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Water resource assessment for the Roper catchment

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

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Important disclaimer

CSIRO Roper River Water Resource Assessment acknowledgements

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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); NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; Office of Northern Australia; Qld Department of Agriculture and Fisheries; Qld 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 Australia; Parks and Water Security; NT Department of Industry, Tourism and Trade; Regional Development Australia; NT Farmers; NT Seafood Council; Office of Northern Australia; Roper Gulf Regional Council Shire

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 its release.

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For further acknowledgements, see page xxii.

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

Looking along the Roper River at Red Rock, Northern Territory. Source: CSIRO – Nathan Dyer

Part IV Economics of development and accompanying risks

Chapters 6 and 7 describe economic opportunities, constraints and risks for water development in the Roper catchment. This information covers:

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

Melon crop under cultivation on the Sturt Plateau in the Mataranka area

Photo: CSIRO – Nathan Dyer

6 Overview of economic opportunities and constraints in the Roper catchment

Authors: Chris Stokes, Diane Jarvis, Shokhrukh Jalilov

Chapter 6 examines which types of opportunities for irrigated agriculture development in the catchment of the Roper River are most likely to be financially viable. The chapter considers the costs of building new infrastructure (both within the scheme and beyond), the financial viability of different 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 intention is not to provide a full economic analysis, but to focus on costs and benefits that are the subject of normal market transactions. Commercial factors are likely to be one of the most important criteria in deciding between potential development opportunities. Those options that can be clearly identified as being commercially non-viable at the pre-feasibility stage could likely be deprioritised. More detailed and project-specific agronomic, ecological, social, cultural and regulatory assessments could then be focused on those opportunities identified as showing the most commercial promise. Non-market impacts and risks are dealt with in Chapter 7, and would need to be considered for any financially viable development opportunities.

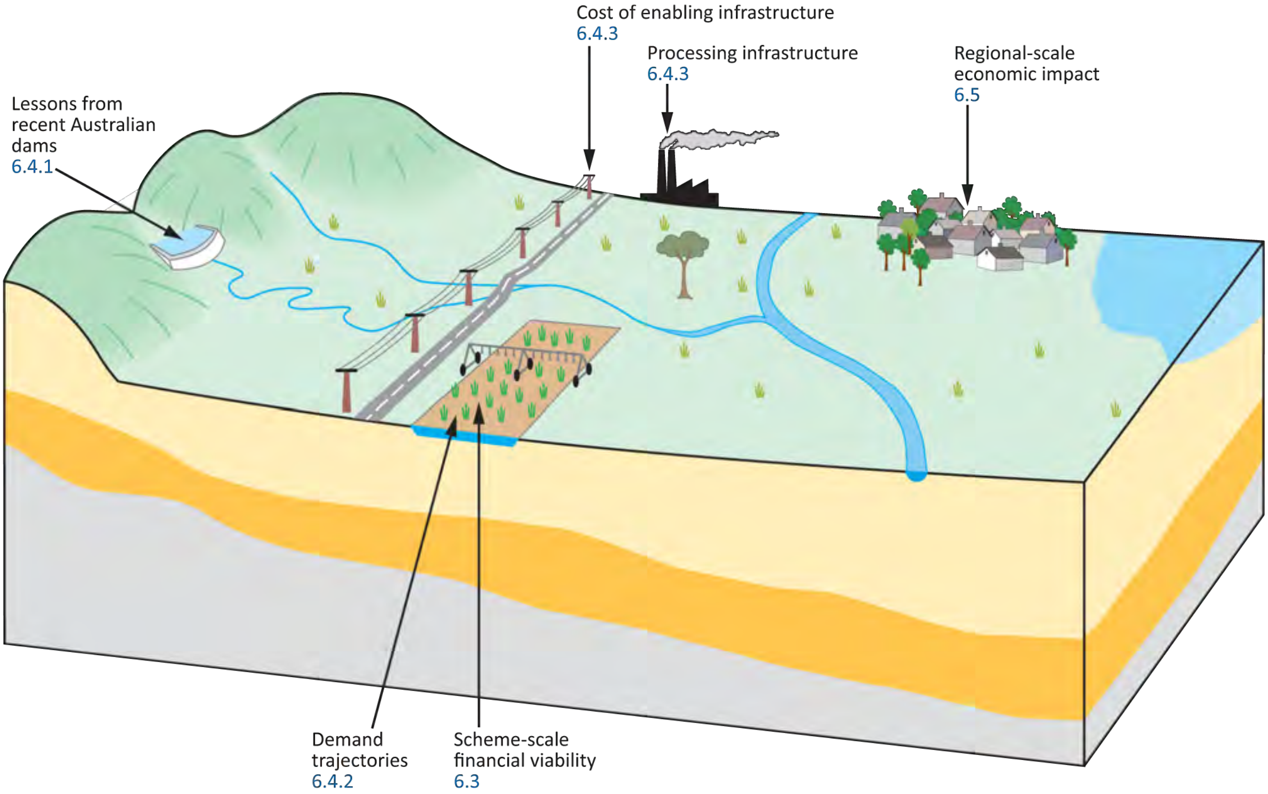


Figure 6-1 Schematic diagram of key components affecting the commercial viability of a potential greenfield irrigation development

6.1 Summary

6.1.1 Key findings

Scheme-scale financial viability

New investment in irrigation development in the Roper catchment would require 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 indicated that large dams in the Roper catchment are unlikely to be viable (if public investors targeted full cost recovery at a 7% internal rate of return (IRR) and do not provide assistance) because water from the most cost-effective dam sites would be too expensive for irrigators to afford, but could be marginally viable if public investors accepted a 3% IRR. On-farm water sources provide better prospects and, where sufficiently cheap water development opportunities can be found, these could likely support viable broadacre farms and horticulture with low development costs. Horticulture with high development costs (like fruit orchards) in the Roper catchment would be more challenging unless farm financial performance could be boosted by finding niche opportunities for premium produce prices, savings in production and marketing costs, and/or high yields.

Farm performance can be affected by a range of risks, including water reliability, climate variability, price fluctuations, and learning to adapt farming practices to new locations. Setbacks that occur early on after an irrigation scheme is established have the largest effect on scheme viability. There is a strong incentive to start any new irrigation development with well-proven crops and technologies, and to be thoroughly prepared for the anticipatable agronomic risks of establishing new farmland. Risks that cannot be avoided need to be managed, mitigated where possible, and accounted for in 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 highlighted some areas where cost–benefit analyses (CBAs) for water infrastructure projects could be improved, particularly regarding more realistic forecasting of demand for water. This chapter provides information for benchmarking a range of assumptions commonly used in such CBAs, including demand forecasting, that can be used to check when proposals for new dams are being unrealistically optimistic (or pessimistic).

