Bradfield Regional Assessment and Development Panel

REPORT



Acknowledgement of Country

The Bradfield Regional Development and Assessment Panel (the panel) acknowledges the Traditional Owners and custodians of the lands and waters across the State of Queensland, and pays its respects to Elders past, present and emerging.

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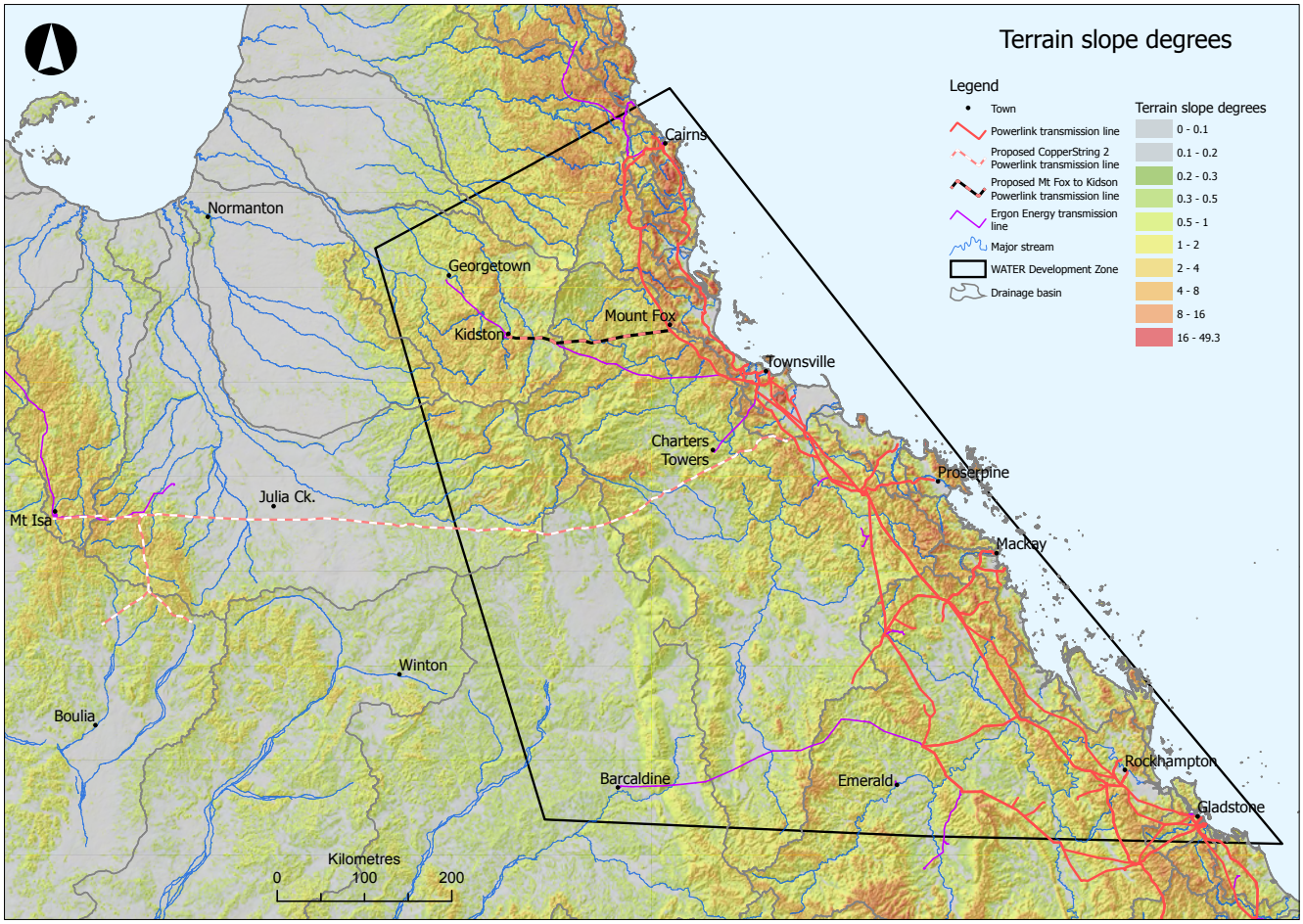
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Map: Land slope and water in central and northern Queensland.

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Section 1



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01

Chapter 1

Summary and recommendations

Summary and recommendations



The heavy rainfall and large river flows of northern and central Queensland are a major regional, state and national asset with economic, environmental, social and cultural significance.

More than 80 years ago, eminent Australian engineer Dr John Bradfield proposed a water infrastructure project of breathtaking scale and potential impact to use this asset. It was conceptually similar to, and considerably greater in scale than, the later Snowy Mountains Scheme.

The Bradfield Scheme aimed to capture part of the water from the Tully, Herbert and Burdekin rivers in northern Queensland and to divert it through the Great Dividing Range into rivers flowing west (towards the Gulf of Carpentaria) and then south into central Queensland (through the Channel Country to Lake Eyre). This would allow the irrigation of vast semi-arid and arid areas and the growth of remote communities. The Bradfield vision has attracted people with ambitions for regional Queensland and inland Australian development ever since. Several variations on the original scheme have been designed.

The Bradfield Regional Assessment and Development Panel (the panel) was appointed by the Queensland Government in late 2020 to examine the many versions of the Bradfield proposal (including Bradfield-like ideas) and to assess whether any of them have overall value for Queensland and Australia today. The panel was asked to consider economic and related matters affecting development in central and northern Queensland. These included new energy infrastructure (with specific reference to the CopperString Project), and potential for new industries (such as hydrogen). The panel was asked to exercise independent judgement in providing advice to the government and the community.

The panel commenced with the view that large-scale regional development in central and northern Queensland through making good use of water was a laudable policy goal. The water falling in apparent abundance in the areas close to the Great Dividing Range in northern and central Queensland has immense value for the state and the nation and can indeed be used to promote regional development on a transformative scale. The panel's assessment of the opportunities has confirmed this view.

What has changed since the original Bradfield proposal?

Since the original Bradfield proposal in 1938, a number of important matters related to the use of water from northern and central Queensland have changed considerably.

1. There has been dynamic economic development in northern and central Queensland based on using large amounts of water near to where it falls. Development has included dams on the Barron, Tully, Pioneer, Burdekin, Fitzroy and Burnett rivers to support economic growth. This has contributed to major agricultural development and the growth of a globally significant coal industry underpinning the state's electricity generation. Small regional towns have become the major cities of Bundaberg, Gladstone, Rockhampton, Mackay, Townsville and Cairns. The population of coastal and near inland northern and central Queensland grew from about 289,000 in the 1930s to an estimated 1,002,000 in 2020. These established industries and populations depend on the secure availability of water.

2. Knowledge of the value of water for maintaining significant ecosystems has increased. Water flowing to the Pacific Ocean is essential for the survival and good health of natural ecosystems. These include riparian environments, wild-catch fishing industries and the Great Barrier Reef. These flows also have cultural and social value to resident Aboriginal and Torres Straits Islander peoples and other communities. Much more is known about what is required to maintain the health of inland environmental systems, which depend on ephemeral (short-lived) river flows. Transferring too much water from northern Queensland would disrupt the health of all of these environmental systems.
3. From irrigation development in southern Queensland, more is known about how to capture and store wet season flows locally, outside of river channels. There is also greater knowledge about the significant losses that occur when water is transferred along existing water courses.
4. Queensland law and national water policies written into agreements between Commonwealth and state governments now require water allocation decisions to consider the flows necessary for environmental health, cultural outcomes, and for water security.
5. It was not known then, but is now, that the increase in greenhouse gases in the atmosphere is changing climate in ways that have large implications for water availability for new economic uses and the environment. Queensland law and national water policy, reflected in federal–state agreements, require climate change to be considered when deciding to allocate water to new economic uses. There is now awareness that food production systems face a triple challenge of providing food security and nutrition for a growing global population, the need to support the livelihoods of those working along the food supply chain and contributing to environmental sustainability.
6. Global movements towards zero net carbon emissions have greatly increased the economic value of water used to support zero-emissions activity globally. The more valuable uses include growing plants to capture carbon in soils and in biomass, and in using harvested biomass to provide alternatives to coal, oil and gas in many industrial processes.
7. Global movement towards zero emissions has given large economic value to the renewable energy resources that are abundant in central and northern Queensland. The value of wind and solar energy can be enhanced by balancing their intermittent output with the hydro-electric and pumped hydro-electric storage potential of the Great Dividing Range and energy from biomass.
8. The relationship between water and energy has become more important to regional development. Together with population, the well-developed infrastructure and industrial base of the major coastal cities of central and northern Queensland, water and renewable energy resources contain immense opportunity for regional development in the emerging zero-emissions world.
9. Non-Indigenous Australians have learned more about Aboriginal and Torres Strait Islander heritage, values, and social and economic aspirations, and accord them greater respect. Queensland and Australian law and policy now require this to be built into decisions to change water and land use. Many Aboriginal and Torres Strait Islander peoples aspire to be equity partners in the development of land and water resources.
10. The price of capital has fallen through the twenty-first century, reducing the cost of long-term investment in water and other economic infrastructure. The lower cost of capital, as well as improved technology and reduced equipment costs for renewable energy, have also reduced the economic cost of pumping water.

The expansion of knowledge outlined above suggests that Queensland, as Australia's most decentralised state with rich water, land, solar and wind resources in the vicinity of major established industrial centres, has before it an immense opportunity to expand incomes, employment and population. Indeed, Queensland Premier Annastacia Palaszczuk has recognised the state's transformational opportunity in an October 2021 statement:

"Queensland will be a renewable energy superpower. That is my vision"[1].

The Premier's vision is solidly grounded in reality.

In Gladstone on 10 October 2021, the Premier joined four of her senior ministers and the Chairman of Fortescue Future Industries in announcing a decision to build the world's largest hydrogen electrolyser manufacturing plant.

Managing water well is essential for realising this vision. Realisation requires a cohesive, long-term approach across three levels of government, the private business sector and the community.

Queensland's history contains occasions when the state has successfully reorganised planning and policy-making institutions and administrative processes to take advantage of emerging opportunities for transformative economic development. Late last century, such a reorganisation saw Queensland grasp opportunities created by economic growth in Northeast Asia to expand mining in Queensland's northwest, minerals processing in Gladstone and Townsville, the coal industry of the Bowen basin, and the tourism industry in Cairns and along the Great Barrier Reef. Judicious and timely government action, including adapting planning, decision-making processes and delivery structures to lever these opportunities, gave great impetus to economic growth in central and northern Queensland.

Another example is the management of immense population and economic growth in South East Queensland through the 1990s and early 2000s. Whole-of-government coordination in planning for land use, water, energy (gas and electricity), transport (road and rail), health, education and other community services enabled the absorption of this growth.

Realising the new water and energy-based opportunity in northern and central Queensland requires similarly coordinated regional planning involving the whole government. It requires a strong focus on using water and energy strategically for long-term regional development, while at the same time minimising, or potentially even reversing, negative impacts on the region's environmental and cultural values.

Assessment of Bradfield and Bradfield-like options

The panel has formed the view that building any one of the many immense Bradfield-type projects would, on balance, detract from regional development in central and regional Queensland. It would absorb resources, including water, that would add more positively to regional development if applied wisely to other priorities.

Before proceeding to a detailed evaluation of the Bradfield concept, the panel examined assessments from 80 years ago up to today about the water available for diversion west and south. The volumes of water are simply not available to support the proposals in their original forms. In fact, the water was never available in the required volumes, and developments since the original Bradfield work have reduced the amounts available. A CSIRO report commissioned by the Commonwealth Government[2] developed a variation on the Bradfield idea; one of the Bradfield-like concepts the panel considers in its analysis. This variation made smaller demands on water. However, the CSIRO variation still would require much more water than could be made available today.

If water had been more abundant, and the panel had found that there was enough water to justify Bradfield-scale developments on the Upper Burdekin and Wet Tropics rivers, other constraints might still have been insurmountable. Some engineering problems were daunting, although CSIRO's version of Bradfield suggested solutions. Transforming inland rivers from ephemeral to steadily flowing systems would have required great care in meeting environmental and Indigenous cultural objectives. Finally, there is likely to be a net loss of economic value when immense quantities of water are moved over long distances when there are similarly good opportunities to use the water much closer to where the rain falls. There are also more cost-effective ways of utilising the human capital, urban infrastructure and other capacities of the regions to which the water would have been transferred.

The disadvantages of large-scale movement of water to major new economic centres include:

- the high costs of moving water
- the water lost in evaporation and seepage along the way
- the higher evaporation that would be experienced in inland agriculture
- soils and growing conditions that are not obviously superior to many closer to the source of water
- a greater need for new investment in urban and other local infrastructure.

The panel examined alternative uses of rain falling in central and northern Queensland near the Great Dividing Range in contemporary circumstances, linked to the effective use of other economic advantages. The panel concluded that the alternatives, discussed in Section 2 of the report, could support economic development on a vastly larger scale than Bradfield and his successors envisaged. The panel also learned there are valuable alternative opportunities for development in the Gulf and Lake Eyre Basin regions which would have been the major beneficiaries of the Bradfield proposals.

Opportunities for development

If developed with care and innovation, there is great development opportunity along the coasts, through the Great Dividing Range and in the near inland. Large amounts of water have always been available in the catchments of rivers flowing into the Gulf of Carpentaria. Appendix 3 shows a good chance of these being augmented by increased rainfall from climate change, modified by increases in evaporation. This provides rich opportunities for agricultural and related development through the Flinders, Gilbert, Mitchell and Cape York catchments. Modest but significant amounts of water are also available in northern flowing catchments in the Isaac and Barcaldine Regional Council areas. While contemporary opportunities are not so abundant in most of the Lake Eyre Basin, judicious regional development policy, planning and program delivery that combines water, land and energy for local development could generate enough growth in employment and population to replace decline with moderate expansion at a reasonable cost.

Queensland's economic future depends on making effective use of development opportunities in central and northern Queensland. There are compelling reasons for giving priority to enhancing what is already in place above developing just one immense water storage and transfer infrastructure and resettling large numbers of people to what had been small towns or villages. One reason is that it costs much less to use under-utilised capacity or to expand what is already in place than to build completely new centres of economic activity. The second is what eminent Australian economist Professor

Max Corden called the 'conservative social welfare function'—the natural and valid tendency of humans to value more highly what is already here than the new and exotic[3]. Replacing a 10 per cent decline in jobs in a town that employs 1,000 people with a 10 per cent increase is incomparably cheaper and much more socially and economically valuable than building a completely new town in which 200 people are employed. Consequently, the panel has given first priority to sustaining and enhancing what exists, where it is realistic and economically, environmentally, culturally and socially sustainable.

Prepare for additional changes

There are uncertainties around some matters that are important to these conclusions. Climate change is affecting average rainfall and is increasing its variability. A warmer climate is generally associated with higher average rainfall in tropical latitudes, as well as greater evaporation. The coast and near inland of Queensland near the Burdekin, however, appear to be among the exceptions to the tendency to higher rainfall above the Tropic of Capricorn. During the next few years, it will become clear if the international community will achieve the Paris Agreement goals from December 2015 to hold global average temperature increases below 2 degrees and as close as possible to 1.5 degrees, and clearer what the effect on rainfall will be. More is learned and experienced every year about the effects of warming on rainfall, so there are advantages in avoiding commitments to very large and indelible investments until the shape of the future climate is clearer. Indeed, Queensland already has a legacy of non-performing water assets and others seem to be at risk from being stranded by climate change.

The economic value of water in alternative uses is crucial in investment decisions on water infrastructure. Value will be higher in the zero-carbon world economy, but it will take time for us to learn how much higher in different locations. It is known that storing carbon in soils and living plants will have great value in the zero-emissions world economy, with relevant climate and economic models suggesting that global prices will end up above current European levels (approaching $100 per tonne of carbon dioxide or $350 per tonne of carbon in September 2021). It is also known that sustainably harvested biomass is valuable and will have greater value when converted to carbon or hydrocarbon for zero-emissions production of goods including some fuels and chemical products (including plastics) that are currently made from coal, oil and gas. Australia could be the sustainable economic source of much of the world's supply of these new products if the right policy settings were in place.

Farmers are able greatly to expand agricultural output when irrigation water is available to promote germination, early growth and biomass density or for wider use in agricultural and forestry systems. The renewable energy resources of central and northern Queensland have great value for industry, and this value will be greater still if the variability of solar and wind resources is balanced by hydro- and biomass-generated power.

Our society is, however, in the early stages of the research and commercial development that will reveal the value of the new uses of water in agricultural, forestry and food and fibre processing systems. Learning more about the value of new ways of using water will strengthen assessments of the economic costs and benefits of investments in water infrastructure.

The original Bradfield vision, like the Snowy, relied on large value coming from hydro-electricity as well as from irrigation agriculture. There is stronger economic justification for investment in water infrastructure in northern and central Queensland if value ('value stacking') is contributed from hydro-power and pumped hydro-electric storage as well as from irrigation agriculture.

Recommendations

Recommendation 1

There is no economic, environmental, social or cultural heritage case for immense storage of water in northern Queensland with a view to its movement over long distances west and south for irrigation. The panel recommends against proceeding with any of the Bradfield or Bradfield-like proposals.

Recommendation 2

There is a strong case for planning and investing in the use of water closer to where it falls to accelerate regional development in central and northern Queensland, including in the Gulf of Carpentaria and Lake Eyre Basin areas.

Across central and northern Queensland, the potential for development is much larger in scale, less risky, and more widely distributed than anything anticipated by Bradfield. The opportunity for transformative regional development comes from the integrated use of water and complementary resources that include:

- agricultural land, which can be profitably augmented by water for irrigation
- solar energy west of the Great Dividing Range
- wind energy at particular places in the west and, in the Great Dividing Range, where major environmental, social and cultural costs can be avoided
- the hydro-electric and pumped hydro-electric storage potential of the Great Dividing Range
- the critical mineral resources of northwest Queensland and parts of the Great Dividing Range

- the population, infrastructure, industrial traditions, skills and business capacity accumulated in the large industrial towns along the coast of central and northern Queensland, especially Gladstone and Townsville
- the skills, physical infrastructure, and business and social capacity accumulated for specialised agri-industrial and agricultural service activities in Bundaberg, Rockhampton, Mackay, Bowen and Cairns and, on a more modest scale, in smaller inland towns, including at least Lakeland, Mareeba, Hughenden, Georgetown, Julia Creek, Richmond, Charters Towers, Barcaldine, Longreach, Moranbah and Emerald
- the established electricity transmission, telecommunications, rail and road transport connections joining the coastal towns to each other and to the western hinterlands of Bundaberg, Gladstone, Rockhampton, Mackay, Townsville and Cairns, including through the coal mining towns of the Bowen Basin.

This approach to regional water development would contribute to what the panel calls the Water Agri-business Technology Energy Region (WATER) Development Zone through the coastal cities of central and northern Queensland and west from Rockhampton and Townsville along the railways and electricity transmission lines through the Great Dividing Range to the closer inland plains. This WATER Development Zone could become one of the main world centres for zero-emissions industry based on use of renewable energy, biomass and hydrogen. The WATER Development Zone could be the epicentre for focus of any new regional development institution that has responsibility for region-wide planning and policy; an institution supporting and coordinating the work of place-based planning in sub-regions built around catchment-level Regional Water Grids.

Recommendation 3

Within this development framework, explore the feasibility of four 'Mini-Bradfield Grids', referred to as Regional Water Grids in this report.

The panel suggests taking a place-based approach to regional water development that facilitates the emergence of sustainable and highly resilient agri-industrial hubs covering individual catchments. It involves some additional investment in water infrastructure (both hard and soft) to store, move and manage water. Each individual element is much smaller in scale than proposed by the Bradfield-like proposals. The four Regional Water Grids are the:

1. Tablelands–Cairns Regional Water Grid
2. Burdekin–Townsville Regional Water Grid
3. Fitzroy–Rockhampton–Gladstone Regional Water Grid
4. Burnett–Bundaberg Regional Water Grid.

Recommendation 4

Explore and, where viable, build links between these Regional Water Grids so a temporary abundance of water in one grid can be used to balance a temporary dearth in another.

Linking catchments extends the scope of water trading and improves efficiency in water use as well as increases water security across all catchments.

Recommendation 5

Make available water work better within individual catchments in northern and central Queensland outside the Regional Water Grids.

This also requires a place-based approach to planning and policy-making, nested within a government planning framework focused on regional water development. Outside the Regional Water Grids, in what the panel has termed the Making Water Work regions, effective place-based water development planning could lead to some targeted investment in hard water infrastructure. Attention would be given to innovative in-stream storages, the more productive use of overland flows or offstream capture and storage, and new approaches to groundwater use and management, including managed aquifer recharge. There is particular opportunity in the effective use of northern water moving towards the Gulf of Carpentaria. Other options include the building of soft infrastructure, through establishing efficient water trading platforms; research, development and extension (RD&E); and supply chain development. The main basins or catchments for such a place-based approach are the:

- Cape York Water Plan Area (up to 503 gigalitres of water currently available)
- Mitchell Water Plan Area (up to 70 gigalitres currently available)
- Gilbert Catchment Area (up to 464 gigalitres currently available)
- Flinders Catchment Area (up to 173 gigalitres currently available. This volume is identified in the water plan and has not been updated to reflect the latest release of unallocated water)
- Whitsunday–Pioneer Water Plan Area (up to 28 gigalitres available)
- Lake Eyre Basin water plan areas (up to 11 gigalitres available for Cooper, and Georgina and Diamantina Water Plan areas).

The WATER Development Zone could be the epicentre of focus of any new regional development institution that has responsibility for supporting and coordinating place-based policy and planning effort needed to drive the delivery of the proposed catchment-based Regional Water Grids and Making Water Work regions.

Recommendation 6

Increase public funding for research into the value of the use of water and land for agriculture, carbon sequestration and biomass for industry.

This should include expanding the capability of existing crop suitability tools and research into cropping systems so the most valuable cropping types can be identified and prioritised. Research needs to cover domestic processing to enhancing the value of new and old crops, including through the intensive use of renewable energy in which northern and central Queensland have a globally significant advantage.

Recommendation 7

Review all matters affecting pricing of inputs into, and the use of, infrastructure. This should ensure cost-reflective pricing emerges from competitive markets (including water, energy and ecosystem service markets) and encompassing other development inputs. The review particularly needs to examine opportunities for expanding innovation in the role of water markets.

Where genuine competition is not possible as a result of monopolistic structures in the supply of water and energy, input pricing should reflect the real cost of capital in contemporary circumstances (i.e. interest rates currently close to zero in real terms for public infrastructure). Within this context, water prices need to reflect the real costs of efficient delivery of water to users and encourage the optimal water and land use. Services to the wider community from water infrastructure also need to be paid for by government on behalf of the community and not just by users of water. Public purposes subsidies (e.g. Commonwealth subsidies for northern development) need to be transparently recognised as community service payments.

Recommendation 8

Move promptly to establish the proposed new approaches to water development planning. Delays will cause bottlenecks for infrastructure needed to build the WATER Development Zone and to deliver development for adjacent regions in central and northern Queensland.

Preconditions for success

The panel's role did not extend to recommending which pieces of storage and connective infrastructure warrant building within the suggested approach to regional water development in northern and central Queensland. Promising opportunities that could be explored in each of the Regional Water Grids and in each of the Making Water Work regions are set out in chapters 6 and 7 of this report.

One feature of the Bradfield vision and The Queensland Great Dividing Range Scheme variation is the integration of agricultural and energy values. This integration is a necessary condition for getting good value from water infrastructure.

Attachment 1, produced by the Centre of Policy Studies (CoPS) at Victoria University, has undertaken general equilibrium analysis of the economic effects of some of the possible infrastructure investments within the Regional Water Grids. This has shown positive impacts (differently at regional, state and national scales) from the modelled investments in the Barron, Burdekin and Burnett catchments under specified conditions. Insufficient data were currently available to enable comparable analysis in the Fitzroy catchment. The positive effects are much greater if the proportion of the allocated water that is utilised is higher than in the past. Interestingly, the CoPS work identifies a national economic interest in providing some Commonwealth subsidy to these developments, enhancing the case for central and northern Queensland development to be seen as a national opportunity. Part of the national case for central and northern Queensland development is the opportunity it provides for spreading agricultural risk across climatic zones. For example, irrigators, food processors and agricultural support industries exposed to climate and water risk in southern Australia can spread risk by operating in northern Australia as well. This mirrors the practice of Far North Queensland farmers in reducing risk by shifting a substantial part of their production from vulnerable coastal areas to the Atherton Tablelands and Lakeland region after cyclones Larry and Yasi. Information on the energy value of water infrastructure was not available for inclusion in the modelling.

If these recommendations are to achieve the envisaged economic transformation, the panel's report identifies a number of preconditions for success. The following are the most important.

1. **Continue to maintain, update and improve the current water planning system under Queensland law to ensure adequate water is available both to protect environmental and cultural values and to support and grow established economic activity. Good economic outcomes require the maintenance of security and confidence in existing water entitlements.**
2. **Strengthen institutional arrangements that integrate state infrastructure planning, major project facilitation and regulatory action with strong, regionalised, place-based community inputs.** The Queensland Government needs to manage and coordinate access to and use of water resources through an integrated framework of development planning and implementation for central and northern Queensland. This needs to be closely linked to Commonwealth authorities involved in water resource decisions.

3. **Create an appropriate local institutional structure nested within the government planning framework to ensure place-based partnerships in and contributions to regional water development planning in the Regional Water Grids and Making Water Work catchments.** Some relevant lessons for institutional structure can be drawn from the Tasmanian approach to irrigation development.
4. **Recognise that new agricultural development needs to deliver zero net greenhouse emissions, avoid significant ecological damage in Cape York, the Wet Tropics, the Gulf and the Lake Eyre Basin, and reduce nutrient, sediment and pesticide loads into the Great Barrier Reef.** This is achievable with improvements in catchment design, farm practices and adequate public investment in scientific research on technology development and associated environmental management issues.
5. **Aboriginal and Torres Strait Islander peoples across northern and central Queensland must be integral partners in the development process, ensuring their cultural values are respected and the aspirations of emerging generations are achieved through active and inclusive involvement in the development of economic opportunities.**
6. **Recognise that contemporary development opportunities are very different from those of the past and require local research and knowledge-sharing on topics including:**
    - new economic opportunities and threats to economic activity from climate change and its mitigation
    - new ways of generating economic value in a zero-carbon economy
    - new and lower cost technologies for water storage and management
    - developments in information technology and agritech.

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[1] Palaszczuk, 2021

[2] Barber et al., 2020

[3] Corden, 1974

02

Chapter 2

The Bradfield vision

The Bradfield vision

Australia is the world's driest inhabited continent, but it's not all dry. The east coast and adjacent Great Dividing Range in Far North Queensland receive some of the highest annual rainfall on earth. The rivers flowing into the Pacific in central and northern Queensland and into the Gulf of Carpentaria have immense annual flows by any standards.

Australian economic activity and population over the past two centuries grew mainly in the temperate climates of southern Australia. The Murray–Darling Basin, extending into southern Queensland, was the richest area of pastoral and agricultural activity. The warming and drying of southern Australia threatens established economic activities and communities. This has given new life to old thoughts about using the abundant water of northern Australia to enrich agricultural activity in drier parts of the continent.

The Bradfield Scheme is the grandest of the thoughts

In 1938, Dr John Job Crew Bradfield, a former New South Wales Government engineer and the principal designer of the Sydney Harbour Bridge and Brisbane's Story Bridge, presented the Queensland Government with a paper entitled, *Queensland, The Conservation and Utilisation of Her Water Resources*. This paper, together with subsequent journal articles, defined what came to be known as the Bradfield Scheme. The scheme involved the capture of water in a dam at Hells Gates on the Burdekin River. The flows in the Upper Burdekin at Hells Gates were to be augmented by transfers from the Tully and Herbert rivers. Water from the dam was to move through tunnels into the Flinders and then to the Thomson, from whence it would travel downstream to Cooper Creek and Lake Eyre. The 1942 Bradfield variant transferred water directly into the Thomson catchment. Both involved dams much larger than any in Australia then or now. Both involved transfers of water between catchments several times larger than the Snowy Mountains scheme. Both variants involved substantial generation of hydro-electric power.

Bradfield's 1938 manual scripts note, "the site chosen for the final impounding of water on the eastern side of the Divide is at 'Hells Gates', a gorge on the Burdekin River".

The scripts go on to note, "the consequent backing up of water along the Clarke River, a west–east flowing tributary of the Burdekin, would permit the access of Tully, Herbert and Burdekin waters to within a short distance of the Main Dividing Range through which they can be taken by tunnel. Once through the Divide, the waters would be discharged into the Flinders River or one of its tributaries and a suitable corridor (gorge) dammed, in order to create a large artificial water basin". From the Flinders, water would be transferred into one of the tributaries of the Thomson River, from which it would flow by gravity past Longreach into Cooper Creek and on to Lake Eyre.

The 1942 Bradfield scheme aimed to irrigate 60,000 square miles (15,500,000 hectares) to support industries and communities through agricultural development. Evaporation from irrigation canals and dams and water in Lake Eyre was seen as generating benefits from higher rainfall and lower temperatures (local climate modification through changing the region's water cycle). Greater population density and economic activity was intended to support stronger transport infrastructure and contribute to national defence and security. The total cost was estimated at £30,000,000. The proposal was rejected at the time by then Queensland Premier William Forgan-Smith. It was thought the up-front cost of the scheme would not be recouped from direct charges to water users or compensated by the increased economic activity envisaged[1].

The Bradfield vision was brilliant in conception. The design was extraordinary in its accuracy when account is taken of the limited financial and human resources available to Bradfield, and the level of technology available at that time.

Various interpretations of the scheme have since been advocated and assessed:

- a review of the scheme in 1945 by the Chifley Government in the context of post-war reconstruction (where the Snowy Mountains Scheme and the Ord River Scheme were preferred)
- a Bureau of Meteorology assessment in 1945 (which identified a need for investigation by soil management and engineering experts and queried whether the scheme's contribution to climatic improvement had been "overestimated")
- investigations by William Nimmo (Chief Engineer of the Stanley River Works Board) in 1947 concluding there were technical deficiencies in Bradfield's analysis including assumptions around ground elevations, over-estimation of water supply capability and under-estimation of costs
- a 1981 parliamentary sub-committee report by Dr Eric Heidecker, Mr Roy Stainkey and Mr Bob Katter, assessing a revised Bradfield scheme, finding that it may enable some million acres of cotton and wheat cultivation and probably 750 megawatts of hydro-electric generating capacity

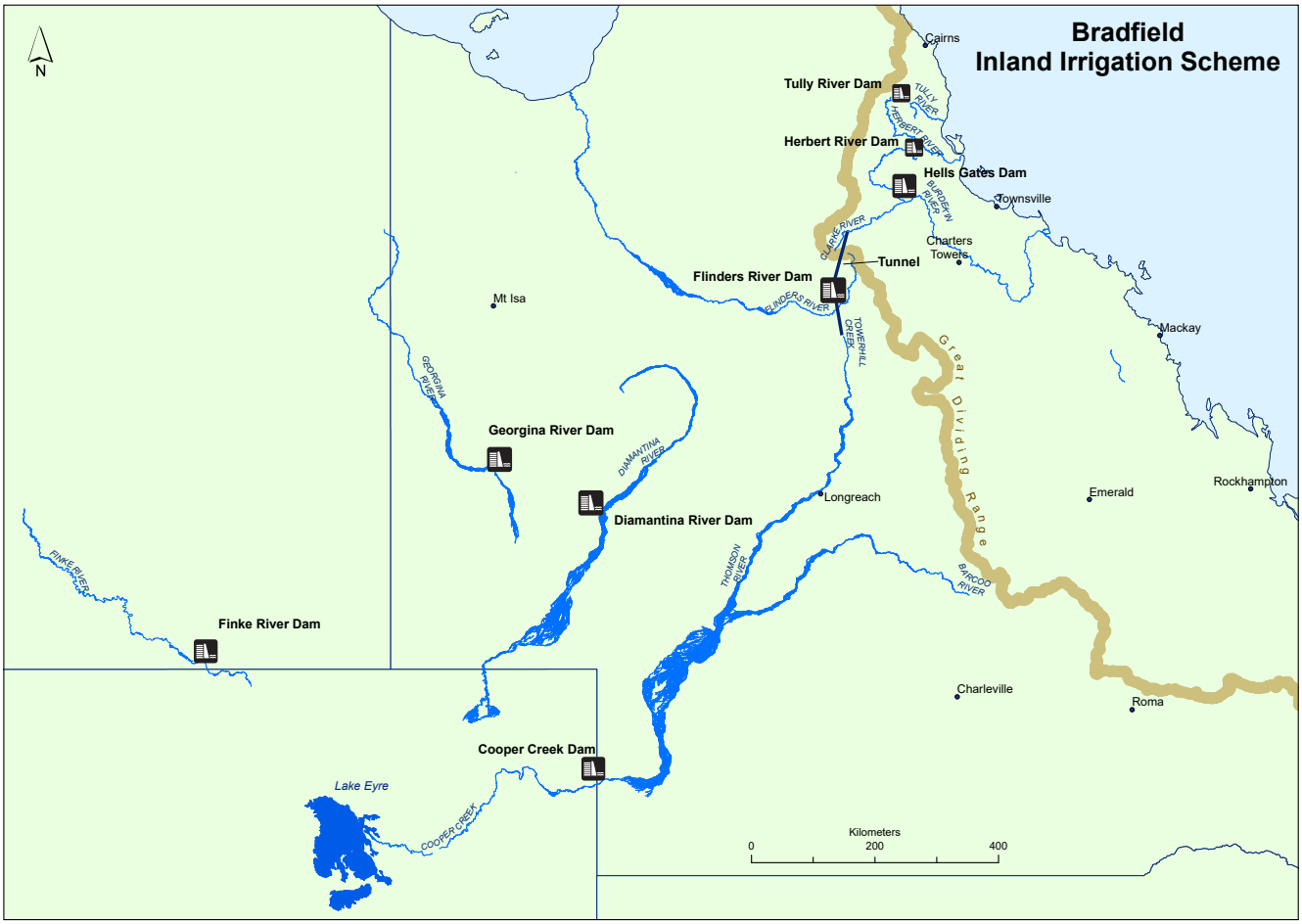


Figure 2-1: The Bradfield Inland Irrigation Scheme.

