). For a project to be considered commercially viable, it needs to meet its target IRR, and the NPV has to be greater than zero at a discount rate appropriate to the risk profile of the development and alternative investment opportunities available to investors. A target IRR of 7% is typically used when evaluating large public investments (with the sensitivity analysis set at 3% and 10%) (Infrastructure Australia, 2021b). Private agricultural developers usually target an IRR of 10% or more (to compensate for the investment risks involved). A back-calculation approach is used in the tables below to present the threshold GMs and water prices that would be required in order for investors to achieve specified target IRRs (the NPV would be equivalent to zero at these discount rates).

The ‘project evaluation periods’ used in this chapter matched the ‘life spans’ of the main infrastructure assets: 100 years for large off-farm dams and 40 years for on-farm developments. To simplify the tracking of asset replacements, four categories of life spans were used: 15 and 40 years for farms and 25 and 100 years for off-farm infrastructure. It was assumed that the shorter-life-span assets would be replaced at the end of their life, and that costs would have been accounted for in full by the actual year of their replacement. At the end of the evaluation period, a ‘residual value’ was calculated to account for any shorter-life-span assets that have not reached the end of their working life. Residual values were calculated as the proportional asset life remaining multiplied by the original asset price.

The ‘capital costs’ of infrastructure were assumed to be the costs at completion (accounted for in full in the year of delivery), such that the assets commenced operations the following year. In some cases, the costs of developing the farmland and setting up the buildings and equipment were considered separately from the costs of the water source, so that various water source options could be compared on a like-for-like basis. Where an off-farm water source was used, the separate investor in that water source would receive payments for water at a price that the irrigator could afford to pay.

The main ‘costs for operating’ a large dam and the associated water distribution infrastructure are (i) fixed costs for administering and maintaining the infrastructure, expressed here as percentage of the original capital cost, and (ii) variable costs associated with pumping water into distribution channels.

At the farm scale, fixed overhead costs are incurred each year, whether or not a crop is planted in a particular field that year. ‘Fixed costs’ are dominated by the fixed component of labour costs, but also include maintenance, insurance, professional services, and registrations. An additional allowance is made for annual operation and maintenance (O&M), budgeted at 1% of the original capital value of all assets (with an additional variable component in maintenance costs when machinery is used for cropping operations).

A 'farm annual gross margin' (GM) is the difference between the gross income from crop sales and variable costs of growing a crop each year. 'Net farm revenue' is calculated by subtracting the fixed overhead costs from the GM. 'Variable costs' vary in proportion to the area of land planted, the amount of crop harvested and/or the amount of water and other inputs applied. Farm GMs can vary substantially within and between locations, as described in Chapter 4. The GMs presented here are the values obtained before subtracting the variable costs of supplying water to farms; these water supply costs are, instead, accounted for in the capital costs of developing water resources. (The equivalent unit costs of supplying each ML of water are presented separately below.)

The CBA analyses first considered the case of irrigation schemes built around public investment in a large off-farm dam in the Victoria catchment and then considered the case developments using on-farm dams and bores.

Cost and benefit streams, totalled across the scheme, were tracked in separate components, allowing for both on-farm and off-farm sources of new water development. For farms, these streams were: (i) the capital costs of land development, farm buildings and equipment (including replacement costs and residual values), (ii) the fixed overhead costs, applied to the full area of developed farmland, and (iii) the total farm GM (across all farms in the scheme), applied to the mean proportion of land in production each year. If an 'on-farm water source' was being considered, then those costs were added to the farm costs. Farm developers were treated as private investors who would seek a commercial return.

When an 'off-farm water source' (large dam >25 GL/year) was evaluated, its investor was treated as a separate public investor to whom payment was made by farmers for water supplied (which served as an additional stream of costs for farmers, and a stream of benefits for the water supplier, at their respective target IRRs). For the public off-farm developer, the streams of costs were: (i) the capital costs of developing the water and associated enabling infrastructure (including replacement costs and residual values), and (ii) the costs of maintaining and operating those assets.

Threshold gross margins and water pricing to achieve target internal rate of return

New irrigation schemes in the Victoria catchment would be costly to develop, so many technically feasible options are unlikely to be profitable at the returns and over the time periods expected by many investors. The results presented below suggest it would be difficult for any farming options to fully cover the costs of a large off-farm dam development. However, there is greater prospect of viable developments using on-farm sources of water for broadacre and cost-efficient horticulture.

The costs of developing water and land resources for a new irrigation development vary widely, depending on a range of case-specific factors that are dealt with in other parts of this Assessment. These factors include the type and nature of the water source, the type of water storage, geology, topography, soil characteristics, water distribution system, type of irrigation system, type of crop to be grown, local climate, land preparation requirements, and level to which infrastructure is engineered.

The financial analyses, therefore, have used a generic approach for exploring the consequences for the development costs of this variation, and other key factors that determine whether or not an irrigation scheme would be viable (e.g. farm performance and the level of returns sought by investors). The analyses used the discounted cashflow framework described above to back-calculate and fit the water prices and farm GMs that would be required for respective public (off-farm) and private investors (irrigators) to achieve their target IRRs. The results are summarised in tables showing the thresholds that must be met for a particular combination of water development and farm development options to meet the investor's target returns. The tables allow viable pairings to be identified based on either threshold costs of water or required farm GMs. Financial viability for these threshold values was defined and calculated as investors achieving their target IRR (or, equivalently, that the investment would have an NPV of zero and a BCR of one at the target discount rate).

Assumptions

Analyses first considered the case of irrigation schemes built around public investment in a large off-farm dam in the Victoria catchment. The analyses then considered the case of developments using on-farm dams and bores. To keep the results as relevant as possible to a wide range of different development options and configurations, the analyses here do not assume the scale at which a water development would be undertaken. Instead, all costs are expressed per hectare of irrigated farmland and per ML per year of water supply capacity, facilitating comparisons between scenarios (which can differ substantially in size). To illustrate how this slightly abstract generic approach can be applied to specific development projects, a worked example shows the indicative off-farm infrastructure costs that would be involved in development of a representative dam site in the Victoria catchment (Table 6-2).

Table 6-2 Indicative capital costs for developing a representative irrigation scheme in the Victoria catchment

The dam costings already allow for a road; an indicative allowance has been added for a bitumen road to the irrigation development from the Victoria Highway, a transmission line from Kununurra, and electricity distribution lines to which farms can connect.

ITEM	LEICHHARDT CREEK COST ($)
Capital costs	
Dam	396,000,000
Weir	15,000,000
Reticulation	15,000,000
Roads and electricity	150,000,000
Total	~575,000,000
Summary metrics	
Irrigated area (ha)	6,900
Cost per hectare (~$/ha)	80,000

Source: Dam and weir costings are based on data from the companion technical report on surface water storage for the Victoria catchment (Yang et al., 2024), and reticulation costings based on a per hectare rate from Devlin (2024) and include contingencies; see those reports for full details of cost breakdowns and assumptions

To enhance like-for-like comparisons across the various development scenarios, a set of standard assumptions have been made about the breakdown of development costs (by life span) and associated ongoing operating costs (Table 6-3). Three indicative types of farming enterprise represent different levels of capital investment, associated with the intensity of production and the extent to which farming operations are performed on-farm or outsourced (Table 6-3). The capital costs and fixed costs are higher for horticulture than for broadacre farming, but the more expensive irrigation systems used (such as drippers) apply water more precisely and efficiently to crops. The indicative 'Broadacre' farm could, for example, represent hay or cotton farming using furrow irrigation on heavier clay soils. The indicative capital-intensive 'Horticulture-H' farm could, for example, represent high-value fruit-tree orchards with high standard on-farm packing and cold room facilities and include accommodation for seasonal workers travelling to very remote Victoria catchment farms. The indicative less-capital-intensive 'Horticulture-L' farm option could, for example, represent a row crop, such as melons, with packing directly to bins and use of off-farm accommodation for seasonal workers (which reduces the upfront capital cost of establishing the farm, but increases ongoing costs for outsourced services, which reduces farm GMs).

Table 6-3 Assumed indicative capital and operating costs for new off- and on-farm irrigation infrastructure

Three types of farming enterprise represent a range of increasing intensity, value and cost of production. Indicative base capital costs for establishing new farms (excluding water costs) allow on- and off-farm water sources to be added and compared on an equal basis. Annual operation and maintenance (O&M) costs are expressed as a percentage of the capital costs of assets. The Horticulture-H farm, with higher development costs, includes on-farm packing facilities, cold storage, and accommodation for seasonal workers. The Horticulture-L farm, with lower development costs, does not include these assets and would have to outsource these services if required (reducing the farm gross margin). IRR = internal rate of return.

SCHEME COMPONENT	ITEM	VALUE			UNIT	O&M COST (% capital cost/y)
Off-farm infrastructure development capital and operating costs (large dam and enabling infrastructure)						
Capital costs	Total capital costs (split by life span below)	Indicative >50,000 (analysed range: 20,000–150,000)			$/ha	
	Longer-life-span infrastructure (100 y)		85		%	0.4
	Shorter-life-span infrastructure (40 y)		15		%	1.6
Operating	O&M (by life-span categories)	% capital cost			$/ha/y	
	Off-farm water source pumping costs	~2 (additional)			$/ML/	
Target IRR	Base (with sensitivity range)		7		%	
Farm development capital and operating costs		**Broadacre**	**Horticulture-L (low capital)**	**Horticulture-H (high capital)**		
Capital costs	Base (excluding water source)	9000	25,000	70,000	$/ha	
	Water source (on- or off-farm)	Indicative >4000 (analysed range: 3000 to 15,000)			$/ha	
	Longer-life-span infrastructure (40 y)	50	50	50	%	1.0
	Shorter-life-span infrastructure (15 y)	50	50	50	%	1.0
Operating	O&M (by life-span categories)	% capital cost			$/ha/y	
	Farm water source pumping costs	~2 (additional)			$/ML/	
	Fixed costs	600	1,500	6,500	$/ha/y	
Water use	Crop water use (before losses)	6	6	6	ML/ha	
	On-farm water use efficiency	70	90	90	%	
Gross margin	Indicative gross margin	4,000	7,000	11,000	$/ha/y	
Target IRR	Base (with sensitivity range)	10	10	10	%	

For consistency, all costs of delivering water to the farm at the level of the soil surface are treated as the costs of the water source (so the costs of the various water source options can be compared on a like-for-like basis). Subsequent farm pumping costs of distributing and applying the supplied water to crops are treated as part of the variable costs of growing crops and are already accounted for in the crop GMs presented in Chapter 4. The pumping costs for the water supplier are highly situation-specific for the various water sources. In particular, these pumping costs are affected by the elevation of the water source relative to the point of distribution to the farm: for example, the height water needs to be pumped from a weir to a distribution channel, or from a farm dam to a field; or the dynamic head required to lift bore water to the field surface. For this reason, water source pumping costs have not been included in the summary tables of water pricing, but should be added separately as required at a cost of approximately $2 per ML per m dynamic head. This is mainly a consideration for groundwater bores, but also applies when water needs to be lifted from rivers or irrigation channels. For more information on water infrastructure costs, see Chapter 5 (and the companion technical reports referenced there). For more information on crop GMs, see Chapter 4 (and the companion technical reports referenced there).