Regional economic impacts

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

6.2 Introduction

There is a growing emphasis in Australia on greater accountability and transparency for large new infrastructure projects. This includes 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). Part of this shift has involved greater scrutiny of the costs and benefits of potential large new public dams. Large infrastructure projects, such as new irrigation developments in the Roper catchment, would be complex and costly investments. The difficulty in accurately estimating costs and the chance of incurring unanticipated expenses during construction, or not achieving projected water demand and revenue trajectories when completed, means that there are risks to the viability of developments if they are not thoroughly planned and assessed. For example, in a global review of dam-based megaprojects, Ansar et al. (2014) found forecast costs were systematically biased downwards, with three-quarters of projects running over budget and the mean of actual costs almost double the initial estimates (which 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 one of the most important criteria in deciding the scale and types of potential development opportunities in the Roper catchment. Ash et al. (2014), in an assessment of 13 agricultural developments in northern Australia, found that while the natural environments are challenging for agriculture, the most important factors determining the viability of developments were management, planning and finances. Even at a pre-feasibility stage, those options that can be clearly identified as being financially non-viable could likely be deprioritised, instead focusing expensive, more detailed and project-specific agronomic, ecological, social, cultural and regulatory assessments on more promising opportunities. This chapter aims to assist in planning and evaluating investments in new irrigated development by highlighting the types of projects that are more likely to be viable, quantifying the costs, benefits and risks involved. The intention is to provide a generic information resource that is broadly applicable to a range of irrigated agriculture development opportunities, rather than examining any specific options in detail. Results are presented in a way that allows readers to estimate whether specific projects they are interested in are likely to be financially viable, using costs, risks and farm productivity specific to those particular opportunities. The information also serves as a set of benchmarks for establishing realistic assumptions and thresholds of financial performance for water and farm developments, individually and in combination, to be financially viable.

Chapter 4 assesses the viability of new irrigated agriculture opportunities in the Roper catchment at the enterprise level, and Chapter 5 assesses the opportunities for developing water sources to support those farms. Section 6.3 provides information from a financial analysis framework to determine whether those farming options and water sources can be paired into viable developments, presenting the financial criteria that would have to be met for new farms to be able to cover costs of those developments. Section 6.4 highlights some key considerations for evaluating costs and benefits for new publicly funded dams, including lessons learned from recent dam projects in Australia. Section 6.4 also provides indicative costs for some of the additional enabling infrastructure required (that is typically additional to what is included in project CBAs). Finally, Section 6.5 considers the knock-on effects of new irrigated development in the Roper 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 threshold farm gross margins and water costs/pricing that would be required to cover infrastructure costs. These serve as tools that allow users to answer their own questions about agricultural land and water development. Some examples of the questions that can be asked, and which tools to use to answer them, are summarised below 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 supporting generalised assumptions.)

QUESTION (WITH EXAMPLE ANSWER)	RELEVANT TABLE
1) How much can different types of farms afford to pay per ML of water they use?	Table 6-4
A broadacre farm with a gross margin (GM) of $4,000/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 $5,000 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 known development cost, what is the equivalent $/ML price of water?	Table 6-8
A farm dam that had a capital cost of $1,500 for each ML/y supply capacity (yield) to develop would be equivalent to purchasing water at cost of $190 for each ML (at a 10% target IRR).	
4) What farm GM would be required to fully cover the costs of an off-farm dam? **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 $5,701/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)). A broadacre farm with a GM of $4,000/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 (about 50% of the full costs of building and operating that infrastructure).	
5) What GM would be required to cover the costs of developing a new farm, including a dam or bores?	Table 6-7
A horticultural farm with low overheads ($1,500/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 to irrigate it) would require a GM of $6,702/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 multiplied by 1.18 (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 to cover the costs of the farm development would increase from $5,825/ha to $6,874 after accounting for risks of water reliability.	
7) How would risks associated with 'learning' (initial farm underperformance) affect estimates?	Table 6-11
If a farm 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 GMs above would need to be higher by a factor of 1.26 (26% higher). For example, in Q6, the required farm GM would increase to $8,661/ha after accounting for 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 Roper catchment would require balancing three key determinants of irrigation scheme financial performance to find combinations that might collectively constitute a viable investment:

1. Farm financial performance (relative to development costs and water use) (Chapter 4)
2. Capital cost of development, for both water resources and farms (Chapter 5 and Section 6.3.1)
3. Risks (and associated required level of investment return) (Section 6.3.5).

Other assumptions were limited as much as possible, restricting these to factors 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 is likely to provide a silver bullet to meet the substantial challenge of designing a commercially viable new irrigation scheme. Balancing benefits to meet costs to find viable investments would likely require contributions from each of the above factors, with careful selection to piece together a workable combination. However, to understand the discussions of how these factors influence irrigation scheme financial performance, some background information on the analysis approach is provided first.

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 (Stokes et al., 2023), 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, an irrigation scheme was taken to be all the costs and benefits from the development of the land and water resources to the point of sale for farm produce.

A *discounted cashflow analysis* considers the lifetime of costs and benefits following capital investment in a new project. Costs and benefits that occur at different times are expressed in constant real dollars (June 2021 dollars), with a discount rate applied to streams of costs and benefits. This section explains the terminology and standard assumptions used.

The *discount rate* is the percentage by which future cost 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–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 *internal rate of return* (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, where the NPV is greater than zero at a discount rate appropriate to the risk profile of the development and alternate investment opportunities available to investors. A target IRR of 7% is typically used when evaluating large public investments (with sensitivity analysis at 3% and 10%) (Infrastructure Australia, 2021b), while 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 threshold GMs and water prices that are required for investors to achieve specified target IRRs (and therefore, equivalently, NPV is zero at these discount rates).

Project evaluation periods used in this chapter matched the *lifespans* 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 the shorter life span assets would be replaced at the end of their life, and costs were accounted for in full in 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 had not reached the end of their working life. Residual values were calculated as the proportional asset life remaining multiplied by the original asset price.

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 different water sources could be compared on a like-for-like basis. Where an off-farm water source was used, this was treated as a separate investor receiving payments for water at a price that the irrigator could afford to pay.

The main *costs for operating* a large dam and associated water-distribution infrastructure are fixed costs for administering and maintaining the infrastructure, expressed here as percentage of the original capital cost, and 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 to maintenance costs when machinery was 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 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 indicated in Chapter 4. GMs presented here are the values before subtracting the variable costs of supplying water to farms, with these costs instead accounted for in the capital costs of developing water resources. (Equivalent unit costs of supplying each ML of water are presented separately below.)

CBA analyses first considered the case of irrigation schemes built around public investment in a large *off-farm* dam in the Roper 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.

In cases where an *off-farm water source* (large dam >25 GL/year) was evaluated, this was treated as a separate public investor whom farmers paid 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 Roper catchment would be costly to develop, such that even when technically feasible options are found, many of these are unlikely to be profitable at the returns and over the time periods expected by many investors. The results presented below suggest that it would be difficult for any farming options to fully cover the costs of a large off-farm dam development, but that there is more 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 can 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, the water distribution system, the type of irrigation system, the type of crop to be grown, local climate, land preparation requirements, and the level to which infrastructure is engineered.

Financial analyses therefore used a generic approach to explore the consequences of this variation in development costs, and other key factors that determine whether or not an irrigation scheme would be viable, such as 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 (irrigators) investors to achieve their target IRRs. The results are then summarised as tables showing threshold criteria that would be required for a pair of water development and farm development options to combine together and meet investors’ target returns. The tables allow viable pairings to be identified in either of two ways: based on the threshold costs of water or farm GMs required. 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 consider the case of irrigation schemes built around public investment in a large off-farm dam in the Roper catchment, and then consider 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 what scale a water development would be. Instead, all costs are expressed (i) per hectare of irrigated farmland and (ii) per megalitre per year of water supply capacity, facilitating comparisons between scenarios (that can differ substantially in size). To illustrate how this slightly abstract generic approach can be applied to specific development scenarios, two worked examples are provided for indicative off-farm infrastructure costs required to develop the most cost-effective dam sites in the Roper catchment (Table 6-2).