- a 2007 version of the Bradfield Scheme outlined by then-Queensland Premier Peter Beattie focusing on the long-term health of the Murray-Darling system.

The main components of the original Bradfield Scheme are shown in Figure 2-1. They include:

- a dam on the Tully River in the Wet Tropics to support movement of water through a tunnel to the Herbert
- a dam on the Herbert to allow diversion of water through a tunnel to a huge dam at Hells Gates
- movement of water by pipe and tunnel to the Flinders River.

A dam on the Flinders blocked movement of water to the Gulf and allowed transfer through a short tunnel into Torrens Creek, a tributary to the Thomson River, from whence it moved through Cooper Creek to Lake Eyre.

CSIRO has recently completed an assessment of the Bradfield Scheme, commissioned by the Commonwealth Government through the North Queensland Water Infrastructure Authority (NQWIA). CSIRO identified some engineering weaknesses. It proposed some substantial modifications for the original Bradfield Scheme, including a reduction in scale of water storage and optimisation of transfers of water from the Hells Gates Dam. CSIRO also undertook a screening level analysis of various dam sites in the Upper Burdekin to assess whether Hells Gates was the best site for such a dam.

A larger modern variant has been developed recently by three eminent Queenslanders: Sir Leo Hielscher, Sir Frank Moore and Mr Detlef Sulzer (The Queensland Great Dividing Range Scheme). This is designed to support 2 million hectares of new irrigation in the west and south, mostly along the Thomson and its tributaries, together with 50,000 hectares of irrigation in the Upper Burdekin near Hells Gates. The strongest focus of this variant is on the potential for rejuvenating the pastoral economies of the west:

"For the Western regions, it is evident they are declining in relevance as shops shut, population declines, families are disrupted, as students sent away for higher education do not return home because there is no vocation for them there."[2]

The Queensland Great Dividing Range Scheme allows 5,400 gigalitres of annual average discharge down the Burdekin from the Hells Gates dam. This would be used to generate large amounts of hydro-electric power at Hells Gate (with two gigawatts of power and great depth of storage). Another 100 megawatts would be powered from the flows west through the Great Dividing Range.

The following summarises main features of four of the Bradfield concepts.

Table 2-1: Summary of four main Bradfield concepts.

Scheme	Description
1938 Bradfield	Water diversions from the Tully and Herbert rivers to the headwaters of the Burdekin. Construction of a 122-metre high dam at Hells Gates. Diversion of flows via a 144-kilometre tunnel to west of the Great Dividing Range to the headwaters of the Flinders and Thomson rivers
1942 Bradfield	Variation on the 1938 scheme, with a 152-metre high Hells Gates dam and approximately 400 kilometres of twin pipes to the headwaters of the Thomson River only
CSIRO 1942 Bradfield Variant	A recent (2021) variation of the 1942 Bradfield proposal, with a 97.5-metre high dam at Hells Gates with a 679-kilometre channel to the Thomson River (near Aramac Creek), replacing the twin pipes proposal outlined in the 1942 proposal
The Queensland Great Dividing Range Scheme, 2021	Variation of the 1938 Bradfield Scheme, with water diversions from the Herbert River only, a 108-metre high Hells Gates dam with a 90-kilometre tunnel and extensive excavation at the inlet and outlet of the tunnel, to the west of the Great Dividing Range to the headwaters of the Flinders and Thomson rivers

The Bradfield ideas, several variations on the theme and an assessment of them, are discussed in more detail in Appendix 5.

The starting point for the panel's assessment of the Bradfield vision has been the amount of water that is available for capture in the eastern parts of central and northern Queensland for use in the west and south. This water is currently absorbed or used locally or flows in streams and rivers to the Pacific coast (including the Great Barrier Reef Lagoon). The panel set out to answer two central questions about available water and its use:

1. How much water is going to be available for new uses after provision has been made for conservation of downstream ecosystems and Indigenous cultural values and irrigated agriculture and other economic activity already built on access to water from the Burdekin?
2. Will benefits to Queenslanders and Australians be greater from using the water in a Bradfield-type scheme, or in some other way?

[1] Wooding, 2008

[2] Hielscher et al, 2021



Chapter 3

The availability of water

The availability of water



The availability of water for new economic activity raises both the most fundamental and most complex of water planning matters affecting regional development. Widely divergent views generate fierce disagreements about what water is available and what infrastructure should be built to make good use of it. The panel invested more time and effort on water availability issues than any other matters.

In this chapter, the panel provides a summary of its considerations and conclusions. Appendix 2 presents more detail on the Tully, Herbert and Burdekin catchments (central to consideration of Bradfield-type schemes). It also presents information on the Great Artesian Basin (GAB) under the Lake Eyre Basin in western Queensland (as it was intended as the main beneficiary of the Bradfield schemes).

The amounts of rainfall in and east of the Great Dividing Range in central and northern Australia are immense. Much is absorbed by soil and vegetation, while more of it seeps into the earth (as groundwater) and evaporates into the atmosphere. As such, much water disappears from the rivers on its journey from rainfall to the ocean.

Some water has always been used by Aboriginal and Torres Strait Islander peoples in traditional economies and for cultural purposes. The amounts extracted by humans have increased greatly since European settlement, and especially over the past half-century of larger-scale economic development. Some is extracted directly from streams and rivers for agricultural and pastoral activities, towns and industry. More is now drawn from water storages developed over the past century.

Over the past three decades, there is much greater awareness about the amount of water that flows down the rivers to the oceans and its value for the health of riverine and marine ecosystems, environments and important fisheries. Most Australians acknowledge that environmental health has high value in itself. It is also important for the sustainability and security of many economic activities and the value of established legal entitlements. That limits the amount of water that can be extracted from rivers for new economic activities.

Using water to achieve maximum benefits requires careful assessment of quantities of water that are available for one use or another, and the balancing of many values and interests in decisions on its allocation among competing uses. This is easier said than done. It requires interventions by government (as the steward to the resource) to allocate water among competing uses.

Australians have become increasingly aware over time that water resources are not so abundant that their allocation can be left to a free-for-all, with private parties making their own decisions on who is allowed to do what. A free-for-all can exist without disastrous impact while the amount of water that flows down rivers greatly exceeds demand, even when it can be taken without a price being paid for it. But as the value of water in each location rises with demand for goods that it can help to produce, claims on water come to exceed availability. Conflicts emerge. There is conflict between individual and community interests[1]. Total economic value is diminished, and

environmental and cultural outcomes are compromised. This is where policy makers must have the right tools to manage the synergies and the trade-offs which includes an evidence-informed program of decision-making.

Effective regulation was introduced too late to avoid great damage in what has been Australia's economically most valuable river system, the Murray–Darling. The problems of the Murray–Darling Basin were an important motivation to develop a national approach to water regulation in the 1990s and 2000s, and cooperation within the Australian Federation became known as the National Water Initiative (NWI). Queensland water planning laws were introduced that are consistent with the national agreements. These laws now govern access to water for new water infrastructure and economic activity. This legislated framework has been introduced before a free-for-all could erupt in northern and central Queensland, dissipating economic and other value in these rivers.

The water laws establish rights to use of water for economic purposes that are consistent with other claims on the resource. These rights (water entitlements) provide certainty to investors in business activities that they will have access to a specified amount of water.

Appendix 2 describes Queensland's approach to water planning. If Queenslanders respect and implement well the water planning laws, a reasonable balance will be established among conflicting environmental, cultural, established economic and new economic values. Replace the framework with a free-for-all, and the outcome will not be some interests gaining more at the expense of others. A free-for-all leads to loss of total economic as well as environmental, social and cultural values.

Queenslanders and all Australians should be able to agree on the importance of the integrity of the state's water planning framework, its consistency with Commonwealth policy, and the high value of retaining it. All should be able to agree on the need for adaptive scientific assessment of the amount of water that will flow through rivers, based on historical experience and analysis of all of the evidence on climate change. Environmental and cultural objectives need to be defined clearly and scientific analysis applied to defining the amount of water required to achieve the objectives.

It is well known that the law has allocated rights to use water for economic purposes, and there is good reason to honour those rights. There will inevitably be differences in view over whether some claims to unallocated water for future economic development (including infrastructure construction) have more value than others. Total economic value is raised to its maximum if conflicts among competing economic interests are resolved through market exchange or, where this is not possible, allocation through regulatory processes of unallocated water resources to where it generates most value.

The panel strongly supports the state's approach to water planning undertaken within the NWI. The legislation provides for regular reviews of the plans. New knowledge can change what is possible and what is desirable, so the periodic reviews of the water plans are important, as are the engaged and science-based approach to those reviews. The interests of regional development in Queensland and the wider interests of citizens will be served well by discussing alternative uses of water within the legislated framework.

An overview of water availability

There are now more than 120 years of observational records of streamflows at different locations in the rivers of importance to the panel's work. These flows are highly variable. That variability is itself important to natural systems.

Water planning involves assessment of how much water is likely to be in the rivers, how much of that is committed to supporting established patterns of human use (including for Aboriginal and Torres Strait Islander cultural values as well as modern economic activity), how much is necessary to maintain the health of established ecosystems, and then, how much could be available for new economic activity. For the water that is available for economic activity, economic value is greater when more allocations can be traded and therefore purchased to expand the most economically productive activities.

Considering investment in new water infrastructure begins with calculating the amount of water that would have been flowing down the rivers in the absence of extraction for modern economic activity. Changes resulting from climate change need to be measured as accurately as possible. The amounts that must be allowed to flow down the river to meet recognised Indigenous cultural values must be calculated, as must the amount necessary to maintain the health of natural ecosystems to agreed standards. The amount that has been allocated to established economic activity—the agricultural and pastoral enterprises, the mines, the industrial plants and the town water supplies—must be deducted. Some of the allocated water may not be utilised, due to weather conditions, input costs, international commodity prices and other factors. The public or private proponents of a new economic use of water are free to purchase entitlements if available, or trade water entitlements from existing owners, or seek allocations from the unallocated reserves within the water plans.

A secure water entitlement is a financial asset that contributes to the value of a business. It can be traded, provided as security for debt, or used to reduce climate insurance premiums. Any change to the water plan process or questioning of its stability reduces business confidence and therefore investment and future production.

This is the water planning framework the panel considered deeply and accounted for in its assessment of water availability for the Bradfield concepts, and for alternative approaches to using water for regional development in central and northern Queensland.

Availability of water in the Upper Burdekin

The availability of water at Hells Gates on the Upper Burdekin was centrally important to the panel's work. The Department of Regional Development, Manufacturing and Water has assessed the total mean annual streamflow from the Burdekin River catchment at Hells Gates to be 1,657 gigalitres. This assessment is based on the department's Burdekin hydrologic model which was developed to support and underpin the current Burdekin Water Plan. The Burdekin model was developed in accordance with contemporary modelling processes, methodologies and procedures, and quality assurance procedures, using model calibration techniques based on historical records where possible. This work has been externally peer reviewed.

The CSIRO has assessed the total mean annual streamflow at Hells Gate Dam to be 1,603 gigalitres. This shows reasonable similarity of data between the Queensland Government and CSIRO and provides a firm basis on which the panel makes its finding. Chapter 4 compares availability with the requirement for a Bradfield-type scheme.

Environmental flow objectives are defined as required by Queensland's legislation across all three of the catchments that would provide water for the proposed dam at Hells Gates. Water entitlements that support existing and prospective economic activities at and beyond Hells Gates in the Burdekin catchment are also defined and protected by the Queensland legislative framework. The water that must be set aside to maintain these objectives accounts for nearly all of the total water available in the Upper Burdekin itself at the Hells Gates gorge. Within the Burdekin Water Plan, only 20 gigalitres remains free for allocation to new economic uses in the Upper Burdekin.

Any revision of the water plan to make available some additional water for a dam at Hells Gate would need to consider the impacts this will have on existing entitlements and environmental flows. Minimising impacts to water users and the environment from increased water take is one of the primary purposes of a water plan. Some transfers would be possible within efficient trading systems, but these would not fundamentally change the constraints.

For these reasons, the Bradfield proposals depend on transfers from the Wet Tropics rivers. Substantial transfers would be technically possible and may be environmentally sustainable and economically viable. That would need to be tested rigorously. But the amounts available fall well short of what would be required to justify a large dam at Hells Gates for transferring immense amounts of water to the west.

These matters are discussed in detail in Chapter 4 and Appendix 2.

Effects of climate change

Over the past 30 years, another influence became apparent that must be understood in deciding water use for new economic activity: climate change. Queensland's water planning processes recognise the importance of climate change on water availability and the need to consider it in water allocations. Considerable work has been done on the possible effects of climate change for use in reviews of the plans. So far, the relevant water plans have not been updated.

Appendix 3 discusses the good work that has been proceeding to analyse the impact of climate change on water availability in central and northern Queensland.

The panel finished this report in late October 2021, on the eve of an historic meeting under United Nations auspices in Glasgow in November. The meeting will discuss the next steps in international cooperation to limit the damage from human-induced climate change. The approach to Glasgow is a reminder that there is uncertainty about the extent to which the international community will contain the damage from climate change that would follow from continuation of business as usual.

If the international community succeeds in the goals agreed in Paris in December 2015—to limit increases in temperature to below 2 degrees and as close as possible to 1.5 degrees—people today will already have experienced most of the human-induced increases in temperature they will ever see. There has already been an increase of 1.1 degrees on average over the surface of the earth since pre-industrial times, and about 1.4 degrees on average over land in Australia[2]. Observation of what has already happened can reveal quite a lot about the total effects of climate change on river flows. But if the international community fails comprehensively to achieve the Paris objectives, the world is in the early stages of immense and potentially catastrophic changes in rainfall and river flows.

Figure 3-1, which appears with more explanatory context in Appendix 3, illustrates the changes in rainfall over Australia that have accompanied the increases in temperature so far. The three maps across the top of Figure 3-1 show rainfall:

- in the first eight decades of measurement, with little increase in average temperature
- on average for the last three decades of last century, with the beginnings of significant warming
- in the first two decades of the current century, with larger temperature increases.

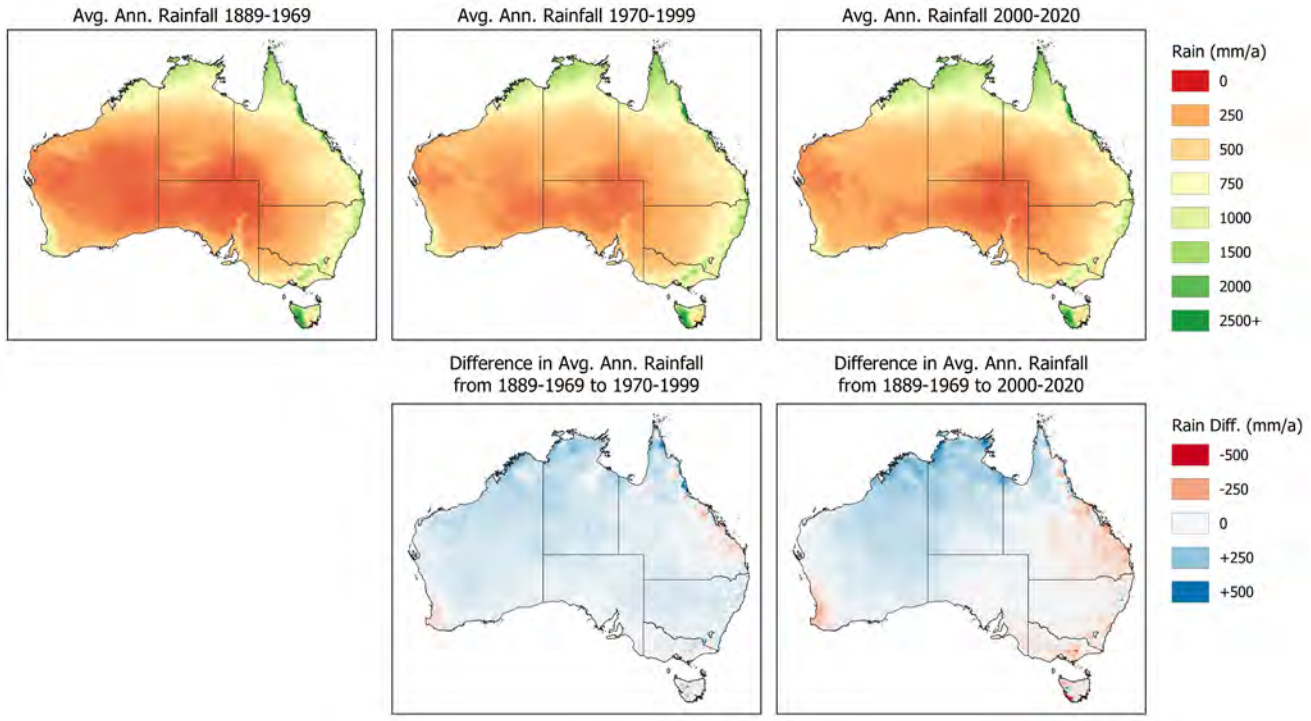


Figure 3-1: SILO average annual rainfall for selected periods.

Note: Water years begin 1 July. This means the 2020 water year is from 1 July 2020 to 30 June 2021.

The second row of maps shows differences from:

- the first eight decades of observation (1889–1969) to the last three decades of last century (1970–1999)
- the first eight decades of observation (1889–1969) to the first two decades of this century (2000–2020).

The twenty-first century so far has seen substantial rainfall reduction in the regions of southern Australia that have contributed most to the value of Australian agricultural and pastoral production in the past. The drying has extended up the Queensland coast to around Townsville. Western central and northern Queensland, on the other hand, has experienced increases in average rainfall, with the largest being in northern regions, including parts of the Far North Queensland coast.

Appendix 3 presents knowledge gleaned from the Queensland Government's use of climate models to anticipate future climate change. The models focus on two main scenarios: a moderate miss on the Paris targets (RCP 4.5) and comprehensive failure (RCP 8.5). The government is using the results from 11 models and focusing on the median of the results. The median of the projections of future rainfall from the models used by Queensland officials predict substantial increases in evaporation and reductions in rainfall in the Burdekin and the three other proposed regional water grid catchments discussed in Chapter 6. The models point to broadly similar increases in temperature, and the observed reality so far is consistent with the modelling results. The spread of projected changes in rainfall and evaporation is wide. The 11 models all have scientific legitimacy so use of the median can only be the most general of guides to more probable outcomes.

The median suggests moderate reductions in water availability in all four regional water grid catchments. This is supported by twenty-first century observations so far for the Burdekin and the Flinders, but not for the Wet Tropics catchments or the Burnett. This is good reason for caution in allocating entitlements to water in future in the regional water grid catchments, especially in the Burdekin and the Fitzroy. It is good reason to avoid fully allocating firm rights to water and building water infrastructure in the Burdekin that would only be justified if rainfall continued at or above the average levels of the first 80 years of data. It adds to the case against building a dam at Hells Gates to transfer large amounts of water to the west. It also strengthens the case for conscientiously examining the potential to transfer water from the Wet Tropics for use in the Burdekin and exploring regional water grids to improve water security.

Both the models and the twenty-first century experience so far suggest that there is and will be some increase in rainfall in Far North Queensland away from the east coast and more widely across inland northern and central Queensland, accompanied by higher evaporation in most places (Appendix 3). Valuable development opportunities in central and northern Queensland will be wasted if planning is not undertaken for the timely good use of larger amounts of water if the improvement of the science and unfolding of climate reality over the years and decades ahead confirm that water is more abundant than historical experience suggests.

The models of climate change used by the Queensland Government show rainfall in northern and central Queensland arriving in more concentrated and intense episodes. This creates the need to plan for productive, opportunistic use of increased water when it is available, especially across the regions once seen as beneficiaries of a Bradfield scheme which are likely to experience higher average rainfall.

The certainty of change in climate and the uncertainty about its precise effect on rainfall and evaporation argue for an adaptive approach to allocative and investment decisions that adjust, at low cost, to changes in knowledge about the availability of water. The certainty of climate change argues for a higher proportion of allocation to be contingent on the availability of water. It argues against making irreversibly large decisions on investment that depend on specified levels of water availability before the knowledge exists to support such decisions with confidence.

The increased variability of rainfall and water supply that is likely to accompany continued global warming requires a similar response. There are likely to be times when water is available in great abundance, interspersed with deeper and longer dry periods. Sound water planning will lead to rushes of water being put to good use while avoiding investment that turns out to be wasteful through the cycles of wet and dry times.

Rich new economic opportunities are emerging in the low-carbon world economy for products of land and water that do not depend on large, steady supplies of water, and which can take advantage of variable water supplies. Knowledge that the availability of water in the future is highly variable must play a role in selecting and managing crops. It must also play a role in decisions on infrastructure investment, increasing the priority of assets that can be used flexibly as water availability changes or departs from expectations. At the same time, there is greater value than ever in using highly secure water resources to support investment and production in high-value agriculture. Ways of increasing the security of water supply, including through linking regional arrangements, are discussed in Chapter 6.

The special case of water in Lake Eyre Basin development

The Queensland portion of the Lake Eyre Basin was the main locus of expanded irrigation and economic activity in the classic Bradfield schemes and the CSIRO variant. The Lake Eyre Basin covers the area of the seven regional shire councils of the Remote Areas Planning and Development Corporation (RAPAD) based at Longreach in the Central West. This is a vast area covering almost 30 per cent of Queensland but with a declining population now below 13,000.

Water availability through this region is underpinned by the GAB. This massive and valuable natural resource was depleted through the first century of its exploitation by a free-for-all on its use for modern economic activity. Over recent years, it has been subject to tighter management and regulation and even resource restoration. Several schemes have been introduced to discourage waste and encourage its more effective use. GAB management is discussed in Appendix 2.

The GAB is a great success story of contemporary environmental management although there is still more to be done. Commonwealth and state funding to complete capping the bores and allocating sustainable yields of water from the amounts saved would be a cost-effective way to expand the water available for development across the Queensland Lake Eyre Basin. Supported by research on the use of water for the new economic uses of plants that have become more valuable in the zero-emissions world economy, this could help to convert economic decline into moderate expansion in the west of Queensland. This could be complemented by effective use of water from the Belyando tributary of the Burdekin in the northeast of the RAPAD region for development locally and in easily accessible nearby areas. Apart from direct contributions to greater water availability, this could free some artesian water for alternative uses.

[1] Hardin, 1968

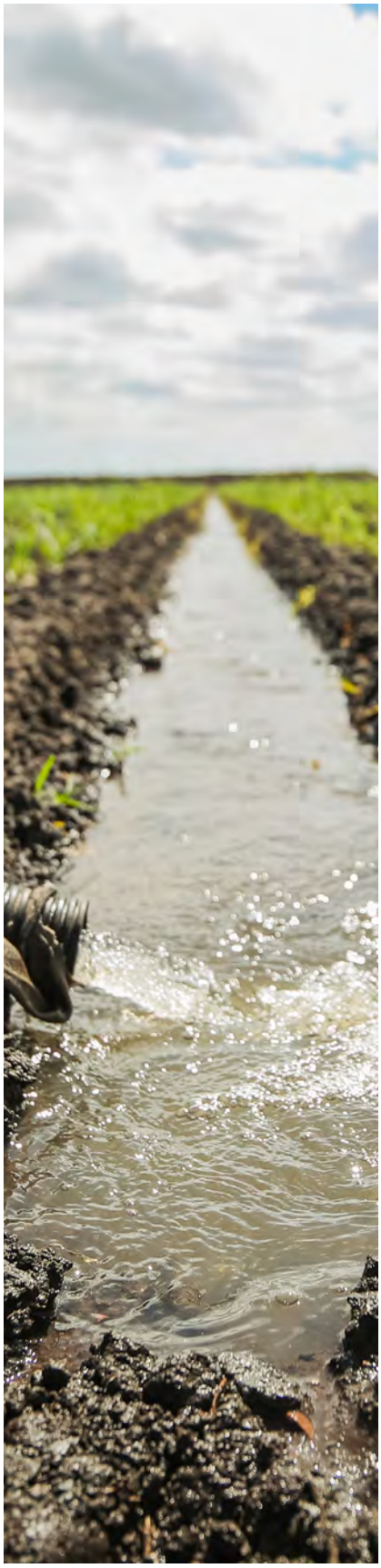
[2] Masson-Delmotte et al., 2021

04

Chapter 4

Bradfield assessment

Bradfield assessment



A project as grand as Bradfield's must be tested for its engineering, economic, environmental, social and cultural impacts, and all in the context of its resilience in a warming climate. There were flaws in the original engineering but the CSIRO work shows these can mostly be corrected. The environmental challenges are daunting downstream in the Burdekin and the Great Barrier Reef Lagoon and in the disruption of ephemeral inland rivers.

As a standalone project, the economic implications are helped by the fall in global interest rates and the new sources of economic value from plants in a zero-emissions world economy. But the costs of capital for water infrastructure have fallen proportionately as much and the value of water increased as much or more, closer to where the rain falls. The panel took these and other considerations into account in assessing the various Bradfield proposals. It has concluded that Bradfield and its variant all faltered at the first hurdle: the availability of water.

The water availability issue is discussed at length in Appendix 2. The panel's assessments on this and other matters were assisted by a report carried out in 2021 by the CSIRO for the National Water Grid Authority[1] (NWGA). The presently unpublished report[2] provided to the panel:

- presents a more detailed assessment of the scheme than was originally designed by Bradfield
- applies contemporary information and modelling techniques in the assessment, albeit at a scoping study level
- develops functional solutions where engineering flaws were identified in the original Bradfield proposal
- identifies ways of improving cost effectiveness and scheme value.

The panel also draws upon a technical assessment of the Bradfield Schemes commissioned by the Chief Engineer for Water and Dam Safety in the Queensland Department of Regional Development, Manufacturing and Water, from the engineering consultancy Water Resources Pty Ltd. The Paton Report looks at a number of questions asked by the panel, including:

- What infrastructure might be required to draw water from the Tully and Herbert Rivers across to the Burdekin, and how much water can be transferred?
- Given the storage sizes at Hells Gates that Bradfield contemplated in his 1938 and 1942 options, is there a better storage solution?
- Given the heights of these storages and the levels of the Flinders and Thomson Rivers, is it possible to transfer water to the west of the Divide via a tunnel as contemplated under the 1938 version?
- Are the twin tunnels from Hells Gates to Webb Lake, as contemplated in the 1942 Bradfield option, feasible?
- Are there other feasible options for transporting water west of the Divide?

Table 4-1: CSIRO assessment of Upper Burdekin dam sites.

Impoundment option	Commentary
Lake Lucy	• The highest possible site in the assessment in the upper Burdekin • Was proposed by Nimmo (1947) as an alternative to Hells Gates for conveying water to the Flinders River • Yield is only approximately 15 per cent of Hells Gates due to the smaller catchment (without the Tully and Herbert diversions)
Greenvale	• Lowest modelled capital cost per gigalitre of the five sites • Yield is approximately 46 per cent of Hells Gates (without the Tully and Herbert diversions)
Mount Fullstop	• Slightly upstream of Hells Gates • Similar yield to Hells Gates with Tully and Herbert diversions and similar unit cost
Hells Gates	• Synonymous with the Bradfield scheme • Higher yield than the Lake Lucy and Greenvale options • Lower unit cost per gigalitre compared with Lake Lucy, Greenvale and Mount Foxton
Mount Foxton	• Downstream of Hells Gates • 17 per cent more yield than Hells Gates due to the larger catchment area • Over 40 per cent more expensive per gigalitre than Hells Gates • Lower level would make gravity water diversions west of the Divide difficult

The Koombooloomba Dam has been constructed on the Tully River since Bradfield proposed his scheme. CSIRO considered that using the Koombooloomba Dam to divert water by tunnel to a new dam on Nitchaga Creek in the Herbert Catchment, followed by a diversion tunnel to Sunday Creek in the Herbert Catchment, would be more cost effective than the Bradfield proposal.

While not considered a good dam site, a dam could be constructed at the Herbert Falls Dam, which could divert flows to the upper Burdekin River. CSIRO proposed a 6.5-metre diameter tunnel to achieve this. A hydraulic grade line (HGL) was developed that showed the intended flowrate could be achieved.

CSIRO noted that, from an engineering perspective, the gorge at Hells Gates is part of a land formation that is a favourable location for a dam. CSIRO undertook a screening analysis of various dam sites in the Upper Burdekin to assess whether Hells Gates was the best site. CSIRO looked at five sites on the eastern side of the Divide and a summary of their assessment is provided in Table 4-1.

CSIRO did not find any of the alternatives to be better for diverting water to the west of the Divide, to the Flinders or Thomson rivers. There are conscientious advocates for others, notably Dr John Kell's representations to the panel on Mount Foxton.

Bradfield's original proposal was conceptual with limited specific or technical detail. CSIRO made engineering changes to make the scheme work or work better.

Water availability at Hells Gates for Bradfield-type schemes

The availability of water at Hells Gates on the Upper Burdekin was centrally important to the panel's work.

Chapter 3 introduced the Department of Regional Development, Manufacturing and Water assessment that the total mean annual streamflow from the Burdekin River catchment at Hells Gates is 1,657 gigalitres.

CSIRO provides an alternative assessment[3]. It calculated the mean annual streamflow from the Burdekin at Hells Gates was 1,603 gigalitres. It judged it possible to harvest and divert some 1,236 gigalitres of water on average per annum from the Tully and Herbert Rivers to the headwaters of the Burdekin. Hence, for the purpose of its assessment, CSIRO concluded the mean annual streamflow at Hells Gates would be 2,839 gigalitres, including diversions from the Tully and Herbert rivers.

CSIRO calculated these volumes using hydrological models that have been calibrated against streamflow gauges across the three catchments. The modelled streamflows correlated reasonably well with past studies, in particular the 1982 report on the Bradfield scheme by Cameron McNamara Consultants. CSIRO also utilised a reservoir and diversion water balance model to determine the volumes of water that could be transferred from the Tully and Herbert catchments and taken from an impoundment at Hells Gates. The amount of water passing Hells Gates (not including diversions from Tully and Herbert rivers), estimated from the Queensland Government models used for the water plans, were similar to those from the CSIRO models.

Environmental flow objectives are defined as required by Queensland's legislation across all three catchments. The water that must be set aside to maintain these objectives accounts for a considerable proportion of the total water available at the Hells Gates Gorge. Water must also be put aside to respect allocations to support established economic activities and various other requirements. Within the Burdekin Water Plan, only 20 gigalitres remain free for allocation to new economic uses at Hells Gates, apart from any that might be diverted from the Tully and the Herbert. There are already plans to use most of this to construct a new weir at Big Rocks near Charters Towers.

In its assessment, CSIRO did not limit the volume of water that could be diverted from the Hells Gates Dam to allow for environmental flows. It simply determined the total amount of water in the river at Hells Gates and the capacity of different infrastructure options to transfer the water to west of the Divide. Its assessment is that it may be technically possible to transfer 2,272 gigalitres per annum to the Thomson River, via a 680-kilometre channel from the Hells Gates Dam.

CSIRO then assessed the impact of extracting such flows from the Burdekin, Tully and Herbert rivers on both environmental flow objectives and downstream user reliability. CSIRO's assessment of the impact on the environmental flow objectives has two parts:

- upstream of the Burdekin Falls Dam, the mean and median annual flows fall by 39 and 36 per cent respectively
- at the end of the Burdekin River system, the mean and median annual flows fall by 18 and 28 per cent respectively.

CSIRO included in its assessment the strategic and general reserves that have already been set aside for future potential developments in the Burdekin Water Plan (these reserves are discussed in more detail in Appendix 2). Water plans, legal instruments and, once approved, water cannot be accessed or used for purposes other than those nominated without due process. Diverting water from uses envisaged in water plans is possible after following a rigorous process set down in the legislation, but it involves costs that must be considered in any assessment of the value of the proposed alternative uses.

Even a minimalist approach to commitments to downstream environmental values and established and proposed new economic uses would not support the large transfers of water to the west envisaged by the CSIRO version of the Bradfield scheme.

The panel does not exclude the possibility that reasonable diversions from the Wet Tropics to the Upper Burdekin may be economically attractive and consistent with the Water Plans for the Tully and Herbert catchments (the Wet Tropics Water Plan). That requires analysis. Such transfers would increase the water available in the Burdekin but not by enough to justify any of the Bradfield concepts discussed in the previous chapter.