The analyses presented below consider (i) the case of irrigation schemes built around a large dam and its associated supporting off-farm infrastructure (Section 6.3.3); (ii) the case of self-contained, modular farm developments with their own on-farm source of water (Section 6.3.4). For both cases, the water price that irrigators can afford to pay provides a useful common point of reference for identifying suitable water sources for various types of farm developments (Section 6.3.2). The initial analyses assumed that all farmland was in full production and performed at 100% of its potential (and assumed 100% reliable water supplies) from the start of the development. Section 6.3.5 provides a set of adjustment factors that quantify the risks of various sources of underperformance that can be anticipated.

6.3.2 Price irrigators can afford to pay for a new water source

Table 6-4 shows the price that the three different types of farms could afford to pay for water, while meeting a target 10% IRR, for different levels of farm water use and productivity. For prices to be sustained at this level throughout the life of the water source, the associated farm GM (in the first column of Table 6-4) would also need to be maintained over this period. The table is therefore most useful when assessing the long-term price that can be sustained to pay off long-lived water infrastructure (rather than temporary spikes in farm GMs during runs of favourable years).

The lowest GM in the first column of Table 6-4 for each farm is the value below which the farm would not be viable, even if water was free. This does not necessarily mean that such GMs could readily be achieved in practice: for the capital-intensive Horticulture-H farm, in particular, it would be challenging in the Victoria catchment to reach the $17,000 per ha per year GM to cover the farm’s other costs, even before considering the costs of water.

These water prices are likely to be most useful for public investors in large dams, because the sequencing of development creates asymmetric risks between the water supplier and the irrigators. Irrespective of the planned water pricing for a dam project, once the dam is built, irrigators have the choice of whether to develop new farms; they are unlikely to act to their own detriment by making an investment if they cannot do so at a water price that will allow them to obtain a commercial rate of return. These water prices, together with estimates of likely attainable farm GMs (available in Chapter 4), provide a useful benchmark for checking assumptions about any potential public dam developments in the Victoria catchment.

For on-farm water sources, these water prices can assist in planning water development options that cropping operations could reasonably be expected to afford. The tables in the next sections allow comparisons of water development options by converting capital costs of developing on- and off-farm water sources to volumetric costs ($ per ML supplied). All water prices are based on volumes supplied to the farm gate or surface (after losses in transit) per metered ML supplied.

Table 6-4 Price irrigators can afford to pay for water, based on the type of farm, the farm water use and the farm annual gross margin (GM), while meeting a target 10% internal rate of return (IRR)

Analyses assume water volumes are measured on delivery to the farm gate or surface: pumping costs involved in getting water to the farmland surface would be an additional cost of supplying the water (indicatively $2 per ML per m dynamic head), while pumping costs in distributing and applying the water to the crop are considered part of the variable costs included in the GM. Indicative GMs that the three types of farms could attain in the Victoria catchment are $4000 and $7000 per ha per year for Broadacre and Horticulture-L farms, respectively (blue-shaded rows), and $11,000 per ha per year for Horticulture-H (Table 6-3, Chapter 4). Note that the Horticulture-H farm cannot pay anything for water until it achieves a GM above $17,000 per ha per year.

GROSS MARGIN ($/ha/y)	PRICE IRRIGATORS CAN AFFORD TO PAY ($/ML at farm gate/surface)							
	Farm water use (ML/ha including on-farm distribution and application losses)							
	4	**5**	**6**	**7**	**8**	**9**	**10**	**12**
	Broadacre ($9,000/ha development costs, $600/ha/y fixed costs, 70% on-farm efficiency)							
2,000	25	20	17	14	12	11	10	8
2,500	86	69	57	49	43	38	34	29
3,000	147	118	98	84	74	65	59	49
3,500	209	167	139	119	104	93	83	70
4,000	270	216	180	154	135	120	108	90
5,000	392	314	262	224	196	174	157	131
	Horticulture-L ($25,000/ha development costs, $1,500/ha/y fixed costs, 90% on-farm efficiency)							
5,000	39	31	26	22	19	17	16	13
6,000	241	193	161	138	121	107	97	80
7,000	444	355	296	254	222	197	178	148
8,000	646	517	431	369	323	287	259	215
10,000	1051	841	701	601	526	467	421	350
12,000	1456	1165	971	832	728	647	583	485
	Horticulture-H ($70,000/ha development costs, $6,500/ha/y fixed costs, 90% on-farm efficiency)							
17,000	203	162	135	116	101	90	81	68
20,000	810	648	540	463	405	360	324	270
25,000	1823	1458	1215	1042	911	810	729	608
30,000	2835	2268	1890	1620	1418	1260	1134	945
40,000	4860	3888	3240	2777	2430	2160	1944	1620
50,000	6885	5508	4590	3934	3443	3060	2754	2295

6.3.3 Financial targets required to cover full costs of large, off-farm dams

The first generic assessment considered the case of public investment in a large dam in the Victoria catchment and whether the costs of that development could be covered by water payments from irrigators (priced at their capacity to pay). The public costs of development include the cost of the dam and water distribution, and of any other supporting infrastructure required. Costs are standardised per unit of farmland developed, noting that a smaller area could be developed for a crop with a higher water use (so the water development costs per hectare would be higher).

Target farm gross margins for off-farm public water infrastructure

shows what farm annual GM would be required for various costs of water infrastructure development at the public investors' target IRR. As expected, higher farm GMs are required in order to cover higher capital costs and attain a higher target IRR. The tables in this section can be used to assess whether water development opportunities and farming opportunities in the Victoria catchment are likely to combine in financially viable ways. Indicative farm GMs that could be achieved in the Victoria catchment are approximately $4000, $7000 and $11,000 per ha per year for Broadacre, less-capital-intensive Horticulture-L (including penalising GMs if outsourcing occurs) and capital-intensive Horticulture-H, respectively (Table 6-3). A dam and supporting infrastructure would likely require at least $50,000/ha of capital investment (Table 6-2). None of the three farming types is likely to be viable at these farm GMs and water development costs (at a 7% target IRR for the public investor). However, Broadacre and Horticulture-L farming might be marginally viable at a 3% target IRR for the public investor. Broadacre and lower-cost Horticulture-L could both achieve a target 10% IRR for the farm investments while contributing $20,000 to $30,000 per ha (25%–38%) towards the cost of a dam (including enabling infrastructure and ongoing O&M costs) that cost $80,000/ha to build. That is a higher proportion of costs than irrigators have historically contributed towards irrigation schemes in some other parts of Australia (approximately a quarter of capital costs (Vanderbyl, 2021)), and would involve a decision for the Australian and NT governments in accordance with their expectations, priorities and investment criteria.

Table 6-5 Farm gross margins (GMs) required in order to cover the costs of off-farm water infrastructure (at the supplier's target internal rate of return (IRR))

Assumes 100% farm performance on all farmland in all years, once construction is complete. Costs of supplying water to farms are consistently treated as costs of water source development (and not part of the farm GM calculation). Risk adjustment multipliers are provided in Section 6.3.5. Blue-shaded cells indicate the capital costs that could be afforded by farms with GMs of $4000 (Broadacre), $7000 (Horticulture-L) and $11,000 (Horticulture-H) per ha per year. Blue-shaded column headers indicate the most cost-effective dam development options in the Victoria catchment (Table 6-2).

TARGET IRR (%)	FARM GROSS MARGIN REQUIRED IN ORDER TO PAY FOR OFF-FARM WATER INFRASTRUCTURE ($/ha/y)							
	Total capital costs of off-farm water infrastructure ($/ha)							
	20,000	**30,000**	**40,000**	**50,000**	**70,000**	**100,000**	**125,000**	**150,000**
	Broadacre ($9,000/ha development costs, $600/ha/y fixed costs, 70% on-farm efficiency)							
3	2,604	3,016	3,428	3,840	4,664	5,900	6,930	7,960
5	2,977	3,569	4,160	4,751	5,933	7,707	9,185	10,663
7	3,359	4,139	4,920	5,701	7,263	9,605	11,558	13,510
10	3,941	5,013	6,085	7,157	9,301	12,516	15,196	17,876
12	4,333	5,601	6,869	8,137	10,673	14,478	17,648	20,818
	Horticulture-L ($25,000/ha development costs, $1,500/ha/y fixed costs, 90% on-farm efficiency)							
3	5,584	5,996	6,408	6,820	7,645	8,881	9,911	10,941
5	5,985	6,576	7,167	7,759	8,941	10,715	12,193	13,671
7	6,370	7,150	7,931	8,712	10,274	12,616	14,569	16,521
10	6,952	8,024	9,096	10,168	12,312	15,528	18,208	20,887
12	7,345	8,613	9,881	11,149	13,685	17,489	20,659	23,829
	Horticulture-H ($70,000/ha development costs, $6,500/ha/y fixed costs, 90% on-farm efficiency)							
3	16,618	17,068	17,518	17,967	18,867	20,217	21,342	22,467
5	17,164	17,789	18,413	19,038	20,288	22,162	23,724	25,286
7	17,610	18,416	19,222	20,027	21,638	24,055	26,070	28,084
10	18,215	19,301	20,387	21,472	23,644	26,901	29,615	32,330
12	18,607	19,884	21,161	22,438	24,992	28,823	32,015	35,207

Target water pricing for off-farm public water infrastructure

Table 6-6 shows the price that a public investor in off-farm water infrastructure would have to charge to fully cover the costs of development of off-farm water infrastructure, expressed per unit of supply capacity at the dam wall. Pricing assumes that the full supply of water (i.e. reservoir yield) would be used and paid for every year over the entire lifetime of the dam, after accounting for water losses between the dam and the farm. It can be challenging for farms to sustain the high levels of revenue over such long periods (100 years) to justify the costs of building expensive dams. For these base analyses, the water supply is assumed to be 100% reliable; risk adjustment multipliers to account for reliability of supply are provided in Section 6.3.5.

For example, in the Victoria catchment, one of the most cost-effective dam opportunities would cost approximately $9,000 per ML per year of supply capacity at the dam wall after including the required supporting off-farm water infrastructure (Table 6-2). This would require farms to pay $966 per ML extracted to fully cover the costs of the public investment at the base 7% target IRR for public investments (read from value between 8,000 and 10,000 in Table 6-6). Comparisons with what irrigators can afford to pay (Table 6-4) show that it is unlikely any farming options could cover the costs of a dam in the Victoria catchment at the GMs farms are likely to be able to achieve (Table 6-3, Chapter 4). When a scheme is not viable (BCR < 1), the water cost and pricing tables can be used as a quick way of estimating the BCR and the likely proportion of public development costs that farms would be able to cover. For example, a Broadacre farm that uses 8 ML/ha (measured at delivery to the farm) with a GM of $4000 per ha per year could afford to pay $135/ML extracted (Table 6-4), which would cover 13% ($135/$966) of the $966/ML price (Table 6-6) required to cover the full costs of the public development. The BCR would, therefore, be 0.13 (the ratio of the amount the net farm benefits can cover to the full costs of the scheme). As for the example in Table 6-5, it would be a decision for the public investor as to what proportion of the capital costs of infrastructure projects they would realistically expect to recover from users.