Table 6-2 Indicative capital costs for developing two irrigation schemes based on the most cost-effective dam sites in the Roper catchment

'$ CapEx per ML/y at dam' is the capital expenditure on developing the dam and supporting off-farm infrastructure for each ML/y of the dam's supply capacity measured at the dam wall.

ITEM	WATERHOUSE COST ($)	FLYING FOX COST ($)
Capital costs		
Dam	253,000,000	318,000,000
Weir	0	89,000,000
Reticulation	126,400,000	12,000,000
Roads and electricity	90,000,000	35,000,000
Total	469,400,000	454,100,000
Summary metrics		
Irrigated area (ha)	10,100	5,485
Cost per hectare ($/ha)	46,500	82,800
Dam water yield (ML/y)	89,000	68,000
$ CapEx per ML/y	5,300	6,700

Source: Dam, reticulation, and weir costings are from Petheram et al. (2023) and include contingencies, see that report for full details of cost breakdowns and assumptions. The dam costings already allow for a road and electricity grid connection to the dam: an indicative allowance is added for supporting off-farm roads and electricity distribution that farms can connect to (assumed 40 km of linear infrastructure for Waterhouse, and 15 km for Flying Fox, at a combined linear infrastructure cost of $2.3 million/km).

To further assist in making like-for-like comparisons across different development scenarios, a set of standard assumptions are made about the breakdown of development costs (by lifespan) and associated ongoing operating costs (Table 6-3). Three indicative types of farming enterprise are used to 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). Capital costs and fixed costs are higher for horticulture than 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 a high standard of on-farm packing and cold room facilities, and include accommodation for seasonal workers travelling to remote Roper catchment farms. The indicative less capital-intensive 'Horticulture-L' farm option could, for example, represent a row crop like melons, with packing directly to bins and using off-farm accommodation for seasonal workers (which reduces the upfront capital cost of establishing the farm, but increases ongoing costs for outsourced services that 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 were represented to cover 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 to 150,000)			$/ha	
	Longer lifespan infrastructure (100 year)	85			%	0.4
	Shorter lifespan infrastructure (40 year)	15			%	1.6
Operating costs	O&M (by lifespan categories)	% capital cost			$/ha/y	
	Off-farm water source pumping costs	additional, ~2			$/ML/m	
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)	9,000	25,000	70,000	$/ha	
	Water source (on- or off-farm)	indicative >4,000 (analysed range: 3,000 to 15,000)			$/ha	
	Longer lifespan infrastructure (40 year)	50	50	50	%	1.0
	Shorter lifespan infrastructure (15 year)	50	50	50	%	1.0
Operating costs	O&M (by lifespan categories)	% capital cost			$/ha/y	
	Farm water source pumping costs	~2 (additional)			$/ML/m	
	Fixed costs	600	1,500	6,500	$/ha/y	
Water use	Crop water use (before losses)	6	6	6	ML/ha/y	
	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 required to deliver water to the farm at the level of the soil surface, are treated as the costs of the water source (so that different water sources can be substituted for each other on a like-for-like basis). Subsequent farm pumping costs to distribute and apply 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. Pumping costs for the water source are highly situation-specific for different water sources: in particular, these pumping costs are affected by the elevation of the water source relative to the point of distributing to the farm, for example, the height water needs to be pumped from a weir to a distribution channel, 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 are not included in summary tables of water pricing but should be added separately as required at a cost of about $2 per ML per m dynamic head (which is mainly a consideration for groundwater bores, but also applies where water needs to be lifted from rivers or irrigation channels). For more information on water infrastructure costs see Chapter 5 (and companion technical reports referenced there) and for crop GMs see Chapter 4 (and companion technical reports referenced there).

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

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 would be able to afford to pay for water, while meeting a target 10% IRR, for different levels of farm water use and productivity. For the prices to be sustained at this level throughout the life of the water source, the associated farm GM (in the row headings 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 Roper 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 most useful for public investors in large dams, because the sequencing of development creates asymmetric risks between the water supplier and irrigators. Irrespective of the water pricing that was planned for a dam project, once the dam is built irrigators have the choice of whether to develop new farms or not, and are unlikely to act to their own detriment in making that investment if they cannot do so at a water price that will allow them to attain a commercial rate of return. These water prices, together with estimates of likely attainable farm GMs in other parts of the Assessment, provide a useful benchmark for checking assumptions on any potential public dam developments in the Roper catchment.

For on-farm water sources, these water prices can be used to assist in planning water development options that cropping operations could reasonably be expected to afford. Tables in the next sections allow these comparisons by converting capital costs of developing on- and off-farm water sources to volumetric costs ($/ML supplied). All water prices are based on volumes supplied to the farm gate/surface (after losses getting to that point) 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 annual gross margin (GM) of the farm

Analyses assume water volumes are measured on delivery to the farm gate/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 Roper catchment are $4,000, $7,000 and $11,000 per ha per year, respectively (highlighted rows): note however that the third type of 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)							
Below 16,000	Farms cannot afford to pay for water (or their other costs) at GMs lower than this							
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 Roper 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 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

Table 6-5 shows what farm annual GM would be required for different costs of water infrastructure development at the public investors' target IRR. As expected, higher farm GMs are required to cover higher capital costs and attain a higher target IRR. These tables can be used to assess whether water development opportunities and farming opportunities in the Roper catchment are likely to pair together in financially viable ways. Indicative farm GMs that could be achieved in the Roper catchment are about $4,000, $7,000 and $11,000 per ha per year for 'Broadacre', less capital-intensive 'Horticulture-L' (including penalty to GM for outsourcing), and capital-intensive 'Horticulture-H', respectively (Table 6-3, Chapter 4). 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 are likely to be viable at these farm GMs and water development costs (at a 7% target IRR for the public investor). However, broadacre and less capital-intensive 'Horticulture-L' farming might be marginally viable at a 3% target IRR for the public investor. Alternatively, 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 (40% to 60%) towards the cost of a dam (including enabling infrastructure and ongoing O&M costs) that cost $50,000/ha to build. That is a higher proportion of costs than irrigators have historically contributed towards irrigation schemes in some other parts of Australia (about a quarter of capital costs; Vanderbyl, 2021), but would be a decision for the Commonwealth and Northern Territory governments based on their expectations, priorities and investment criteria.

Table 6-5 Farm gross margins (GMs) required to cover the costs of off-farm water infrastructure (at the suppliers' 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). Risk adjustment multipliers are provided in Section 6.3.5. Blue shading of rows indicates the capital costs that could be afforded by farms with GMs of $4,000, $7,000 and $11,000 per ha per year, respectively, for the farm types in the three sections of the table below. Blue shading of columns indicates the range of the most cost-effective dam development options in the Roper catchment (Table 6-2).