That does not mean there are no viable water infrastructure projects in the Burdekin. The panel examines a range of options in the Burdekin–Townsville Regional Water Grid in Chapter 6. It may be that some diversion from the Wet Tropics is warranted to increase the amount of water in the Upper Burdekin. This water could serve environmental, cultural, or new or old economic purposes, or offset future reductions in water availability from climate change. Local transfers of water could also be considered around the Belyando–Suttor (a southern tributary to the Burdekin) and the Bowen-Broken catchment. Any of these alternatives would need to be subject to rigorous analysis within a new approach to regional development planning for central and northern Queensland, and within the framework of the water plans.

CSIRO's work on Bradfield

CSIRO undertook modelling in the water requirements of the classic Bradfield schemes. The modelling indicates that inflows would fall far short of justifying the massive storages for the Bradfield dams (54,950 and 142,350 gigalitres, respectively). The CSIRO study stated that a 97.5-metre dam

optimised the dual objectives of minimising unit capital cost and maximising yield.

The original Bradfield concepts were conceived with limited hydrological and topographical data. At the time, Bradfield relied on what is known as aneroid levels without water (measures of atmospheric pressure from a barometer) to determine elevation levels. CSIRO noted that, despite this limitation, many of the levels used were reasonably accurate. Bradfield's work within the tools of his day can reasonably be described as brilliant in the accuracy of its conclusions. Some important aspects of these conclusions, however, were not correct.

For hydrological data, Bradfield used rainfall and runoff relationships established in Germany. For example, this produced mean annual streamflow estimates for the Upper Tully, Herbert, Upper Burdekin and Flinders catchments, which totalled 7,192 gigalitres. These are twice the volumes determined by CSIRO (3,306 gigalitres) based on climate and hydrological data and tools that were unavailable to Bradfield. The Queensland Government's hydrological modelling calculates that the mean annual flow for these catchments prior to any water resource development was 3,267 gigalitres[4].

Since Bradfield described the original scheme in 1938, there has been considerable water-based development across all three catchments. In the Burdekin River downstream of the Hells Gates Gorge, there are now five weirs plus the Burdekin Falls Dam. These storages collectively provide nearly 100 gigalitres of high-priority water and 1,000 gigalitres of medium-priority water to agricultural, urban and mining users in the region. There are some 90,000 hectares of irrigated agriculture downstream of the Burdekin Falls Dam. There are also a number of small-scale water use allocations that rely on natural runs of the river between the Hells Gates Gorge and the Burdekin Falls Dam.

CSIRO's analysis concludes there would be minimal impact on user reliability downstream of Hells Gates Dam, for a scheme that diverts a total of 2,272 gigalitres per annum to the west of the Great Dividing Range. These impacts for downstream water users cannot be assumed and need to be subject to diligent water availability assessments.

CSIRO observes that Bradfield-type diversions of water from the Tully would also diminish the operation of the Kareeya Hydro Power Station at the Tully Falls Weir. This cost needs to be considered in assessing the economic effects of the scheme but is small in the scheme of things. It could possibly be recouped by upgrading the power capacity to be more suitable for firming intermittent renewables.

The Burdekin Water Plan only allows for 20 gigalitres to be reserved for new uses in the Burdekin upstream of the Burdekin Falls Dam. A business case prepared by Townsville Enterprises Limited (TEL) has indicated that Big Rocks Weir would absorb 10–20 gigalitres if a future decision was made to release the unallocated water identified in the water plan. The Queensland and Commonwealth governments have committed to provide $3 million each to pre-construction activities to move the Big Rocks Weir project towards an investment decision. Subject to the outcomes of these activities and further Queensland Government consideration, the two governments have committed a further $27 million each towards construction.

Confident planning for the use of water requires consideration of the effects of climate change. This is undertaken in Appendix 3. The evidence currently before the panel suggests climate change may lead to a small decrease in average availability of water in the Burdekin catchment. There is uncertainty. It is more likely to be a reduction in mean availability than an increase. Uncertainty argues for caution in committing to full use of the water currently thought to be available in the Upper Burdekin River sub-catchment until more of the climate change future has revealed itself.

Flood mitigation benefits of Herbert River and Hells Gates dams

Flood mitigation dams are constructed to reduce the impacts on downstream communities. Typically a flood mitigation dam is strategically located in a catchment at a suitable dam site which allows it to intercept the flows of the major rivers and streams within a catchment. Wivenhoe Dam west of Brisbane is one such example of a flood mitigation dam located to provide the best possible mitigation benefit to downstream communities. Flood mitigation dams don't prevent floods but rather reduce the peak and therefore downstream damage which would have otherwise occurred. Flood mitigation dams are also designed to provide maximum effect, and this usually involves the installation of gates or similar structures which allow human control to regulate downstream releases during high flow events.

A flood mitigation dam located at the proposed site on the Herbert River would provide only marginal flood mitigation to downstream communities. It is located very high in the catchment with a small catchment area and which therefore reduces flood mitigation benefit. Hells Gates Gorge in the upper reaches of the Burdekin River would provide little flood mitigation benefit to downstream communities. The small catchment area that it would intercept would not substantively lessen the effects of floods in the Burdekin catchment, since population centres are a long way downstream and are exposed to 86 per cent of the Burdekin River catchment.

Assessment of the CSIRO variant of Bradfield 1942

CSIRO, in its variant of the 1942 Bradfield Scheme, sought to deal with engineering problems, reduce costs and maximise value. CSIRO notes that by using a channel to divert water west of the Great Dividing Range, a lower offtake point can be used to draw water from Hells Gates. This increases the functional capacity of this storage compared with the 1938 tunnel. This alternative allowed CSIRO to optimise the size of the Hells Gates Dam, having regard to inflows, storage evaporation and other factors. Highlights of the CSIRO variant include:

- CSIRO determined the 152-metre high Hells Gates Dam that formed part of the 1942 concept would never fill as evaporation across the increased surface area of the lake would exceed inflows.
- The higher the dam, the more costly it would be to build. This is not only because of the additional height but because longer saddle dams are required to tie back to a point in the valley at the dam crest level.
- CSIRO calculates that the yield of Hells Gates peaks at a point that is close to the lowest cost per gigalitre.
- CSIRO concludes that the optimal storage at Hells Gates would have a dam wall that is 97.5 metres high.The 122-metre-high dam contemplated in the 1938 Bradfield concept would cost approximately $5.7 billion, compared with $1.8 billion for the 97.5-metre-high dam contemplated in this variant.

The CSIRO variation to the 1942 Bradfield scheme introduces a 679-kilometre channel to replace the twin pipes to divert the water across the Great Dividing Range, extending from Hells Gates through to the junction of Aramac Creek with the Thomson River. The channel introduces the additional water into the Thomson River at a point where erosion can be minimised and where there are more suitable soils for irrigation. The channel is 50 metres wide and four metres deep. CSIRO analyses a route that enables the flow of water by gravity along the entire length.

A summary of this scheme's characteristics against the panel's pre-requisites for success is provided in the following table. At this scoping study stage, this variation appears technically viable. In the panel's assessment, the water is not available for this limited version of the Bradfield scheme, even with flows from the Tully and the Herbert. There are also large questions about whether this would be the most valuable use of water that is available. Environmental, cultural and social impacts would be large, requiring assessment.

Other Bradfield variants

The Great Dividing Range proposal relies heavily on larger transfers of water from the Wet Tropics, arguing this has flood mitigation advantages. The panel respects the good work in the public interest that has gone into this proposal. But the proposal has water availability challenges that are immensely larger than those of the CSIRO contemporary Bradfield scenario. It has minimal analysis of the environmental, economic, cultural and social costs and benefits of the scheme.

Other uses of water from the Upper Burdekin

Even if the quantities of water from the Upper Burdekin presumed in the CSIRO study were available, the transfer west would have to compete with alternative uses in the Upper Burdekin and downstream.

For the Upper Burdekin uses, the SMEC group has been engaged by TEL, funded by the Commonwealth Government, to complete the reference design for a dam at Hells Gates as part of the detailed business case (DBC) for the Hells Gates Irrigation Scheme. The DBC proposes a much smaller dam at 52 metres, providing some 542 gigalitres of water to adjacent irrigation, possibly with some diversions by pipeline to the Pentland region. The Chief Engineer's assessment based on the Water Resources Pty Ltd report concludes that even this smaller dam, used for irrigation and without transfers from the Herbert and the Tully, would greatly exceed the water available.

Several other proposals are competing for the remaining unallocated water reserves in the Burdekin Basin Water Plan area. These include:

- the raising of the Burdekin Falls Dam to meet the needs of additional demand from agriculture, mining, and urban growth requirements in Townsville and Bowen
- the Burdekin to Moranbah Pipeline, which would duplicate an existing pipeline to meet presumed additional demand from coal mining. (As the panel notes in Chapter 6, Appendix 3 and Attachment 1, this could possibly become redundant, as coal mining would expand only in the context of the failure of international cooperation on climate change. A pipeline to Moranbah might possibly have some value for other uses.) This would increase demand for water from Burdekin Falls Dam
- a pipeline from Burdekin Falls Dam to the Bowen region for both agriculture and urban use.

Table 4-2: Assessment of CSIRO variant against prerequisites for success.

Prerequisites for success	Assessment of CSIRO variant of the 1942 Bradfield concept
Water availability	The scheme is based on CSIRO hydrological models that have been calibrated to streamflow gauges. The option and assessment does not allow for either environmental flow requirements or existing user requirements as set out in the water plans for the three catchments.
Ecological impacts	The transformation of the intermittent flows of the Thomson River system would require close analysis and assessment. This impact on the inland rivers would most likely be large and negative. The effects on environmental flows downstream in the Burdekin may be large and require some limitations on scale of water diversion. Effects on the Tully and the Herbert would be less problematic but require analysis and careful response.
Technical viability	The scoping study determines the scheme is technically capable of diverting some 2,272 gigalitres of water per annum to the west of the Great Dividing Range. This seems a reasonable conclusion at scoping study level. Detailed planning, survey, geotechnical studies, and design would confirm this or reject it.
Agricultural feasibility	A desktop soil suitability study identified areas adjacent to the Thomson River potentially capable of carrying 30,000 hectares of citrus and 150,000 hectares of cotton. CSIRO assesses it is likely cotton would require 40 per cent more water and citrus 25 per cent more water, compared with regions closer to the source of the water. The panel thinks there are likely to be alternative crops that use water more effectively in a hotter world and generate substantially higher value in a carbon-constrained world, but the research has not been done to assess the contribution they could make.
Economic viability (including risk analysis)	On the CSIRO assumptions, the scheme could support 30,000 hectares of citrus and 150,000 hectares of cotton at a water price of $470 per megalitre. This would only cover 51 per cent of costs over the lifetime of the scheme. CSIRO uses a discount rate of 7 per cent above the rate of inflation in assessing the cost of capital, which is a serious overestimate in contemporary circumstances, leading to overestimates of the cost of water. More economically realistic assessments of the cost of capital and allowance for higher-value crops in a zero-emissions world economy may allow costs within the CSIRO framework to be covered. However, if the water were available, it is not likely such use would generate as high a value as use closer to the source of the water. More modest interventions could contribute much more cost-effectively to enhancing incomes, employment and population in the catchments of the Lake Eyre Basin that would have benefited from the CSIRO Bradfield.
Social impacts	CSIRO analysis states the scheme could create up to 15,000 jobs in the vicinity of Longreach during construction and 13,000 full-time equivalents (FTE) if all 180,000 hectares were developed. While modest expansion of employment and the population would be clearly positive for the benefit of affected communities, transformation on the scale proposed would be more problematic.
Cultural and Indigenous impacts	The CSIRO report notes Aboriginal and Torres Strait Islander peoples have secured a range of legally recognised native title and cultural heritage rights (requiring negotiation) in the assessment area and notes that these communities would be likely to have concerns about major inter-catchment transfers.

In the absence of transfers from the Wet Tropics, there is insufficient water available for the smaller TEL dam at Hells Gates, let alone the greater use of water from the Burdekin Falls Dam in the Lower Burdekin. However, with augmentation from the Tully and Herbert on the scale modelled by the CSIRO report, there would be room for substantial local irrigation expansion at Hells Gates and raising of the Burdekin Falls Dam, as well as some expansion of other uses from the Burdekin catchment.

Other developments in the Upper and Lower Burdekin become possible if substantial flows from the Wet Tropics were made, along the lines investigated by CSIRO. The panel has no basis for expressing a view on assessing the scale of possible transfers. This should be the subject of further analysis.

Large-scale (multiple hundreds of megawatts of power, and more) hydro-electric opportunities in the Upper and Lower Burdekin are worth consideration as part of larger work on regional planning for water development in northern and central Queensland. Bradfield-type transfers of water to the west would actually exclude such possibilities. The daily flow of water through turbines at times of peak demand in the electricity grid does not in itself withdraw water. Neither does it necessarily disrupt the use of the water downstream, although it would do so without appropriate management. Detailed work would need to be done on timing of flows to assess environmental and other impacts.

Our preliminary analysis suggests a major hydro-electric facility at Burdekin Dams Falls would be well-located in relation to balancing intermittent power supply to rapidly expanding industry in Townsville and, with major augmentation of electricity transmission, central Queensland. This would not depend on water transfers from the Wet Tropics. This is an example of productive 'value stacking', with major value coming from peaking power generation on a substantial scale, dam safety and increased irrigation value. For the longer term, hydro-electric power generation in the Upper Burdekin would also be well-located to play a major role in firming supply of low-cost solar and wind power through new transmission infrastructure (of which CopperString could be part) and to industrial activities in Townsville and central Queensland. In Chapter 5, the panel discuss how, with the potential use of water from the Herbert and Tully systems, hydro-electricity potential in the Upper Burdekin may justify substantial water infrastructure investment. This could, in turn, enable some additional water supply for irrigation in the Upper and Lower Burdekin at relatively low cost.

Even if the water were available and the value of use was expected to generate a reasonable return for the community from investing in one of the Bradfield schemes, good planning for Queensland regional development would require state policy-makers to satisfy themselves that the value would be greater than using the water closer to where it falls as rain. Relevant considerations include:

- the high costs of moving water
- the water lost in evaporation and seepage along the way
- the higher evaporation that would be experienced in inland agriculture
- the observation that soils and growing conditions are not obviously superior to many closer to the source of water
- the proximity to existing infrastructure closer to the source of water compared to the greater need for new investment in urban and other local infrastructure in the west
- the exceptional opportunities for integrating large-scale use of water, biomass, energy and low carbon industrial development in the port cities to the east, alongside smaller-scale versions of similar developments in parts of the west.

These points must be considered by policy makers who are faced with multiple objectives and multiple policy instruments where there are both synergies and trade-offs. Where there are synergies, interested parties can work together on optimising outcomes and sharing benefits. However, for trade-offs, decisions between competing objectives are usually difficult to reconcile particularly where there are disagreements over facts, diverging interests and differences over values. Robust evidence is needed to understand the trade-offs but the final decision is not only a technical one.

Assessment summary and other relevant considerations

The panel concludes that the CSIRO version of Bradfield is more likely to succeed than any of its predecessors but still faces an unbridgeable gap on water availability. Like its predecessors, it is also unlikely to generate as much development value as the effective use of water closer to where it falls.

The CSIRO variant, like its predecessors, would also raise a number of large questions relating to cultural heritage, native title and environmental concerns.

Since Bradfield proposed his original scheme, Aboriginal and Torres Strait Islander peoples have secured legally recognised native title rights in land and water across the assessment area. Such rights cannot be compromised. Major inter-catchment transfers as proposed under the Bradfield Scheme would need to be judged by Indigenous communities themselves to be compatible with their values and development objectives.

The Bradfield Scheme would affect a wide range of environmentally significant regions of northern and western Queensland. It would have an impact on two World Heritage areas: the Wet Tropics of Queensland and the Great Barrier Reef. The Wet Tropics World Heritage Area

spans 450 kilometres of the tropical North Queensland coastline between Cooktown and Townsville. The area meets all four natural heritage criteria for World Heritage listing. It represents a major stage of the earth's evolutionary history and is an outstanding example of ongoing ecological and biological processes. It contains superlative natural phenomena and the most important natural habitats for conservation of biological diversity.

The Great Barrier Reef is the world's largest and most complex reef system and is globally recognised as having immense heritage value. It is vulnerable to economic activities that are already occurring in its vicinity.

Bowling Green Bay at the delta of the Burdekin River is one of Queensland's five Ramsar-listed internationally important wetlands for migratory water birds. It contains examples of the richest coastal habitats in northeast Australia's coastal wet-dry tropics and is home to a rich and varied bird life.

There are a significant number of nationally important wetlands in the assessment area that form part of the Directory of Important Wetlands of Australia.

CSIRO's modelling shows that the environmental flow objectives, particularly within the Burdekin River, would be severely compromised.

When preparing a new water plan following review and public consultation, the Department of Regional Development, Manufacturing and Water must adequately consider environmental impacts. As low, medium and high flows have separate important ecological functions, the department's consideration needs to include variations in as well as the average levels of flows. In the Burdekin Basin, high-flow conditions to and beyond the mouth of the river matter as they:

- deliver nutrients and organic matter to floodplains and internationally recognised wetlands at Bowling Green Bay
- mobilise coarse sands that are deposited at Cape Bowling Green
- provide freshwater flows to the estuary and Great Barrier Reef lagoon which supports different coastal communities and triggers fish migration.

Some of the infrastructure proposed for the Bradfield Scheme in the Tully catchment lies within the Wet Tropics World Heritage Area. CSIRO notes in its report that the impoundment necessary to divert flows from the Tully River would flood nearly 400 hectares of endangered regional ecosystems in this area. It also notes that the proposed Herbert River Falls Dam would inundate nearly 6,000 hectares of ecosystems designated as being of regional concern. Hells Gates would inundate a further 30,000 hectares of land with the same classification. The volume of water diversions proposed by the various schemes would change the Thomson River from an ephemeral to a continuous river system, thus significantly altering existing ecosystems and favouring invasive or pest species. Changes in land use to irrigated agriculture along the Thomson River would also potentially impact ecosystems designated as endangered or of regional concern. As noted by Ebner[5], water transfers such as those contemplated under the Bradfield Scheme, pose a major biosecurity risk to species across these catchments.

Analysis has drawn attention to major uncertainties relating to the eventual value of the Bradfield proposals. Occasionally, infrastructure can be developed in stages to minimise risk. The Bradfield Scheme and any of the variants cannot be staged in a way where work could cease at a natural stage as the unfolding of history reveals that there is no longer justification for the whole project.

There is always uncertainty about the outcomes of investment and there is option value in smaller, more diverse and flexible commitments. Nevertheless, immense projects sometimes have large value and are warranted despite the risk. This is a time of unusually large uncertainty, as the extent and nature of the effects of climate change on rainfall reveal themselves, and as policies develop in major countries and the world as a whole affecting the value of water used to sequester carbon and grow biomass. The option value of incremental and flexible investments is especially high at this time.

The panel concludes there is no prospect of a Bradfield-type scheme involving a dam at Hells Gates and massive transfers of water to the west for irrigation being an optimal use of water for regional development in northern and central Queensland. The idea of conscientiously thinking about how to use the great asset of water in northern Queensland, however, is sound and important. The aspiration to use this asset to expand economic activity, employment and population in northern and central Queensland is sound, important and achievable on a scale beyond that contemplated by Bradfield. The idea of arresting decline in employment and population in Queensland's west is worthy, important and achievable on a worthwhile scale at modest cost. Some of the ideas developed by Bradfield and his successors are worth careful evaluation within a new approach to regional development for northern and central Queensland.

To make the best use of Queensland's northern water asset, regional development needs to be looked at in a different way from that of Bradfield eight decades ago. This is the subject of Section 2 of the panel's report.

[1] Petheram et al., 2021

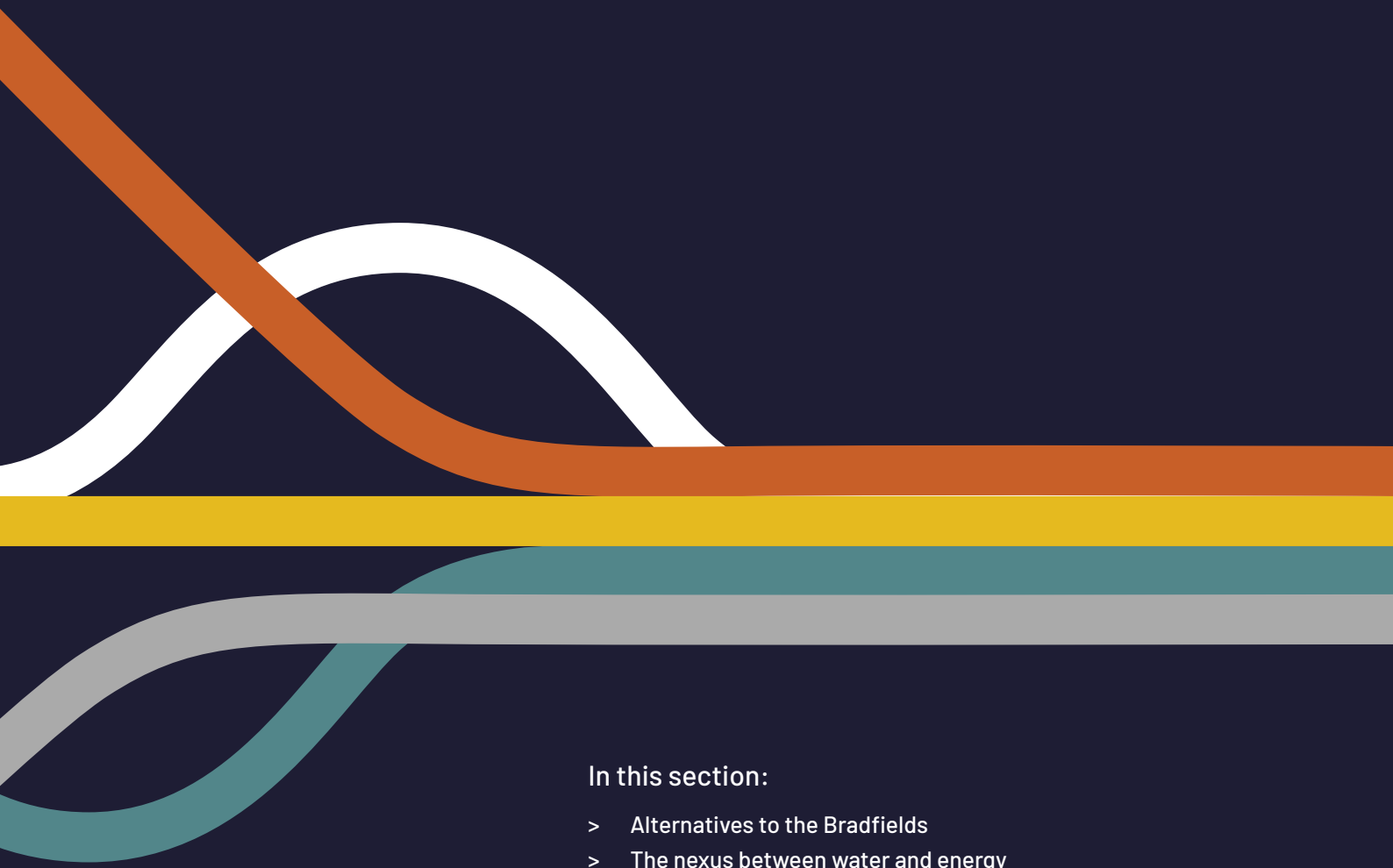
[2] Barber et al., 2020

[3] Barber et al., 2020

[4] Barber et al., 2020

[5] Ebner et al., 2020

Section 2



In this section:

- Alternatives to the Bradfields
- The nexus between water and energy
- The Regional Water Grids Scenario (Mini-Bradfield Grids)
- The Making Water Work Scenario
- The preconditions for success
- Water for central and northern Queensland regional development

Alternatives to the Bradfields

The attraction of the original Bradfield Scheme explored in Section 1 was the use of abundant water falling in the Wet Tropics and the Upper Burdekin. The scheme aimed to promote the economic development and expansion of communities, employment and incomes in the drier west and southwest of Queensland.

Later variations on the original Bradfield also looked to use northern water to solve deep water shortages in the Murray–Darling River system, compensating for the drying effects of climate change and earlier over-allocation.

The panel's exploration of the various Bradfield schemes has shown the water is simply not available to support the grand proposals inspired by Bradfield and his successors. Our work also raised questions about whether massive transfers of water for use in drier and hotter areas west and south of where the rain falls would be the most effective way of using infrastructure funding and promoting development in those remote regions.

The panel's work, however, has also revealed that substantial expansion of economic activity in the regions that were intended to benefit from Bradfield water can be achieved cost-effectively through other water-based development interventions. It has also shown that water that is already available to support new economic development can be used to promote transformative growth in employment and incomes closer to where the rain falls. This has led the panel to explore two alternative and complementary scenarios for the use of available water.

The first is a series of region-specific water storage and distribution solutions, which the panel has termed the Regional Water Grids Scenario. In referring to a grid, the panel has in mind the catchment-scale design of water development options in ways that maximise water security, efficiency, affordability and access. This approach can be, in the right situations, enhanced by moving water around the landscape to help achieve these objectives. The scenario is based on the development of long-term programs applying hard and soft infrastructure to use water more effectively. The four proposed Regional Water Grids regions encompass the main agri-industrial catchments in central and northern Queensland (centred on Cairns, Townsville, Rockhampton–Gladstone and Bundaberg). These are regions with substantial amounts of water available for new water infrastructure development. In the northern half of the area, all of the available water would have been absorbed into the proposed Bradfield Scheme. The Regional Water Grids can achieve substantial and, in some cases, transformative regional development. They can do this by making systematic use of many diverse opportunities for effective use of water and other resources in agricultural, energy, industrial, mining and related urban development.

The Bradfield variants were built around transferring massive amounts of water from northern Queensland to the Gulf of Carpentaria and Lake Eyre Basin (and away from the proposed Regional Water Grids regions). Bradfield aimed to stimulate water-based agricultural development in these economically challenged rural and remote regions. Securing a prosperous future for Australians in these regions was, and still is, a worthy policy objective. It can, however, be achieved more effectively in other ways. Beyond the four Regional Water Grids regions, the panel has identified six catchments in central and northern Queensland in which good systems of regional water development planning could achieve attractive outcomes without the transfers of water from the Tully, Herbert and Burdekin rivers. They would use locally available water (often in substantial amounts) to work more effectively for locally based development.

Several of these regions were the intended beneficiaries of the Bradfield schemes. The Gulf catchments, however, already have abundant water available for development that may be augmented by higher rainfall with climate change, after taking higher evaporation into account. The challenge is greater in the Lake Eyre Basin, which was the entire focus of transfers of water in the 1942 Bradfield scheme and the recent Great Dividing Range proposal. But there, too, making water work with wise regional development planning could reverse recent tendencies towards decline in economic activity and population.

The panel has included several other catchments in our Making Water Work Scenario because they have similar opportunities for lifting development outcomes by improving the use of water as well as other resources. In exploring these catchments, the panel has reviewed a number of data sets and government statements with implications for defining the Regional Water Grids and our Making Water Work catchments. These have included:

- relevance to the various Bradfield proposals
- the *Queensland Bulk Water Opportunities Statement (QBWOS)*
- CSIRO's Flinders and Gilbert Agricultural Resource Assessment and Northern Australia Water Resource Assessment (NAWRA) studies
- planning associated with the Lake Eyre Basin and GAB[1]

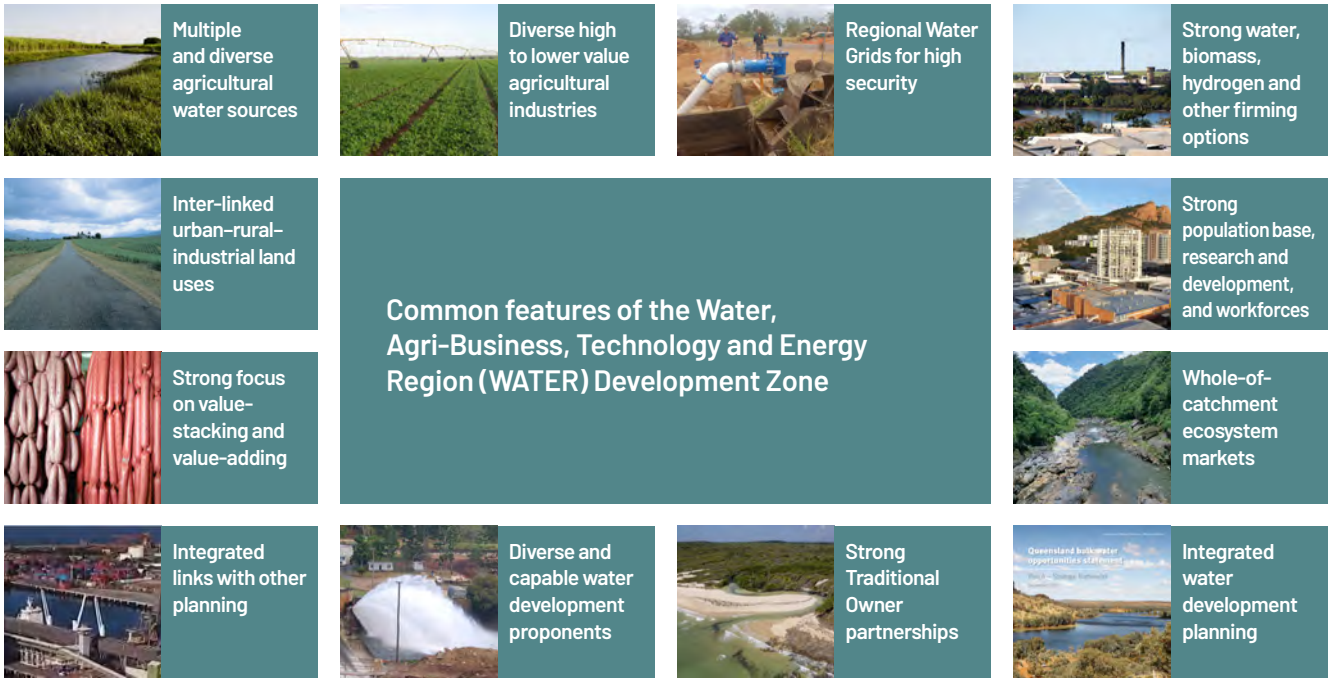


Figure 5-1: Interlinked features of the opportunities for catchments in the WATER Development Zone.

- the CopperString proposal, the *Powering Queensland Plan* and the Queensland Government statement on renewable energy zones
- several studies of relevance to the future of the North West Minerals Province
- the *Queensland Hydrogen Industry Strategy 2019–2024*
- several statutory regional plans and the *State Infrastructure Plan*
- the relevant water plans (Appendix 2) and the assessments of the effects of climate change on average levels and variability of rainfall, as discussed in Appendix 3.

The opportunities combine to provide in the WATER Development Zone, an exceptional economic development opportunity for coastal Queensland (illustrated in Figure 5-1).

The area in central and northern Queensland that was the source of water development in the Bradfield proposals turns out to lie within a region with immense development opportunities in the period ahead. The area of exceptional opportunity is bounded by Cairns in the northeast, Gladstone in the southeast, Barcaldine in the southwest and Hughenden in the northwest. The panel refers to this as the Water, Agri-Business, Technology and Energy Region (WATER) Development Zone. The WATER outlines a region of exceptional opportunity for economic expansion and employment and population growth in the emerging zero-emissions world.

In the west through and beyond the Great Divide, the WATER has globally exceptional combinations of wind and solar energy resources and, through the Divide, of hydro-electric and pumped hydro storage potential. It contains rich water resources.

The WATER Development Zone has no near comparators in Australia as a region of substantial cities away from the state capitals. The main industrial cities are linked to their western hinterlands by diverse and substantial transport infrastructure. The energy, water, transport and urban infrastructure through the Bowen Basin coalfields provides decentralised opportunities for new industry based on renewable energy and biomass (including the valorisation of organic by-products as well as new products that do not compete with food).

The WATER contains well-established agricultural and horticultural industries that can expand and be refocused as major sources of biomass for industry in the zero-emissions economy. This region, with Gladstone and Townsville leading the way, is naturally a major global centre of zero-emissions industrial activity. It has potential for regional development on a scale well beyond anything previously known in regional and northern Australia. To make a start, however, it will need reliable water in substantial quantities. Even if the water had been available for one of the Bradfields, such use would have to generate exceptional value to compete with the value of its use in the WATER Development Zone.

Regions adjacent to the WATER benefit from growth in incomes, services and infrastructure within the WATER, and they have their own opportunities for economic expansion in the new economy.

Chapter 5 explores the integration of water and energy development that could underpin thinking about the development of these scenarios. The panel then unpacks the two alternative scenarios in detail. Chapter 6 discusses the Regional Water Grids Scenario and Chapter 7, the Making Water Work Scenario. Finally, Chapter 8 describes the elements of an approach to regional water development planning that represents a fundamental precondition for success.

Our descriptions in chapters 6 and 7 of existing economic activity and options for development that might be considered in the Regional Water Grids and Making Water Work scenarios are merely indicative. The descriptions of options for future development are simply possibilities to be examined within the new framework of regional water development that the panel proposes in Chapter 8.