Table 6-6 Water pricing required in order to cover costs of off-farm irrigation scheme development (dam, water distribution, and supporting infrastructure) at the investors target internal rate of return (IRR)

Assumes the conveyance efficiency from dam to farm is 70% and that supply is 100% reliable. Risk adjustment multipliers for water supply reliability are provided in Table 6-9. Pumping costs between the dam and the farm would need to be added (e.g. ~$30/ML extra to lift water ~15 m from the weir pool to distribution channels). '$ CapEx per ML/y at dam' is the capital expenditure on developing the dam and supporting off-farm infrastructure per ML per year of the dam's supply capacity measured at the dam wall. Blue-shaded cells indicate $/ML cost of water. Blue-shaded column headers are indicative of the most cost-effective large dam options available in the Victoria catchment (Table 6-2).

TARGET IRR (%)	WATER PRICE THAT WOULD NEED TO BE CHARGED IN ORDER TO COVER OFF-FARM INFRASTRUCTURE COSTS ($/ML charged at farm gate)								
	Capital costs of off-farm infrastructure ($ CapEx per ML/y at dam)								
	3,000	**4,000**	**5,000**	**6,000**	**8,000**	**10,000**	**12,000**	**14,000**	**16,000**
3	162	215	269	323	431	538	646	754	861
5	239	319	399	479	638	798	958	1117	1277
7	322	429	537	644	859	1073	1288	1502	1717
10	448	598	747	897	1196	1495	1794	2093	2392

6.3.4 Financial targets required in order to cover costs of on-farm dams and bores

The second generic assessments considered the case of on-farm sources of water. Indicative costs for on-farm water sources, including supporting on-farm distribution infrastructure, vary between $4,000 and $15,000 per ha of farmland. Costs depend on the type of water source, how favourable the local conditions are for its development, and the irrigation requirement of the farming system. Since the farm and water source would be developed by a single investor, the first analyses considered the combined cost of all farm development together (without separating out the water component).

Target farm gross margins required in order to cover full costs of greenfield farm development with water source

Table 6-7 shows the farm GMs that would be required in order to cover different costs of farm development at the investor's target IRR. Note that private on-farm water sources are typically engineered to a lower standard than public water infrastructure and have lower upfront capital costs, higher recurrent costs (higher O&M and asset replacement rates) and lower reliability. Based on the indicative farm GMs provided earlier (Table 6-3) and a 10% target IRR, a Broadacre farm with a $4000 per ha per year GM could cover total on-farm development capital costs of approximately $20,000/ha. A lower capital cost Horticulture-L farm with a GM of $7000 per ha per year could afford approximately $40,000/ha of initial capital costs, and a capital-intensive Horticulture-H farm with a GM of $11,000 per ha per year could pay approximately $30,000/ha for farm development (Table 6-7). This indicates that on-farm water sources may have better prospects of being viable than large public dams in the Victoria catchment, particularly for broadacre farms and horticulture with lower development costs, if good sites can be identified for developing sufficient on-farm water resources at a low-enough cost.

Table 6-7 Farm gross margins (GMs) required in order to achieve target internal rates of return (IRR), given various capital costs of farm development (including an on-farm water source)

Assumes 100% farm performance on all farmland in all years, once construction is complete. Risk adjustment multipliers are provided in Section 6.3.5. Blue-shaded cells indicate the capital costs that could be afforded by farms with GMs of $4000 (Broadacre), $7000 (Horticulture-L) and $11,000 (Horticulture-H) per ha per year.

TARGET IRR (%)	FARM GROSS MARGIN REQUIRED IN ORDER TO ACHIEVE THE FARMER'S TARGET IRR ($/ha/y)							
	Total capital costs of farm development, including water source ($ CapEx/ha)							
	10,000	15,000	20,000	30,000	40,000	50,000	70,000	100,000
	Broadacre ($600/ha/y fixed costs, 70% on-farm efficiency)							
5	1,516	1,957	2,398	3,279	4,160	5,042	6,804	9,449
7	1,669	2,181	2,694	3,718	4,742	5,767	7,815	10,888
10	1,923	2,554	3,185	4,447	5,709	6,972	9,496	13,282
12	2,105	2,821	3,537	4,968	6,400	7,832	10,696	14,991
15	2,389	3,238	4,087	5,785	7,483	9,181	12,578	17,672
20	2,882	3,963	5,044	7,206	9,368	11,530	15,854	22,340

TARGET IRR (%)	FARM GROSS MARGIN REQUIRED IN ORDER TO ACHIEVE THE FARMER'S TARGET IRR ($/ha/y)							
	Total capital costs of farm development, including water source ($ CapEx/ha)							
	10,000	**15,000**	**20,000**	**30,000**	**40,000**	**50,000**	**70,000**	**100,000**
	Horticulture-L ($1,500/ha/y fixed costs, 90% on-farm efficiency)							
5	2,469	2,909	3,350	4,231	5,113	5,994	7,757	10,401
7	2,637	3,149	3,661	4,685	5,710	6,734	8,783	11,856
10	2,915	3,546	4,177	5,439	6,702	7,964	10,488	14,274
12	3,114	3,830	4,546	5,978	7,409	8,841	11,705	16,001
15	3,424	4,273	5,122	6,820	8,519	10,217	13,613	18,708
20	3,962	5,043	6,124	8,286	10,448	12,610	16,934	23,420
	Horticulture-H ($6,500/ha/y fixed costs, 90% on-farm efficiency)							
5	7,760	8,201	8,642	9,523	10,404	11,286	13,048	15,692
7	8,012	8,524	9,036	10,060	11,085	12,109	14,158	17,231
10	8,427	9,058	9,689	10,951	12,213	13,475	15,999	19,785
12	8,720	9,436	10,152	11,584	13,016	14,448	17,312	21,607
15	9,177	10,026	10,875	12,573	14,271	15,970	19,366	24,461
20	9,963	11,044	12,125	14,287	16,449	18,611	22,935	29,421

Volumetric water cost equivalent for on-farm water source

Table 6-8 converts the capital cost of developing an on-farm water source (per ML of annual supply capacity) into an equivalent cost for each individual megalitre of water supplied by the water source. The table can be used to estimate how much a farm could spend on developing required water resources by comparing the costs per ML with what farms can afford to pay for water (Table 6-4). For example, a Broadacre farm with a GM of $4000 per ha per year, an annual farm water use of 8 ML/ha and a target 10% IRR could afford to pay $135/ML for its water supply (Table 6-4), which would allow capital costs of up to $1000 for each ML/year supply capacity for developing an on-farm supply (Table 6-8). Approximate indicative costs for developing on-farm water sources range from $500/ML to $2000/ML (based on the range of per hectare costs above), which confirms, by this alternative approach, that there are likely to be viable farming opportunities using on-farm water development in the Victoria catchment.

Table 6-8 Equivalent costs of water per ML for on-farm water sources with various capital costs of development, at the internal rate of return (IRR) targeted by the investor

Assumes the water supply is 100% reliable. Risk adjustment multipliers for water supply reliability are provided in Table 6-9. Pumping costs to the field surface would be extra (e.g. ~$2 per ML per m dynamic head for bore pumping). Blue-shaded cells indicate $/ML cost of water.

TARGET IRR (%)	WATER VOLUMETRIC COST EQUIVALENT UNIT FOR VARIOUS CAPITAL COSTS OF WATER SOURCE ($/ML)								
	Capital costs for on-farm water infrastructure ($ CapEx per ML per y at farmland surface)								
	300	**400**	**500**	**700**	**1000**	**1250**	**1500**	**1750**	**2000**
3	22	29	37	51	74	92	110	129	147
5	26	35	44	61	87	109	131	153	175
7	31	41	51	72	102	128	154	179	205
10	38	51	63	89	127	159	190	222	254
12	43	58	72	101	144	180	216	252	288
15	51	68	85	120	171	213	256	299	342
20	65	87	109	152	217	271	326	380	434

6.3.5 Risks associated with variability in farm performance

This section assessed the impacts of two types of risks on scheme financial performance: those that reduce farm performance through the early establishment and learning years, and those occurring periodically throughout the life of the development. The effect of these risks is to reduce the expected revenue and expected GM.

Setbacks that occur soon after a scheme is established were found to have the largest effect on scheme viability, particularly at higher target IRRs. There is a strong incentive to start any new irrigation development with well-established crops and technologies, and to be thoroughly prepared for those agronomic risks of establishing new farmland that can be anticipated. Analyses showed that delaying full development for longer periods than the learning time had only a slight negative effect on IRRs, whereas proceeding to full development before learning was complete had a much larger impact. This implies that it is prudent to err on the side of delaying full development (particularly given that, in practice, it is only possible to know when full performance has been achieved in retrospect). An added benefit of staging is the limiting of losses when small-scale testing proves initial assumptions of benefits to be overoptimistic and that full-scale development could never be profitable (even after attempts to overcome unanticipated challenges).

For an investment to be viable, farm GMs must be sustained at high levels over long periods. Thus, variability in farm performance poses risks that must be considered and managed. GMs can vary between years because of either short-term initial underperformance or periodic shocks. Initial underperformance is likely to be associated with learning as farming practices are adapted to local conditions, overcoming initial challenges to reach their long-term potential. Further unavoidable periodic risks are associated with water reliability, climate variability, flooding, outbreaks of pests and diseases, periodic technical or equipment failures, and fluctuations in commodity prices and market access. Unreliability of water supply is less easy to avoid than other periodic risks. Risks that cannot be avoided must be managed, mitigated where possible and accounted for in determining the realistic returns that can be expected from an irrigation development. This would include having adequate capital buffers for survival through challenging periods. Another perceived risk for investors is the potential future policy changes and delays in regulatory approvals. Reducing this, or any other sources of risk, in the Victoria catchment would help make marginal investment opportunities more attractive.

The results of the analyses of both the periodic and the learning risks are shown below. The right to farm and other sovereignty risks, especially with regard to access to water, may become key factors in future years, based on experience from elsewhere, but these are not the subject of the risk discussion presented here.

Throughout this section, farm performance in a given year is quantified as the proportion of the long-term mean GM that a farm attains; 100% performance is when this level is reached and zero % equates to a performance in which revenues only balance variable costs (GM = zero).

Risks from periodic underperformance

The analyses considered periodic risks generically, without assuming any of the particular causes listed above. To quantify their effects on scheme financial performance, periodic risks were characterised by three components:

- reliability – the proportion of 'good' years, in which the 'full' 100% farm performance was achieved, with the remainder of years being termed 'failed' years, in which some negative impact was experienced
- severity – the farm performance in a 'failed' year, in which some type of setback occurred
- timing – in 'early' timing (in relation to a 10-year cycle), the 'failed' years came early in each 10-year cycle (e.g. 80% reliability meant that 'failed' years occurred in the first 2 years of the scheme and in the first 2 years of each 10-year cycle after that). In 'late' timing, the 'failed' years came at the end of each 10-year cycle. In 'random' timing, each year was allocated the long-term mean farm performance of 'good' and 'failed' years (frequency weighted).

Table 6-9 summarises the effects of a range of reliabilities and severities for periodic risks on scheme viability. Periodic risks had a consistent proportional effect on target GMs, irrespective of development options or costs, so the results were simplified as a set of risk adjustment multipliers. The multipliers can, therefore, be applied to the target farm GMs in Section 6.3.2 (the GMs required in order to cover capital costs of development at the investor's target IRRs at 100% farm performance) to account for the effects of various risks. These same adjustment factors can be applied to the water prices that irrigators can afford to pay (Table 6-4), but would be used as divisors to reduce the price that irrigators could pay for water.