TARGET IRR (%)	FARM GROSS MARGIN REQUIRED 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

TARGET IRR (%)	FARM GROSS MARGIN REQUIRED 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**
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 Roper catchment some of the most cost-effective dam opportunities would cost about $5000 for each ML/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 $537 for each ML extracted to fully cover the costs of the public investment (at the base 7% target IRR for public investments, Table 6-6). Comparisons against what irrigators can afford to pay (Table 6-4), show that it is unlikely any farming options would be able to cover the costs of a dam in the Roper catchment at the GMs farms are likely to be able to achieve (Table 6-3, Chapter 4). In cases where 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 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, which would cover 25% ($135/$537) of the $537/ML price required to cover the full costs of the public development: the

BCR would therefore be 0.25 (the ratio of the full costs of the scheme to the proportion the net farm benefits can cover). As for the example discussed for 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 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. about $30/ML extra to lift water about 15 m from weir pool to distribution channels). '$ CapEx per ML/y at dam' is the capital expenditure on developing the dam and supporting off-farm infrastructure for each ML/y of the dam's supply capacity measured at the dam wall. Highlighted values are indicative of the most cost-effective large dam options available in the Roper catchment (Table 6-2).

TARGET IRR (%)	WATER PRICE THAT WOULD NEED TO BE CHARGED 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 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 hectare of farmland, depending 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 to cover full costs of greenfield farm development with water source

Table 6-7 shows the farm GMs that would be required to cover different costs of farm development at the investors 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 same indicative farm GMs as before (Table 6-3) and 10% target IRR, a broadacre farm with $4,000 per ha per year GM could cover total on-farm development capital costs of about $20,000/ha, a lower capital cost 'Horticulture-L' farm with GM of $7,000 per ha per year could afford about $40,000/ha of initial capital costs, and a capital-intensive 'Horticulture-H' farm with GM of $11,000 per ha per year could pay about $30,000/ha for farm development (Table 6-7). This indicates that on-farm water sources may have more prospects of being viable than large public dams in the Roper 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 low-enough cost.

Table 6-7 Farm gross margins (GMs) required to achieve target internal rate of return (IRR) given different 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 shading of rows indicates the capital costs that could be afforded by farms with GMs of $4,000, $7,000 and $11,000 per ha per year, respectively, for the farm types in the three sections of the table below.

TARGET IRR (%)	FARM GROSS MARGIN REQUIRED TO ACHIEVE FA’MER'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
	Horticulture-L ($1500/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 ($6500/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 ML 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 $/ML costs against 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 and annual farm water use of 8 ML/ha could afford to pay $135/ML for its water supply (Table 6-4), which would allow capital costs of $700 to $1000 for each ML/year supply capacity for developing an on-farm supply. Indicative costs for developing on-farm water sources range from about $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 Roper catchment.

Table 6-8 Equivalent costs of water per megalitre for on-farm water sources with different 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. about $2 per ML per m dynamic head for bore pumping).

TARGET IRR (%)	WATER VOLUMETRIC COST EQUIVALENTUNIT FOR DIFFERENT CAPITAL COSTS OF WATER SOURCE ($/ML)								
	Capital costs for on-farm water infrastructure ($ CapEx per ML/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 negative risks is to reduce the expected revenue and expected GM.

Setbacks that occur early on 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 the anticipatable agronomic risks of establishing new farmland. 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 would be prudent to err on the side of delaying full development (particularly given that in practice, it would only be possible to know when full performance was achieved in retrospect, not in advance). An added benefit of staging would be limiting losses where small-scale testing proves initial assumptions of benefits to be overoptimistic and that full-scale development could never be profitable, even after trying to overcome unanticipated challenges.

For an investment to be viable, farm GMs need to be sustained at high levels over long periods. Thus, variability in farm performance poses risks that need to be considered and managed. GMs can vary between years either because of short-term initial underperformance or because of 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. There would be further unavoidable periodic risks associated with water reliability, climate variability, flooding, outbreaks of pests and diseases, periodic technical/equipment failures, and fluctuations in commodity prices and market access. Periodic risks, such as reliability of water supply, are less easy to avoid. Risks that cannot be avoided need to 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 to survive through challenging periods. Another perceived risk for investors is that of uncertainty around future policy changes and delays in regulatory approvals. Reducing this, or any other sources of risk, in the Roper catchment would contribute to making marginal investment opportunities more attractive.

Results for analyses of both periodic and learning risks are shown below. Throughout this section, farm performance in a given year is quantified as the proportion of the long-term mean GM a farm attains, where 100% performance is when this level is reached and zero % equates to a performance where revenues only balance variable costs (GM = zero).

Risks from periodic underperformance

Analyses considered periodic risks generically, without assuming any of the particular causes listed above. Periodic risks were characterised in terms of three components to quantify their effects on scheme financial performance:

- reliability: the proportion of ‘good’ years where the ‘full’ 100% farm performance was achieved, with the remainder of years being ‘failures’ where some negative impact was experienced
- severity: the farm performance in a ‘failed’ year where some type of setback occurred
- timing: for ‘early’ timing a 10-year cycle was used where, for example, with 80% reliability failures would occur in the first 2 years of the scheme and the first 2 years of each 10 years in a cycle after that. For ‘late’ timing, the ‘failures’ came at the end of each 10-year cycle. Where ‘random’ timing was used, each year was represented as having the long-term mean farm performance of ‘good’ and ‘failed’ years (frequency weighted).

Table 6-9 summarises the effects of a range of different 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 results were simplified as a set of risk adjustment multipliers. The multipliers can therefore be applied to the target farm GMs in the previous section (required to cover capital costs of development at investors’ 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 would be expected, the greater the frequency and severity of ‘failed’ years, the greater the impact on scheme viability and the greater the increase in farm GMs that would be required to offset these impacts. As an example, the reliability of water supply is one of the more important sources of unavoidable variability in productivity of irrigated farms. In such cases, water reliability (proportion of years where the full supply of water is available) is the same as the ‘reliability’ in

Table 6-9, and the mean percentage of water available in a ‘failed’ year (where less than the full supply is available) is equivalent to 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 on average 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 to achieve a target IRR (and irrigators’ capacity to pay for water would be ~4% lower) than if water could be supplied at 100% reliability. For crops where the quality of produce is more important than the quantity, such as annual 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 reliability and severity (level of farm performance in ‘failed’ years) of periodic risks

Results are not affected by discount rates. ‘Good’ years = 100% farm performance; ‘Failed’ = <100% performance. ‘Failed year performance’ is the mean farm GM in years where 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 summarises how 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 no (long-term frequency, weighted mean performance) timing.

These results show that any negative disturbances that reduce farm performance will have a larger effect if they occur early on 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 (where setbacks occur in the in the last three 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, so impacts of early setbacks are more severe and the farm GM would have to be 23% higher than if farm performance were 100% reliable.

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

Assumes 50% farm performance during ‘failed’ years, where 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 Roper catchment, and includes setbacks from delays, such as gaining regulatory approvals and adapting farming practices to Roper catchment conditions. 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 if developers are well prepared, there are likely to be 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 weed 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: represented as described before, as 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 before, learning had consistent proportional effects on target GMs, so results were simplified as a set of risk adjustment factors (Table 6-11). As would be 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 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 the anticipatable agronomic risks of establishing new farmland. 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.

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

As indicated in the examples above, the influence of each risk individually can be quite modest. However, it is the combined influence of all foreseeable risks that need to be accounted for in planning and the cumulative effect of these risks can be substantial. For example, see the last question in Table 6-1 for the combined effect of just two risks (where farm GMs would need to be about 50% higher), and see Stokes and Jarvis (2021) for the effects of a common suite of risks on the financial performance of a Bradfield-style irrigation scheme.