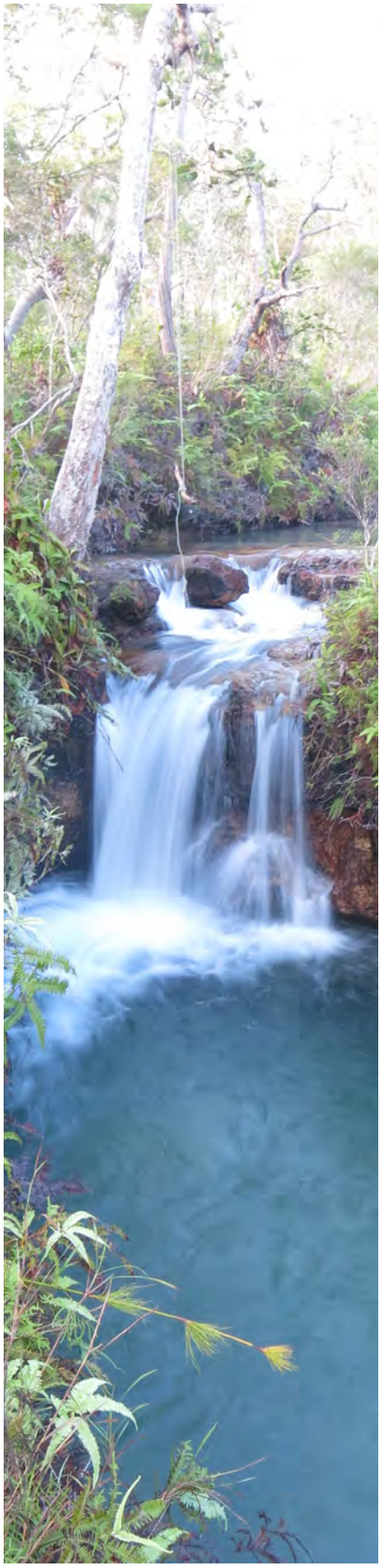
[1] Department of Regional Development, Manufacturing and Water, 2021

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Chapter 5

The nexus between water and energy

The nexus between water and energy



The largest regional development opportunities involve integrating water, energy and land resources with the industrial and agricultural traditions and infrastructure in central and northern Queensland.

This industrial potential based on renewable energy has become apparent over the past few years as the world has faced up to the implications of moving to a net zero-emissions economy.

WATER Development Zone: Globally competitive energy and biomass for industry

Australia has unequalled opportunities for generating solar and wind energy at low cost. WATER has among the best combinations of them in the country. In addition, it has the water for growing biomass and opportunities in the Great Dividing Range for using hydro-electric potential to balance intermittent renewable energy.

Queensland has Australia's greatest area of farmland, and in central and northern Queensland large potential for expansion of production through more efficient use of unusually abundant water. Agriculture is critical to the WATER Development Zone and making Queensland a superpower of the zero-carbon world economy. Increasingly, agriculture and forestry will be a source of renewable fuels, sequestration of carbon and zero-emissions substitutes for coal, oil and gas. Much work needs to be done to integrate the use of water for energy and for agriculture in regional development.

WATER's combinations of solar, wind and rainfall for biomass are superior to any others in eastern Australia (see maps in this chapter) and are among the best in the world.

Solar and wind, with hydro-electric in the best sites, are now by far the lowest cost sources of energy. Solar and wind resources are much more abundant than hydro-electric and will supply most of the requirements of a greatly expanded WATER economy. They are variable or intermittent energy resources, depending on the sun shining and the wind blowing. To form the foundations for low-cost energy supply to industry, their intermittency must be balanced by:

- demand management (curtailing use of power when it is scarce and expensive, which is achieved economically with electrolysers producing hydrogen from water, and desalination plants)
- thermal peaking plants (in the zero-emissions economy, bio-energy peakers; gas peakers with carbon capture and storage work technically but would be more expensive than the alternatives)
- hydro-electric or pumped hydro-electric storage (PHS)
- battery storage
- connecting geographically dispersed sources of intermittent sun and wind power, to average out supplies of intermittent power in what the WWF has called a 'rhombus of reliability' joining Gladstone, Barcaldine, Hughenden and Townsville, and points in between, within and adjacent.

All of these means of balancing intermittent renewable energy will be important in the WATER Development Zone.

WATER and adjacent areas to the south, north and west have access to water and large areas of land presently outside high-value agricultural use to produce biomass for energy and industrial inputs at low cost (maps 5-2a and b). The available water can stack value from capturing carbon in soils and plants and growing biomass for industry on top of established income sources. If environmental risks can be managed, the region has potential for low-cost hydro-electric and PHS production through the Great Dividing Range. Where this is important, the value of water infrastructure for energy and agriculture can be 'stacked' in assessment of the economic viability of investments. It is an advantage that there are promising hydro-electric or PHS sites to be investigated behind the heavy industrial cities of Townsville and Gladstone and the agri-business and potentially bio-industrial cities of Mackay and Rockhampton. There are sites with suitable geography inland in the mountains behind Cairns but at least many of them are excluded on environmental grounds.

Hydrogen is of central importance in the emerging industrial economy. It is made with zero emissions from renewable electricity by electrolysis or from steam reformation of methane from biomass. Electrolysis is easily turned up and down with variations in the availability and price of renewable energy, so it fits well into an electricity system dominated by variable wind and solar.

Biomass can produce dispatchable energy, with generation independent of the timing of sunshine or wind, alongside other industrial inputs. Some bagasse (the residue from extraction of sugar from cane) is used now to produce electricity and heat for sugar refineries, with some export to the grid. Much is not used to produce economic value. It is potentially a valuable source of hydrocarbon to replace oil, coal and gas in a wide range of chemical manufacturing processes. Companies refining sugar in northern Queensland are involved in manufacturing goods from bagasse outside Australia. Bagasse could be used for pyrolysis to produce bio-char and bio-oil. Bio-char has high value in agricultural systems in the zero-carbon world:

- as a stock food additive that improves digestion and so reduces methane emissions by increasing the proportion of food converted into meat, wool or milk
- to improve soil fertility and water retention
- as a recognised source of long-term carbon sequestration.

It has high value as a pure form of renewable carbon in many industrial processes. Bio-oil has high value as an alternative to petroleum in liquid fuels and chemical manufactures.

Rather than being burned for energy or converted by pyrolysis into bio-char and bio-oil, bagasse can be used directly in chemical industrial processes. Sorghum and agave provide similar opportunities in different climatic and soil conditions. All of these crops can use available water opportunistically and, unlike the high-value fruit trees, do not depend on regular supplies of water. Many native Australian eucalypts and acacias and agave from the Mexican deserts have high value in the zero-emissions world economy. Having adapted to a highly variable Australian or hot and dry Mexican desert climate, they can add great value when water is available and survive when it is not.

So biomass, solar, wind and hydro-electric power add up to a remarkable range of energy and biomass-based inputs for low-cost, zero-emissions industrial production.

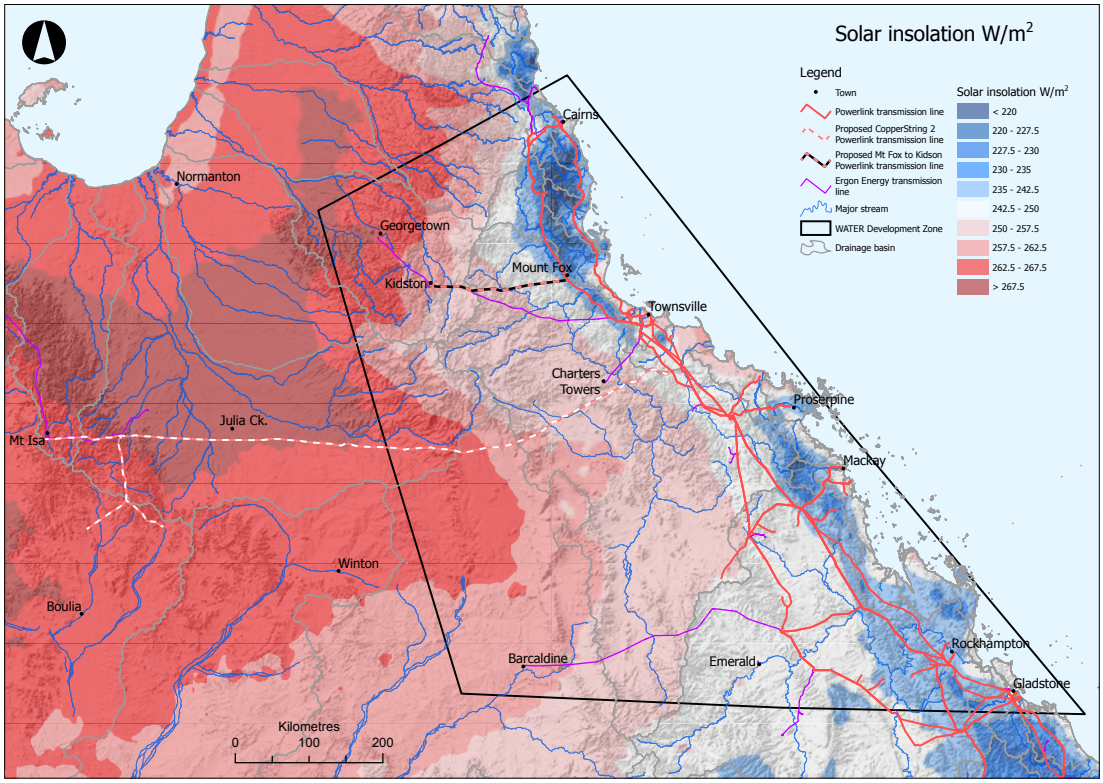
Complementary assets

Central and northern Queensland have other complementary assets for regional development in the zero-emissions economy. The northwest of Queensland in particular, but also some parts of the Great Dividing Range and the Atherton Tablelands, contain rich deposits of critical minerals needed for the equipment on which the future zero-emissions economy will run. These include copper, cobalt, vanadium, rare earths, silicon and others for batteries, solar panels and wind turbines. The International Energy Agency foresees growth in demand for critical minerals by over seven times by 2030, creating upward pressure on prices and vast opportunities for expanded production in Queensland[1]. Townsville is the port of the northwest's minerals province, and a natural location for energy-intensive processing of the ores and concentrates into metals and other higher-value products. Other minerals available in northern Queensland for supporting large-scale metals production are magnetite for iron and bauxite for alumina and aluminium.

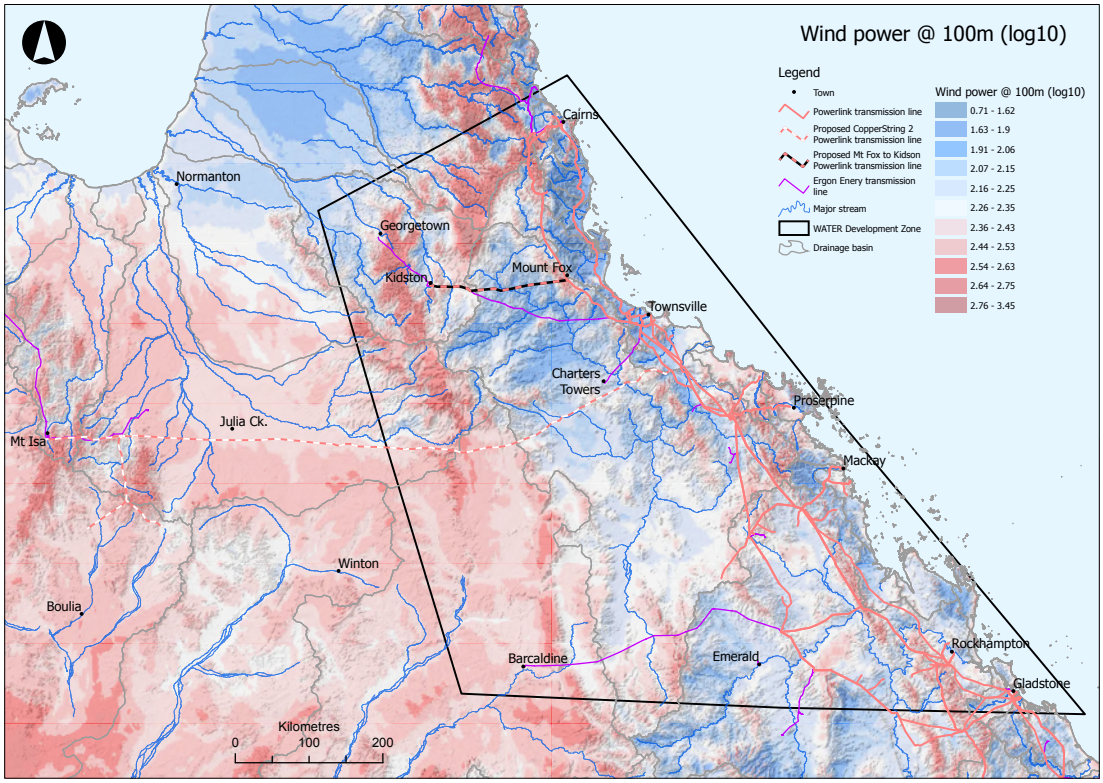
Gladstone and Townsville are well-established industrial cities, with port, energy, water and other industrial infrastructure. It is an advantage that they, along with Rockhampton, Mackay, Cairns and Charters Towers, have a good base of industrial and commercial skills, and the education and training facilities to expand them.

Central Queensland has prospered in the fossil energy world. It is the world's main source of internationally traded metallurgical coal. Its liquefied natural gas helps to make Australia one of the world's two largest exporters. Thermal coal is a major export commodity and has helped Gladstone to convert Queensland bauxite into alumina and aluminium. The infrastructural and industrial legacy of coal gives the WATER region a head start in the zero-carbon economy. The transport, electricity transmission and water infrastructure legacy of the Bowen Basin alongside its biomass, hydro-electric, wind and access to nearby solar potential make it a natural home for the first generation of some new energy-intensive manufactures, including ammonia production from hydrogen produced by electrolysis and biomass-based methane

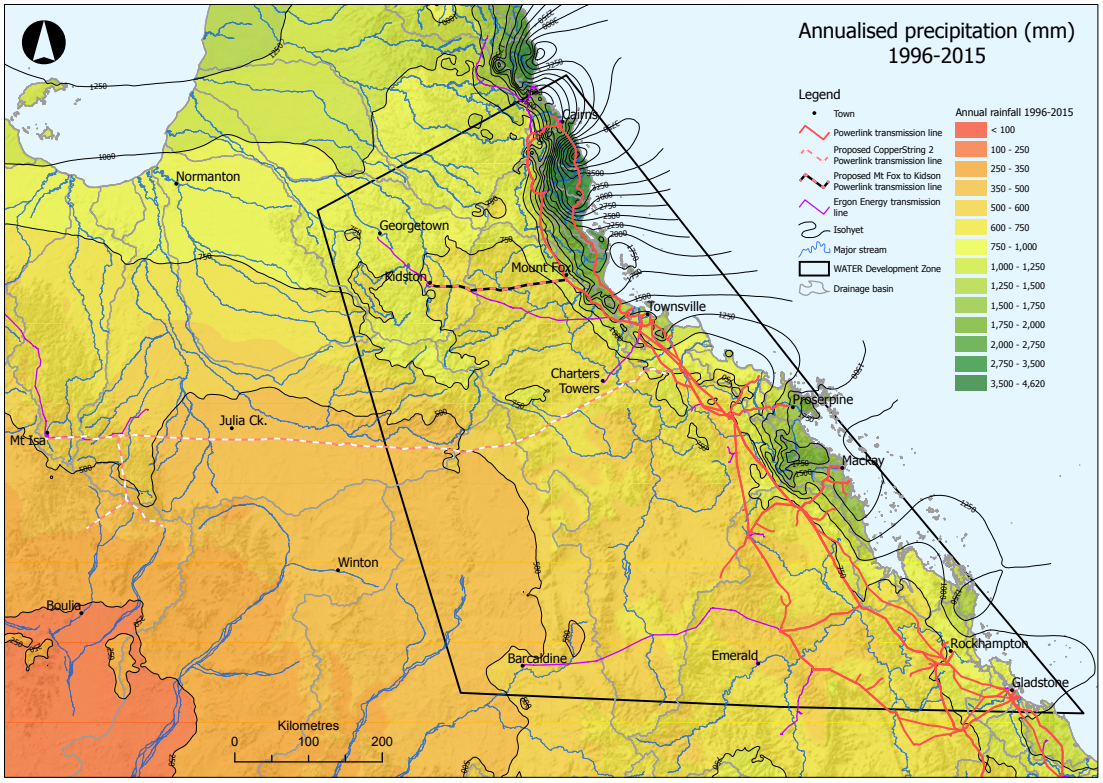
Map 5-1a (overleaf) shows the exceptionally high quality of the solar resource west of the Great Divide, not too far from the major coastal industrial cities of Gladstone and Townsville.



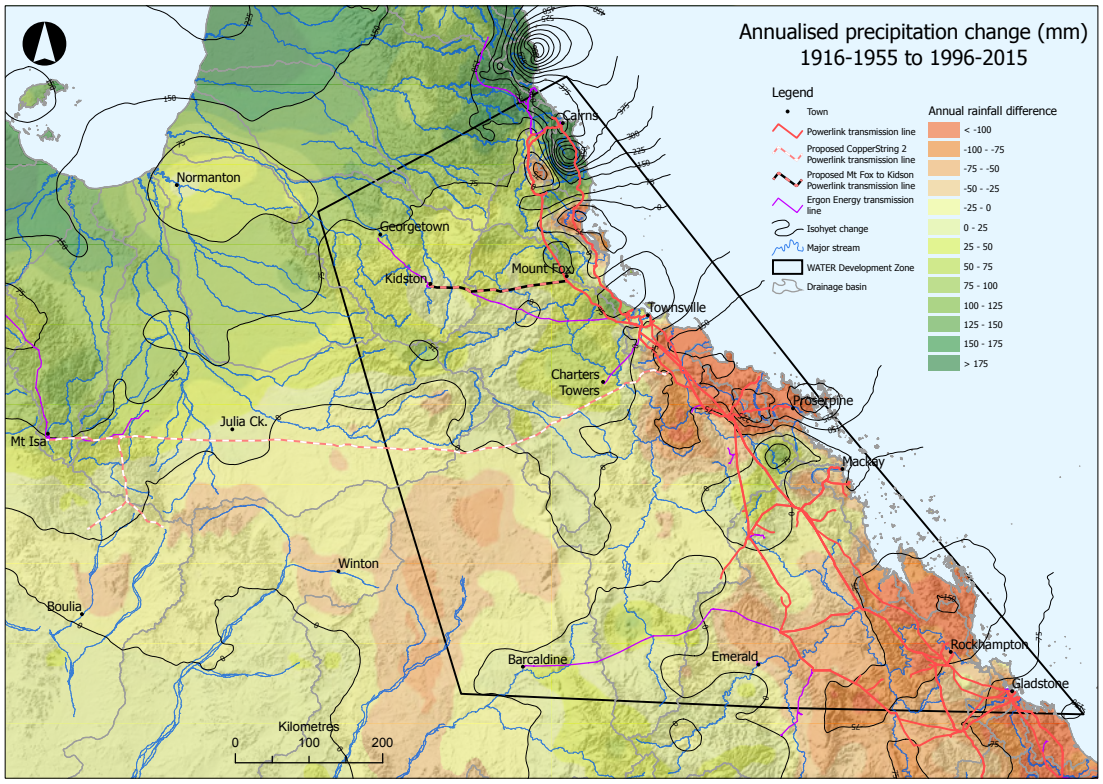
Map 5-1a: Central, western and northern Queensland solar resources.



Map 5-1b: Central, western and northern Queensland wind resources.



Map 5-2a: Central, western and northern Queensland precipitation 1996–2015.



Map 5-2b: Changes in precipitation with early climate change 1916–1955 to 1996–2015.

Note: The continuous lines represent the existing high voltage transmission lines and the dotted lines the proposed lines for CopperString out to Mt Isa and from the Kidston PHS to the main transmission near Townsville.

There is high quality wind on higher country on the plains west of the Divide, which could utilise transmission systems developed to bring low-cost solar power to the coastal industrial cities. The water resources of the region for growing biomass and carbon sequestration are exceptional (Map 5-2a). The scientific models suggest that climate change will affect precipitation unevenly across WATER, reducing it in much of the coast and increasing rainfall inland (Appendix 3). But it will remain a wet region. Experience in the past quarter century under the influence of higher temperatures, compared with the mid-twentieth century, supports that expectation (Map 5-2b). The region will remain richly endowed with water for growing biomass. The hydro-electric and PHS potential increases the value of variable wind and solar for industrial use.

Hydro-electric power for balancing solar and wind

Hydro-electric power from good sites sits alongside demand management as the cheapest peaking power. It fills the gaps when solar and wind generation is low. It is ideally suited to underwriting power security and reliability. It is cheaper than PHS from good sites because it augments power supply rather than diminishing it through power losses on the round trip through pumping and generation. It does not consume water, except for the non-trivial increase in evaporation from the exposed surface of the dam. It can operate close to 'run of river' when a dam is full, with water running through turbines for some hours each day flowing downstream with less than 12 hours' interruption. The hydro-electric system would be designed to operate with large power generation at times when power was scarce and expensive—typically the early evening and early morning straddling sunshine hours. A plant built on a dam with 100-metre fall would require annual flow of about 1,400 gigalitres to generate one gigawatt (more than Gladstone Power Station) for five hours per day. At a good dam site—with total and standard dam construction and generator costs considered, as well as the current value for peaking power—it would be financially attractive without any contribution from agricultural value. The value of peaking power is likely to rise as solar and wind become more important in the electricity system. The availability of greatly increased hydro-electric energy would improve the competitiveness of industry in the region. Costs would depend on the site and transmission. Of course, whatever the site, the project would depend on properly answering the large environmental questions.

A preliminary look suggests that the vicinity of Townsville may have good large-scale hydro-electric potential, Burdekin Falls Dam provides an excellent opportunity for evaluation for early development. These and other Burdekin sites warrant close analysis for large-scale systems. By large-scale, the panel means multiple hundreds of megawatts of power, and more—far larger in scale than any that has been assessed for the old, fossil-energy-based economy.

PHS absorbs power rather than adds to its supply but has a large role to play in balancing intermittent renewables. Around 20–30 per cent of power taken into a facility is lost on the round trip—about 30 per cent in the case of Snowy 2.0, without accounting for transmission losses on transport of power to the site. Capital costs for PHS vary with site but can be as high per megawatt of power and megawatt hours of energy as a hydro-electric facility despite absorbing energy rather than contributing it. The Kidston PHS facility, currently under development, is well-located for Townsville and the CopperString transmission line to the west. There are promising PHS sites around Nebo close to Mackay, and at Broadsound, Bouldercombe and Awoonga near Gladstone and Rockhampton.

The panel has not conducted detailed studies of any of these hydro-electric or PHS sites. It is aware of work within the government on sites with rich potential that should be the subject of early evaluation. Where value from energy contributes a substantial part of the costs of water infrastructure, the revenue required from irrigated agriculture to justify investment is correspondingly reduced.

Replacing temporary advantages with sustainable ones

Any advantages for domestic manufacturing industry from fossil energy resources have largely disappeared and will turn into disadvantages as the world moves to zero emissions.

There was no advantage for domestic iron and steel production from Australia's metallurgical coal resources in the old economy because low international shipping costs meant that the cost of Queensland coal in Shanghai or Kobe was no higher and sometimes lower than in Australia.

There was once an advantage from low-cost domestic gas for Australian industry, but this disappeared when Gladstone became a major exporter of LNG and domestic prices rose to and, for a while, above export parity levels.

Coal and gas export prices are currently high as inhibitions and restrictions to investment in new capacity restrict supply in many countries. Existing producers, and Queenslanders and Australians, can enjoy the high revenues from established facilities while they last. But the same factors that are inhibiting investment in coal and gas in other countries and raising current coal and gas prices will be influential in blocking expansion in Australia. Global movement towards zero net emissions will mean gradual decline in volumes of coal and then gas production, to low levels by mid-century.

By contrast, the competitive advantages of low renewable energy costs to the manufacturing industry in Australia will not

be eroded by low international transport costs, and there is no carbon risk to their future expansion.

WATER's diverse industrial opportunity: processing minerals

There are many elements of WATER's industrial future. The large alumina and aluminium plants in Gladstone would be likely to close in the current decade if they remained tied to coal-based power, as their owner has committed itself to decarbonisation. Use of the zero-emissions energy potential of WATER would see the alumina refinery and aluminium smelter revitalised and expanded.

Processing critical minerals can be expected to play a major role in Townsville's industrial future. Large amounts of low-cost renewable energy will be the foundation of globally competitive production.

Hydrogen and industry

Gladstone is a large importer of ammonia for making explosives for mining. Ammonia will be produced onshore from renewable hydrogen for explosives for mining and nitrogenous fertilisers for agriculture.

Queensland has magnetite resources, and the Grattan Institute says, Gladstone has advantages for smelting iron with hydrogen even if ore has to be brought from Western Australia[2]. Use the opportunity well and one per cent of Australian iron ore exports could be turned into metal in Gladstone and Townsville, producing more iron than Port Kembla and Whyalla together and being well-placed for converting it into steel. If the early projects are successful, one per cent would be an early staging point to larger developments.

Some of the opportunities for using hydrogen with local biomass for zero-emissions industrial production extend along the railway line west of Rockhampton, and through the coal mining and power generation towns of the Bowen Basin. The alternative technology for making zero-emissions hydrogen is steam reforming of methane from biomass. This makes the agri-business cities of the sugar coast from Bundaberg through to Rockhampton and Mackay to Cairns and Mareeba natural homes for hydrogen-based as well as other chemical industry.

Water, electricity, electrolysers, land and biomass are the essential inputs into zero-emissions electricity and hydrogen. WATER has them all in unique abundance.

Hydrogen, probably embedded in ammonia as a carrier, is likely to emerge as a major export itself.

Central and northern Queensland are well-placed to supply zero-emissions hydrogen, first of all to the renewables-poor industrial countries of Northeast Asia (Korea, Japan and, one day, China). Using imported Australian hydrogen may be Korea's and Japan's lowest-cost path to zero-emissions electricity.

Exports of hydrogen in ammonia or other carriers will probably be less important than hydrogen used for processing materials in WATER. Nevertheless, hydrogen will be a large export. Korea and Japan would need to use more than 200 million tonnes of hydrogen per annum to replace imports of coal, LNG and oil to achieve zero emissions by 2050. They have poor domestic renewable energy resources themselves but would generate some of their own requirements. Assume home generation of renewable energy and offset purchases meets half of Korea's and Japan's requirements. Australia is the best-placed external supplier. If Korea and Japan purchase from Australia imports of renewable hydrogen in some form (liquefied or embedded in ammonia or other carriers) in as high a proportion as they do for coal and LNG (more than one-third), they would be drawing perhaps 40 million tonnes per annum of hydrogen from Australia. Central and northern Queensland are best placed among Australian regions, especially in the early stages of market development. A total of around 10 million tonnes per annum from Gladstone and Townsville by 2050 is not an unrealistically high share.

Korea and Japan are the most immediately attractive of many potential markets for Australian hydrogen and hydrogen-based products. The European Union and the UK are also looking for zero-emissions hydrogen in large quantities. By far the biggest potential market for hydrogen and hydrogen-based manufactures, as for other resources, is China, if and when Australia–China political relations allow.

Korea, Japan and the industrial countries of western Europe will have to import hydrogen or zero-emissions iron to keep their massive steel industries competitive in a zero-carbon world. The Korean steelmaker POSCO has spoken publicly[3] about importing five million metric tons per annum of hydrogen for its own requirements, with Australia as a leading supplier. Transport costs from Australia would be much lower for hydrogen embedded in iron than liquefied or converted into ammonia and then back again.

Water requirements of new industry

It seems reasonable to presume that WATER would be the economically optimal location for production of about one-fifth of the ammonia currently used in Australia. A majority of ammonia used is currently imported in one form or another. This would require a bit over one gigalitre per annum of water. Turning one per cent of Australia's iron ore exports into metal using hydrogen would require about three gigalitres per annum of water. Replacing five per cent of the coal, oil and gas imported into Korea and Japan each year with hydrogen would require about 100 gigalitres of water. Opportunities would extend to

processing other minerals and supply to European, Chinese and other Asian markets.

These are large amounts of water. They are not beyond the region's supply capacities now and into the future. But planning now for the future, we should think about the prospects of larger developments and stronger demands.

New industries face many challenges. They are more likely to emerge quickly if basic services like water are provided to them from established facilities, so that they do not have to add them to a long list of development challenges. Water is available in the WATER Development Zone for new industry to make a start. Investment in water infrastructure will have to stay ahead of the rapidly growing demands of industry. The local water infrastructure discussed in Chapter 6 has an important role.

As hydrogen and other industrial production expand, a time will come when it is cost-effective to invest in desalination in the coastal cities, freeing up water resources for agriculture and other uses in the hinterland. The costs of desalination are falling rapidly with the cost of renewable energy and as increases in the global scale of desalination brings down the cost of equipment. One challenge of desalination, however, is safe disposal of salt. Large, diverse industrial cities like Gladstone and Townsville can develop commercial uses of salt. Deep sea disposal is possible but adds to costs.

So far, this report has focused mainly on the inter-relationship between water and energy in hydro-electricity and hydrogen. The inter-relationships go far beyond that.

Saving water from coal and gas

Large amounts of water in the Burdekin and Fitzroy systems are currently allocated for coal mining and power generation. Queensland public corporations plan for growth in water demand from coal. The reduction of coal-based generation and coal and gas exports will gradually free this water for other uses in WATER.

The coal generators at Gladstone, Stanwell and Callide have access to around 50 gigalitres of fresh water. These generators are scheduled to be wound out between the late 2020s and the 2040s. This water will be available for other uses.

Beyond coal power generation, it is not an easy matter to work out how much water is allocated to coal and gas mining. The total is well over 100 gigalitres per annum. The Commonwealth Government anticipates a reduction in coal production by a bit more than half by mid-century[4]. Other developed country governments are seeking a more rapid winding down of global use of coal than Australia. They see that as being necessary to reach the Paris climate objectives. If the President of the United States and the leaders of other developed countries and China succeed in holding temperature increases close to 1.5 degrees, coal exports will fall more rapidly than the Australian Government says that it expects. That would accelerate the decline in the coal industry's demand for water in the WATER Development Zone.

It follows that a substantial quantity of water currently used by coal and gas mining and power generation will gradually become available for other uses over the next three decades.

Saving water while producing energy: floating solar

Evaporation from dams absorbs huge amounts of water in Queensland. The losses are increasing with climate change (Appendix 3). Evaporation is proportionately reduced if part of a dam surface is covered by floating solar panels. Floating solar power is increasing in countries in which land is scarce and expensive. As it is deployed more extensively in Japan, Korea, Europe and elsewhere, costs are coming down, towards land-based systems. In hot regions like Queensland, high temperatures in summer reduce the amount of power generated from solar panels. This loss is avoided or greatly reduced by the cooling effect of floating on dam surfaces. The value of floating solar is even higher on a dam that is used for hydro-electric or PHS power generation because the large-scale electricity transmission is already in place.

There are limits. Floating solar would be vulnerable to cyclonic wind, so it is not feasible close to the coast in central and northern Queensland. Some dams in the central highlands or the Upper or Lower Burdekin may be far enough away from extreme winds to avoid damage from this source. Massive overflows after torrential tropical rain in some locations would be a threat and have insurance implications for such infrastructure. These considerations would be a focus of due diligence in assessing a case for investment. The whole dam cannot be covered, as some sunlight is necessary for water health. Where the surface area of the dam varies with the water level, the maximum area covered by solar panels is less than the minimum surface area.

The power generation capacity of floating solar within these constraints could be large. If they were suitable, the large established dams of central and northern Queensland would support floating solar generators many times larger than any solar farm currently operating or being built in Australia. It would be wise to assess potential on many dams. Covering 15 square kilometres, or one-tenth of the full surface area of the Fairbairn Dam at Emerald, for example, would produce about 600 megawatts of power. This is well within the range of floating solar facilities currently under consideration elsewhere in the world. This is a large amount of power. However, it is a minor part of what will be required as WATER realises its

economic potential. It could also reduce evaporation by about 35 gigalitres per annum, which is a non-trivial augmentation of water availability. Floating solar would be more straightforward and proportionately more valuable in smaller and shallower storages in which evaporation losses represent a higher proportion of available water.

Industrial sources of water: desalination

The potential for more desalination is another link between water and energy. Energy is the main operating cost of desalination. Electricity use in desalination is ideally suited to integration into an energy system that relies heavily on intermittent solar and wind energy: the plant can be shut down quickly when electricity is scarce and expensive. The costs of renewable electricity for desalination are now low, and lower still when its use can be curtailed when prices are high. The cost of desalination equipment is falling rapidly as its use expands and the overall costs in this capital-intensive activity have fallen with global interest rates.

New industrial strengths in Gladstone and Townsville will emerge more easily if abundant water is available to them at the beginning through established infrastructure. This argues for building large, secure water supply links now into the systems of the hinterlands of the industrial cities. But as industry and urban populations grow, a time will come when the value of water used inland for growing plants is greater than the cost of desalination on the coast. From that time, large coastal desalination plants will provide secure and reasonably priced water in the cities, and the established pipelines will balance water supply and demand between the cities and the hinterland. Integrating cities into inland water systems allows the gradual evolution of supply, from initial dependence on water diverted from rivers, into water from industrial sources when demand has reached adequate levels, the costs of desalination declined, and the value of water in agriculture and alternative uses increased.

Saline aquifers may provide some opportunities for desalination in the drier inland, where renewable energy resources are exceptionally rich and water has high value. In the inland, desalination will be possible only in locations with opportunities for safe disposal of salt at relatively low cost.