As expected, the greater the frequency and severity of 'failed' years, the greater the impact on the scheme viability and the greater the increase in farm GMs required in order to offset these impacts. As an example, the reliability of water supply is one of the more important sources of unavoidable variability in the productivity of irrigated farms. Water reliability (proportion of 'good' years, in which the full supply of water is available) is shown as 'reliability' in Table 6-9, and the mean percentage of water available in a 'failed' year (in which less than the full supply of water is available) is shown as the 'failed year performance' in Table 6-9 (assuming the area of farmland planted is reduced in proportion to the amount of water available). For example, if a water supply was 85% reliable and provided a mean of 75% of its full supply in 'failed' years, a risk adjustment factor of 1.04 (Table 6-9) would have to be applied to baseline target GMs (Table 6-5 and Table 6-7) and the prices irrigators can afford to pay for water (Table 6-4). This means that a 4% higher GM would be required in order to achieve a target IRR (and the irrigator's capacity to pay for water would be ~4% lower) than if water could be supplied at 100% reliability.

For crops for which the quality of the produce is more important than the quantity, such as horticulture, the approach of reducing planted land area in proportion to available water in 'failed' years would be reasonable. However, for perennial horticulture or tree crops, it may be difficult to reduce (or increase) areas on an annual basis. Farmers of these crops would, therefore, tend to opt for systems with a high degree of reliability of water supply (e.g. 95%). For many broadacre crops, deficit irrigation could partially mitigate impacts on farm performance in years with reduced water availability, as could carryover effects from inputs (such as fertiliser) in a 'failed' year that reduce input costs the following year (see Section 4.3.4).

Table 6-9 Risk adjustment factors for target farm gross margins (GMs), accounting for the effects of the reliability and severity (level of farm performance in 'failed' years) of the periodic risk of water reliability

Results are not affected by discount rates. 'Good' years = 100% farm performance; 'failed' years = <100% performance. 'Failed year performance' is the mean farm GM in years in which some type of setback is experienced relative to the mean GM when the farm is running at 'full' performance.

FAILED YEAR PERFORMANCE (%)	RISK ADJUSTMENT MULTIPLIER FOR TARGET FARM GROSS MARGINS (VS BASE 100% RELIABILITY TABLES) (unitless ratio)									
	Reliability (proportion of 'good' years)									
	1.00	**0.90**	**0.85**	**0.80**	**0.70**	**0.60**	**0.50**	**0.40**	**0.30**	**0.20**
85	1.00	1.02	1.02	1.03	1.05	1.06	1.08	1.10	1.12	1.14
75	1.00	1.03	1.04	1.05	1.08	1.11	1.14	1.18	1.21	1.25
50	1.00	1.05	1.08	1.11	1.18	1.25	1.33	1.43	1.54	1.67
25	1.00	1.08	1.13	1.18	1.29	1.43	1.60	1.82	2.11	2.50
0	1.00	1.11	1.18	1.25	1.43	1.67	2.00	2.50	3.33	5.00

Table 6-10 shows how the timing of periodic impacts affects scheme viability, providing risk adjustment factors for a range of reliabilities for an impact that had 50% severity, with late timing, early timing and random (long-term frequency, weighted mean performance) timing.

These results indicate that any negative disturbances that reduce farm performance will have a larger effect if they occur soon after the scheme is established, and that this effect is greater at higher target IRRs. For example, at a 7% target IRR and 70% reliability with 'late' timing (in which setbacks occur in the last 3 of every 10 years), the GM multiplier is 1.13, meaning the annual farm GM would need to be 13% higher than if farm performance were 100% reliable. In contrast, for the same settings with 'early' timing, the GM multiplier is 1.23, meaning the farm GM would need to be 23% higher than if farm performance were 100% reliable. The impacts of early setbacks are more severe than the impacts of late setbacks.

Table 6-10 Risk adjustment factors for target farm gross margins (GMs) accounting for the effects of reliability and the timing of periodic risks

Assumes 50% farm performance during 'failed' years, in which 50% farm performance means 50% of the GM at 'full' potential production. IRR = internal rate of return.

TARGET IRR (%)	TIMING OF FAILED YEARS	RISK ADJUSTMENT MULTIPLIER FOR TARGET FARM GROSS MARGINS (VS BASE 100% RELIABILITY TABLES) (unitless ratio)								
		Reliability (proportion of 'good' years)								
		1.00	**0.90**	**0.80**	**0.70**	**0.60**	**0.50**	**0.40**	**0.30**	**0.20**
3	**Late**	1.00	1.05	1.10	1.16	1.22	1.30	1.39	1.50	1.63
	Random – no bias	1.00	1.05	1.11	1.18	1.25	1.33	1.43	1.54	1.67
	Early	1.00	1.06	1.13	1.20	1.28	1.37	1.47	1.58	1.70
7	**Late**	1.00	1.04	1.08	1.13	1.19	1.26	1.35	1.46	1.59
	Random – no bias	1.00	1.05	1.11	1.18	1.25	1.33	1.43	1.54	1.67
	Early	1.00	1.07	1.15	1.23	1.32	1.41	1.51	1.62	1.74
10	**Late**	1.00	1.03	1.07	1.12	1.17	1.24	1.32	1.42	1.56
	Random – no bias	1.00	1.05	1.11	1.18	1.25	1.33	1.43	1.54	1.67
	Early	1.00	1.08	1.16	1.25	1.35	1.45	1.55	1.66	1.77

Risks from initial 'learning' period

Another form of risk arises from the initial challenges in establishing new agricultural industries in the Victoria catchment; it includes setbacks from delays, such as gaining regulatory approvals, and adapting farming practices to conditions in the Victoria catchment. Some of these risks are avoidable if investors and farmers learn from past experiences of development in northern Australia (e.g. Ash et al., 2014), avoid previous mistakes and select farming options that are already well proven in analogous northern Australian locations. However, even well-prepared developers are likely to face initial challenges in adapting to the unique circumstances of a new location. Newly developed farmland can take some time to reach its productive potential as soil nutrient pools are established, soil limitations are ameliorated, suckers and weeds are controlled, and pest and disease management systems are established.

'Learning' (used here to broadly represent all aspects of overcoming initial sources of farm underperformance) was assessed in terms of two simplified generic characteristics:

- initial level of performance – the proportion of the long-term mean GM that the farm achieves in its first year
- time to learn – the number of years taken to reach the long-term mean farm performance.

Performance was represented as increasing linearly over the learning period from the starting level to the long-term mean performance level (100%).

The effect of learning on scheme financial viability was considered for a range of initial levels of farm performance and learning times. As described above, learning had consistent proportional effects on target GMs, so the results were simplified as a set of risk adjustment factors (Table 6-11). As expected, the impacts on scheme viability are greater the lower the starting level of farm performance and the longer it takes to reach the long-term performance level. Since these impacts, by their nature, are weighted to the early years of a new development, they have more impact at higher target IRRs. To minimise the risks of learning impacts, there is a strong incentive to start any new irrigation development with well-established crops and technologies, and to be thoroughly prepared for those agronomic risks of establishing new farmland that can be anticipated. Higher-risk options (e.g. novel crops, equipment or practices that are not currently in profitable commercial use in analogous environments) could be tested and refined on a small scale until locally proven.

As indicated in the examples above, the influence of each risk individually can be quite modest. However, the combined influence of all foreseeable risks must be accounted for in planning, and the cumulative effect of these risks can be substantial. For example, the last question in Table 6-1 shows that the combined effect of just two risks requires farm GMs to be approximately 50% higher than they would be without the risks. See Stokes and Jarvis (2021) for the effects of a common suite of risks on the financial performance of a Bradfield-style irrigation scheme.

Table 6-11 Risk adjustment factors for target farm gross margins (GMs), accounting for the effects of learning risks

Learning risks were expressed as the level of initial farm underperformance and time taken to reach full performance levels. Initial farm performance is the initial GM as a percentage of the GM at 'full' performance. IRR = internal rate of return.

TARGET IRR (%)	INITIAL FARM PERFORMANCE (%)	RISK ADJUSTMENT MULTIPLIER FOR TARGET FARM GROSS MARGINS (VS BASE 100% RELIABILITY TABLES) (unitless ratio)					
		Learning time (years to 100% performance)					
		2	**4**	**6**	**8**	**10**	**15**
3	**85**	1.01	1.02	1.03	1.03	1.04	1.05
	75	1.02	1.03	1.04	1.05	1.07	1.10
	50	1.04	1.06	1.09	1.12	1.14	1.21
	25	1.06	1.10	1.14	1.19	1.23	1.35
	0	1.08	1.14	1.20	1.26	1.33	1.53
7	**85**	1.02	1.03	1.04	1.05	1.05	1.07
	75	1.03	1.05	1.06	1.08	1.09	1.13
	50	1.06	1.10	1.13	1.17	1.21	1.29
	25	1.09	1.15	1.22	1.28	1.35	1.51
	0	1.12	1.21	1.31	1.41	1.52	1.83
10	**85**	1.02	1.03	1.05	1.06	1.07	1.09
	75	1.04	1.06	1.08	1.10	1.11	1.15
	50	1.08	1.12	1.17	1.21	1.26	1.35
	25	1.12	1.20	1.28	1.36	1.44	1.65
	0	1.16	1.28	1.41	1.55	1.69	2.10

6.4 Cost–benefit considerations for water infrastructure viability

6.4.1 Lessons from recent Australian dams

CBA is widely used to help decision makers evaluate the net benefits likely to arise from implementing a proposed project, particularly for investments in large-scale public infrastructure. Despite this wide usage of CBAs, there are few examples for which the estimated costs and benefits used to justify the project have been revisited at a later date. Such ex-post evaluations allow the outcomes of completed projects to improve planning, management and risk mitigation in future projects (Infrastructure Australia, 2021a).

The few examples in which water infrastructure CBAs have been evaluated have focused on exploring the accuracy of the forecast capital costs. An international study of large water infrastructure projects showed that actual construction costs exceeded contracted costs by a mean of 96% (Ansar et al., 2014). Similarly, an Australian-focused study found mean cost overruns of 120% (Petheram and McMahon, 2019). There is evidence of a systematic tendency across a range of large infrastructure projects for proponents to substantially under estimate development costs (Ansar et al., 2014; Flyvbjerg et al., 2002; Odeck and Skjeseth, 1995; Wachs, 1990; Western Australian Auditor General, 2016).

Ex-post evaluations of project benefits are even scarcer. One international study found that large dam developments frequently underperformed, whereby 'irrigation services have typically fallen short of physical targets, did not recover their costs and have been less profitable in economic terms than expected' (World Commission on Dams, 2000). In particular, this study highlighted inaccurate and overestimated forecasting of future irrigation demand for water from dam developments.

Review of recent Australian dams

The Roper River Water Resource Assessment technical report on agricultural viability and socio-economics (Stokes et al., 2023) conducted a systematic review of the five most recently built dams in Australia (Figure 6-2, Table 6-12) to address the gap in the ex-post evaluations. The goal was to assess how well Australian dam projects have achieved their anticipated benefits and to make the learnings available for future planning. These lessons provide context for interpreting CBAs from project proponents, independent analysts, and the financial analyses provided in the previous section. The key lessons from that review are summarised below, and the full details are reported in Webster et al. (2024).