6.4 Cost–benefit considerations for water infrastructure viability

6.4.1 Lessons from recent Australian dams

CBA is widely used to assist decision makers in evaluating the likely net benefits that would arise from implementing a proposed project, particularly for investments in large-scale public infrastructure. Despite this wide usage of CBAs, there are few examples where the estimated costs and benefits used to justify the project have been revisited at a later date. The main purpose of such ex-post evaluations '**is not to find fault in the implementation of the project, but to capture lessons that can improve future planning, delivery and risk mitigation**' (Infrastructure Australia, 2021a).

Of the limited examples where water infrastructure CBAs have been evaluated, the focus has been 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) and 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 under-performed, 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, 2000a, 2000b). In particular, this study highlighted inaccurate, and over-estimated, forecasting of future irrigation demand for water from dam developments.

Review of recent Australian dams

The companion 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 on the ex-post lessons that can be learned from how well Australian dam projects have achieved their proposed benefits. These lessons provide context for interpreting CBAs from project proponents and independent analysts, and the financial analyses provided in the previous section. The key lessons from that review are summarised below (full details are covered in Stokes et al. (2023)).

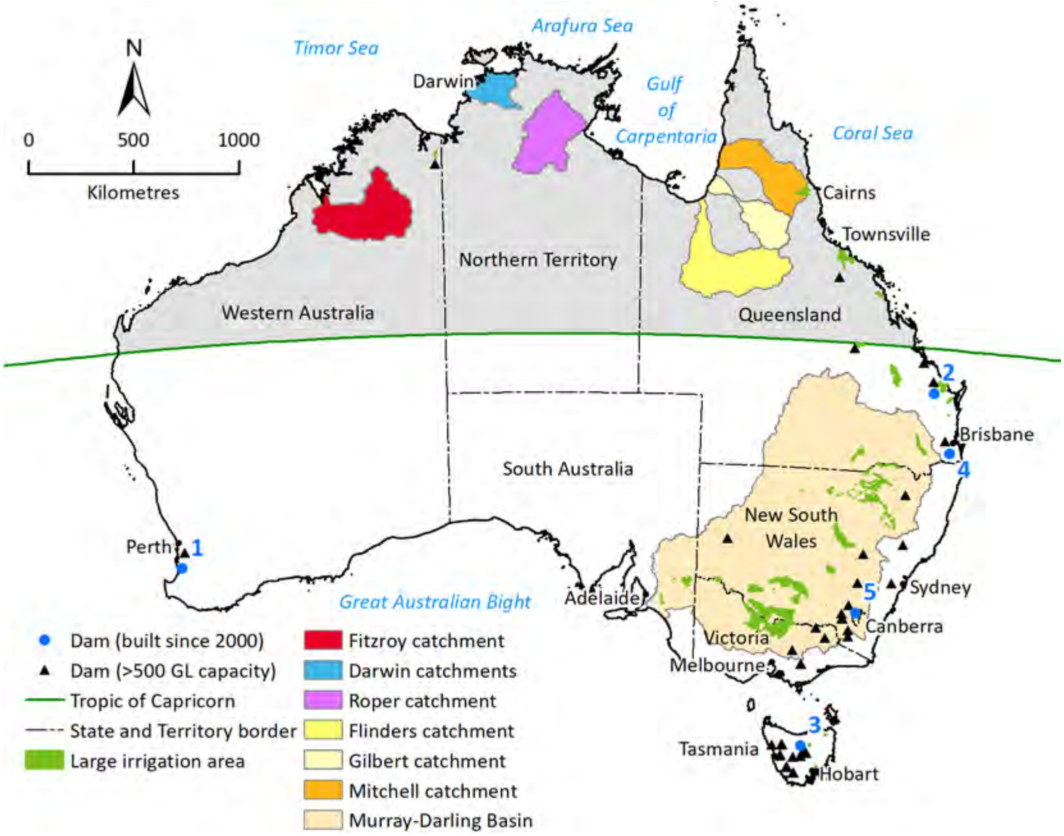


Figure 6-2 Map showing locations of the five case study dams used in this review

The case study 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 (Stokes et al., 2023).

	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	59 GL	300 GL	43 GL	103 GL	78 GL
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 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 actual CBA report unavailable)

Summary of key issues identified

This review has highlighted a number of issues with historical use of CBAs for recently built dams in Australia together with ways that they could be more rigorously addressed (Table 6-13). These issues arise both 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 nor water infrastructure alone – 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/competing investments with exaggerated CBRs.

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

	KEY ISSUE	POTENTIAL IMPROVEMENTS
1	**Lack of clear documentary evidence regarding the actual outcome of dam developments compared to assumptions** made in ex-ante proposals, EISs and CBAs. Ex-post evaluations or post-completion reviews have either not been prepared, or not made publicly available.	Conducting **ex-post evaluations** of developments and making these publicly available (as recommended by 2021 guidance from Infrastructure Australia, and in the 2022 National Water Grid Investment Framework) would enable lessons learned to be shared and to 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 over estimating the magnitude and rate at which new benefit would flow.	**Recognising the tendency towards a systematic bias** of over stating benefits and under stating 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 realistically achievable benchmarks** for evaluating proponents' assumptions and financial performance claims, (iii) using past experiences and **lessons learned** from previous projects with similar context to inform the analysis presented in the proposals (building on Issue 1 above), and (iv) presenting a like-for-like comparison of **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 of 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 for Issue 2 in 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 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 be formally presented alongside**. This information would be 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.
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.	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

KEY ISSUE	POTENTIAL IMPROVEMENTS
Dams provide a form of insurance against the risk that water may not be available when needed in future. **Assessing the value of this insurance** requires consideration to be given to the cost of lack of water supply when needed, and the likelihood that this could occur.	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 precedence to, other information regarding the proposal including the estimated NPV, rather than attempts be made to 'force' the benefit into an NPV calculation which is ill equipped to deal with such a benefit.

In the short term, the main value of the information provided here is to assist in more critically interpreting and evaluating CBAs, warts and all, 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 where the claims of proponents warrant critical scrutiny. In the longer term, this analysis supports many of the similar issues 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

If horticulture is to continue to grow in the Roper catchment and the rest of the NT, 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 to ensure assumed demand trajectories for water (and the associated value that can be generated from new high-value horticulture 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 for horticultural in the NT (Figure 6-3).

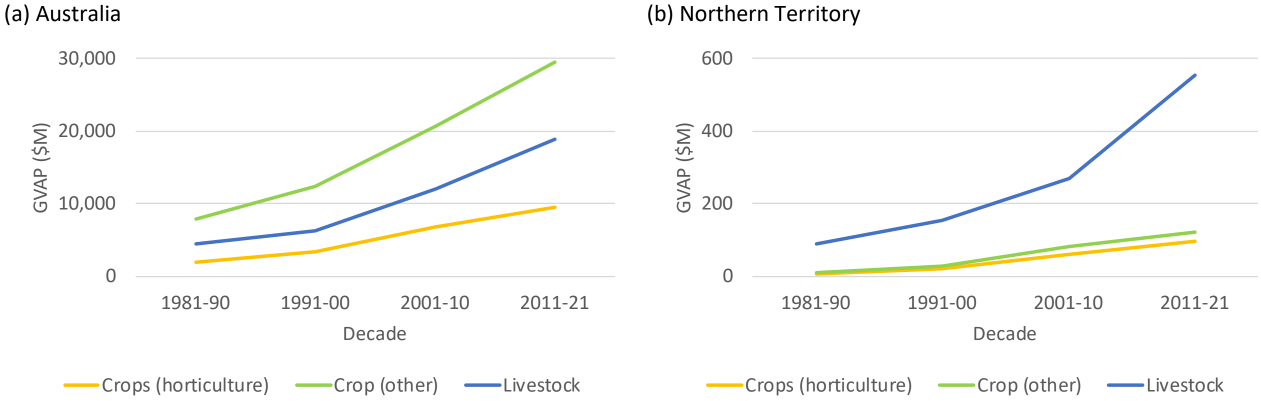


Figure 6-3 Trends in gross value of agricultural production (GVAP) in (a) Australia and (b) the NT over 40 years (1981–2021)