Energy costs and agriculture

Energy costs are high, despite huge levels of public subsidy for the state corporation supplying rural Queensland. Wise use of central and northern Queensland's natural strengths in renewable energy would turn a source of competitive disadvantage for Queensland agriculture into an advantage.

Electricity is a material expense of providing water delivery services, both for moving large amounts of bulk water, and in local distribution systems through to on-farm. High costs of electricity are one reason for underutilisation of water currently available from dams in rural Queensland. Pumping costs could be expected to have fallen radically in central and northern Queensland with renewable energy costs. Removing the barriers to more economic pricing of electricity for movement of water would quickly become a focus of place-based planning systems.

The panel noted the present Sunwater three-year trial related to water delivery services in six supply schemes across Queensland, which allows the direct cost of electricity to pass through to growers. In the first year it has returned $3.13 million to growers in four of the six schemes but more work is required in this area to facilitate increased utilisation of water allocations.

Businesses in the agricultural sector (including agri-processors) are significant stakeholders in the carbon mitigation, energy from waste, bioenergy and renewable energy (and transport) sectors. There are established as well as new technology opportunities emerging for the sector, to add value to resource streams and agricultural by-products to realise bio-economy efficiencies and maximise financial returns.

These opportunities can be integrated within the panel's proposed Regional Water Grid catchments (see Chapter 6). The principles also have relevance in the panel's Making Water Work regions (Chapter 7).

Water and energy availability and the emergence of WATER

A start can be made with accelerated development in WATER within current water and electricity infrastructure. Using water more productively can yield large gains in the Regional Water Grids as well as the Making Water Work regions. There is some limited electricity transmission capacity into Gladstone, Townsville and the agri-business centres of WATER to support the early stages of the industrial transformation. But it will not be long before the most dynamic centres of development run into water and energy constraints.

Effective regional planning is essential in preparation for easing these constraints. Good planning will recognise the opportunity for using water freed by gradual decline in the industries based on coal and gas to expand its use in agriculture and other industry. Good planning will make good use of opportunities for saving water as well as producing power from floating solar. Good planning will ensure transmission is available to supply massive amounts of solar and wind from the adjacent west to the coastal industrial cities. Good planning will ensure that the opportunities for making water work throughout central and

northern Queensland are developed alongside the emergence of the coastal cities as globally significant centres of zero-emissions industrial activity. Good planning from the beginning will be assessing the role of desalination in the big industrial cities in freeing water for increasingly valuable uses closer to where the rain falls.

This is the focus of chapters 6, 7 and 8.

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1 International Energy Agency, 2021

2 Wood et al., 2020

3 Macdonald-Smith, 2021

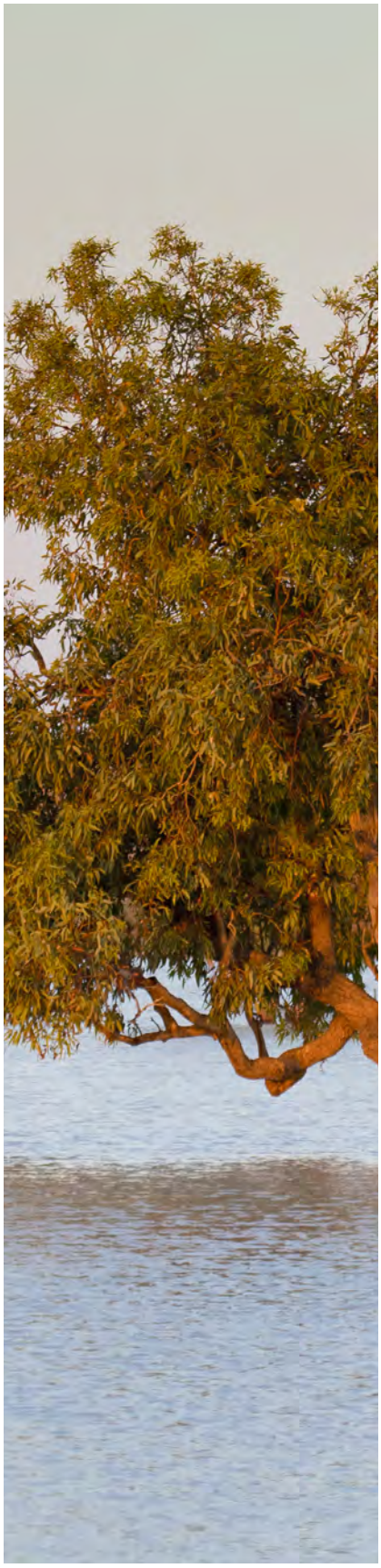
4 Department of Industry, Science, Energy and Resources, 2021, "Australia's long-term emissions reduction plan: A whole-of-economy Plan to achieve net zero emissions by 2050"

06

Chapter 6

The Regional Water Grids Scenario (Mini-Bradfield Grids)

The Regional Water Grids Scenario (Mini-Bradfield Grids)



Building massive water infrastructure and shifting huge quantities of water over long distances introduces engineering, economic, agricultural, social and environmental risks. The Regional Water Grids Scenario spreads that risk without compromising the integrity of established water allocations. The panel also envisages innovative producers from southern Australia investing in northern land and water opportunities to spread their risk across climatic zones.

The Regional Water Grids Scenario involves developing four initially independent grids to create new, regionally-centred agri-industrial hubs (Map 6-1). These are:

1. the Tablelands–Cairns Regional Water Grid
2. the Burdekin–Townsville Regional Water Grid
3. the Fitzroy–Rockhampton–Gladstone Regional Water Grid
4. the Burnett–Bundaberg Regional Water Grid.

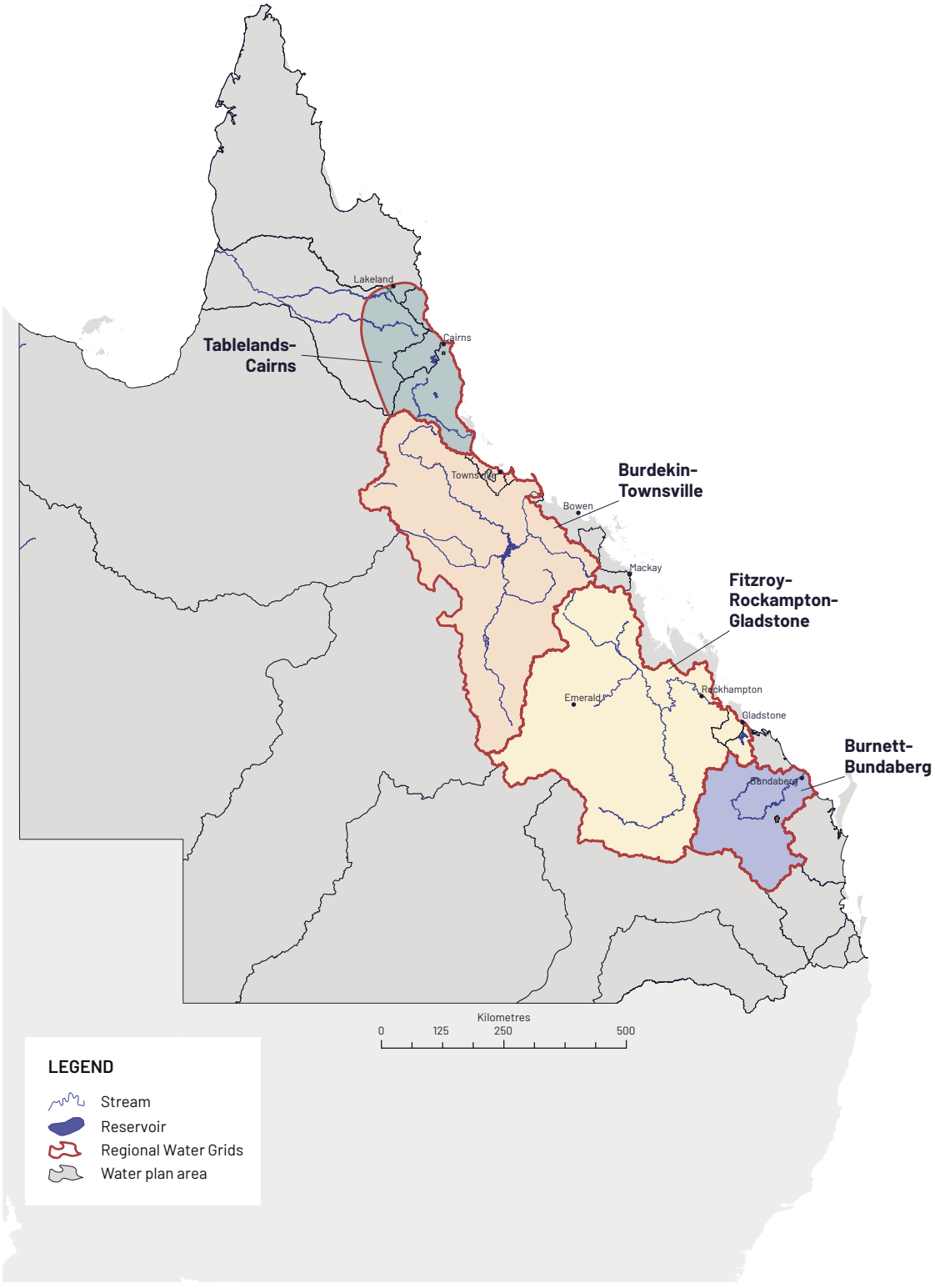
Each of these grids would include:

- new or enhanced smart water storages where water is available
- increased grid-like integration of water storages across the region, where viable, to allow use of water where it is most valuable
- better linkages and trade between mining and agricultural opportunities in the upper catchments and urban and industrial development in major regional towns
- maximising the sum of energy and agricultural sources of water value from all water infrastructure (value stacking), recognising the firming potential of energy from hydro-electric, PHS and biomass
- a stronger focus on research to lift agricultural, water and energy productivity efficiency, and to manage catchment and farms to meet reef water quality targets.

With four working grids in place, the value of inter-linking them could be assessed to provide greater water security and more efficient water use through trade in allocations across regions. There could be some linking of northern and central Queensland Regional Water Grids where this could be achieved at low cost.

Agricultural, energy and industrial uses of water are more closely intertwined in the zero-emissions economy. The amount of water available in each region is affected by climate change and by the gradual reduction in water used in coal mining and power generation as the world moves to zero net emissions by 2050. The demand for water in agriculture and agroforestry is increasing with the premium on carbon sequestration and zero-emissions industrial inputs.

Regional Water Grids development would support, and be supported by, the development of biomass resources in the Wet Tropics and Burdekin, the Whitsunday–Pioneer and Burnett–Mary catchments, and on the railway and highway corridors west from Townsville and Rockhampton.



Map 6-1: The four Regional Water Grids regions and linkages between them.



If these Regional Water Grids proposals are to deliver efficient regional development, there are several preconditions to success:

- effective Federal–state–local government collaboration in water development and energy planning through a strong regional planning institution, providing leadership through to implementation
- effective place-based participation by industry, the finance sector, communities, and Aboriginal and Torres Strait Islander peoples in water planning decisions
- strong, evidence-based water planning and monitoring systems, protecting allocations for established economic uses, environmental reasons and cultural values
- enforcement of high environmental standards related to Great Barrier Reef water quality, as well as world heritage values (the Wet Tropics and reef regions)
- recognition and protection of Aboriginal and Torres Strait Islander peoples' rights and interests in water
- effective identification of options to capture, store and transfer available wet season flows (especially in the Tablelands–Cairns Regional Water Grid).

Table 6-1: Introductory descriptors of the four possible Regional Water Grids.

Regional Water Grid name	Description
Tablelands–Cairns Regional Water Grid 	This grid explores linking the present Mareeba–Dimbulah Irrigation Area (MDIA) with the proposed North Johnstone Diversion, Palmer and Woodleigh dams and the existing Quaid's Dam. To achieve additional security in the grid, innovative capture, storage and transfer of wet season flows under the Wet Tropics Water Plan should be examined. Strategies would be developed to improve supply chains, add value and increase water and energy use efficiency. Small-scale hydro and pumped hydro opportunities could be incorporated. The grid strengthens opportunities for biomass for manufacturing and has longer term regional urban and industrial water security benefits. Subject to future feasibility work, the transfer of some wet season flows in the Upper Herbert into the Burdekin grid could be considered.
Burdekin–Townsville Regional Water Grid 	This grid proposal considers raising the Burdekin Falls Dam and includes Big Rocks Weir. It explores the potential transfer of water from the Wet Tropics to enable hydro-electric power generation and additional irrigation in the Upper Burdekin through a flow-of-river system based on a series of storages and weirs. Regional water planning assessments could include current and proposed pipelines to Townsville and pipelines to the agricultural lands in which water is most valuable. It would serve strong industrial development in Townsville and biomass production expansion in the Lower and Upper Burdekin (e.g. Pentland). Townsville's industrial focus would include increasing the processing of minerals including magnetite from the west and production of hydrogen for minerals processing and export. Subject to future feasibility work, consideration would be given to whether water had higher value closer to its source in the Belyando–Suttor rather than downstream. Consideration would also be given to the merits of transferring water from Burdekin Falls Dam to the Bowen region or into the Fitzroy grid.
Fitzroy–Rockhampton–Gladstone Regional Water Grid 	This proposal envisages exploring connecting Rookwood Weir, Eden Bann, the Fitzroy Barrage and other local sources with Awoonga Dam for agricultural development and for industrial and urban expansion in Gladstone and Rockhampton. Strategies to improve supply chains and water use efficiency and value adding would be required. Large-scale PHS would be important for the expansion of the large cities, complemented by several small, pumped hydro and hydro opportunities. The potential would be explored to reduce Fairburn Dam's vulnerability to climate change by connecting it by grid to one or more of the eastern parts of the Fitzroy basin, the proposed Nathan and Connors dams, and/or the Burdekin Grid. The panel notes the relevance of, but has reservations about, connecting the proposed Nathan Dam into the northeast Murray–Darling.
Burnett–Bundaberg Regional Water Grid 	This grid would build on the current Coalstoun Lakes proposal to deliver water from an appropriate source for high-value agricultural development in the Burnett River area and to increase regional water security. Considerations for development in this grid would include better understanding of the volume of available water with the Paradise Dam's potential restoration and the issues around use of water from Boondooma Dam to secure urban supply in the South Burnett (Kingaroy). Other possibilities include a new pipeline to high-value crops in the Kingaroy and South Burnett areas or the release of water down the Boyne River and new regulating weirs for agriculture to Mundubbera. There are opportunities to increase the effective use of water available within the grid area by converting high-priority allocations to medium-priority allocations.

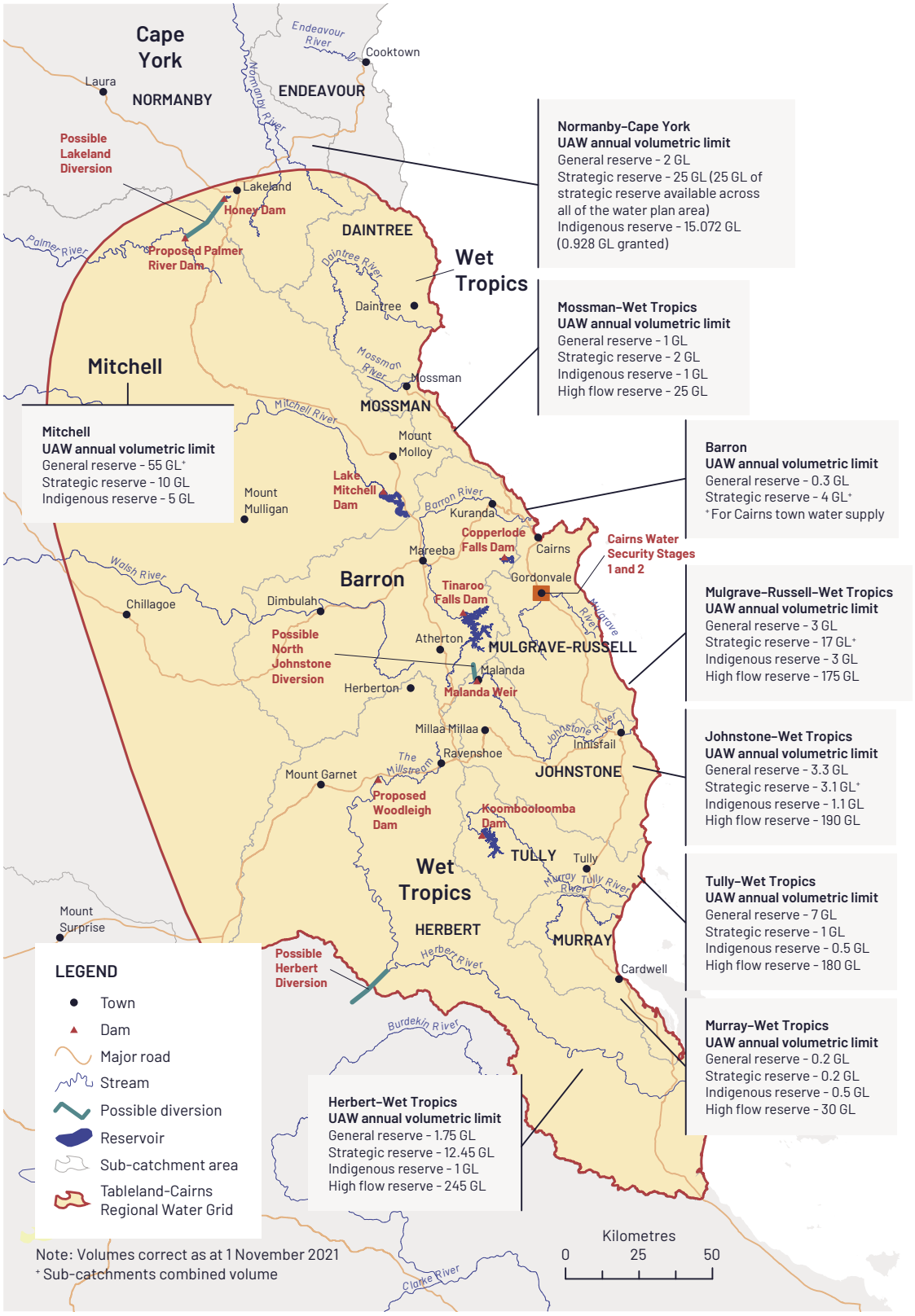
The Tablelands–Cairns Regional Water Grid

Map 6-2 shows the Tablelands–Cairns Regional Water Grid area with the water available for new development and current infrastructure proposals. Within this area, some 331 gigalitres of water have already been allocated to agricultural, industrial and urban uses. There are substantial opportunities for more effective water use and greater integration with energy development.

The usual resident population of the Far North Queensland Regional Organisation of Councils area (closely aligned with the grid) in 2016 was 264,000, with the majority in Cairns[1]. Agricultural gross value production (GVP) of the Wet Tropics Natural Resource Management (NRM) region was $1.05 billion at the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) census for 2016[2], dominated by crops (which accounts for some 86 per cent of GVP), with bananas 38 per cent, sugar 35 per cent, and cattle at 11 per cent. This was produced by some 1,800 businesses, on 970,000 hectares of land, with 12 per cent irrigated (mostly for sugar). Small to medium manufacturing value around Cairns was around $0.9 billion.

Subject to options analysis, water availability, feasibility and impact assessment, some specific actions that could be considered in a place-based approach to the development of this grid include:

- the North Johnstone Diversion transfer to improve security in the MDIA
- implementation of stages 1 and 2 of the *Cairns Water Security Strategy*
- the potential transfer of water from Quaid's Dam into the MDIA
- the potential development of Palmer River Dam and local distribution systems to Lakeland
- the potential development of Woodleigh Dam and local distribution systems
- innovative capture and storage of overland flow reserves and wet season flow reserves (including new underground dam technologies in several upper catchments in the Wet Tropics Water Plan)
- targeted new hydro, pumped hydro and refurbishment opportunities
- potential biomass for energy and industrial development from the sugar coast and Tablelands
- potential future desalination developments in Cairns, freeing up water for agriculture.



Map 6-2: The Tablelands–Cairns Regional Water Grid.

The Burdekin–Townsville Regional Water Grid

For the proposed Burdekin–Townsville Regional Water Grid area, the potential water available for new development and current infrastructure proposals is outlined in Map 6-3. Within this area, some 1,452 gigalitres of water have already been allocated to agricultural, industrial and urban uses, though significant opportunities remain for the more effective use of that water and for greater integration with energy development.

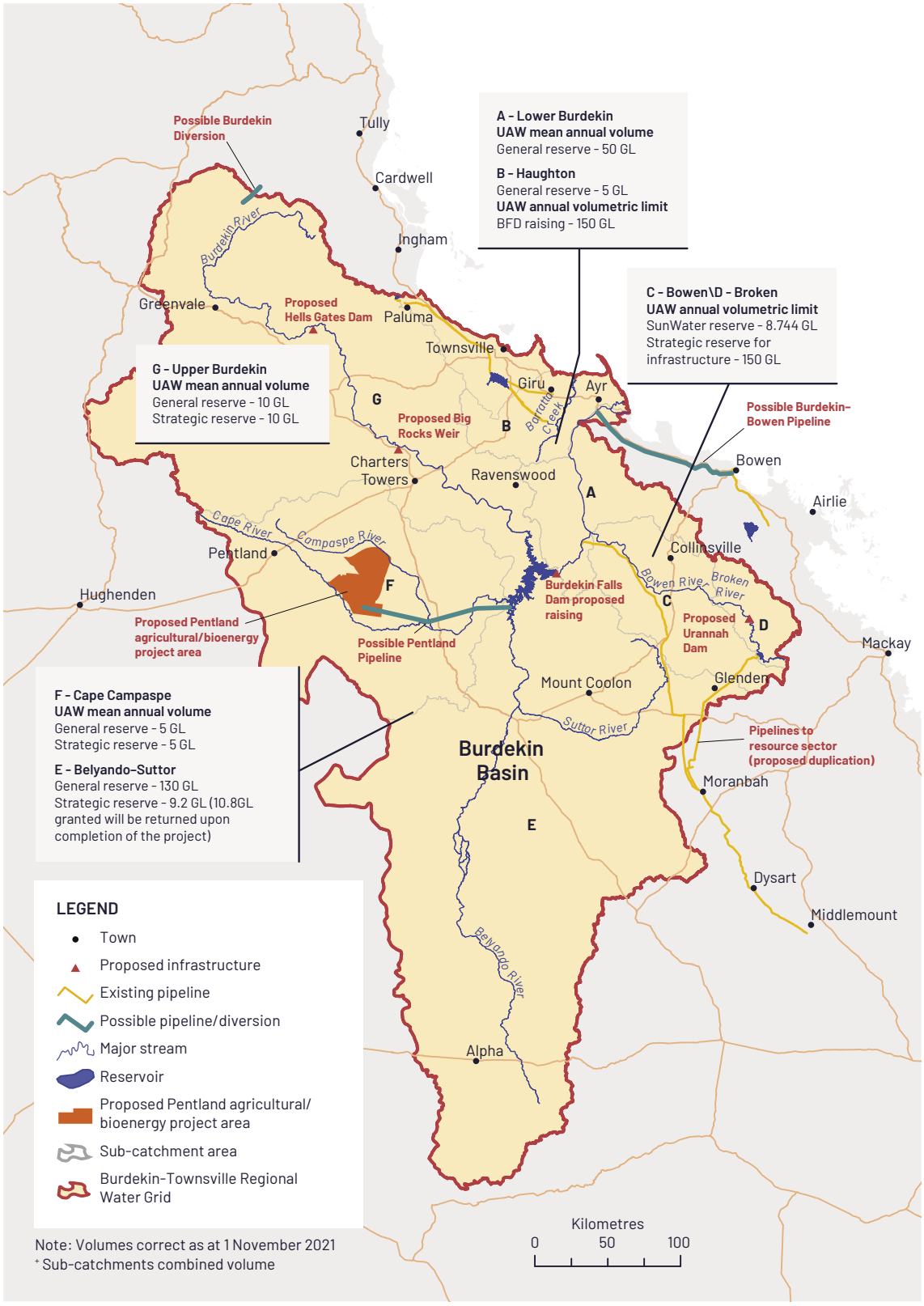
The resident population of the North Queensland Regional Organisation of Councils region (closely aligned to the Burdekin–Townsville Regional Water Grid) is around 240,000, with the vast majority in Townsville. Agricultural GVP in the Burdekin NRM region was $1.5 billion in 2016, balanced between crops at 50 per cent (of which sugar was 29 per cent) and livestock for beef (49 per cent). The total area of agricultural holdings within the Burdekin region is 11.1 million hectares, of which only one per cent is irrigated. Among 1,547 agricultural businesses in the Burdekin NRM region, seven per cent produce vegetables, with 80 per cent of these using irrigation. Medium- to small-scale manufacturing value in the Townsville region is estimated to be around $1.1 billion.

Again subject to analysis, potential developments or actions that could be assessed in a place-based approach to the development of this grid include:

- better use of the existing Burdekin Falls Dam and the possible raising of the dam wall, with the potential to shift water to various locations within and beyond the catchment, and large-scale hydro-electric and PHS options
- the Big Rocks Weir in the Upper Burdekin (already the recipient of state and Commonwealth funding for feasibility and commitments for development)
- the Urannah Dam (currently developing its full business case and impact assessment with Commonwealth funding) and other storage options in the Bowen–Broken catchment, including hydro options, but the current business case is challenged by the likely shrinkage of demand from coal mining in future years
- smaller scale in-stream and offstream storages in the Belyando–Suttor for local use, and small-scale water infrastructure
- current water pipeline developments between Townsville and the Burdekin Falls Dam
- strategies to support more effective use of some 200 gigalitres of allocated but underused water in the Lower Burdekin
- potential biomass for industrial and energy development from the Lower and Upper Burdekin (e.g. Pentland and elsewhere)
- the general integration of renewable energy and firming proposals to support industrial growth, including strengthening electricity transmission in the WATER Development Zone, with the proposed CopperString line from Mt Isa to Townsville and its links to stronger transmission through the WATER.

In this context, cross-regional water availability and security options for consideration include:

- the transfer of innovative wet season flows from the Upper Herbert to the Burdekin
- pipeline water transfer (from Burdekin Falls Dam or Urannah) to the Bowen horticultural district
- pipeline water transfer to the Central Highlands (agriculture) and Moranbah (resources with transition to industry and agriculture) from Urannah or the Burdekin Falls
- local pipelines of modest scale for cross-basin transfer from the Belyando-Suttor catchment to Alpha and along the railway and highway corridor through Jericho and Barcaldine to Longreach.



Map 6-3: The Burdekin–Townsville Regional Water Grid.

The Fitzroy–Rockhampton–Gladstone Regional Water Grid

In the proposed Fitzroy–Rockhampton–Gladstone Regional Water Grid area, the water available for new development and current infrastructure proposals are outlined in Map 6-4. Within this area, some 905 gigalitres of water have already been allocated to agricultural, industrial and urban uses. There are significant opportunities for the more effective use of water and greater integration with energy development.

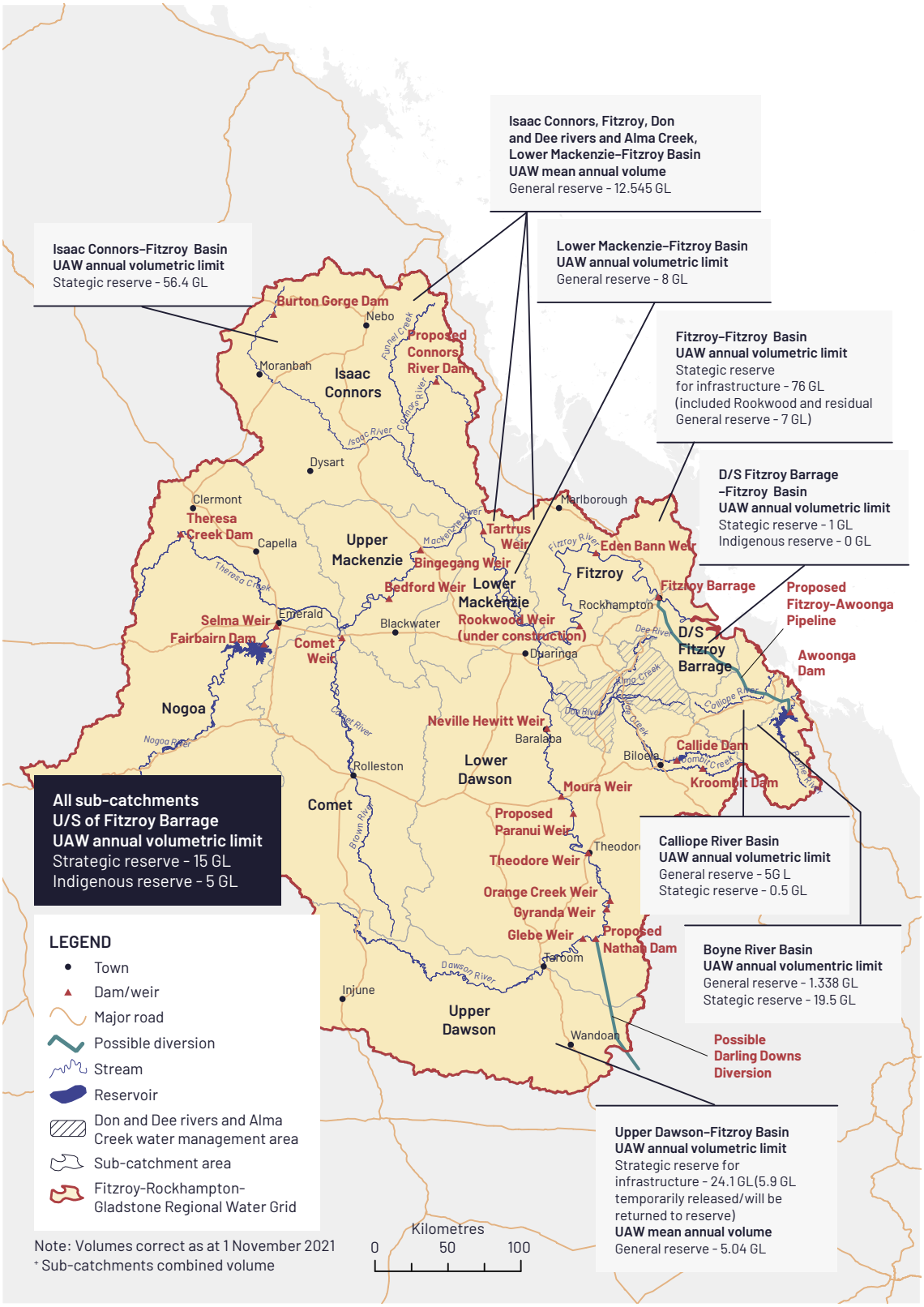
The total population for the region (Banana, Central Highlands, Gladstone, Livingstone and Rockhampton local government areas) was estimated as 221,000 in 2016, with a majority in the coastal cities of Rockhampton (36 per cent) and Gladstone (28 per cent). GVP in the Fitzroy NRM region in 2016 was $1.8 billion, with 81 per cent being livestock (largely cattle). Rockhampton is a major cattle processing, export and servicing city. Crops accounted for 18 per cent of GVP (including cotton at four per cent and grain sorghum, three per cent). The total area of agricultural holdings is 15 million hectares (grazing 88 per cent) across 2,579 businesses, with little irrigation.

Developments or actions that might be considered in a place-based approach to the development of this grid include:

- Rookwood Weir and associated water distribution systems
- the raising of the Eden Bann Weir and Fitzroy Barrage
- domestic water supply distribution to Mount Morgan
- a two-way water distribution pipeline from Rookwood to Awoonga Dam
- the proposed Paranui Weir, Connors River Dam and the Nathan Dam
- the exploration of pumped hydro potential within the region, including Awoonga, Broadsound and other sites behind Gladstone and Rockhampton.

Within this context, potential cross-regional water transfer options include:

- pipeline water transfer to the Central Highlands (for agriculture) and Moranbah (currently coal, but potentially other uses) from the Burdekin
- pipeline water transfer from the proposed Nathan Dam to St George, preserving farming that is already in place but threatened by climate change in the northeastern Murray–Darling Basin.



Map 6-4: The Fitzroy–Rockhampton–Gladstone Regional Water Grid.