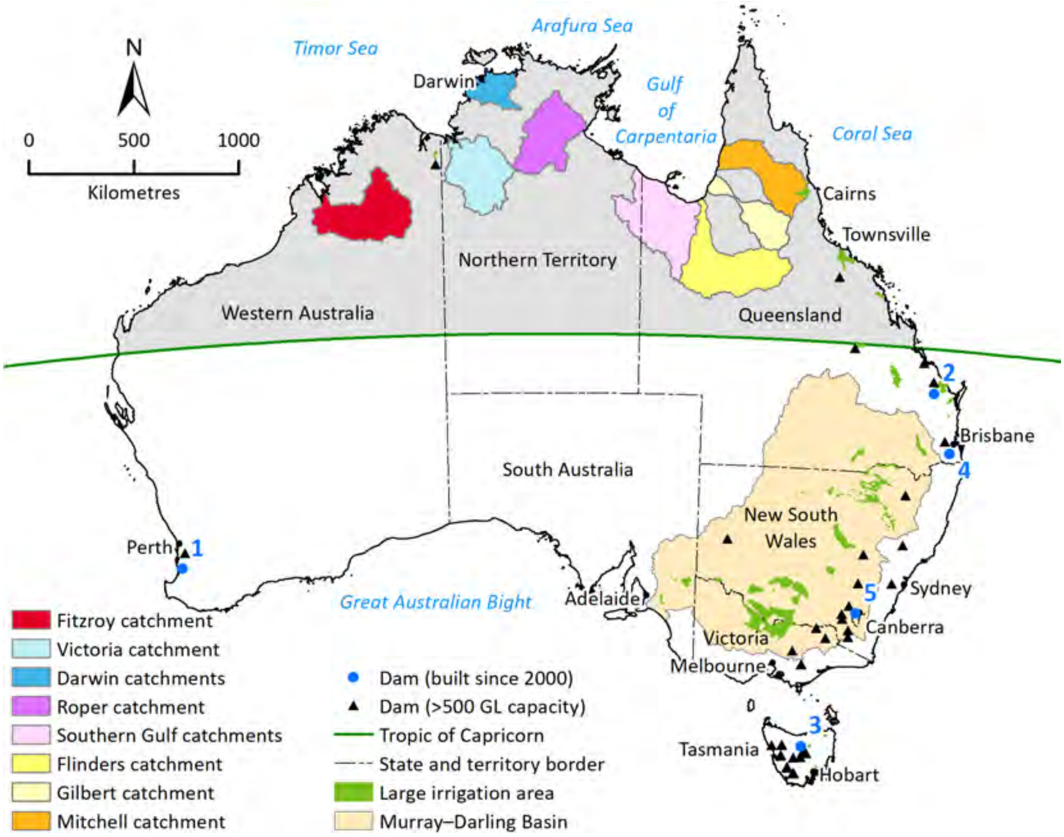


Figure 6-2 Locations of the five dams used in this review

The dams are numbered in blue as 1: New Harvey Dam, 2: Paradise Dam, 3: Meander Dam, 4: Wyaralong Dam and 5: Enlarged Cotter Dam.

Table 6-12 Summary characteristics of the five dams used in this review

Documents reviewed for each dam are cited in the companion technical report on agricultural viability and socio-economics (Webster et al., 2024). CBA = cost–benefit analysis.

	NEW HARVEY DAM	PARADISE DAM	MEANDER DAM	WYARALONG DAM	ENLARGED COTTER DAM
State/territory	WA	Qld	Tas	Qld	ACT
Date completed	2002	2005	2008	2011	2012
Capacity (GL)	59	300	43	103	78
New dam or redevelopment of existing dam?	Replaces Harvey weir (built 1916, extended 1931), capacity of ~10 GL	New	New	New	Replaces original Cotter Dam (built 1915, extended 1951), capacity of ~4 GL
Primary use(s) proposed for water from dam	Irrigated agriculture	Irrigated agriculture, water supply	Irrigated agriculture, environmental flows, hydro-electric power	Water supply to south-east Queensland	Water supply for Canberra
Type of key project documents used for this review	Proposed water allocation plans (no CBA available)	CBA and economic impact assessment	CBA	Environmental Impact Statement (EIS) (no CBA available)	EIS (which included CBA information, but the actual CBA report was unavailable)

Summary of key issues identified

This review highlighted a number of issues with the historical use of CBAs for recently built dams in Australia together with ways they could be more rigorously addressed (Table 6-13). These issues arise because of the complexity of the forecasts and estimates required to plan large infrastructure projects and because of pressures on proponents that can introduce systematic biases. However, this report acknowledges that flaws with the use of CBAs in large public infrastructure investment decisions are not unique to regional Australia or to water infrastructure – they are systemic and occur in many different types of infrastructure globally. Under such circumstances it would be inequitable to apply more rigor to CBAs only for some select investments, geographic regions and infrastructure classes before the same standards are routinely applied in all cases. And there is no incentive for individual proponents to apply more rigor to CBAs if those proposals would suffer from unfavourable comparisons to alternative or competing investments with exaggerated cost–benefit ratios (CBRs).

Table 6-13 Summary of key issues and potential improvements arising from a review of recent dam developments

	KEY ISSUE	POTENTIAL IMPROVEMENTS
1	**There is a lack of clear documentary evidence regarding the actual outcome of dam developments compared with the assumptions** made in ex-ante proposals, Environmental Impact Statements (EISs) and cost–benefit analyses (CBAs). Ex-post evaluations or post-completion reviews have either not been prepared or not been made publicly available.	Conducting **ex-post evaluations** of developments and making these publicly available (as recommended by 2021 guidance from Infrastructure Australia (Infrastructure Australia, 2021a, 2021b) and in the 2022 National Water Grid Investment Framework (NWGA 2022)) would enable lessons learned to be shared and benefit future developments.
2	**Predicted increases in water demand** from specific developments generally **do not appear to arise at the scale and/or within the time frame forecast**. While the reasons for this are varied and context-dependent, there does appear to be a systematic bias towards overestimation of the magnitude and rate at which new benefit would flow.	**Recognising the tendency towards a systematic bias** of overstating benefits and understating costs, CBAs in project proposals could be improved by: (i) further efforts to present unbiased financial analysis (e.g. **independent review**) and ensuring appropriate sensitivity analysis is included in all proposals, (ii) developing **broadly applicable and realistically achievable benchmarks** for evaluating proponents' assumptions and financial performance claims, (iii) using past experiences and **lessons learned** from previous projects with a similar context to inform the analysis presented in the proposals (building on Issue 1 above), and (iv) presenting a like-for-like comparison of **cost-to-benefit ratios** (**CBRs) for the proposed case vs standard alternatives** (such as water buybacks or a smaller dam, possibly better matched to realistic future demand).
3	The **systematic bias towards optimism** in proposals is **exacerbated by mismatches between forecast demand and the full supporting infrastructure required** to enable this demand to be realised, resulting in additional capital investment (pipelines, treatment plants, etc.) being required that was not costed in the original proposal.	The same improvements as for Issue 2 (recognising and **addressing inherent bias**) apply here.
4	Developments are justified based on a complex mix of multiple market and **non-market benefits**, many of which are **hard to monetise** and capture in a single net present value (NPV) figure.	CBAs could be improved by presenting clear information on the full portfolio of benefits (and costs and disbenefits) anticipated to arise from a project. While the quantitative part of the CBA would analyse the easily monetised costs and benefits (with metrics such as CBR and NPV), **benefits that are hard to monetise could also be formally presented** in whatever form is most appropriate to the magnitude and nature of that particular benefit. This presentation would enable the relative importance of each element of the mix to be weighed and given appropriate consideration, rather than attention being focused on a single NPV figure, which may have omitted key elements of the project.

	KEY ISSUE	POTENTIAL IMPROVEMENTS
5	Improved **water security and reliability** of supply is often the most important benefit offered by dam developments, while also being the hardest to monetise. Dams provide a form of insurance against the risk that water may not be available when needed in the future. **Assessing the value of this insurance** requires consideration of the cost of lack of water supply when needed and the likelihood that this could occur.	CBAs could be improved by **providing clear information on exactly how the development will serve to improve water security**, the likelihood that such insurance will be required (i.e. an estimate of the risk), and the estimated social and economic impacts if the insurance was not there when required. Such information could be presented alongside, and given equal prominence with, other information regarding the proposal, including the estimated NPV. This is preferable to attempting to 'force' the benefit into an NPV calculation that is ill equipped to deal with such a benefit.

In the short term, the main value of the information provided here is to enable more critically interpretation and evaluation of CBAs so that more-informed decisions can be made about the likely viability (and relative ranking) of projects in practice. In particular, it highlights several aspects of CBAs regarding which the claims of proponents warrant critical scrutiny. The longer term value of this analysis is that it has identified many issues similar to those raised in past review cycles of Infrastructure Australia's CBA best-practice guidelines and the recommendations that are being progressively added to those guidelines to improve how large public investments are evaluated (Infrastructure Australia, 2021a, 2021b).

6.4.2 Demand trajectories for high-value water uses

For irrigated agriculture to expand in the Victoria catchment, additional water will be required. Forecasting that growth in demand is essential, both for planning new water infrastructure and for evaluating individual water infrastructure proposals. This will ensure assumed demand trajectories for water, and the associated value that can be generated from irrigated agriculture to justify the costs of that infrastructure, are reasonable. Australian Bureau of Statistics data series on historical agricultural production and water use were analysed to derive trends and relationships for benchmarking realistic growth trajectories in the NT (Figure 6-3).

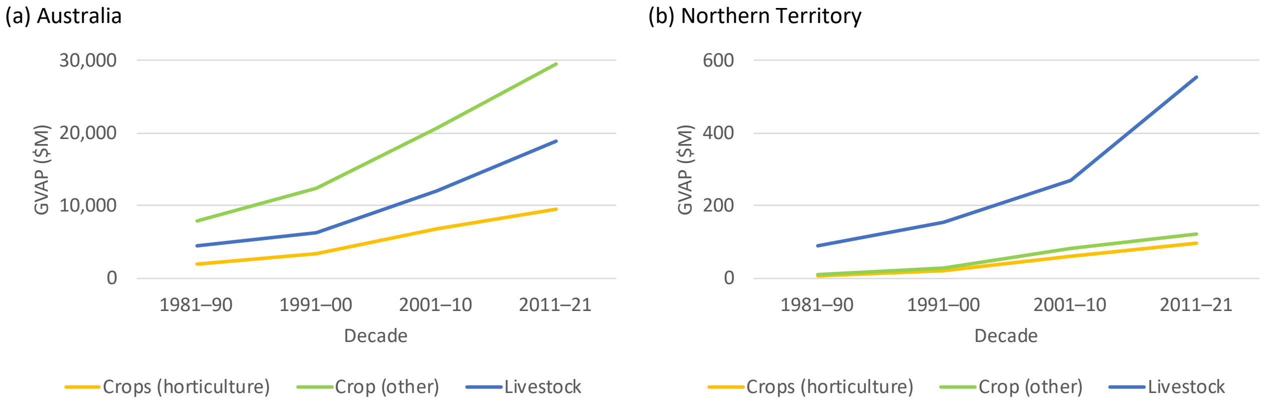


Figure 6-3 Trends in gross value of agricultural production (GVAP) in (a) Australia and (b) the NT over 40 years (1981–2021)

Data points are decade averages of annual values. The 'Crop (other)' category is predominantly broadacre farming.