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

Source: (ABS, 2022)

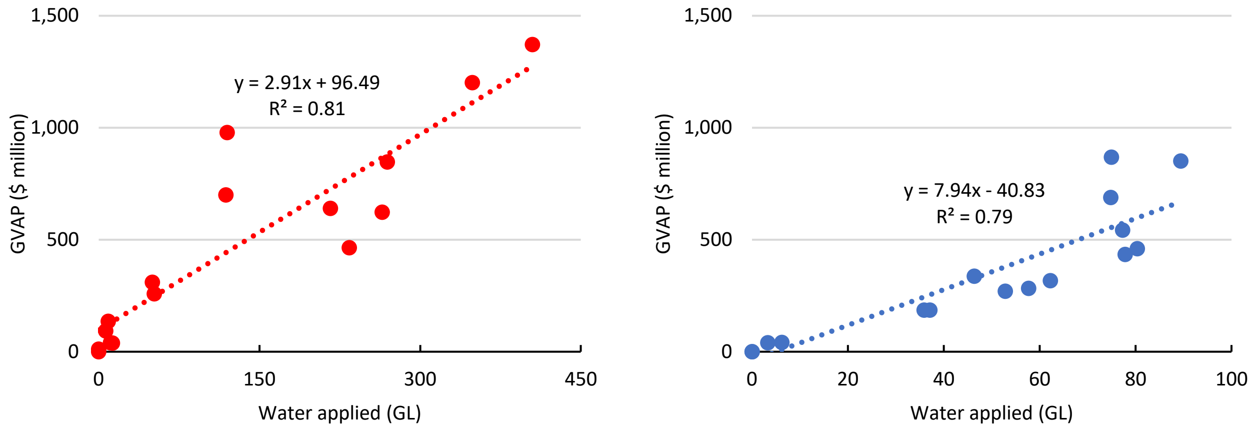
Horticultural produce is typically perishable and expensive to store and transport, with stringent phytosanitary standards for export, so most Australian horticultural produce (about 70%) is sold domestically for consumption shortly after harvest. Growth in horticultural industries is therefore constrained 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 2001–10 to 2011–21 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 associated demand for high-priority water) could grow towards the ultimate scheme potential.

In addition, the scale of new horticultural 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 that 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:

- 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)
- 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) and are a combination of increases in both product volumes and the increase in value per unit product. Unlike horticultural crops, bulk broadacre commodities are stored and traded on large global markets, with multiple competing international buyers, that could easily absorb the scale of increases in production that would be possible from the Roper catchment. However, supply chains, rather than markets, pose a challenge for new broadacre production. Despite the closer geographic proximity of northern Australia (compared to southern Australia) to many key markets, supply chains are longer because most agricultural exports leave through southern ports. For example, currently no bulk food-grade containers are handled by Darwin Port (either import or export). The challenge is to not just develop transport and handling capacity for exports, but to balance that with the compatible imports to avoid the added cost of dead freighting empty containers (CRCNA, 2020).

(a) Fruits (b) Vegetables



(d) Fruits and vegetables combined (d) Total agriculture

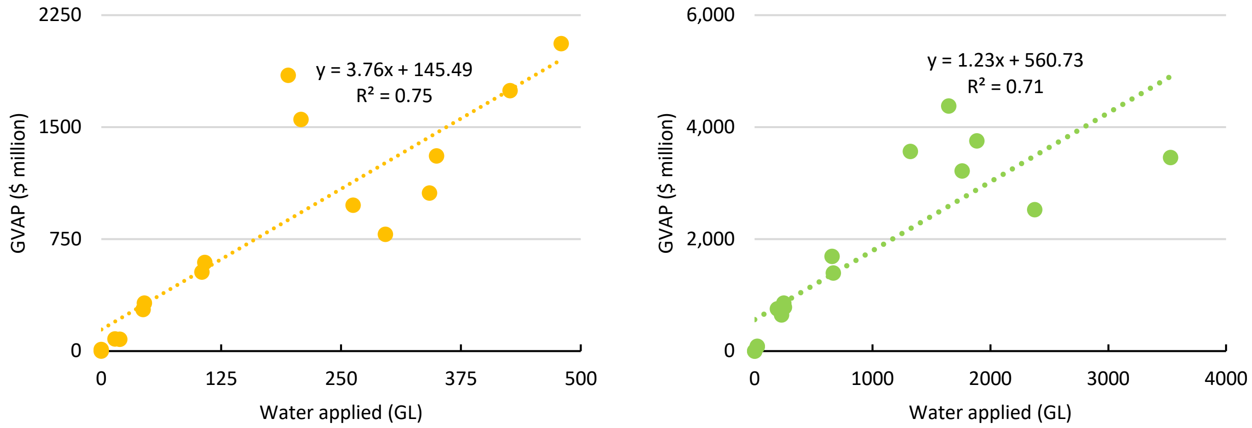


Figure 6-4 Trends for increasing gross value of irrigated agricultural production (GVIAP) as available water supplies have increased for (a) fruits, (b) vegetables, (c) fruits and vegetables combined, and (d) total agriculture

Source: (ABS, 2021)

6.4.3 Costs of enabling infrastructure

A range of infrastructure would be required to support development of a new irrigation scheme in the Roper 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 utilised effectively (and to achieve its proposed benefits), will require additional 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. Such enabling infrastructure can be considered ‘hard’ or ‘soft’, which within the context of a large irrigation development can be broadly defined as follows:

- Hard infrastructure refers to the physical assets necessary for the functioning of a development and can include water storage, roads, irrigation supply channels and energy, but also processing infrastructure, such as sugar mills, cotton gins, abattoirs and feedlots.
- Soft infrastructure refers to the specialised services required to maintain 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, 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 is developed. For example, a review of the Ord-East Kimberley Development Plan (for expansion of the Ord irrigation system by about 15,000 ha) found that there were additional costs of $114 million to the Western Australian Government, beyond the planned $220 million state investment in infrastructure to directly support the expansion (Western Australian Auditor General, 2016).

The purpose of this section is to provide 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 here is not to diminish the potential benefits of development and population growth in a region, but to highlight potentially overlooked costs that are required to realise those benefits.

Costs of hard infrastructure

Establishing new irrigated agriculture in the Roper catchment would involve the initial costs of land development, water infrastructure (which could include distribution and re-regulating or balancing storages), and farm set-up costs 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.

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 also listed (Table 6-16). All tables are summarised from information provided in the companion technical report on agricultural viability and socio-economics (Stokes et al., 2023).