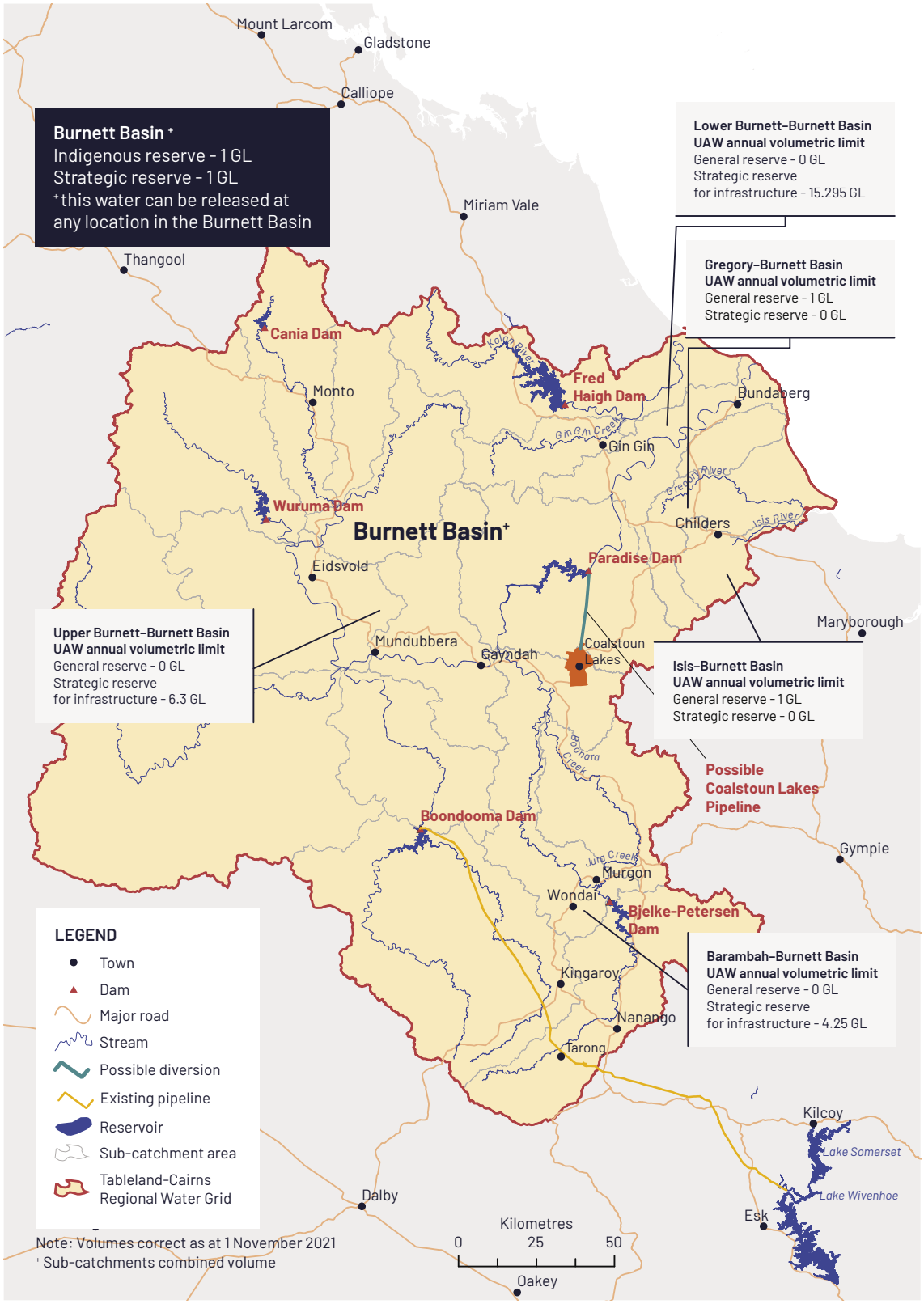
The Burnett–Bundaberg Regional Water Grid

In the proposed Burnett–Bundaberg Regional Water Grid area, the potential water available for new development and current infrastructure proposals are outlined in Map 6-5. Within this area, some 677 gigalitres of water have already been allocated to agricultural, industrial and urban uses. Significant opportunities remain for the more effective use of that water and greater integration with energy development.

The total population for the wider region's local government areas was estimated as being 179,000 in 2016, with more than 86 per cent in coastal cities of Bundaberg (52 per cent) and Maryborough (34 per cent). In 2015–16, agricultural GVP was $1.5 billion, balanced between crops (59 per cent) and livestock (36 per cent). Major crops include vegetables (18 per cent), sugar cane (nine per cent) and fruits and nuts (26 per cent, including mandarins, macadamias, avocados and lemons). The total area of agricultural land holdings within the Burnett–Mary NRM region is 3.2 million hectares across 2,974 businesses, with by far the biggest land use being grazing (beef cattle). Crops use less than two per cent of the land and are mostly irrigated (e.g. 86 per cent in fruit and nuts and 89 per cent in sugar).

Developments or actions that might be considered in a place-based approach to the development of this grid include:

- the Coalstoun Lakes proposal to enable the delivery of water from an appropriate source for high-value agricultural development to the Burnett River area and to increase water security
- assessment of the volume of available water from Paradise Dam, given dam safety issues and the need for restoration investment
- the use of water from Boondooma Dam to secure urban supply in the South Burnett (Kingaroy)
- other water transfer possibilities including a new pipeline to high-value crops in South Burnett or the release of water down Boyne River and new regulating weirs for agriculture down to Mundubbera
- increases to water use efficiency by converting underutilised high-priority allocations to medium-priority.



Map 6-5: The Burnett–Bundaberg Regional Water Grid.

General equilibrium modelling of economic effects of the Regional Water Grids

General equilibrium modelling, undertaken by CoPS at Victoria University in Melbourne, has been used to assess the potential regional, state and national economic benefits of some of the possible investments in each of the Regional Water Grids. The CoPS modelling allows a whole-of-economy approach to economic analysis rather than a project-by-project assessment. Attachment 1 sets out the results of the CoPS modelling. The analysis is limited to the small number of projects for which cost estimates are readily available, and so excludes most of the projects discussed within our Regional Water Grids Scenario. It could include only economic value from established crops for which data are available, and not the new crops that are expected to generate additional carbon and biomass value in the emerging zero-emissions economy. Neither did the panel have the data for hydro-electric power or PHS, and so these are necessarily excluded from the analysis.

The modelling assumes that water infrastructure is financed equally by the Commonwealth and state governments, with on-farm infrastructure funded by local interests, and capital costs recouped from users of water. The Commonwealth effectively transfers to the state its share of the capital expenditure. Government expenditure is funded by external debt at an interest rate of 2.5 per cent plus inflation. For the purpose of the modelling, private sector investment in water infrastructure is not included. It would, of course, be possible, reducing the debt incurred by the Commonwealth and state, and raising the cost of capital.

There is a high level of underutilisation of water allocations in some water schemes across Queensland. The modelling base case assumes the rate of utilisation of water allocations from new development is the same as it was on average over the past 12 years from old allocations: 59 per cent in the Atherton Tablelands, 67 per cent in the Burdekin-Bowen, 42 per cent in the Burnett, and 43 per cent in the Dawson-Darling Downs. This is a strong assumption, as rates of use of water allocations are very low in some Queensland irrigation systems. As discussed in Appendix 2 and in Chapter 3, there is a strong case for institutional and pricing reform to increase water use (including water trading and pricing reform). The CoPS modelling runs an alternative case with higher rates of use of the new water: 90 per cent in the Tablelands, Burdekin–Bowen and Burnett, and 65 per cent in the Dawson–Darling Downs. Some investments would not be justified at historical rates of water use but warranted if reform led to higher use rates—with benefits from existing as well as new schemes. Reform to raise efficiency of water use should be assessed alongside decisions on new investment.

The base case assumes climatic conditions match the past average. To keep climate change in mind, the modelling includes one case called climate change, in which agricultural productivity everywhere is assumed to fall moderately, and the prices of crops from irrigated agriculture to rise a little. The 'climate change' case shows moderately better economic outcomes than the base cases because gains from higher prices exceed losses from lower productivity. While not in CoPS' 'climate change' case, climate change may reduce the productivity of irrigated agriculture in central and northern Queensland much less than elsewhere in Australia and much of the world. The positive effects would be larger than suggested in Attachment 1. This is simply a reminder that investment decisions will need to take climate change into account in a realistic way.

With all of the qualifications, the results of the analysis are illuminating.

For the Tablelands, the analysis covers only investment in Quaid's Dam and the North Johnstone river diversion. The base case shows extremely large local and national welfare gains, and moderate gains for Queensland. The local and Australian gains are much larger with higher water use rates, but not gains for the state. The 'climate change' assumptions show a small increase in the large local and national welfare gain and a slightly lower positive outcome for Queensland.

For the Burdekin, the modelling examines the effects of four possible infrastructure investments:

- raising the Burdekin Falls Dam
- a new pipeline from Burdekin Falls to Moranbah
- a pipeline from Burdekin Falls to the Bowen Basin
- the proposed weir at Big Rocks.

The base case shows large negative outcomes locally and in Queensland, and small negative effects in the Australia as a whole. Higher water use rates give larger negative effects locally and in Queensland, but positive effects in the whole of Australia. The base case with 'climate change' gives positive national but negative local and Queensland effects. The Burdekin projects modelled are possibly positive in economic terms for Australia but not for people in the Burdekin or more generally in Queensland.

In the Burnett, the modelling looks at the rehabilitation of Paradise Dam, a pipeline at Coalstoun and offstream storage at Glendorff. The base case gives substantial positive value in Queensland and locally. More complete water use turns the outcomes strongly positive at local, state and national levels. This is a clear case where reform to improve use rates is critical to the business case for investment.

In the Dawson–Darling Downs, the CoPS modelling only covers the building of the Nathan Dam and infrastructure to transfer water to the northeastern Darling Downs. This generates

strongly negative effects on welfare at all levels. Higher use rates (but with only 65 per cent assumed) give positive local effects but the state and national outcomes remain strongly negative. Whether the assumption of continuing high underuse rates is justified warrants a closer look. The outcome is affected by an assumption that substantial on-farm investment is required to use the new water, which might require modification to the extent that the new water replaces water lost by the drying and warming from climate change in the Darling Downs.

Lack of project data excluded analysis of developments in a wider Fitzroy-based Regional Water Grid to which local communities attach high importance, including increased use of water from the Eden Bann Weir and the Fitzroy Barrage.

One of the interesting outcomes of the modelling is the generally positive effects on national welfare, despite half of the water infrastructure costs being funded by the Commonwealth. Australian benefits are often larger than local and Queensland, and sometimes positive when local effects are negative. This is because greater food output in the region reduces prices everywhere and turns the terms of trade against local communities and, to some extent, Queensland, in favour of consumers across the rest of the country. This makes a case for national support for local infrastructure investment.

The panel commends the CoPS approach to analysing the economic impact of possible water infrastructure and other investments and favours its use in future regional development planning.

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1 Australian Bureau of Statistics, 2016

2 Department of Agriculture, Water and the Environment, 2016



07

Chapter 7

The Making Water Work Scenario

The Making Water Work Scenario



The Bradfield Scheme was based on substantial transfers of water from the Tully, Herbert and Burdekin rivers to irrigated agriculture in the Gulf and especially the Lake Eyre Basin.

Chapter 6 looked at how water infrastructure for more productive local use could promote development in four Regional Water Grids. Here, the panel looks at more modest interventions in water and regional development in six other parts of central and northern Queensland. The panel calls this the Making Water Work Scenario. Two of the six Making Water Work regions cover the areas that were to be the main focus of development in the many variations of the Bradfield Scheme: the Flinders Catchment in the Gulf and, particularly, the Queensland Lake Eyre Basin.

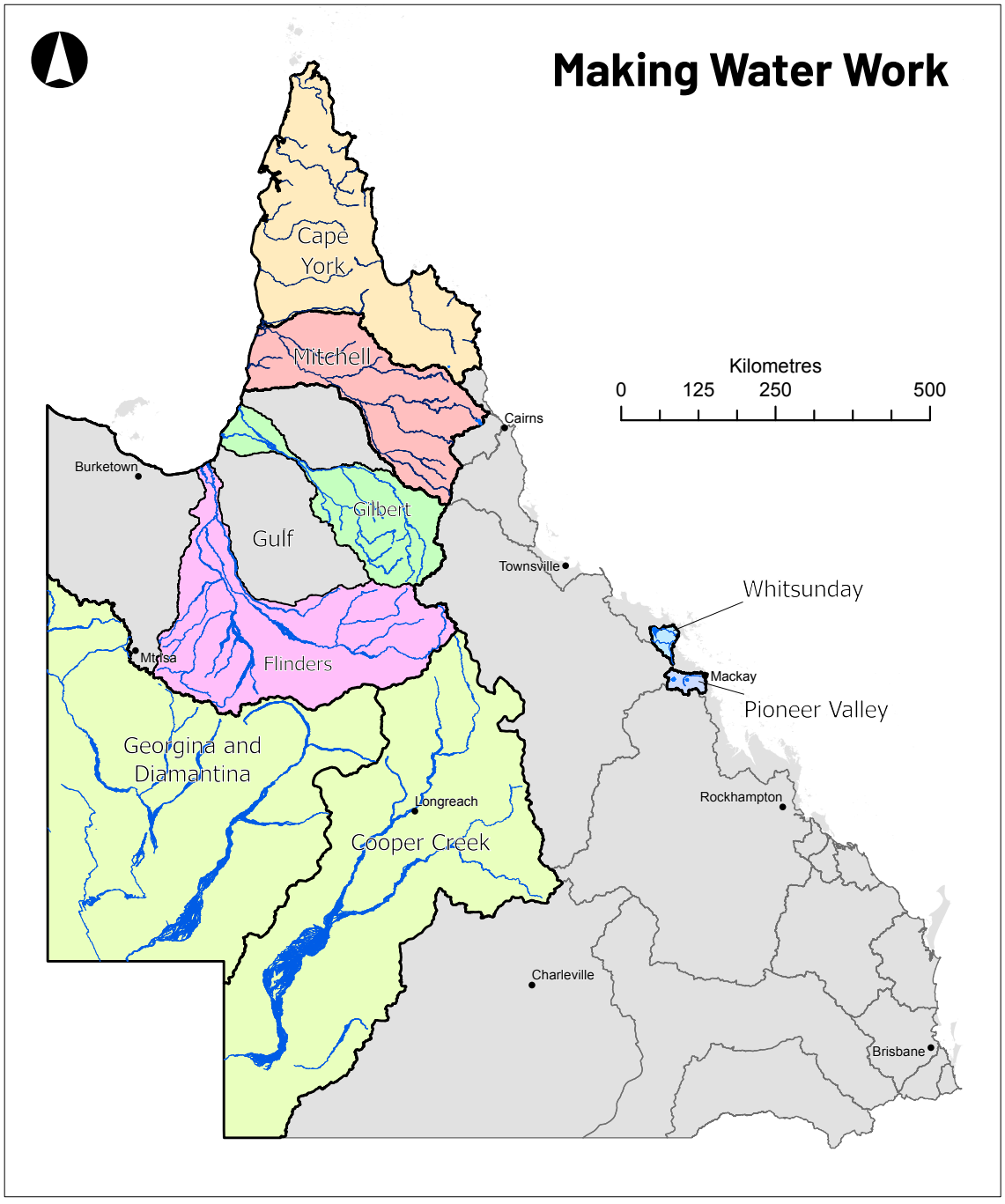
The Making Water Work Scenario seeks regional development through the effective local use of water resources. In the wider Gulf and Cape, there is abundant available water, which is probably being expanded by higher rainfall with climate change, although the greater variability of rainfall presents its own challenges. The Whitsunday–Pioneer region has access to significant water resources and much good land, and this falls within the WATER Development Zone, which also stands to benefit from abundant, reliable, low-cost renewable energy. The drier Lake Eyre Basin (the main recipient of the Bradfield water transfers) presents a greater challenge, but there are opportunities from integrating local insights with more effective state planning for development. This could turn economic decline into modest expansion and prosperity.

As with the Regional Water Grids catchments, the Making Water Work Scenario seeks new agricultural opportunities through innovative water development. The panel envisages increasing economic value by using existing resources more effectively and building skills to do things better—without compromising existing water entitlements, cultural uses of water and environmental values in the Gulf, the Lake Eyre Basin and, in some cases, the Great Barrier Reef. We also seek to strengthen regional water security in the face of climate change and uncertainty.

As in the Regional Water Grids Scenario, the Making Water Work Scenario requires a placed-based approach to regional water development, both where water is reserved for new uses, and where water is limited and development depends on using old water better. We envisage expanding local agriculture or agricultural hubs, agri-business, and local industrial development built on local biomass and renewable energy in the following areas:

- Cape York Water Plan Area
- Mitchell Water Plan Area
- Gilbert Catchment Area
- Flinders Catchment Area
- Whitsunday–Pioneer Water Plan Area
- Lake Eyre Basin water plan areas.

This Making Water Work Scenario envisages the integrated development of several agricultural and industrial precincts within those areas of central and northern Queensland with the requisite combinations of available water, agricultural opportunity, local labour, skills and services, energy and access to markets. While the panel does not envisage movements of water on a massive scale, this scenario could include smaller-scale westward movement of water along existing rail corridors.



Map 7-1: The Making Water Work Scenario catchments.

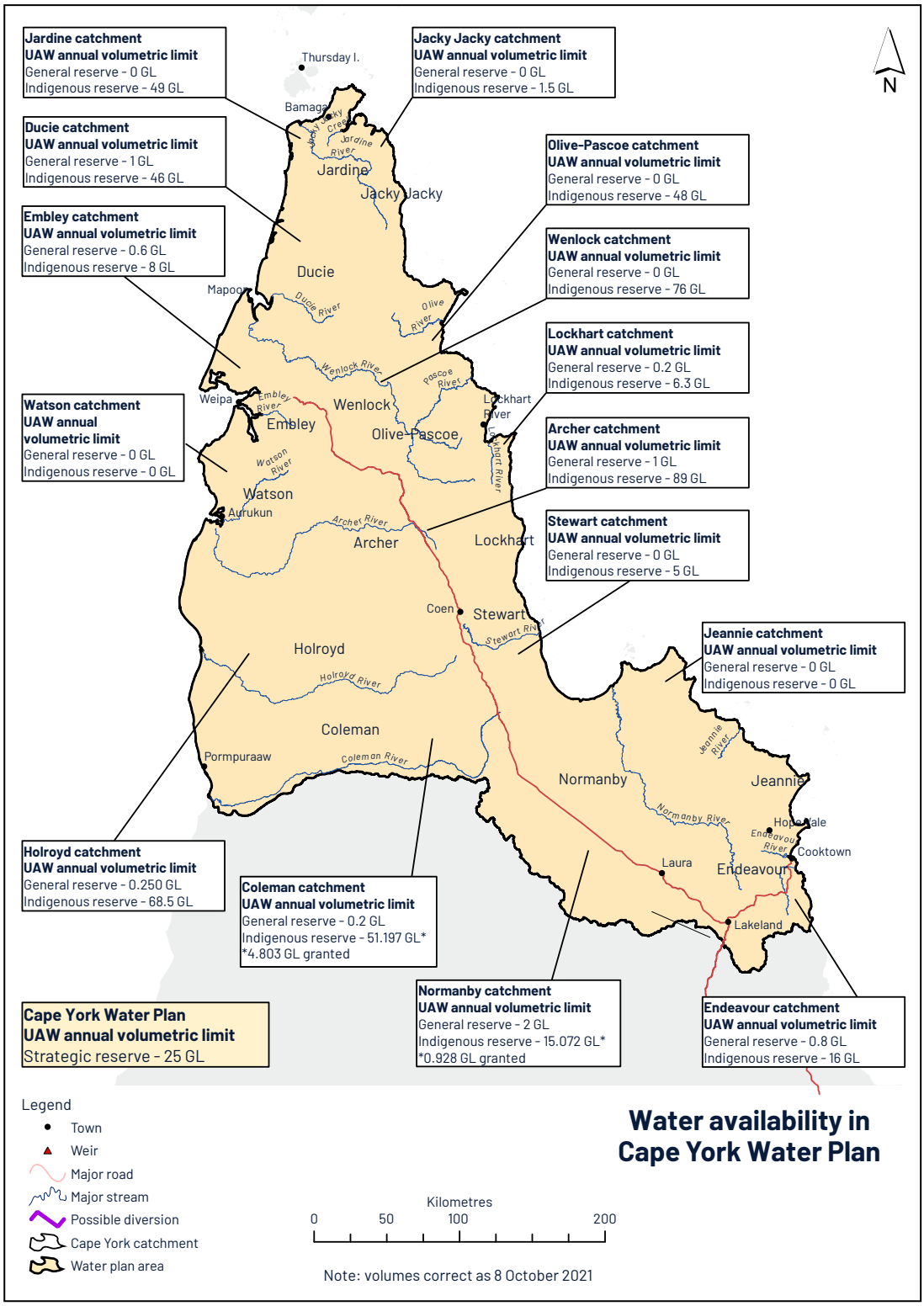
The six Making Water Work regions are shown in Map 7-1. In all six regions, there is value in planning water development in an integrated and well-sequenced way at the basin or catchment scale, rather than assessing individual projects or concepts in isolation from each other. As with the proposed Regional Water Grids, projects that may seem dubious in isolation may contribute positively to value (including economic, social, cultural and environmental benefits) within a wider program of regional development.

A number of new approaches to local development should feature in Making Water Work regions:

- developing new and smarter forms of water storage
- better approaches to overland flow capture and storage at the property and cross-property scale
- innovatively capturing and storing high flows during the wet season
- using groundwater resources, underground dams and managed aquifer recharge where natural water resources permit
- developing and institutionalising effective water trading systems
- exploring system-wide approaches to improving water use efficiency
- using new sources of land and water value in the zero-emissions economy, including carbon credits, fodder for local livestock and export, and biomass for industry
- integrating renewable energy, renewable hydrogen and biomass with new products (including fertilisers and explosives for mining) into supply chains for regional business, and linking these to pastoral, agricultural and aquaculture opportunities
- building a stronger economic link between agriculture, agri-processing, energy, mining and minerals processing through the common use of infrastructure and ecosystem services in local industrial precincts
- mobilising the younger generation's interest in using water to participate in economic development
- focusing on lifting land, water and energy use efficiency through research and extension
- lowering energy costs through the use of local renewable energy through micro-grids
- lowering transport costs across vast distances through the use of local renewable energy and hydrogen in applications, including electric vehicles of all kinds, which offer greater durability and lower maintenance costs.

If these place-based, regional approaches are to deliver valuable regional development, several preconditions to success must be achieved:

- recognising, protecting and mobilising Traditional Owners' rights and interests in water
- enhancing important environmental, social and cultural assets, with Aboriginal and Torres Strait Islander cultural heritage, the Gulf fisheries, the Great Barrier Reef, Cape York Peninsula, the GAB and the Channel Country attracting high international interest
- maintaining stable, evidence-based reconciliation of demands for available water without over-allocation to the catchments, supported by rigorous water use monitoring
- integrating water, energy, transport, urban and other infrastructure decisions
- achieving stable and long-term cooperation across all three spheres of government in water development planning to define objectives, explore options and implement sequential development
- applying land-use planning opportunities that integrate smart infrastructure opportunities and permit the value-stacking of those combined prospects
- considering the changing climate
- using opportunities to lower electricity costs
- having institutional leadership to drive regional water development planning and delivery.



Map 7-2: The Cape York Water Plan Area.



The Cape York Water Plan Area

The Cape York Water Plan Area has a population of about 17,000 people. It covers nearly 107,000 square kilometres. It encompasses 15 hydrological catchments across Cape York Peninsula, draining into the Great Barrier Reef on the eastern coast, the Gulf of Carpentaria on the western coast and the Torres Strait in the northwest.

The region includes 11 local government areas and several sub-regional centres including Cooktown, Aurukun, Pormpuraaw and Weipa. It has vast, relatively undisturbed landscapes and high biodiversity, with Traditional Owners maintaining strong ties and connections to land and water. Many of the catchments have near-natural flow regimes and river systems in pristine condition. These flows provide a range of ecosystem services while maintaining aquatic biodiversity. Mean rainfall varies from 800 millimetres around Lakeland to more than 3,000 millimetres near Lockhart River.

The wet season revives the environment annually, supports its grazing industry, and triggers prawn and barramundi breeding in the Gulf of Carpentaria fisheries. During the dry season, many thousands of tourists visit the area. Water and landscapes hold important cultural and spiritual values for Aboriginal peoples and Torres Strait Islander peoples.

Map 7-2 outlines the water available for new development and current infrastructure proposals in the Cape York Water Plan Area. Some 503 gigalitres of water have been reserved for future agricultural, industrial and urban uses. Some 92 gigalitres of water have already been allocated for existing agricultural, industrial (mainly mining) and urban uses, and there are opportunities for its more effective use.

Current economic activity in this plan area includes:

- water supporting urban and community centres, mining, grazing, agriculture and tourism
- fisheries, including the total Northern Prawn Fishery (extending from Cape York to Cape London Derry in Western Australia); catch was worth an estimated $118 million in 2016–17[1]. The wider Gulf of Carpentaria inshore barramundi catch was worth $8 million in 2017–18[2]
- agriculture, with the GVP in the region in 2019–20 worth $43 million. In 2015-16, GVP of was primarily livestock (90 per cent, mainly beef) with some crops (nine per cent)
- agricultural holdings, with the total area of agricultural holdings in the Cape York NRM region in 2015–16 at 2,296,000 hectares, in 49 businesses, with almost no irrigation.

Unemployment in the region is very high. In the 2016 Census, 14.4 per cent of the combined Aurukun, Cook, Hope Vale, Kowanyama, Lockhart River, Mapoon, Napranum, Northern Peninsula Area, Pormpuraaw and Weipa local government areas was unemployed, and 39.4 per cent in the Hope Vale local government area.

More specific developments or actions that might be considered in a place-based approach to the development of the Cape York region include the following:

- innovative capture and storage of high flows for bioenergy development in the southern Cape
- meeting the food security needs and economic development opportunities for Traditional Owners and 14 Aboriginal and Torres Strait Islander communities
- development of the Lakeland agricultural area through cross-basin transfer from the Palmer River
- meeting the local water needs of mining developments (e.g. Glencore, Metallica, Diatreme)
- planning alternative future use of water now allocated to mining (e.g. Weipa, Cape Flattery)
- best practice for overland flow capture and storage at property scale for the pastoral sector.



The Mitchell Water Plan Area

The Mitchell Water Plan Area has some 6,000 people and encompasses approximately 70,000 square kilometres of Far North Queensland. It covers the western slopes of the Great Diving Range, taking in the fringes of the Wet Tropics World Heritage Area to the Gulf of Carpentaria. Most of its rainfall comes over summer, with tropical cyclones. The mean annual rainfall for the Kowanyama is 1,268 millimetres (2010–2017).

The area contains the Mitchell, Lynd, Walsh (part), Alice and Palmer rivers and their tributaries. The uppermost reaches of the Mitchell and Walsh rivers are part of the Mitchell River catchment but are part of the Mareeba–Dimbulah Water Supply Scheme (i.e. not the Mitchell Water Plan Area). The Mitchell Water Plan Area is one of the largest rivers in the state, accounting for about eight per cent of total runoff in Queensland. The landscape and lives of the people are connected and shaped by the annual wet season, which revives the environment and pasture for grazing and triggers prawn and barramundi breeding for the Gulf of Carpentaria fisheries. Tourism is important in the dry. Water and landscapes hold important cultural and spiritual values for Aboriginal peoples in the region.

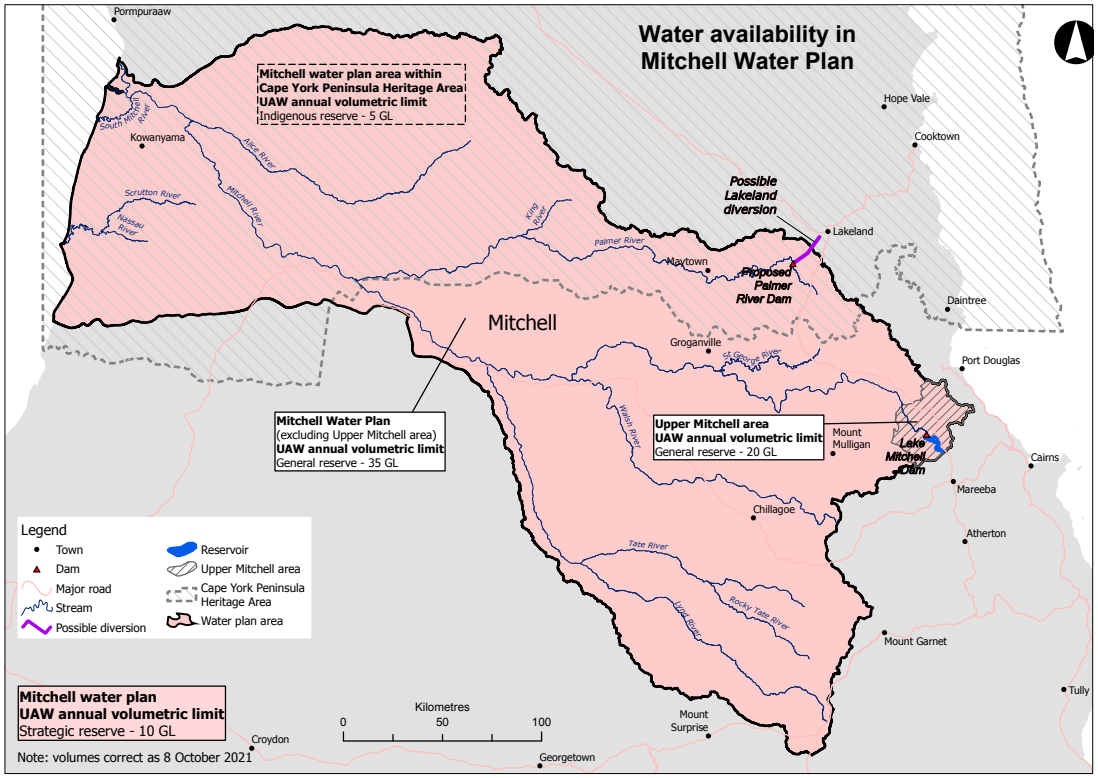
Map 7-3 outlines water available for new development and current infrastructure proposals. Some 21 gigalitres of water have already been allocated for agricultural, industrial and urban uses, with additional opportunities to use the water more effectively.

Current agri-industrial productivity and population in this plan area includes:

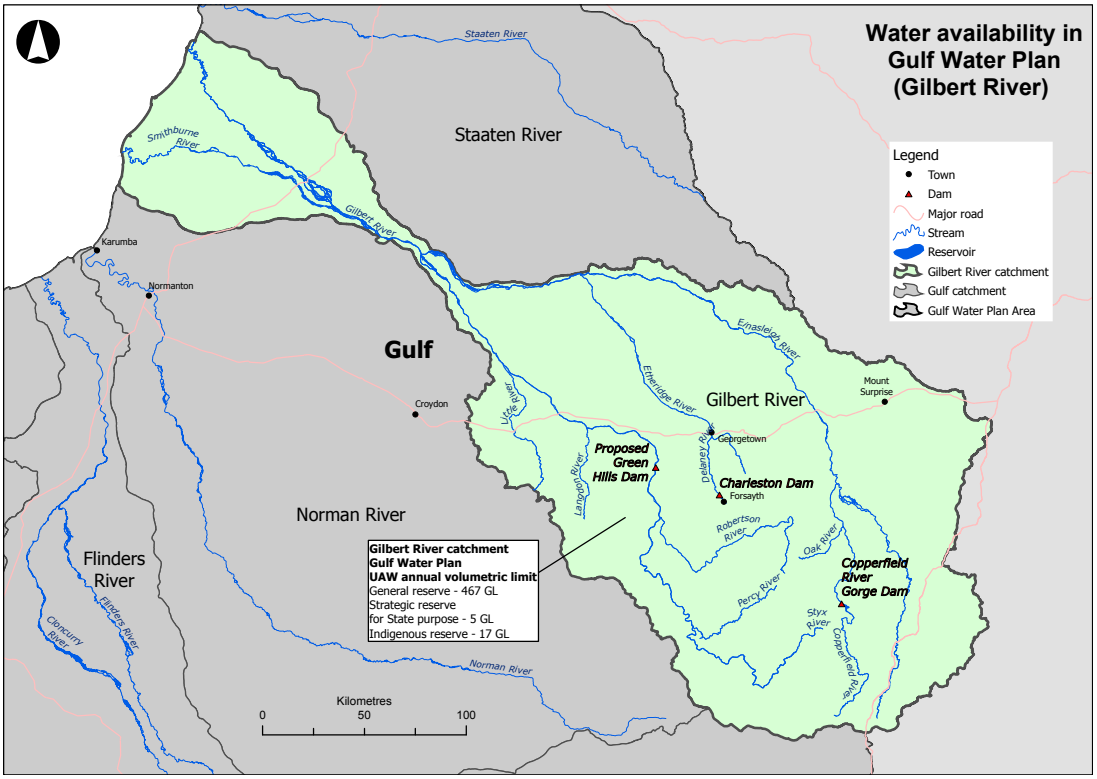
- a small population (uses water for town supply, grazing, aquaculture, small-scale mining and irrigation). The rivers are important for tourism, and commercial and recreational fishing
- the GVP in the wider Northern Gulf NRM region in 2015–16 was $599 million, primarily beef livestock (81 per cent) and some crops (19 per cent) in 337 businesses on 12.4 million hectares, with little irrigation
- the Mitchell catchment has been estimated by CSIRO to have the potential to support 140,000 hectares of irrigated agricultural development, with four large in-stream dams releasing 2,800 gigalitres for agriculture in 85 per cent of years. Offstream water has been estimated as having potential for harvesting of some 2,000 gigalitres with 85 per cent reliability, which would be sufficient to irrigate up to 200,000 hectares of a single dry-season crop such as cotton. Irrigation of this type could be widely distributed across the catchment or concentrated into a smaller number of irrigation areas[3]. Much coastal land is also suitable for lined aquaculture ponds. These opportunities would need to be tested in the context of any review of the Mitchell Water Plan.