Source: (ABS, 2022)

Horticultural produce is typically perishable and expensive to store and transport, and must meet stringent phytosanitary (plant health) standards for export, so most Australian horticultural produce (~70%) is sold domestically for consumption shortly after harvest. Growth in horticultural industries is, therefore, constrained by growth in demand from local consumers. The current rate of growth in the value of Australian horticulture is $2.7 billion per decade, and for the NT it is $35 million per decade (step changes in gross value of agricultural production (GVAP) from 1981–90 to 2011–21 are shown in Figure 6-3). Any new irrigated development would compete for some share of that growth, providing a benchmark guide for the scale of new horticulture that could realistically be included in any new irrigation scheme. It also provides a benchmark for the trajectory at which high-value horticulture (and the associated demand for high-priority water) could grow towards the ultimate scheme potential.

In addition, the scale of new horticultural expansion for any single crop is limited by seasonal gaps in supply, so horticulture in any single location is typically a mix of products that fill the niche market gaps that the location can supply (usually dictated by climate, but sometimes a result of other factors such as backloading opportunities; see Chapter 4), rather than being a monoculture of the most valuable crop alone. Data on how the value of irrigated agriculture has increased with increasing irrigation water availability over time provide an indicative benchmark of how much gross value such a mix of new agricultural activities could generate for each new GL of irrigation water that becomes available (Figure 6-4). Based on the trendlines in Figure 6-4, each extra new GL of water use could produce either:

- an extra $2.9 million of gross value from mixed fruit industries
- an extra $7.9 million of gross value from mixed vegetable industries
- an extra $3.8 million of gross value from mixed horticulture (combined), or
- an extra $1.2 million of gross value from a typical mix of agriculture overall.

Growth trends in the value of broadacre crops are stronger than those for horticulture (Figure 6-3); they are a combination of increases in both product volumes and the value per unit product. Unlike horticultural crops, bulk broadacre commodities are stored and traded on large global markets (with multiple competing international buyers), which could easily absorb the scale of increases in production that would be possible from the Victoria catchment. However, supply chains, rather than markets, pose a challenge for new broadacre production. Despite northern Australia being geographically closer than southern Australia to many key markets, the supply chains for northern Australian produce are longer, because most agricultural exports leave through southern ports. For example, Darwin Port currently does not handle bulk food-grade containers (for either import or export). The challenge is to develop transport and handling capacity for exports and balance that with compatible imports to avoid the added cost of dead freighting empty containers (CRCNA, 2020).

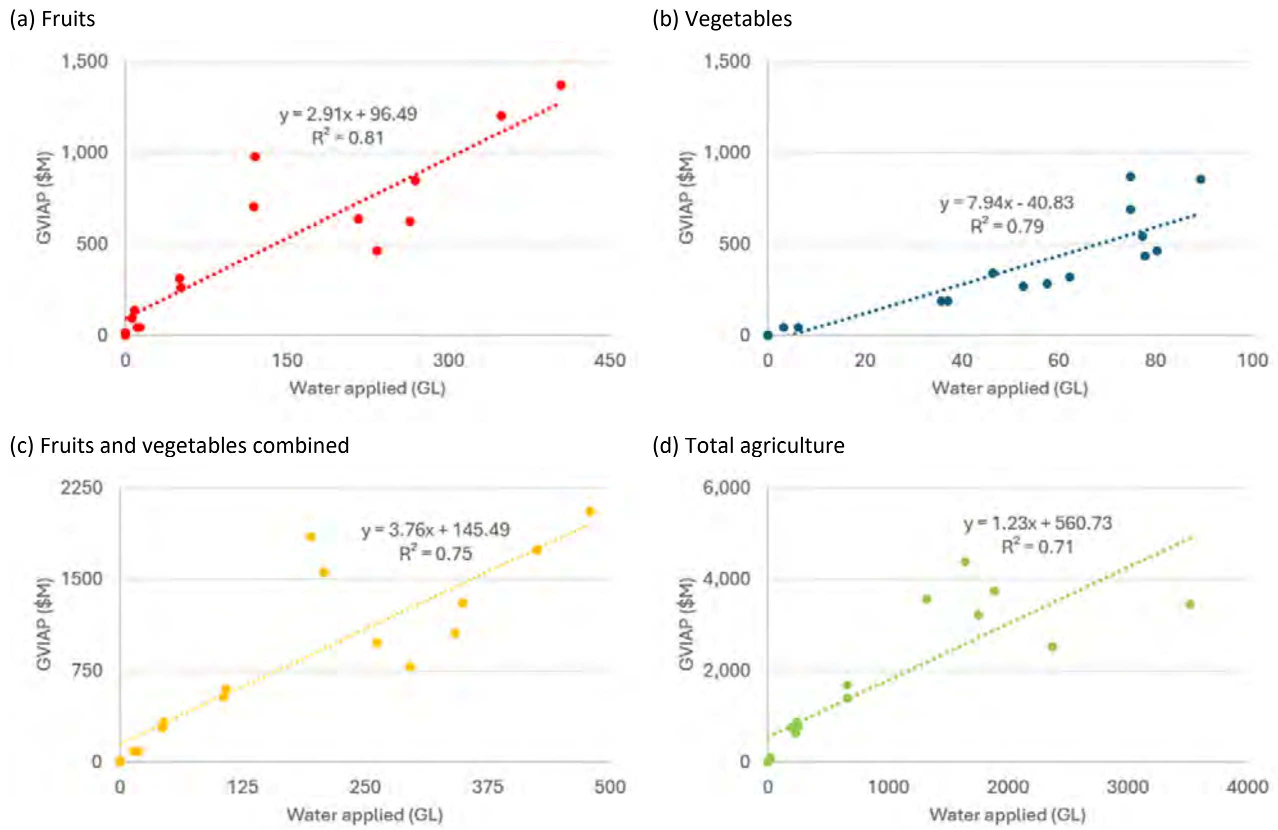


Figure 6-4 National trends for increasing gross value of irrigated agricultural production (GVIAP) as available water supplies have increased for (a) fruits, (b) vegetables, (c) fruits and vegetables combined, and (d) total agriculture
Source: (ABS, 2022)

6.4.3 Costs of enabling infrastructure

A range of infrastructure would be required to support the development of a new irrigation scheme in the Victoria catchment, both within the scheme itself and beyond. Any infrastructure that is not included in the initial water development contract but is required to enable the new water resources to be used effectively (and to achieve their anticipated benefits) will require construction after the contracted project is complete, often at public expense. The types of infrastructure addressed here are those that would not typically be included in a formal CBA or be built by the water infrastructure developer or farmers. Within the context of a large irrigation development, such enabling infrastructure can be considered 'hard' or 'soft', which can be broadly defined as follows:

- Hard infrastructure refers to the physical assets necessary for a development to function. It can include water storage, roads, irrigation supply channels, energy, and processing infrastructure, such as sugar mills, cotton gins, abattoirs and feedlots.
- Soft infrastructure refers to the specialised services required for maintaining the economic, health, cultural and social standards of a population. These are indirect costs of a development and are usually less obvious than hard infrastructure costs. They can include expenses that continue after the construction of a development has been completed. Soft infrastructure can include:

– physical assets, such as community infrastructure (e.g. schools, hospitals, housing)
– non-physical assets, such as institutions, supporting rules and regulations, compensation packages, and law enforcement and emergency services.

New processing infrastructure and community infrastructure are particularly pertinent to large, remote, greenfield developments, and these costs to other providers of infrastructure can be substantial, even after a new irrigation scheme has been developed. For example, a review of the Ord-East Kimberley Development Plan (for expansion of the Ord irrigation system by ~15,000 ha) found additional costs of $114 million to the WA Government beyond the planned $220 million state investment in infrastructure already provided to directly support the expansion (Western Australian Auditor General, 2016).

This section provides an indication of the additional public and private infrastructure required to support a new irrigation development (once the main water infrastructure and farms are built) and the costs of the additional investments required. The intention is to highlight potentially overlooked costs of infrastructure that is required to realise the benefits of development and population growth in a region, rather than to diminish the potential benefits.

Costs of hard infrastructure

Establishing new irrigated agriculture in the Victoria catchment would involve the initial costs of land development, water infrastructure (which could include distribution and re-regulation or balancing of storages), and farm set-up (for equipment and facilities on each new farm). It may also involve costs associated with constructing processing facilities, extending electricity networks, and upgrading road transport.

The costs of water storage and conveyance are provided in Chapter 5. Indicative costs for processing facilities are provided in Table 6-14, and indicative costs for roads and electricity infrastructure are provided in Table 6-15. Indicative costs for transporting goods to key markets are listed in Table 6-16. All tables are summarises of information provided in the companion technical report on agricultural viability and socio-economics (Webster et al., 2024).

Table 6-14 Indicative costs of agricultural processing facilities

ITEM	CAPITAL COST	OPERATING COST	COMMENT
Meatworks	$33 to $100 million	$330/head	Operational capacity 100,000 head/y
Cotton gin	$34 to $37 million	$1.1 million/y plus $24 to $35 per bale	Operational capacity of 80,000 to 95,000 bales/yr Operating costs depend on the scale of the gin, and the source of energy
Sugar mill	$469 million	$39 million/y	Operational capacity of 1000 t cane/h, 6-month crushing season Basic mill producing sugar only (no electricity or ethanol)

Table 6-15 Indicative costs of road and electricity infrastructure

ITEM	CAPITAL COST	COMMENT
Roads		
Seal dirt road	$0.31 to $2.4 million per km	Upgrade and widen dirt road to sealed road
New bridges and floodway	$27.4 million	Costs of bridges and floodways vary widely
Electricity		New generation capacity may also be required
Transmission lines	$0.34 to $1.57 million per km	High-voltage lines deliver bulk flow of electricity from generators over long distances
Distribution lines	$0.22 to $0.49 million per km	Lower-voltage lines distribute power from substations over shorter distances to end users
Substation	$1.3 to $12.2 million	Transformers and switchgear connect transmission and distribution networks

Table 6-16 Indicative road transport costs between the Victoria catchment and key markets and ports

The top section of the table gives trip costs from the Victoria River Roadhouse to key destinations. The bottom section gives distance-based costs of getting goods from within the catchment to the Victoria River Roadhouse (on unsealed roads) and approximate distance-based costs of getting goods from the Victoria River Roadhouse on sealed roads to other destinations (not specifically listed).

DESTINATION	TRANSPORT COST		
	Unrefrigerated	**Refrigerated**	**Cattle**
	Transport costs from Victoria River Roadhouse ($/t)		
Adelaide	440	515	396
Brisbane	515	604	463
Cairns	393	487	354
Darwin	78	92	70
Fremantle	536	639	482
Karumba	306	368	275
Melbourne	584	654	526
Port Hedland	285	344	257
Sydney	616	692	555
Townsville	354	426	319
Wyndham	65	77	59
	Transport costs by distance ($/t/km)		
Properties to Victoria River Roadhouse	0.32	0.38	0.29
Victoria River Roadhouse to key markets/ports	0.15	0.18	0.14

Costs of soft infrastructure

The availability of community services and facilities would play an important role in attracting people to (or deterring them from) living in a new development in the Victoria catchment. If local populations increase as a result of new irrigated developments, then the demand for public services would increase, and provision of those services would need to be anticipated and planned for. Indicative costs for constructing a variety of facilities that may be required for supporting population growth are listed in

Table 6-17. Each 1000 people in Australia require 2.3 (in 'Major cities') to 4.0 (in 'Remote and Very remote areas') hospital beds, served by 16 full-time equivalent (FTE) hospital staff and $3.5 million/year funding to maintain current mean national levels of hospital service (AIHW, 2023). Health care services in remote locations generally focus on providing primary care and some secondary care. More specialised tertiary services tend to be concentrated in referral hospitals, which are generally located in large cities but also serve the surrounding area. Primary schools tend to be smaller and more widespread than secondary schools, which are larger and more centralised.