Table 6-14 Indicative costs of agricultural processing facilities

ITEM	CAPITAL COST	OPERATING COST	COMMENT
Meat works	$35 million	$340/head	Operational capacity 100,000 head/y
Cotton gin	$32 million	$1.1 million/y plus $24 to $35/bale	Operational capacity of 1,500 bales/day Operating costs depend on scale of gin and source of energy
Sugar mill	$409 million	$34 million/y	Operational capacity of 1,000 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	$0.27 to $2.1 million/km	Upgrade and widen dirt road to sealed road
New floodway	about $20 million	Costs of bridges and floodways vary widely
Electricity		New generation capacity may also be required
Transmission lines	$0.4 to $1.2 million/km	High-voltage lines deliver bulk flow of electricity from generators over long distances
Distribution lines	$0.2 million/km	Lower voltage lines distribute power from substations over shorter distances to end users
Substation	$11 to $53 million	Transformers and switchgear connect transmission and distribution networks

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

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

DESTINATION	TRANSPORT COST		
	Unrefrigerated	**Refrigerated**	**Cattle**
	Transport costs from Mataranka ($/t)		
Adelaide	263.13	385.93	289.45
Brisbane	318.26	466.78	350.08
Broome Port	170.34	249.83	187.37
Cairns	245.84	360.57	270.42
Darwin	42.90	62.92	47.19
Karumba Port	177.30	260.04	195.03
Melbourne	371.20	544.43	408.32
Perth	391.38	574.02	430.51
Sydney	387.09	567.73	425.80
Townsville Port	220.23	321.43	241.92
Wyndham Port	73.53	107.84	80.88
	Transport costs by distance ($/t/km)		
Properties to Mataranka	0.26	0.39	0.29
Mataranka to key markets/ports	0.17	0026	0.19

Costs of soft infrastructure

The availability of community services and facilities would play an important role in attracting or deterring people from living in a new development in the Roper catchment. If local populations increase as a result of new irrigated developments, then there would be increased demand for public services, and provision of those services would need to be anticipated and planned. Indicative costs for constructing a range of different facilities that may be required to support 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 primary and some secondary care, while the broadest range of more specialised tertiary services are concentrated in referral hospitals that are mainly located in large cities but serve large surrounding areas. Primary schools tend to be smaller and more widespread, while larger secondary schools are 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 are estimated to be about 30 to 60% higher than those quoted for Darwin. School costs were estimated separately from a range of sources across northern Australia. See companion technical report on agricultural viability and socio-economics (Stokes et al., 2023) for details.

ITEM	CAPITAL COST	COMMENT
Hospital	$0.2 to $0.5 million/bed	Higher end costs include major operating theatre and larger area of hospital 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	$2,400 to $3,450/$m^2$	1 to 3 stories, outside central businesses district

Demand for community services is growing both from population increases in Australia and rising community expectations. New infrastructure that is built to service that demand would occur irrespective of any development in the Roper catchment. However, if new irrigation projects shift people to live in the Roper catchment, this could then shift the locations of where some services are delivered and associated infrastructure is built. The costs of delivering services and building infrastructure is generally higher in more remote locations like the Roper catchment. The net cost of any new infrastructure that is built to support development in the Roper catchment is the difference in the cost of shifting some infrastructure to this more remote location (not the full cost of facilities (Table 6-17) that would otherwise have been built elsewhere).

6.5 Regional-scale economic impact of irrigated development

New irrigated development in the Roper 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 is established, and how much spending from the increased economic activities occurs within the region. Regional economic impacts would be an important consideration for evaluating potential new water development projects.

It was estimated that each million dollars spent on construction within the Roper catchment generated 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). Each million dollars of direct benefit from new agricultural activity was estimated to 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 longer term (operational phase). Those 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, then this provides a stimulus to those businesses from which they purchase, contributing to further economic growth within the region. Furthermore, household incomes increase as a result of those local residents who are employed (as a consequence of the direct and/or production-induced business stimuli). As a proportion of their additional income is spent in the region, this expenditure further stimulates the economic activity within the region. 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 will 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), where 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 stimulus to particular industries, focusing here on construction in the short term and different types of agriculture in the longer term.

It is also possible to estimate the increase in household incomes in the region. From this, an estimate can be made of 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 of the 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 made outside the region), the smaller the resulting economic benefit that will be enjoyed by the region. Conversely, the more of the initial spend and subsequent indirect spend that is retained 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 range 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 Roper 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. The current low unemployment rate within the Roper 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 Roper 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 Roper catchment, it was necessary to use available information and models for the Roper catchment region. Two I–O models were used, one covering the whole of the NT (Murti and Northern Territory Office of Resource Development, 2001) and one based on the adjacent Daly catchment (Stoeckl et al., 2011) (Figure 6-5). For more detail, see the companion technical report on agricultural viability and socio-economics (Stokes et al., 2023).

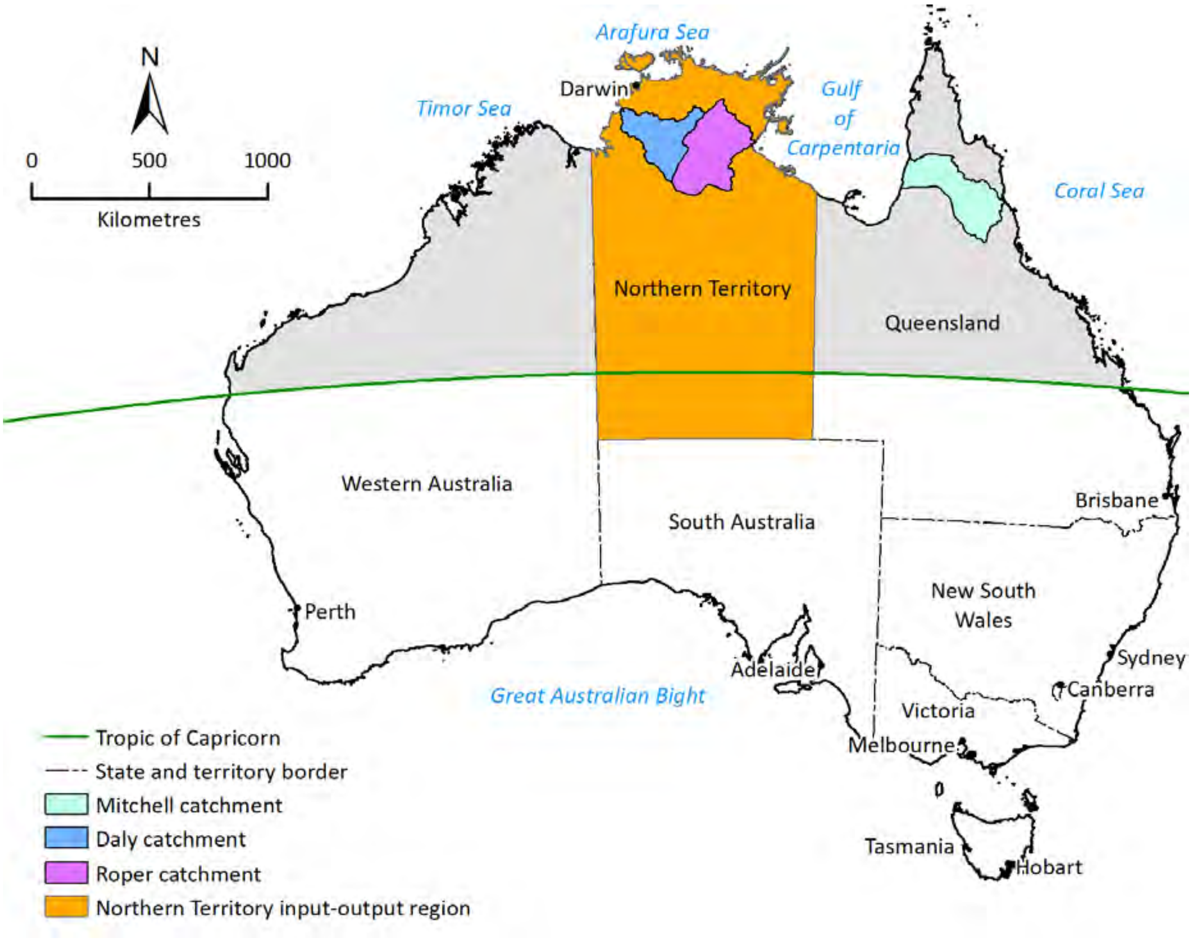


Figure 6-5 Regions used in the input–output (I–O) analyses relative to the Roper catchment assessment area