More specific developments or actions that might be considered within a new regional development planning framework include the following:

- the proposed Palmer River dam seeking up to 120 gigalitres of yield to irrigate 8,000 hectares of high value agriculture
- the potential use of water from the largest existing water storage within the region (Lake Mitchell)
- the St Ronan's water storage proposal (of between 10 and 20 gigalitres)
- the potential for in-stream storages identified by CSIRO's NAWRA studies, where water is available in locations suitable for agricultural development[4]
- exploring innovative capture and storage of overland flow, high flows and groundwater options at property/cross-property scale, particularly in the pastoral sector.



Map 7-3: The Mitchell Water Plan Area.



Map 7-4: The Gilbert Catchment Area.



The Gilbert Catchment Area

The Gilbert catchment has a population of around 2,000 people and forms part of the Gulf Water Plan Area. The catchment drains into the Gulf of Carpentaria and covers approximately 46,000 square kilometres in northwest Queensland. Rainfall in the region is predominantly monsoonal and is highly variable. There are significant agricultural resource opportunities associated with available water.

The major uses of water are mines, pockets of localised irrigated agriculture, tourism, commercial and recreational fishing. The mining industry has been the main driver of new economic activity. The GVP in the wider Northern Gulf NRM Region in 2019–20 was $716 million. In 2015–16, that was made up of livestock 81 per cent (with cattle 78 per cent), with the remainder being crop production (19 per cent). There are some 337 agricultural businesses covering 12.4 million hectares, with little irrigation (0.1 per cent). There are a small number of agricultural developments in parts of the Gilbert, and some proposals for large new cropping-based developments.

The potential water available for new development and current infrastructure proposals in the Gilbert Water Plan Area are outlined in Map 7-4. Within this area, some 29 gigalitres of water have already been allocated for agricultural, industrial and urban uses. There are opportunities for the more effective use of water, and greater integration with energy development.

More specific developments or actions that might be considered in a place-based approach to the development of the Gilbert catchment include the following:

- the Green Hills dam proposal seeking up to 300 gigalitres of yield
- several private sector water storage proposals such as Strathmore and Fodder King
- exploring innovative use of groundwater resources, underground dams, bed sand storage and managed aquifer recharge particular to the Gilbert catchment.



The Flinders Catchment Area

The Flinders catchment has a population of some 4,500 people and forms part of the Gulf Water Plan Area. It drains into the Gulf of Carpentaria and covers approximately 109,000 square kilometres in northwest Queensland. Rainfall is predominantly monsoonal and highly variable. Offstream storages provide the most promising method for supporting large-scale irrigation in the Flinders catchment.

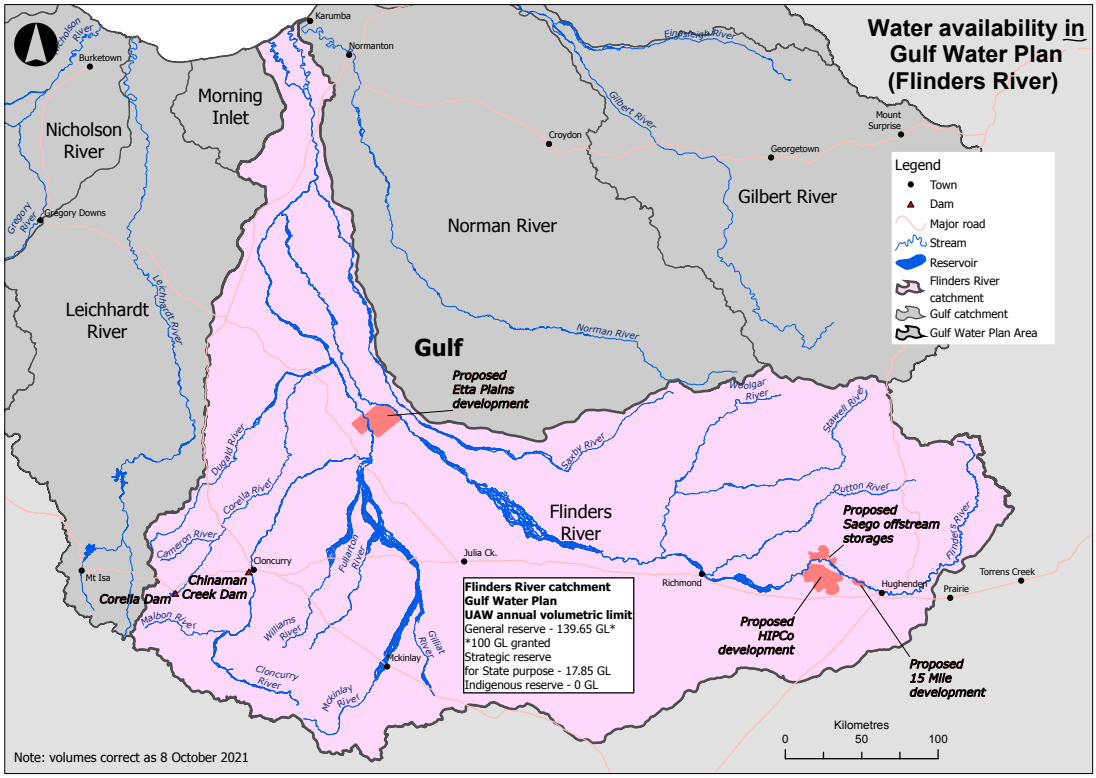
The Flinders catchment population is engaged mainly in the cattle industry, but tourism, mining and commercial fishing make important contributions to the economy. There is little cropping (less than 0.02 per cent of the landscape[5]). This area with abundant renewable energy resources is not connected to the National Electricity market but would be through the proposed CopperString high voltage transmission line connecting the North West Minerals Province and Mount Isa to the National Electricity Market grid south of Townsville (requiring investment of approximately $1.7 billion).

The GVP in the wider Southern Gulf NRM Region in 2019–20 was $745 million. In 2015–16, that was nearly all beef, over 16.2 million hectares and across 328 businesses, with only 500 hectares under irrigation a few years ago[6]. Combined offstream storage is capable of delivering approximately 175 gigalitres of irrigation water to crops in 70–80 per cent of years[7]. Based on the identified water storage and the large areas of agricultural soils suitable for irrigation (more than eight million hectares, two million of which are most promising), there is the potential for an irrigation development totalling 10,000–20,000 hectares, supporting year-round mixed irrigated and dryland cropping[8].

The potential water available for new development and current infrastructure proposals in the Flinders Water Plan Area are outlined in Map 7-5. Within this area, some 227 gigalitres of water have already been allocated for agricultural, industrial and urban uses. Opportunities remain for the more effective use of that water and greater integration with energy development.

More specific developments or actions that might be considered in regional water development planning for the Flinders catchment include:

- the 15 Mile water development seeking 4.5 gigalitres of yield to irrigate 305 hectares
- the HIPCO water development seeking 190 gigalitres of storage to irrigate 7,500 hectares
- several private sector storage proposals (e.g. Etta Plains)
- alignment of bio-energy and bio-industrial development with opportunities opened by CopperString.



Map 7-5: The Flinders Catchment Area.



The Whitsunday–Pioneer Water Plan Area

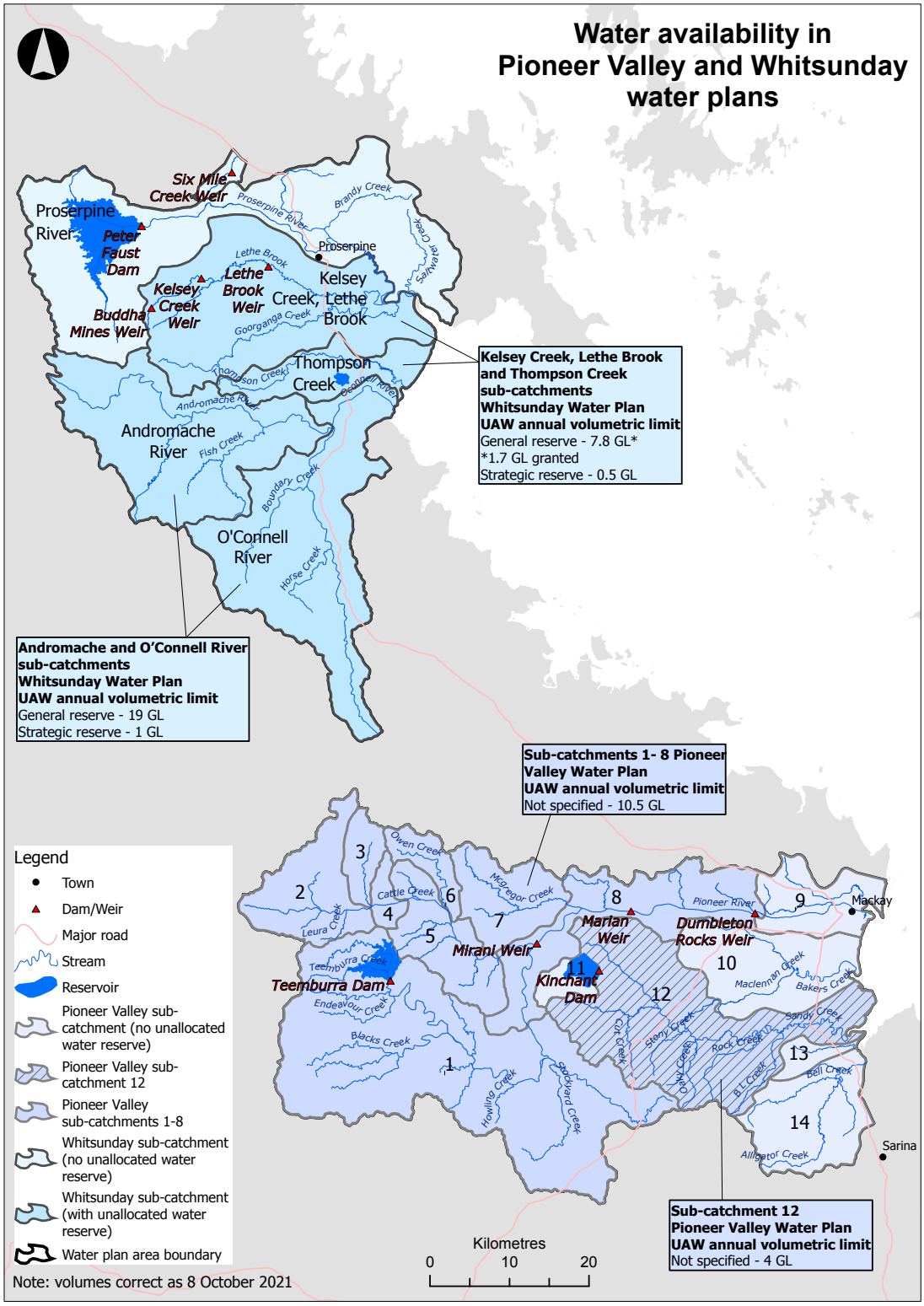
The Whitsunday Water Plan Area has a population of 70,000 people and lies on the east coast and covers around 2,050 square kilometres. It includes the sub-catchments of the Proserpine, Andromache and O'Connell rivers, Kelsey Creek and Lethe Brook, Thompson Creek and part of Six-Mile Creek. Rainfall is highly seasonal and varies under the influences of tropical cyclones and the inter-tropical convergence zone. Peter Faust Dam is the only major water storage and is managed under the Pioneer River Water Supply Scheme.

The GVP in the Mackay Whitsunday NRM Region in 2015–16 was $326 million across some 1,077 business on 553,000 hectares of land. At the time, GVP was primarily crop production (80 per cent, with sugar being 72 per cent of that) and livestock. In the introduction to Section 2, the panel drew attention to questions about the reliability of agricultural GVP data, and indeed, a recent study by ACIL Allen pointed to much higher values of horticultural output. There are also aquaculture aspirations as identified through an aquaculture development area. The land-based marine aquaculture development areas (ADAs) have been identified to promote and grow a sustainable aquaculture industry in Queensland (noting where possible sea water will be used).

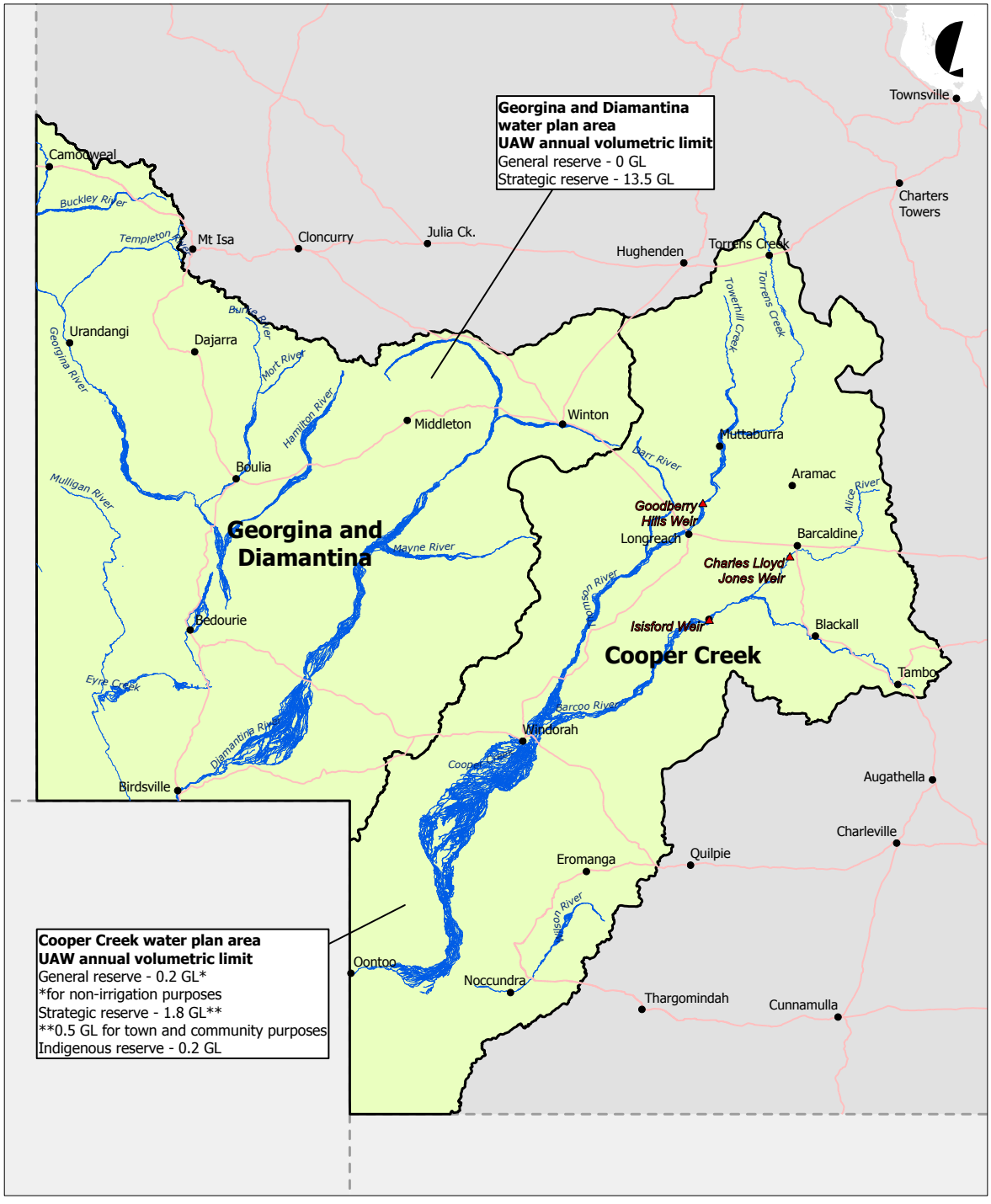
Water is available for a big increase in the value of agriculture. The potential water available for new development and current infrastructure proposals in the Whitsunday–Pioneer Water Plan Area are outlined in Map 7-6. Within this area, some 364 gigalitres of water has been allocated to agricultural, industrial and urban uses. There are significant opportunities for the more effective use of water, including for biomass into local industrial production, and greater integration with energy development.

More specific developments or actions that might be considered in a place-based approach to the development of the Whitsunday–Pioneer Water Plan Area include:

- exploring innovative in-stream storages, hydro and pumped hydro opportunities where local geography, water availability, land quality and energy opportunity are suitable
- exploration of system-wide approaches to improving water use efficiency
- exploring the expansion of higher value horticultural opportunities
- the integration of renewable energy and biomass processing opportunities including the opportunity for a large-scale microgrid.



Map 7-6: The Whitsunday–Pioneer Water Plan Area.



Water availability in Cooper Creek and Georgina and Diamantina water plans

Map 7-7: The water plans of the Lake Eyre Basin.



The water plans of the Lake Eyre Basin

The Queensland catchment had a population of around 15,000 people in 2011, declining by several thousand between then and the 2016 census. It covers the Queensland part of the Channel Country in the Lake Eyre Basin and is represented in three water plan areas. the Georgina and Diamantina; Cooper Creek; and the Great Artesian Basin and Other Regional Aquifers water plans.

The Georgina and Diamantina Water Plan Area covers approximately 266,000 square kilometres in the Georgina, Diamantina and Hay catchments. All streams are ephemeral, most with short flows following rain events, and long periods without flow. Average annual rainfall ranges between 200 millimetres and almost 600 millimetres with the upper catchment receiving most. Rainfall is highly seasonal with 70 per cent on average falling from December to April, driven by monsoonal weather patterns.

The Cooper Creek Water Plan Area encompasses 243,000 square kilometres in southwestern Queensland. The Lake Eyre Basin extends to areas in Queensland, South Australia, New South Wales and the Northern Territory and is recognised nationally and internationally for its outstanding social, cultural and environmental values. Both water plans promote consistency with the *Lake Eyre Basin Intergovernmental Agreement 2001*, to which Queensland is a signatory. The pastoral industry has dominated historically, and renewable energy resources and tourism attractions allow some economic development with limited available water resources.

In the Georgina and Diamantina Water Plan Area there are few water licences, resulting in the rivers retaining a near natural flow regime. The Georgina and Diamantina 2004 Water Plan manages stream extractions, overland flow water harvesting and underground water hydraulically linked to surface water, while setting unallocated water aside for future development. The natural hydrology of the Cooper Creek Water Plan Area is characterised by natural, unrestricted flows in stream channels and across the floodplain, with no significant storages in the plan area. Water is mainly used for town water supply and grazing, with little irrigated agriculture. The system is ephemeral with highly sporadic rainfall and extended dry periods. There is a network of channels, waterholes, wetlands, extensive floodplains and widely distributed shallow, ephemeral lakes. Bores drawing on the GAB are crucial for town and stock water.

The population of the Queensland Lake Eyre Basin region is sparse, with more than 12.5 hectares per person. Some 25 towns vary in size from 15–3,000 people. The rest of the population is scattered across extensive pastoral country; most in the northeast. The natural features of the region are diverse, ranging from large internally draining lakes, dissected residual mountain ranges and sweeping grasslands to environments on the edge of the Simpson Desert[9]. Pastoral activities are the economic backbone of the region—once predominantly sheep and now mainly cattle but with sheep making something of a comeback. The Desert Channels region has around 14 per cent of the Queensland cattle herd. The region's pastures range across the vast Mitchell grass downs, the spinifex and the channel country with its vast floods[10]. Declining population has made it more difficult to manage challenges to the sustainability of the pastoral industry, including wild dogs and intrusions of the invasive plant species prickly acacia.

The potential water available for new development and current infrastructure proposals in the water plans of the Lake Eyre Basin are outlined in Map 7-7. Within this area, some 44 gigalitres of water have already been allocated to agricultural, industrial and urban uses, though significant opportunities remain for the more effective use of that water, and greater integration with energy development.

More specific developments or actions that could be considered in a place-based approach to development of the water plans of the Lake Eyre Basin include:

- completing the successful management reforms of recent years in use of GAB and other groundwater resources and managed aquifer recharge. Providing additional funding for the successful Great Artesian Basin Sustainability Initiative scheme would allow completion of capping free-flowing bores and bore drains, and sustaining the resource, while making additional water available for economic activity
- exploring use of available water from the Belyando tributary of the Burdekin in the region's northeast for local cropping at times of high flows, and for storage and transportation in modest volumes from the vicinity of Alpha towards Barcaldine and Longreach. If feasible, this could substitute for GAB water used for some existing town and stock use
- continuing exploration of system-wide approaches to improving water use efficiency, including more extensive and efficient trading of water allocations from the GAB and the Belyando catchment where connectivity of water stocks allows
- exploring use of land in the region for biomass and carbon credit production, including exploration of the Remote Area Planning and Development Board proposal submitted to the panel for development of a biodiverse tree corridor from the vicinity of Alpha through to Barcaldine, Longreach and Winton. This requires and warrants research on species, water use and conditions for optimal growth
- building on the model being developed in the Barcaldine Renewable Energy Zone industrial precinct, to develop locations for use of renewable energy resources.

The 1942 and the recent Great Dividing Range versions of Bradfield were both concentrated overwhelmingly on irrigation agriculture in the Queensland Lake Eyre Basin. As we have seen, this was a grand vision directed towards a worthy regional development objective. It is not feasible in the form proposed. Regional development within the institutions proposed in Chapter 8 could lead to expansion of economic activity, employment and population in the Queensland Lake Eyre Basin that would turn population decline into moderate expansion, at a small fraction of the Bradfield cost, with less risk.

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1 Laird, 2020

2 Fisheries Research and Development Corporation and the Institute for Marine and Antarctic Studies, 2019

3 Department of Infrastructure, Regional Development and Cities, 2018

4 Department of Infrastructure, Regional Development and Cities, 2018

5 Department of Infrastructure and Regional Development, 2013

6 Department of Infrastructure and Regional Development, 2013

7 Department of Infrastructure and Regional Development, 2013

8 Department of Infrastructure and Regional Development, 2013

9 Desert Channels Queensland, 2016

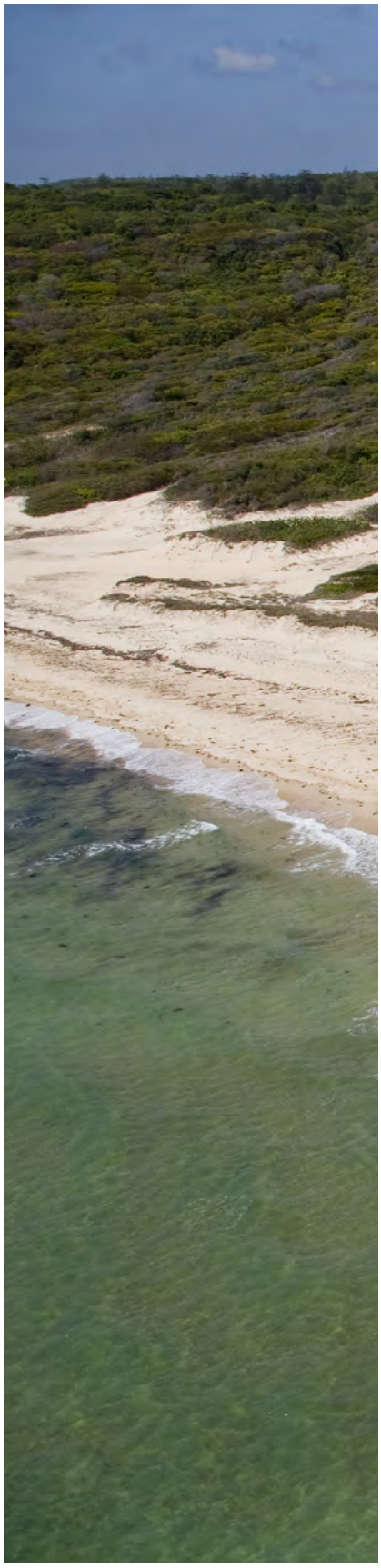
10 Desert Channels Queensland, 2021

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Chapter 8

The preconditions for success

The preconditions for success



Realising central and northern Queensland's immense potential for regional development can be achieved with sound policy, well-designed state and local institutions, and effective leadership in implementing development strategy.

The panel's Regional Water Grids and Making Water Work scenarios define sub-regions in which place-based consultative and participatory processes can operate to make water development effective at a local level. These would be nested within integrated regional development frameworks defined by governments and covering the wider central and northern Queensland region. The following diagram (Figure 8-1) describes the critical inter-relationships.

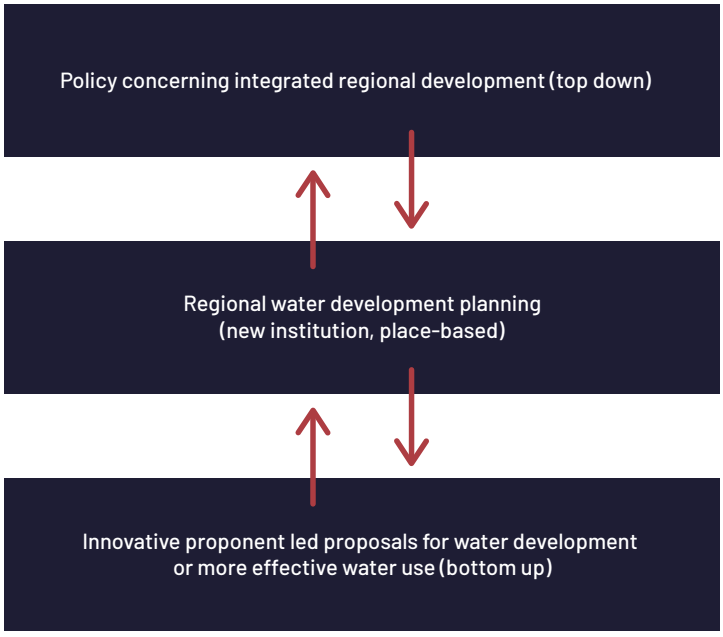


Figure 8-1: Three layers of policy, planning and project development required to successfully implement the Regional Water Grids and Making Water Work scenarios.

Making this work needs changes in some policies and planning institutions.

Effective Queensland–Commonwealth cooperation in broad policy development and state-wide setting of priorities is essential (the top box). A regional water development planning institution or institutions is required to integrate basin-wide inputs into local planning processes with government-level planning and policy (the middle box). The third requirement is mechanisms to enable competent local proposal development (the bottom box) that lever both private and public sector investment. The whole system only works effectively if there are open lines of communication between the three layers of government as well as private business and community partnerships pursuing development and investment.

Getting these arrangements right is a precondition for regional development success at this time of great opportunity.

Big things that are right

On water planning and infrastructure, Appendix 2 describes the central importance of the National Competition Policy, through which Commonwealth and state government leaders agreed to a program of economic reforms in the 1990s and early 2000s. The Council of Australian Governments (COAG) agreed to the NWI in 2004 as the blueprint for water reform. The reforms covered water pricing, rural water schemes, water trading, resource management, institutional arrangements and public consultation. The intergovernmental agreement behind the NWI sought compatible arrangements across the nation to manage surface and groundwater resources for rural and urban use. As the agreement says, "governments have a responsibility to ensure water is allocated and used to achieve socially and economically beneficial outcomes in a manner that is environmentally sustainable"[1].

Appendix 6 looks more deeply at Commonwealth, state and inter-governmental approaches to infrastructure planning and investment. It discusses the *Infrastructure Australia Priority List*, Queensland's *State Infrastructure Plan*, the QBWOS and other relevant policy and institutional settings. This chapter focuses on integrating planning and managing water development with other infrastructure investment, especially for energy. Optimal outcomes require clearly defined lines of responsibility across and within governments. Planning and implementing regional water development must be integrated within a wider regional development system.

The basic framework of the NWI is sound. Cooperation across the nation is necessary because some river basins and catchments cross state boundaries. It is also necessary because the Commonwealth has entered deeply into tied funding of water-related expenditures. While water management is a state responsibility under the Australian Constitution, the Commonwealth's stronger taxing powers and fiscal capacity and its recognition of a wider national interest in central and northern Queensland development have pulled the Commonwealth into the field. Sharing knowledge and experience and working towards common approaches raises the quality of outcomes. Conversely, inadequate consultation and poor cooperation has high costs.

The Queensland Government allocates water rights within the system described in Appendix 2. The system is consistent with the NWI principles and is soundly based. It ensures the water is available to protect the cultural values of Aboriginal and Torres Strait Islander peoples, environmental flows and established economic activities including irrigated agriculture, towns and industry. It requires the administering agency to account for climate change.

Queensland's regulation requires periodic review of the water plans. Informed and engaged adjustments are important to learn by doing and observing the effects. This is essentially adaptive management. Over time, as knowledge that was once undervalued by many Australians is shared, greater understanding of the value of water to Aboriginal and Torres Strait Islander peoples is understood. Over time, there is greater understanding of the effects of changes in water flows on riverine and marine ecosystems, including those of the World Heritage-listed Wet Tropics and Great Barrier Reef. Over time, water is used more efficiently in old economic activities, opening the possibility of improving productivity and releasing water to be allocated or traded for new economic development.

We learn more about how movement towards zero carbon emissions increases the value of plants. Appendix 3 presents publicly for the first time the work that is being undertaken within the Queensland Government on projecting the impact of climate change on water available for new economic activities. Different models applying sound atmospheric physics point to very different effects of warming on rainfall in particular locations. If the international community succeeds in achieving the Paris goal of holding human-induced temperatures close to 1.5 degrees Celsius, Queenslanders have already experienced more than half of the increase that they and many generations will endure into the future. We can learn a great deal from observing how human-induced warming has affected rainfall so far. There is no case for making large, irreversible commitments of economic and social capital to patterns of water use that are based on experience from a past without climate change.

Water planning decisions should be reviewed and updated through the processes embedded in the system. If current disciplines were abandoned arbitrarily to favour particular interests, it would be a matter of time before the over-allocation problems experienced in the Murray–Darling would descend on the rivers, industries and ecosystems of central and northern Queensland.

The NWI favours cost-reflective pricing of water and trade in water allocation rights where possible. It is right to do so. But getting prices right is easier said than done. Arrangements for trading and pricing water need evidence-based adjustments if the power of cost-reflective pricing is to be harnessed to strengthen regional development.

Things that need thought

Government-level regional planning

The NWI framework has frayed in recent times. The NQWIA and newly formed NWGA have been established by the Commonwealth and could either add value or create costly confusion, depending on how they relate to Queensland's state and local planning mechanisms for water into the future. The NQWIA has been charged by the Commonwealth with funding

feasibility studies, and this has been raising community expectations about the future development of particular pieces of water infrastructure. Commonwealth ministers have made prominent announcements about new dams that do not yet have development approval. Variously, consultation and cooperation between individual Commonwealth and state ministers and officials have defused or diminished problems. These processes, however, have not avoided creating expectations within the community that dams and distribution infrastructure will be built that, if all progressed together, would require much more water than is available. Examples include:

- There are several proposals being explored in the Flinders River that would require more water than is currently available under the Gulf Water Plan.
- In the Burdekin, the Commonwealth has funded two separate and mutually exclusive sets of feasibility and impact assessment works related to the building of a dam at Hells Gates. One is focused on local irrigation in the Upper Burdekin, the other on a version of the Bradfield scheme. Both sets of feasibility studies have stirred community, business and political interest, excitement, activity, expectation and expenditure[2]. At the same time, the Urannah Dam and Big Rocks Weir proposals are being assessed, while the state has been exploring the potential raising of the Burdekin Falls Dam.

In the Burdekin, with what is known at present, there is insufficient water available for both the smallest of the proposed Hells Gates and the Burdekin Falls projects in their proposed forms, let alone the other Burdekin proposals. The Queensland Government has constitutional power and responsibility over water allocation. The Commonwealth, however, is in a much stronger position to commit public money to major projects. There is no wider regional planning effort, nor a more specific basin-wide water development planning mechanism, to resolve these fundamental differences and to engage regional communities, Traditional Owners and the private sector in those deliberations. This can only lead to poor decisions and less than optimal regional development and environmental outcomes.

At a higher strategic level, evaluating crucially important cross-basin opportunities such as the potential transfer of high-flows water from the Herbert to the Upper Burdekin has no planning home. Careful assessment of cross-regional opportunities may define a path that can expand opportunities to develop the Burdekin and the wider WATER Development Zone without imposing major costs on Wet Tropics communities. Nor is there a planning home for assessing whether water from the Belyando–Suttor tributaries of the Burdekin has more value for economic development when used close to where it falls and further west or allowed to flow through to users in the Lower Burdekin.

Discordant interventions outside a cooperative regional water development framework have crowded out the considered, thorough analysis necessary for good decisions. In the absence of an agreed, collaborative, strong, evidence-based mechanism to define the best approach to water development in regional water basins, wasteful processes, and poor decisions and outcomes will continue. These outcomes include:

1. Communities with regional development aspirations spend years of effort and their limited strategic resources developing proposals that have little or no chance of success.
2. Collaboration between the Commonwealth, state and local governments, finance and the wider private sector that is necessary for success is derailed or greatly complicated.
3. Potentially cost-effective options for water development are not rigorously developed, compared, tested and optimised.
4. The wider public discourse about sensible, well-sequenced and sustainable water development is fractured.

The panel has not done the work to recommend moving forward with any particular development within our scenario catchments. However, it has done enough work to know that several options for the use of water in northern and central Queensland besides those that are presently the subjects of studies are worth close examination. A rigorous study of options would define an integrated set of irrigation and water-based energy projects that could play an immense and economically efficient role across central and northern Queensland.