Table 6-17 Indicative costs of community facilities

Costs are quoted for Darwin as a reference capital city for northern Australia. Costs in remote parts of northern Australia, including the Victoria catchment, are estimated to be approximately 30% to 60% higher than those quoted for Darwin. School costs were estimated separately based on a number of locations across northern Australia. See the companion technical report on agricultural viability and socio-economics (Webster et al., 2024) for details.

ITEM	CAPITAL COST	COMMENT
Hospital	$0.2 to $0.5 million per bed	Higher end costs include a major operating theatre and a larger hospital area per bed
School	$27,000 to $35,000 per student	Secondary schools tend to be larger and more centralised than primary schools
House (each)	$585,000 to $850,000	Single- or double-storey house, 325 m^2
Unit (each)	$230,000 to $395,000	Residential unit (townhouse), 90 to 120 m^2
Offices	$2400 to $3450 per m^2	1 to 3 storeys, outside central businesses district

The demand for community services is growing, both from population increases in Australia and rising community expectations. New infrastructure would be built to service that demand, irrespective of any development in the Victoria catchment. However, if new irrigation projects encourage people to live in the Victoria catchment, this could then shift the locations at which some services would be delivered and the associated infrastructure built. The costs of delivering services and building infrastructure are generally higher in very remote locations like the Victoria catchment. The net cost of any new infrastructure built to support development in the Victoria catchment is the difference in the cost of shifting some infrastructure to this very remote location (rather than the full cost of the facilities (Table 6-17), which would otherwise have been built elsewhere).

6.5 Regional-scale economic impact of irrigated development

New irrigated development in the Victoria catchment could provide economic benefits to the region in terms of both increased economic activity and jobs. The size of the total economic benefit experienced would depend on the scale of the development, the type of agriculture that was established, and how much spending from the increased economic activities occurred within the region. Regional economic impacts are an important consideration for evaluating potential new water development projects.

It was estimated that each million dollars spent on construction within the Victoria catchment would generate an additional $1.06 to $1.09 million of indirect benefits ($2.06 to $2.18 million total regional benefits, including the direct benefit of each million dollars spent on construction). It was estimated that each million dollars of direct benefit from new agricultural activity would generate an additional $0.46 to $1.82 million in regional economic activity (depending on the particular agricultural industry).

The full, catchment-wide impact of the economic stimulus provided by an irrigated agriculture or aquaculture development project extends far beyond the impact on those businesses and workers directly involved in either the short term (construction phase) or the longer term (operational phase). Businesses directly benefiting from the project would need to increase their purchases of the raw materials and intermediate products used by their growing outputs. Should any of these purchases be made within the surrounding region, this would provide a stimulus to those businesses from which they purchase, contributing to further economic growth within the region. Furthermore, household incomes would increase as a result of the employment of local residents as a consequence of the direct and/or production-induced business stimuli. As a proportion of this additional household income would be spent in the region, economic activity within the region would be further stimulated. Accordingly, the larger the initial amount of money spent within the region, and the larger the proportion of that money re-spent locally, the greater the overall benefits that would accrue to the region.

The size of the impact on the local regional economy can be quantified by regional economic multipliers (derived from I–O tables that summarise expenditure flows between industry sectors and households within the region): a larger multiplier indicates larger regional benefits. These multipliers can be used to estimate the value of increased regional economic activity likely to flow from a stimulus to particular industries, focusing on construction in the short term and various types of agriculture in the longer term.

It is also possible to estimate the increase in household incomes in the region, and then estimate the approximate number of jobs represented by the increased economic activity, including both those directly related to the increase in agriculture and those generated indirectly within other industries in the region.

Not all expenditure generated by a large-scale development will occur within the local region. The greater the leakage (i.e. the amount of direct and indirect expenditure occurring outside the region), the smaller the resulting economic benefit enjoyed by the region. Conversely, the greater the retention of the initial expenditure and subsequent indirect expenditure within the region, the greater the economic benefit and the number of jobs created within the local region. However, a booming local economy can also bring with it a number of issues that can place upward pressure on prices (including materials, houses and wages) in the region, negating some of the positive impacts of the development. If some of the unemployed or underemployed people within the Victoria catchment could be engaged as workers during the construction or operational phases of the development, this could reduce pressure on local wages and reduce the leakage resulting from the use of fly-in fly-out (FIFO) or drive-in drive-out (DIDO) workers, retaining more of the benefit from the project within the local region. However, the current low unemployment rate within the Victoria catchment (Chapter 3) suggests there may be difficulties in sourcing local workers from within the region.

The overall regional benefit created by a particular development depends on both the one-off benefits from the construction phase and the ongoing annual benefits from the operational phase. The benefits from the operational phase may take a number of years to reach the expected level, as new and existing agricultural enterprises learn and adapt to make full use of the new opportunities presented by the development. It is important to note that the results presented here are based on illustrative scenarios incorporating broad assumptions, are derived from an I–O model developed for an I–O region that is much larger than the Victoria catchment study area, and are subject to the limitations of the method.

6.5.1 Estimating the size of regional economic benefits

To develop regional multipliers for the Victoria catchment, it was necessary to use the available information and models for the Victoria catchment I–O region. Two I–O models were used, one covering the whole of the NT (Murti and NT Office of Resource Development, 2001) and one based on the adjacent catchment of the Daly River (Stoeckl et al., 2011) (Figure 6-5). For more details, see the companion technical report on agricultural viability and socio-economics (Webster et al., 2024).

Additional data are presented to show how the economic circumstances of the Victoria catchment compare with those of the two I–O regions (Table 6-18). The Daly I–O region is more similar in some characteristics to the larger NT I–O region than to the Victoria catchment. However, any benefits of development in the Victoria catchment are likely to spill over into the NT's capital, Darwin, and would be captured in the larger NT I–O model. Typically, smaller and more remote geographic areas have smaller I–O multipliers, as inter-industry linkages tend to be shallow and the area's capacity to produce a wide variety of goods is low, meaning that inputs and final household consumption are less likely to be locally sourced than in regions with larger urban centres (Stoeckl and Stanley, 2009; Jarvis et al., 2018).

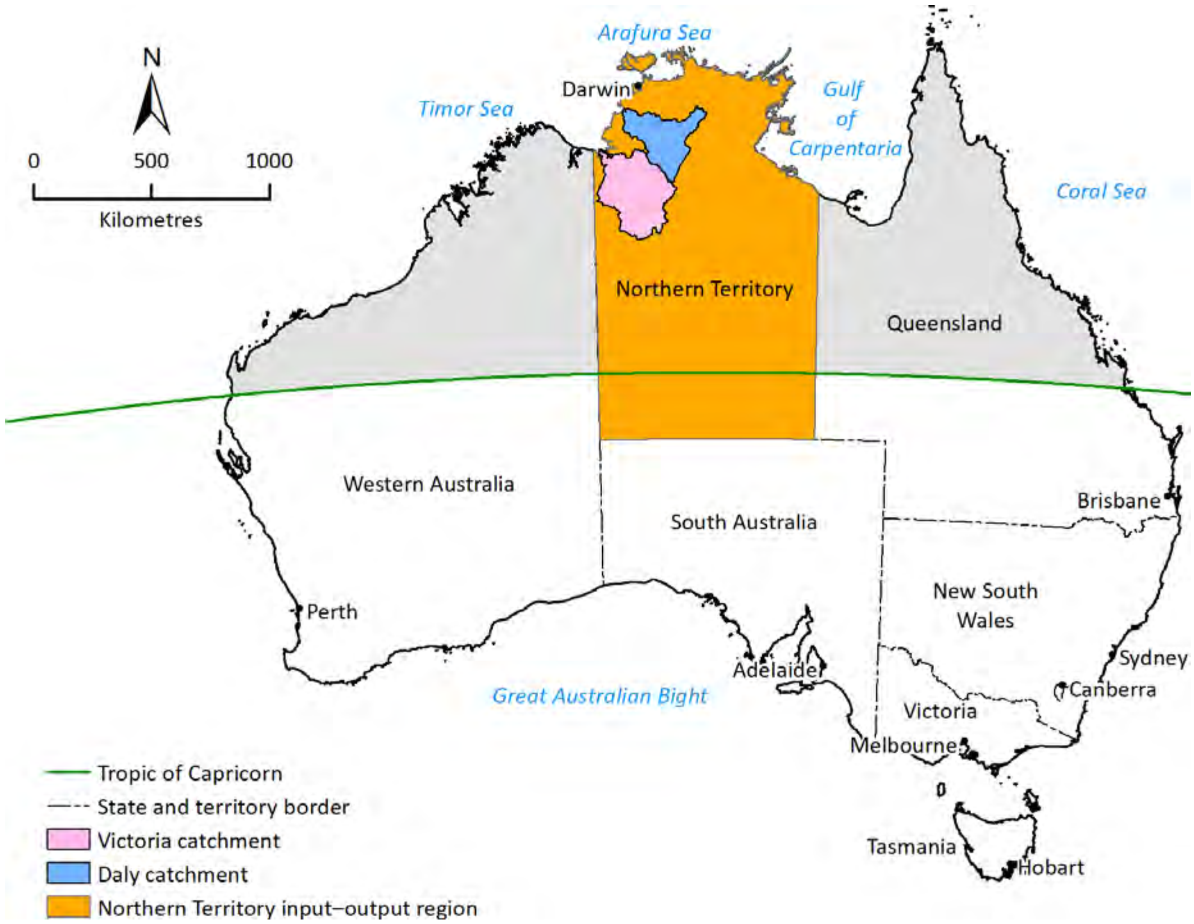


Figure 6-5 Regions used in the input–output (I–O) analyses relative to the Victoria catchment Assessment area

Table 6-18 Key 2021 data comparing the Victoria catchment with the related I–O analysis regions

	VICTORIA CATCHMENT†	DALY CATCHMENT I–O REGION†	NT I–O REGION‡
Land area (km²)	82,232.0	53,088.5	1,348,094.3
Population	1,600	11,233	232,605
Percentage male	50.35%	51.56%	50.53%
Percentage Indigenous	74.68%	32.29%	26.27%
Median age	25	32	33
Median household income	$57,026	$104,505	$107,172
Contribution of agriculture, forestry and fishing to employment in the region	29.2%	6.6%	2.3%
Major industries of employment – top three industries in region (by % of employment 2021)			
Largest employer in region	Agriculture, forestry and fishing	Public administration and safety	Public administration and safety
2nd largest employer in region	Public administration and safety	Health care and social assistance	Health care and social assistance
3rd largest employer in region	Education and training	Education and training	Education and training
Gross value of total	$110 million	$93 million	$746 million

† Statistics for Victoria catchment (ABS, 2021) and Daly catchment (ABS, 2021) regions have been estimated using the weighted mean of ABS 2021 census data obtained by SA2 statistical region, with weighting based on the proportion of relevant ABS SA2 statistical regions falling within each catchment region.
‡ ABS 2021 census data (ABS, 2021).
§ ABS Value of agricultural commodities produced 2020–21 by region, report VACPDCASGS202021 (ABS, 2022).