Additional data are presented to show how the economic circumstances of the Roper catchment compares to that of the two I–O region (Table 6-18). The Daly I–O region has some more similar characteristics with the Roper catchment than the larger NT I–O region. However, any benefits of development in the Roper catchment are likely to spill over into the NT's capital in Darwin, which 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 region's capacity to produce a wide range 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).

Table 6-18 Key 2016 data comparing the Roper catchment with the related I–O analysis regions

	ROPER CATCHMENT[1]	DALY CATCHMENT I–O REGION[†]	NT I–O REGION[‡]
Land area (km²)	77,352.2	53,088.5	1,348,094.3
Population	2,512	11,312	228,833
% male	51.10%	52.07%	51.82%
% Indigenous	73.35%	28.66%	25.45%
Median age	28	32	32
Median household income	$61,852	$84,328	$99,580
Contribution of agriculture, forestry and fishing to employment in the region	14.0%	6.2%	2.0%
Major industries of employment – top three industries in region as % of employment 2016			
• Largest employer in region	Public administration and safety	Public administration and safety	Public administration and safety
• 2nd largest employer in region	Education and training	Health care and social assistance	Health care and social assistance
• 3rd largest employer in region	Agriculture, forestry and fishing	Education and training	Construction
Gross value of total agricultural in region	$60 million	$49 million	$697 million

[†] Statistics for Roper (ABS, 2016a) and Daly (ABS, 2016b) regions have been estimated using the weighted average of ABS 2016 census data obtained by SA2 statistical region, with weighting based on the proportion of relevant ABS SA2 statistical regions falling within each of the catchment region.

[‡] ABS 2016 census data (ABS, 2016c).

[§] ABS Value of agricultural commodities produced 2015-16 by region, report 75030DO005_201516 (ABS, 2017).

There are wide variations in the size of the multipliers for different industries within the NT and Daly I–O region. Those 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 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 the building of 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.

A scenario approach was adopted for the scales of development considered in estimating the regional impact of the construction phase of potential developments. The analyses modelled regional impacts for five different indicative sizes of developments in the Roper catchment, with capital costs from $250 million to $4 billion. These total capital costs include costs of labour and materials required by the project. The smallest scale of development in Table 6-19, with a capital cost of $250 million, would broadly represent about 20 new farm developments with their own on-farm water sources enabling around 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 (Stokes et al., 2023)). The second-smallest scale scenario, $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) that could be required and supported from this scale of agricultural development. Alternatively, the $500 million scale of development could represent a large off-farm water infrastructure development (for example, see Table 6-2) along with related farm establishment costs. The larger scales of development, at $1 or $2 billion shown in Table 6-19, indicate outcomes from combining potential developments in different ways (such as one large off-farm dam and multiple on-farm water sources), and also including investment in indirect supporting infrastructure across the region, such as investment in 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 different costs, including for labour, materials and equipment. For labour costs, it is likely that the wages would be paid to workers sourced from within the region and from elsewhere, with the likely proportion of labour costs relating to each source of workers being dependent 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 Roper catchment is more likely to need to attract many workers from outside the region, either on a FIFO/DIDO basis or by encouraging migration to the region. Similarly, for materials and equipment, some regions may be better able to supply a large proportion of these items from within the region, whereas construction projects in other locations may find they are unable to source what they need locally, and instead import a significant proportion into the region from elsewhere. The low representation of the required supplying industries in the Roper catchment, means that most construction supplies are likely to be sourced from other parts of Australia (and internationally).

Based on a review of different dam projects across the country, it would appear that the proportions of local construction spend sourced within a region (as opposed to being imported, which has no impact on the local regional economy) vary significantly. Thus, analyses considered three levels for the proportion spent locally: 65% (i.e. low leakage), 50% and 35% spent locally (i.e. high leakage). However, it should be noted that for a very remote region like the Roper catchment, the potential exists for leakage to be higher (i.e. <35% spent locally). In cases of high leakage, the knock-on benefits would instead occur in the regions supplying the goods and services (like 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 five scales of scheme capital cost ($0.25 billion to $4 billion) and the three levels of leakage noted 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 with the Roper catchment and its proximity to Darwin, leakage may be towards the high end of the range examined for Roper 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 Roper catchment (and 50% with the wider NT I–O region), the construction multiplier would only apply to the portion spent locally, to give an overall regional economic benefit of $380 million within the Roper 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 where the remaining funds were spent.

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 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 region.

DEVELOPMENT CAPITAL COST ($ billion)	TOTAL REGIONAL ECONOMIC ACTIVITY WITHIN I–O REGION AS A RESULT OF THE CAPITAL COST OF THE DEVELOPMENT ($ billion)					
	Roper catchment based on NT I–O model			**Roper catchment based on Daly catchment I–O model**		
	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 per year) this could represent 10,000 ha of new plantation timber, while the high end ($200 million per year) could represent 10,000 ha of mixed broadacre cropping and horticulture (based on farm financial estimates for different 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 estimates of 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 different industry multipliers estimated for the NT I–O.

Table 6-20 Estimated regional economic impact per year in the Roper 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 region.

DIRECT INCREASE IN AGRICULTURAL OUTPUT PER YEAR NET OF CONTRIBUTION TO CONSTRUCTION COSTS ($ million)	TOTAL VALUE OF INCREASED ECONOMIC ACTIVITY IN I–O REGION – DIRECT, PRODUCTION-INDUCED AND CONSUMPTION-INDUCED ($ million)			
	Roper catchment based on NT I–O model			**Roper 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

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. These additional full-time equivalent 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, should these additional jobs be filled by currently unemployed or underemployed local people, then additional infrastructure would not be necessary. Estimates of the expected increases in incomes were divided between Indigenous and non-Indigenous households, with most increases expected to flow to non-Indigenous households (Table 6-21).

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

Table 6-21 Estimated impact on annual household incomes and full time equivalent (FTE) jobs within the Roper catchment resulting from four scales of direct increase in agricultural output (rows) for the different 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 region.

DIRECT INCREASE IN AGRICULTURAL OUTPUT PER YEAR NET OF ANY CONTRIBUTION TO CONSTRUCTION COSTS ($ million)	TOTAL VALUE OF INCREASED ECONOMIC ACTIVITY IN I–O REGION – DIRECT, PRODUCTION-INDUCED AND CONSUMPTION-INDUCED ($ million or FTE)			
	Roper catchment based on NT I–O model			**Roper 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	111	25	213	102
50	222	50	426	203
100	444	100	852	407
200	888	199	1,704	813

6.6 References

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