There are wide variations in the size of the multipliers for various industries within the NT and Daly I–O regions. Industries with larger local regional multipliers would be expected to benefit more from development within the I–O region. For example, agricultural industries generated smaller multipliers than construction for both I–O models. However, a simple comparison of I–O multipliers can be misleading when considering the different benefits from regional investment, because some impacts provide a short-term, one-off benefit (e.g. the construction phase of a new irrigation development) while others provide a sustained stream of benefits over the longer term (e.g. the production phase of a new irrigation scheme). A rigorous comparison between specific regional investment options would require NPVs of the full cost and benefit streams to be calculated.

6.5.2 Indirect benefits during the construction phase of a development

Initially, building new infrastructure (on-farm and off-farm development, including construction of related supporting infrastructure, such as roads, schools and hospitals) comes at a cost. But the additional expenditure within a region (which puts additional cash into people's and businesses' pockets) would increase regional economic activity. This creates a fairly short-term economic benefit to the region during the construction phase, provided that at least some of the expenditure occurs within the region and is not all lost from the region due to leakage.

The regional impacts of the construction phase of potential developments were estimated using a scenario approach for the scales of development. The analyses modelled regional impacts for five different indicative sizes of developments in the Victoria catchment. Total capital costs, including costs of labour and materials required by the project, ranged from $250 million to $2 billion. The smallest scale of development in Table 6-19, with a capital cost of $250 million, broadly represents approximately 20 new farm developments with their own on-farm water sources enabling approximately 10,000 ha of irrigation for horticulture and broadacre farming (based on costing information from the companion technical report on agricultural viability and socio-economics (Webster et al., 2024)). The second-smallest scenario, with a $500 million capital cost, could represent a similar development to the first but with 20,000 ha of new irrigated farmland; this level of investment could also include a new processing facility (such as a cotton gin) required by (and supported by) this scale of agricultural development. Alternatively, the $500 million development could represent a large off-farm water infrastructure development (e.g. see Table 6-2) and related farm establishment costs. The larger scales of development, at $1 billion or $2 billion, shown in Table 6-19, indicate outcomes from combining potential developments in various ways (such as one large off-farm dam and multiple on-farm water sources). They also include investment in indirect supporting infrastructure across the region, such as roads, electricity and community infrastructure (see indicative costs in Section 6.4.3).

The proportion of expenditure during the construction phase that would be spent within the region depends on the types of costs, including labour, materials and equipment. It is likely that wages would be paid to workers sourced both from within the region and from elsewhere. The likely proportion of labour costs for each source of workers would depend on the availability of appropriately skilled labour within the region. For example, a highly populated region (more than 100,000 people) with a high unemployment rate (more than 10%) and skilled labour force is likely to be able to supply a large proportion of the workers required from within the region. However, a sparsely populated region like the Victoria catchment is more likely to need to attract many workers from outside the region, either on a FIFO or DIDO basis or by encouraging migration to the region. Similarly, some regions may be better able to supply a large proportion of the required materials and equipment from within the region, whereas construction projects in other locations may not be able to source what they need locally and instead need to import a significant proportion into the region from elsewhere. The low representation of the required supplying industries in the Victoria catchment means that most construction supplies would be likely to be sourced from other parts of Australia (and internationally).

A review of five large dam projects across the country showed that the proportions of local construction expenditure sourced within a region (as opposed to being imported, with no impact on the local regional economy) varied significantly. Thus, the analyses considered three levels for the proportion spent locally: 65% (i.e. low leakage), 50%, and 35% spent locally (i.e. high leakage). However, note that leakage might be higher (i.e. <35% spent locally) for a very remote region like the Victoria catchment. In cases of high leakage, the knock-on benefits would instead occur in the regions supplying the goods and services (such as in the wider NT I–O region).

Table 6-19 shows estimates of the regional economic benefit for the construction phase of a new development for four scales of scheme capital cost ($0.25 billion to $2 billion) and the three levels of leakage described above. These results show that the size of the regional economic benefit experienced increases substantially as the proportion of scheme construction costs spent within the region increases. Given the low urban development within the Victoria catchment and its proximity to Darwin, leakage may be towards the high end of the range examined for the Victoria catchment (but to the middle of the range for the NT I–O region, which includes Darwin). For example, if $500 million was spent on construction for a new dam project and 35% of that was spent within the Victoria catchment (and 50% with the wider NT I–O region), the construction multiplier would only apply to the portion spent locally. This would give an overall regional economic benefit of $380 million within the Victoria catchment based on the Daly I–O model estimate (or $520 million for the wider NT region based on the NT I–O model estimate). Additional benefits would flow to other regions receiving the remaining funds.

Table 6-19 Regional economic impact estimated for the total construction phase of a new irrigated agricultural development (based on two independent I–O models)

Estimates represent an upper bound, because some assumptions of I–O analysis are violated in the case of such a large public investment in a region where existing irrigated agricultural activity is so low. Leakage to other regions and other countries is accounted for by reducing the proportion of expenditure (and benefits) within the I–O region.
I–O = input–output.

DEVELOPMENT CAPITAL COST ($ billion)	TOTAL REGIONAL ECONOMIC ACTIVITY WITHIN I–O REGION AS A RESULT OF THE CAPITAL COST OF THE DEVELOPMENT ($ billion)					
	Victoria catchment based on NT			**Victoria catchment based on Daly catchment**		
	Proportion of total scheme-scale capital cost made locally within the I–O region					
	65%	**50%**	**35%**	**65%**	**50%**	**35%**
0.250	0.33	0.26	0.18	0.35	0.27	0.19
0.500	0.67	0.52	0.36	0.71	0.55	0.38
1.000	1.34	1.03	0.72	1.42	1.09	0.76
2.000	2.68	2.06	1.44	2.83	2.18	1.53

6.5.3 Indirect benefits during the operational phase of a development

Regional impacts of irrigation development on the two I–O regions are presented for scenarios using four indicative scales of increase in GVAP ($25, $50, $100 and $200 million per year, indicative of potential outcomes). At the low end ($25 million/year), this could represent 10,000 ha of new plantation timber, while the high end ($200 million/year) could represent 10,000 ha of mixed broadacre cropping and horticulture (based on farm financial estimates for the various crops presented in Chapter 4), with other crop options falling in between. Estimated regional impacts are shown as the total increased economic activity (Table 6-20) in the NT and Daly I–O regions and the associated estimated increases in incomes and employment (Table 6-21) for each category of agricultural activity (beef cattle, agriculture excluding beef cattle, and aquaculture, forestry and fishing for the NT I–O model; and agriculture of all types for the Daly I–O model).

As can be seen from the economic impacts (Table 6-20), an irrigation scheme that promotes aquaculture, forestry and fishing could have a larger regional impact in the NT I–O region than a scheme promoting beef cattle or agriculture excluding beef cattle. These differences result from the various industry multipliers estimated for the NT I–O.

Table 6-20 Estimated regional economic impact per year in the Victoria catchment resulting from four scales of direct increase in agricultural output (rows) for the different categories of agricultural activity (columns) from two I–O models

Increases in agricultural output are net of the annualised value of contribution towards the construction costs. Estimates represent an upper bound because some assumptions of I–O analysis are violated in the case of such a large public investment in a region where existing agricultural activity is so low. Leakage to other regions and other countries is accounted for by reducing the proportion of expenditure (and benefits) within the I–O region.

DIRECT INCREASE IN AGRICULTURAL OUTPUT PER YEAR NET OF CONTRIBUTION TO CONSTRUCTION COSTS ($ million)	TOTAL ANNUAL VALUE OF INCREASED ECONOMIC ACTIVITY IN I–O REGION– DIRECT, PRODUCTION-INDUCED AND CONSUMPTION-INDUCED ($ million)			
	Victoria catchment based on NT I–O model			**Victoria catchment based on Daly catchment I–O model**
	Type of agricultural development			
	Beef cattle	**Agriculture excluding beef cattle**	**Aquaculture, forestry and fishing**	**Agriculture of all types**
25	51	37	70	51
50	103	73	141	102
100	205	146	282	203
200	411	292	563	406

Table 6-21 Estimated impact on annual household incomes and full-time equivalent (FTE) jobs within the Victoria catchment resulting from four scales of direct increase in agricultural output (rows) for the various categories of agricultural activity (columns)

Increases in agricultural output are assumed to be net of the annualised value of contributions towards the construction costs. Estimates are based on Type ll multipliers determined from two independent I–O models for each year of agricultural production. Estimates represent an upper bound, because some assumptions of I–O analysis are violated in the case of such a large public investment in a region where existing agricultural activity is so low. Leakage to other regions and other countries is accounted for by reducing the proportion of expenditure (and benefits) within the I–O region.

DIRECT INCREASE IN AGRICULTURAL OUTPUT PER YEAR NET OF ANY CONTRIBUTION TO CONSTRUCTION COSTS ($ million)	TOTAL ANNUAL VALUE OF INCREASED ECONOMIC ACTIVITY IN I–O REGION – DIRECT, PRODUCTION-INDUCED AND CONSUMPTION-INDUCED ($ million or FTE)			
	Victoria catchment based on NT I–O model			**Victoria catchment based on Daly catchment I–O model**
	Type of agricultural development			
	Beef cattle	**Agriculture excluding beef cattle**	**Aquaculture, forestry and fishing**	**Agriculture of all types**
	Additional incomes expected to flow to Indigenous households from development ($ million)			
25	0.8	0.1	0.9	0.5
50	1.6	0.2	1.7	1.0
100	3.3	0.4	3.4	2.0
200	6.5	0.8	6.8	4.0
	Additional incomes expected to flow to non-Indigenous households from development ($ million)			
25	7.1	1.7	14.3	6.75
50	14.2	3.3	28.7	13.5
100	28.4	6.7	57.4	27.0
200	56.8	13.4	114.7	54.0
	Additional jobs estimated to be created (FTE)			
25	108	24	206	98
50	215	48	413	197
100	430	97	825	394
200	860	193	1,650	788

The results for employment (Table 6-21) are closely related to those for impacts on regional economic activity, but the two measures do reveal some differences. Additional FTE jobs arising in the region may require additional community infrastructure (e.g. schools, health services) if workers move to fill these jobs from other parts of the country, resulting in population growth. However, additional infrastructure would not be necessary should these additional jobs be filled by currently unemployed or underemployed local people. Estimates of the expected increases in incomes were divided between Indigenous and non-Indigenous households, using methods outlined in Jarvis et al. (2018), with most increases expected to flow to non-Indigenous households (Table 6-21).

For example, if new irrigation development in the Victoria catchment directly enabled an extra $100 million of cropping output per year, the region could benefit from an extra $146 million (NT I–O estimate) to $203 million (Daly I–O estimate) of economic activity recurring annually (Table 6-20) and generate approximately 100 to 852 new FTE ongoing jobs, depending on the type of agriculture (Table 6-21).

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