The problems of weak Commonwealth–state coordination are overlaid by the weak integration of energy and water planning. The Burdekin demonstrates this problem and the opportunities that would be opened by the effective coordination of land use, water and energy planning. For the rich solar and wind energy resources from the near inland to underpin zero-emissions industrial growth on a massive scale in Gladstone, Townsville and the cities and towns between them, intermittent power generation must be balanced by stored energy or flexible peaking generation. The Great Dividing Range contains apparently excellent sites for balancing variable renewable energy with hydro-electric generation or PHS. The panel is aware of potential hydro-electric sites within reasonable distance of Townsville, and PHS sites near all of Gladstone, Rockhampton, Mackay and Townsville. These developments would all involve dams and water, and like the water planning discussion above, need to be assessed and taken forward within a clear framework to avoid significant negative environmental, economic, social and cultural impacts. A new dam is more likely to contribute positively to development where it serves both energy and agricultural purposes. Presently, there is no institutional arrangement through which the combined water

and energy value of new infrastructure can be assessed or to encourage Commonwealth–state cooperation in this work.

The Commonwealth is now exploring how the NQWIA can be refined to play more in the central and northern Queensland water development space, as well as how the new NWGA relates to everything else. The fluidity of institutional arrangements and the crowding of this space creates an opportunity for the Commonwealth and the state to define new institutional arrangements designed to secure cooperation in water infrastructure planning, in partnership with regional communities and private sector investors.

The effective coordination between the Queensland and Commonwealth governments on implementation that is a precondition for success on water should extend to integrating planning for water with transport, energy, telecommunications and social infrastructure.

In exploring models for institutional arrangements, the panel has examined the Australian experience of regional water development through the Snowy Mountains Authority. This example embodied Commonwealth–state cooperation in planning and implementation and focused public research on markets and land use choices for irrigated agriculture. It covered energy and water. We see relevance in the Queensland experience with co-ordinated investment in ports, railways, highways, water and energy for coal, alumina, aluminium and mining development in the 1970s and 1980s. The experience with planning for massive urban expansion in southeast Queensland through the late twentieth and early twenty-first centuries is important. We have also examined the experience with Tasmanian Irrigation Pty Ltd (Appendix 6), which has led to significant and sustainable if modest water infrastructure development projects with strong Commonwealth–state cooperation. These are examples of coordination of policy and planning leading to successful regional development.

Successful arrangements bring together analysis of the interactions of different areas of policy in development of a region and the authority to implement development strategy in a coordinated way. Regional development requires authoritative analysis of options to expand economic activities that use water infrastructure and not just of the infrastructure investments themselves. For central and northern Queensland in the period ahead, understanding the new opportunities in the zero-emissions economy is especially important. That understanding has to be brought into the centre of water planning within a wider regional development planning framework. The new activities include uses of water in new crops, in which accumulation of carbon and production of biomass for industry are important sources of value. This requires research on new crops and management practices, just as the establishment of the old Australian agricultural and pastoral activities required research within state agriculture departments, the universities and CSIRO. The research has barely begun. The new activities include new uses of zero-emissions energy, including to produce hydrogen as an input into industrial processes. Here there has been considerable progress in Queensland over the past two years. This needs to be related to wider water, energy and transport planning decisions.

Place-based regional water development planning

In several parts of this report the panel refers to the need to take a place-based approach to regional water development planning, both for the Regional Water Grids and the Making Water Work regions.

A place-based approach is a person-centred, bottom-up approach used to meet the unique needs of people in one location by having them work together to use the best available resources and collaborate to gain local knowledge and insight[3]. A place-based approach considers knowledge, preferences and perspectives of local citizens, community organisations, governments and businesses. The relevant 'local' can be the whole of a region or locally around a project. It can be at a river catchment or a smaller water development district. Its boundaries should be defined by common interests and histories of inter-relationships. Where water is centrally important, and one business's decision affects the opportunities of many others in the same catchment, the catchment is a natural place-based community. Each of our Regional Water Grids and Making Water Work regions could be seen as a natural place-based community for regional water development planning effort.

Place-based development institutions provide mechanisms for local government and people within the relevant community to interact with each other, the state and the Commonwealth to shape priorities and make collective decisions about allocating resources to local public goods. There is much knowledge and wisdom in regional communities about opportunities for and risks from development that will not be available to state authorities and outside investors. Mechanisms to draw on this will enrich the planning process and lead to better regional development outcomes. Local business organisations, whether owned privately or by the community, will see and be motivated to seek ways of reducing costs or expanding opportunities for regional and local development. They will be sensitive to unnecessary cost burdens and wasted opportunities in ways that large institutions from outside the region are not.

Place-based insights are crucial to assessing options and deciding how to stage investment in water development. They ensure plans are highly adaptive to opportunities and to emerging sustainability challenges. They recognise inter-relationships between water supply, energy generation and distribution, supply and value chain development, catchment

management, flood defence, land use planning, discharge controls, and traditional and new opportunities in agricultural development. Within projects, the 'stacking' of contributions to value from different sources, including but not only irrigation and energy, is increasingly important in investment decisions on water infrastructure.

Queensland has developed a solid system of planning for water allocation since the closure of the state's Water Resources Commission in the 1990s. However, it lacks integration of water development at basin or catchment scale, and this has allowed the proliferation of Commonwealth, state and private sector-driven feasibility and impact assessment studies and proposals that make conflicting demands on water availability. This is raising unrealistic expectations in the community. Resources are being wasted. It is inevitable that conflict over water and funding allocations weakens the cooperation that is necessary for successful development.

This lack of integrated regional water development planning also means smaller, less expensive and more effective options for facilitating water-based development are not evaluated, designed or implemented. Examples include water use efficiency measures, flexible innovative water trading opportunities, water scheme modernisation and refurbishment, and developing new crops that yield higher economic value from smaller amounts of water or present new ecosystem service opportunities.

Place-based approaches to regional water development planning are also essential to ensuring a strategic approach to understanding and managing the cumulative impact of many fragmented and, at times, conflicting development proposals. The regulatory constraints to individual projects are often difficult to identify and resolve as they sit within a much wider regional context. Region-wide approaches are needed if we are to achieve new development outcomes while honouring World Heritage obligations for the Wet Tropics and the Great Barrier Reef, managing regional vegetation and biodiversity protection obligations, maintaining the health of the Gulf and Lake Eyre Basin aquatic ecosystems, and negotiating strong partnerships and tenure resolution with Traditional Owners.

Project development, approval and asset management

Whatever the institutional framework for regional water development planning and decision making, success requires the arrangements for regional water development discussed above to bring a much wider range of competent project proponents into the discussion of options and priorities. These should include both existing and new project proponents from the private sector, public–private partnerships and government.

At the regional or basin scale, many elements of existing government owned corporations (GOCs), local government, community and business have contributions to make. The range of participants who can make consistent contributions to project generation is set out in the following chart.

Table 8-1: Present contributors to regional water development projects.

Project stage	Key role standards required	Organisations currently in this space
Conception	• Collaborative and integrated engagement • Preliminary option assessment • Science procurement and assessment • Cohesive multi-party negotiation • Indigenous partnership building and engagement • Demand assessment and preliminary investor wrangling	Private corporations Regional economic development organisations (REDOs) Regional organisations of councils (ROCs) or individual councils GOCs including but not limited to Sunwater, Powerlink and Clean Co Consultants Industry/sector associations
Planning, feasibility and impact assessment	• Collaborative and integrated engagement (under Commonwealth and state infrastructure standards) • Indigenous partnership building and engagement • Multi-criteria analysis, science procurement and assessment • Cohesive multi-party negotiation • Demand assessment and investor wrangling	Private corporations REDOs ROCs or individual councils GOCs Consultants

Project stage	Key role standards required	Organisations currently in this space
Finance closure	• Collaborative and integrated engagement (under Commonwealth and state infrastructure standards) • Cohesive multi-party negotiation	Private corporations Federal and state governments ROCs or individual councils Queensland Treasury Corp GOCs Pension and super funds Finance and equity funds Northern Australia Infrastructure Facility, Clean Energy Finance Corporation, Regional Investment Corporation etc.
Construction	• Dam safety standards • Construction performance standards • Infrastructure procurement standards	Private corporations Councils GOCs
Operation	• Client-focused • Able to meet regulated rules of scheme operation • Able to deliver affordable and secure water to clients • Able to achieve full scheme use within suitable water security limits • Dam safety standards	Private corporations Local area management groups Councils GOCs
Decommissioning and remediation	• Dam safety standards • Deconstruction performance standards • Indigenous partnership building and engagement • Impact assessment standards	Private corporations GOCs Councils Queensland government agencies

If a new institution facilitates consideration of a wider range of water development options, a much larger range of potential project development and delivery leads may also become available. Proponents of projects, however, would need to meet specified standards to play in this arena. This is a policy issue that needs further consideration at the state scale before being deployed regionally. Within each of our proposed Regional Water Grids and Making Water Work catchments, the possible lead proponents might include the following.

Table 8-2: Potential contributors to increase options for regional water development projects.

Water development options	Standards required	Organisations currently in this space
Targeted research, development and extension	• Research capacity • Ethical standards • Indigenous and industry partnership building and engagement	Universities Collaborative Research Centres, Rural Development Corporations, National Environmental Sciences hubs Industry organisations Regional NRM boards and land-care organisations River Trusts
Water use efficiency projects	• Industry partnership-building and engagement • Extension services and industry best management practice standards (BMPs) where applicable • Technical and engineering standards	Industry organisations Landholders Local area management groups Regional NRM boards and land-care organisations Sunwater
Water trading	• Water Management Protocols and other regulated documentation • Trading and market standards • Clarity of water trades and conditions • Indigenous and industry partnership building and engagement	Queensland Government State Government for permanent trades; GOCs (Sunwater) Trading platforms and water traders including tech companies Local area management groups Water holders
Small scale energy and hydro	• Technical and engineering standards	Private or not-for-profit corporations including associations Clean Co and Ergon Network Landholders Landholder cooperatives Local area management groups
On-farm capture and storage	• Technical and engineering standards • Dam safety plans (referrable dams)	Landholders Landholder cooperatives Local area management groups
River improvement works	• Technical and engineering standards • Industry, landholder and community partnership building and engagement	River Trusts Drainage Boards Councils Regional NRM boards and land-care organisations

A strong regional water development planning institution and framework would mobilise many potential players (and investors) into regional water development plan implementation. It would send clear signals to project proponents about the preferred model of development, the likely development sequence, and standards that will be expected (and enforced) of influential players in the system. As suggested by Dale and Marshall[4], this place-based approach can mobilise a far more diverse set of investor and delivery capacity into the regions. Without it, there will be a far larger call on government finance and responsibility, and less innovation in identifying options and delivering projects.

Cost-reflective pricing and the role of markets

The price of water from utilities and the price of what can be made with water shape local development. Getting prices right and making sound judgements about future prices is critically important to successful regional development.

The NWI favours cost-reflective pricing and using markets to determine the price of water. That is good in principle. Working out how it should be applied in practice takes effort.

The cost of water for irrigation for example has two main elements. One is the capital cost of infrastructure (dams, and pipes or channels for moving water to farms). The other is operating and maintenance costs—especially the cost of energy for moving water amongst other considerations. The economic drivers of both sets of costs have fallen dramatically since early this century yet water users have only seen their costs increase. Irrigation water users should bear no more than the efficient and prudent costs of water delivery.

Capital costs have two components: the depreciation and amortisation of the initial capital expenditure over the life of the asset; and the interest cost. Depreciation was once the lesser of the two (for an asset with a 50-year life, two per cent per annum, maintained in real terms). That has not changed much. The interest cost, once the larger element, has fallen dramatically over this century, from an average of around five per cent in real terms to close to zero. This is a long-term shift and not a short-term shock, driven by changes in global decisions on savings and investment[5]. If the 'cost reflective' cost of capital to Australian governments was seven per cent when the NWI was developed near the turn of the century, it is two per cent now. This radically reduces the cost of long-lived infrastructure investments. The reduction has not been accounted for in planning for many public investment and some private investment decisions in Australia. The result is overestimation of the economic costs of infrastructure investments, including dams and water distribution systems. It is not cost-reflective for water authorities to set prices for water on the basis of returns on capital that may once have seemed appropriate but which have been overtaken by events. The panel notes the large influence of the assumed cost of capital on both water and electricity pricing in Queensland.

Capital costs are also affected by the costs of constructing capital assets. It is the panel's impression that Australian (including Queensland) costs of construction for many water and energy assets exceed the norms in other developed countries. Some business representatives attribute this to labour costs, though Australian labour costs after eight years of wage stagnation and exchange rate depreciation are not high by developed country standards. The panel suggests its impressions be tested against international benchmarks. If confirmed, the reasons for Australian costs exceeding norms in comparable countries should be identified and corrected. This is a matter that would receive greater attention with place-based participation in policy-making.

The main operating costs in most irrigation distribution systems derive from using energy to move water. Electricity prices in Queensland rose rapidly over the past decade. This is at first sight puzzling, since new technologies have made it possible dramatically to reduce electricity generation cost in rural and provincial Queensland. Regulatory arrangements tie irrigators into retail monopolies. Opaque public subsidies through the CSO for electricity supply have the effect of locking in old structures rather than supporting transition to new arrangements that will lower farmers' costs now and public subsidy over time. Genuine cost-reflective pricing based on efficient electricity supply would see a lower price of electricity for irrigators.

Competitive markets tend to generate prices related to real costs. That argues for wider and deeper competitive markets for trading rights to water. These are now reasonably well-developed in the Murray–Darling Basin but not in central and northern Queensland. Trade in water allocations in the Murray–Darling is shifting access to water into the uses that generate highest economic value at the time. As the amount of water available for irrigation falls on average over time, the amount supplied into high-value horticulture has increased. That generates a disproportionate decline in access to new water to lower value uses, including for broadacre crops and pastures and some fruits. There are critics of these outcomes. Certainly, there have been losers from the process, including farmers who may have misjudged future market outcomes and sold entitlements at times when market prices were low. There is a case for extensive education around how water markets operate when their role expands into new areas. There have been allegations that monopoly power in the Murray–Darling has been used to distort prices in favour of large owners of water. If this is a real issue, the usual anti-monopoly policy responses apply.

Market exchange of water entitlements is only possible within a single water catchment or across a set of interconnected catchments. Competitive markets are only possible where large amounts of water are available for trade. More irrigation systems in central and northern Queensland will be able to trade water and the deeper markets will work better if interconnection increases. This adds to the case for both the modernisation of existing distribution schemes and the interconnection of Regional Water Grids.

There is high underutilisation of water allocations in several irrigation systems in central and northern Queensland, despite these areas experiencing long-term drought conditions[6]. This suggests market failure. A competitive market would see water

prices fall until the market cleared, unless the operating costs of delivering water exceed the value of the water. Maybe the market failure is in the supply and pricing of electricity. Maybe it is in policy or social inhibitions surrounding participating in trade and the lack of transparency of the market. These matters would receive attention in a place-based local planning and policy system.

The panel suggests detailed scheme-specific assessments of irrigation systems to identify impediments to optimal irrigation water use, reasons for the chronic underutilisation of water and recommended initiatives to overcome these issues and promote higher water use. Consideration should be given to a review of the necessary level of service and efficiency of the channel and supplementary *ad hoc* irrigation systems required to ensure water can be delivered at the right time and the scheme function effectively. Any assessment must also review the historical contractual basis and pricing principles on which the schemes were developed and assess the impact of current pricing principles on the price levels and water use patterns. This is part of the Making Water Work narrative.

The panel's observations suggest that high electricity prices are having important effects now on the utilisation of water allocations on agricultural production in northern and central Queensland. Food, fibre and foliage producers are currently considering the removal of water-efficient irrigation equipment installed earlier to avoid further electricity cost increases[7]. The value of precision irrigation and the benefits from new ag-tech in raising water-electricity productivity on farm must be recognised and supported. The panel was disappointed to hear that energy and water productivity programs for farmers were no longer supported by the Queensland Government. Without effective action to resolve the water efficiency and energy intensity tension in Australian agriculture, perverse and wasteful outcomes are likely.

There is a special pricing issue related to the distinction between high and medium security water. A review could look at how integrating the two categories would affect growers' decisions. Removing the distinction between high and medium security water would increase flexibility and may increase the total value of economic activity over time. The uses of water that have highest value would secure the water needed in dry times by outbidding uses that have lower value.

Investment decisions on long-lived water infrastructure are guided by assessments of the future value of plant products. This is particularly challenging at this time because of the dual effects of climate change and of the movement to a zero-carbon global economy. Climate change is disrupting and reducing average productivity in the old centres of agricultural production. This is raising and expected to raise the average price of food and other agricultural products moderately above the levels of the late twentieth century. This increases the value of water, both near where it falls in central and northern Queensland, and in places to which it could be moved. More importantly, the movement towards a zero-emissions global economy introduces new sources of value: carbon in soils, carbon in plants and biomass harvested sustainably for use in industry.

This is likely to greatly increase the value of water and land. How much? The research has not been done for the panel to know. However, the fact that rural land values across Queensland have risen significantly with lower interest rates despite the widespread drought is suggestive of positive views on the outlook for farm products.

Does it matter whether ownership of water infrastructure assets is private, local collective or state public? The panel has not reached strong general conclusions. Two points are worth keeping in mind. The cost of capital to the public sector is lower and should lead to a lower cost of infrastructure services under true cost-reflective pricing. That points towards more public ownership. Private ownership, however, has clear advantages if the investment decision is being driven by demand from particular private users of water for particular business purposes.

The demand of coal miners is a case in point. Many in the industry presume the demand for Queensland coal will grow over the coming decades, and that an expanding industry will need and be able to pay for more water. Some current dam and pipeline proposals are driven by demand from the coal mining industry. Successful achievement of the Paris goals would see Queensland coal production decline over the next several decades. Water infrastructure to help expand the industry as well as some historical investment could then be stranded. Will the costs of any misjudgement about future coal demand be carried by the people making the business decisions on coal mining expansion? Or will the costs of stranded assets be carried by ordinary Queensland and Australian citizens? It is more likely the risk will be carried by the businesses making the calls on the future markets, who will also benefit from them, if water investment decisions are taken in the private sector.

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1 Council of Australian Governments, 2004

2 Joyce, 2021; Townsville Bulletin, 2021

3 See https://www.iriss.org.uk/resources/irisson/place-based-working

4 Department of Industry, Science, Energy and Resources, 2020

5 Garnaut, 2019; Garnaut, 2021

6 See https://www.longpaddock.qld.gov.au/drought/drought-declarations/

7 Jackson et al., 2010; Jackson et al., 2011

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Chapter 9

Water for central and northern Queensland regional development

Water for central and northern Queensland regional development



Bradfield had a magnificent vision of using the abundant water of northeast Queensland to achieve development across a vast area of inland Australia. He envisioned the expansion of irrigated agriculture on an immense scale: villages growing into cities of tens of thousands of people, and a stronger and geographically more diverse Queensland and national economy. The vision has been kept alive and expanded by contemporary Queenslanders, many of whom have made large personal efforts to promote the public interest in such development.

The panel has found there is not enough water available for diversion west and south to support irrigation on the Bradfield scale. Neither is there enough water available for the smaller CSIRO version of Bradfield. The panel has also found there is great opportunity for development through wise use of the large amount of water that really is available in central and northern Queensland. Use that opportunity well, and Queensland citizens can look forward to regional growth in incomes, employment and population that greatly exceeds the scale of opportunities that would have come from the Bradfield vision.

The Bradfield vision was, and the variation on the theme developed by Sir Leo Hielscher, Sir Frank Moore and Mr Detlef Sulzer is, directed towards development in the western outback, which has been experiencing decline in employment and population. While the greatest opportunities for using water and other resources to enhance regional development now are closer to the coast, significant opportunities are also available to convert decline in the west to moderate expansion, at low cost to the rest of the community.

The coast and near inland from Cairns to Gladstone prospered exceptionally over the eight decades after Bradfield described his vision for regional development in Queensland, and especially over the past half-century. Effective regional planning by government saw Queensland seize opportunities created by historic economic growth and structural change in Northeast Asia. This included international tourism to the Great Barrier Reef and other wonders, a globally important new coal industry, an expanded base metals mining industry in northwest Queensland with processing in Townsville, the refining and smelting of Queensland aluminium ores in Gladstone and, most recently, the emergence of an immense LNG export industry. These developments underpinned the central and northern Queensland population growth from about 290,000 in the 1930s to more than one million today.

The opportunities for regional development over the next several decades are even larger. This time, they are built on the demand for new products created by the world moving to a zero-emissions economy. Central and northern Queensland have the water, people, infrastructure, land, renewable energy and other resources to meet that demand.

In the Wet Tropics north of Townsville, abundant water resources and fertile soil provide rich opportunities for meeting rising global demand for high-value horticulture, biomass for zero-emissions industry and credits for storing carbon in soils and plants. South of Gladstone in the Burnett River catchment, the water and land offer a similar range of large opportunities, of much greater value than the old crops with heavy reliance on sugar for human food. There will be much more opportunity to add value to local agricultural and agri-forestry production through local processing and conversion into zero-emissions industrial products. Cairns, Mackay and Bundaberg in the south are natural centres for agribusinesses servicing and prospering from this new growth.

In sheer scale, the largest opportunities lie within an area bounded by Cairns and Bundaberg on the coast and Hughenden and Barcaldine to the west of the Great Dividing Range: the WATER Development Zone. The combination of renewable energy, land and water resources and established agricultural, industrial, and commercial skills and infrastructure makes this potentially one of the leading regions of the low-carbon world economy.

Within WATER there is well-established, high-value horticulture, including rich irrigation production through the central highlands and along the coast. The coastal cities of Cairns, Rockhampton and Mackay have a strong base in servicing and processing products from the pastoral and agricultural industries and boast a regional advantage in making good use of the new land-based opportunities. The area contains the richest solar resources connected by high voltage transmission to Australia's National Electricity Market grid in the flat open country on the western side of the Great Dividing Range. It also includes excellent wind resources on higher ground through this same country and in places back through the Great Dividing Range. It contains attractive hydro-electric and PHS potential not far to the west of the great cities on the coast.

Beyond the WATER Development Zone to the northwest, water is available to support expanding irrigated agricultural and related investment west of Hughenden into the catchments of the Flinders and other rivers flowing into the Gulf of Carpentaria. Climate change is tending to increase the availability of water across this part of the country, although increased evaporation takes some of the increase in some places and increased variability adds to the challenge of its effective use. Here, the task is to make the substantial amount of available water work more effectively for regional development.

In the southwest corner of the region, there is some opportunity to draw water for growing plants from the Belyando River, a southern tributary of the Burdekin. Thorough analysis will show whether costs and benefits warrant moderate investments in water infrastructure to move some available water further west, along the existing railway and highway corridor through Barcaldine to Longreach. In any case, development in the vast, hot, and mostly dry but occasionally flooded Channel Country stretching west and south over the South Australian border to Lake Eyre depends on using small amounts of water well. There are also new opportunities in the zero-carbon economy here that can be unlocked by research and business innovation. Completing the successful GAB management schemes would free some water for productive new uses. Research on plants that store carbon and grow biomass economically in highly variable rainfall also has a large role to play in identifying opportunities. Variations on the model of renewable-energy-based industrial development being developed in Barcaldine will have applications across several locations.

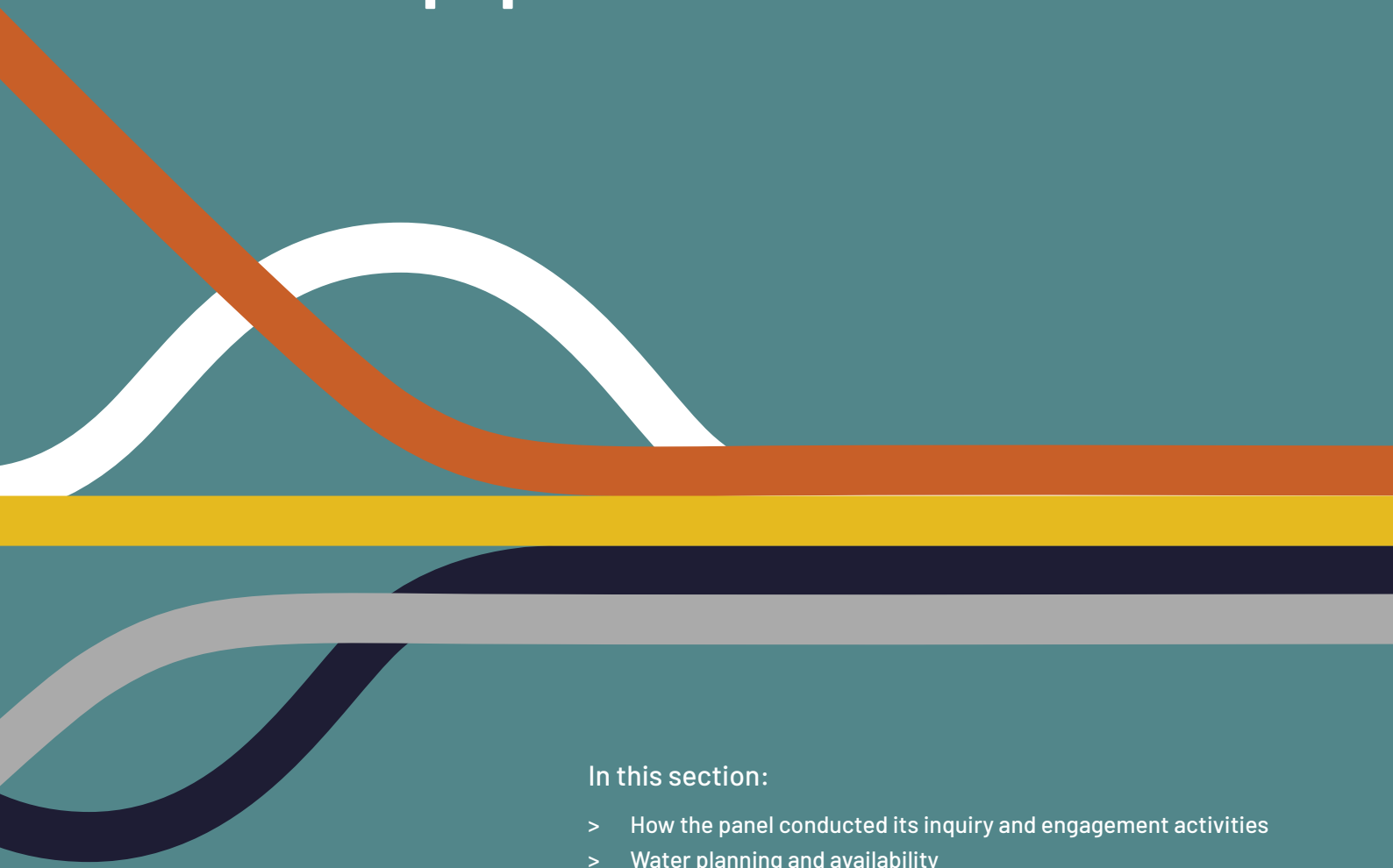
The benefits from these opportunities for historic expansion of economic activity, incomes, employment, and population in central and northern Queensland will only come with effective government, sound planning at government, regional and local levels, and sound policy holding the whole agenda together. It will only come with a larger role in planning for place-based institutions nested in well-designed government planning and policy systems.

Get planning and policy right, and the next generation will see greatly expanded rural and provincial industries effectively using the abundant but finite and precious water that falls on central and northern Queensland. It will see strong expansion of economic activity and population through central and northern Queensland. Townsville, Gladstone, and the towns on the coast will emerge as major drivers of the transformation of the global industrial economy as the world deals with the threat from human-induced climate change. Communities on the coasts north of Townsville, through the Atherton Tablelands, south through Bundaberg and the Burnett River system, and in the catchments flowing into the Gulf of Carpentaria will be flourishing centres of agri-business and agri-industry, leading the world in making zero-emissions products and carbon credits from land and water. The towns of the not-so-distant inland will see moderate economic expansion, displacing current decline. Special efforts in local regional planning supported by well-designed development support will modestly enhance prosperity for a slowly growing rather than declining population further west in the Lake Eyre Basin.

While water is not available in the abundance that could enable the Bradfield vision, the judicious use of water that really is available could build something that Queenslanders tomorrow will judge to be even better.



Appendices



In this section:

- How the panel conducted its inquiry and engagement activities
- Water planning and availability
- Climate change and the supply and value of water
- Indigenous interests in water development
- Bradfield Scheme assessment and background
- Water infrastructure planning and assessment frames



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Appendix 1

How the panel conducted its inquiry and engagement activities

How the panel conducted its inquiry and engagement activities

Background to the Bradfield Scheme

In 1938, prominent engineer Sir John Bradfield proposed a scheme to capture the plentiful water of tropical North Queensland and divert it west across the Great Dividing Range to open vast new swathes of the state for irrigation. Sir John Bradfield's original concept also envisaged hydro-electric power generated to pump water. Since that time, the scheme has periodically been the subject of renewed political and public interest.

About the work of the panel

The Bradfield Regional Assessment and Development Panel (the panel) was established on 2 September 2020 to undertake an independent assessment of the financial, economic, environmental, social and technical viability of a Bradfield Scheme or Bradfield-like concepts.

The panel was tasked with preparing a report for the Minister for Natural Resources and Water. After the 2020 Queensland election, the report was prepared for the Minister for Regional Development, Manufacturing and Minister for Water. The Queensland Government will consider the panel's recommendations.

Panel members

Prof Ross Garnaut (Chair)

Ross Garnaut is Emeritus Professor of Economics at the University of Melbourne. He has been Professorial Research Fellow in Economics at the University of Melbourne; Distinguished Professor of Economics at The Australian National University; Chair of the International Food Policy Research Institute; and Chair of the Australian Centre for International Agricultural Research.

He is a Companion of the Order of Australia (AC) for services to climate change and energy; an Officer of the Order of Australia (AO) for services to education and international relations; Distinguished Fellow of the Australian Economics Society; Distinguished Life Member of the Australian Agricultural and Resource Economics Society; Fellow of the Australian Academy of Social Sciences; and Honorary Professor of the Chinese Academy of Social Sciences.

Ross is the author of the *Garnaut Climate Change Review* (2008) and *Australia and the Global Response to Climate Change* (2011). He is the author of many books, including most recently *RESET: Restoring Australia After the Pandemic Recession* (2021), *Superpower: Australia's Low Carbon Opportunity* (2019); *China's 40 Years of Economic Reform* (2018); *Dog Days* (2013); and *The Great Crash of 2008* (2009).

He is a Director of the renewable electricity and hydrogen retailer ZEN Energy, and Chairman of its sister company, Sunshot Industries, which works with industrial companies on the use of renewable energy and hydrogen.

Dr Georgina Davis

Georgina Davis is Chief Executive Officer of the Queensland Farmers' Federation (QFF), which is the united voice of agriculture in Queensland, representing the interests of national and peak state agriculture organisations. QFF engages in a broad range of economic, social, environmental and regional issues of strategic importance to the productivity, sustainability and growth of the agricultural sector. QFF's mission is to secure a strong and sustainable future for Queensland farmers.

Georgina is a Chartered Environmentalist (CEnv) and holds several Board positions and various roles on government bodies and statutory authorities.

Prof Allan Dale

Allan Dale is a Professor of Tropical Regional Development at The Cairns Institute, James Cook University, and the independent Chief Scientist for the Collaborative Research Centre for Northern Australia (CRCNA).

He has global policy and practical expertise in building strong governance systems in regional and Aboriginal and Torres Strait Islander development and natural resource management.

Allan was previously the regulator for the social impact assessment of development in Queensland; the past Chair of Regional Development Australia—Far North Queensland and Torres Strait; and the past Chief Executive Officer of Terrain Natural Resource Management. He has an agricultural, social research and environmental sciences background.

How the panel approached the task

The panel was asked to examine Bradfield's original proposal from a twenty-first century perspective and to formulate findings that could assist the government to assess the viability of opportunities that Bradfield-like concepts may present.

The panel's terms of reference provided guidance on those matters to be explored and canvassed when conducting the independent inquiry, including direction on stakeholder engagement and the geographic area to be considered. The full terms of reference as published by the Queensland Government are included at the end of this appendix.

The project area for the panel was from the Wet Tropics to the Burdekin, across the Great Dividing Range to Queensland's western regions and as far south as the Queensland Murray–Darling Basin. The terms of reference also identified six themes to be examined:

- Theme 1: Analysis of the Bradfield Scheme to date
- Theme 2: Economic benefits to regional communities and agricultural production
- Theme 3: Analysis of the project area and its current infrastructure
- Theme 4: Opportunities to leverage current infrastructure within the project area
- Theme 5: New opportunities within the project area
- Theme 6: Neighbouring opportunities outside of the project area.

The panel met formally each month, usually over two days, and more frequently as required. The formal meetings established and prioritised a focused work program to undertake the assessment and develop the final report.

The panel collaborated with technical experts to inform their deliberations and assessment. To support the panel's analysis, the Centre of Policy Studies at Victoria University was engaged to complete an independent appraisal of the economic impacts of the project, using computable general equilibrium (CGE) modelling. CGE modelling is a well-regarded analytical framework used to compute large numerical values, combining economic theory with real world data to identify the impacts of policies or shocks on an economy. It can simulate the impact of particular projects and policy scenarios. This modelling is outlined in the main body of the panel's report.

The panel worked with the National Water Grid Authority (NWGA) and sought its permission to reference some of the work under way through its Science Program to review the Bradfield Scheme and variations of the original idea. These scientific studies were considered important to the panel's understanding of available contemporary science and drew on the expertise of Australia's leading science agencies: CSIRO, the Bureau of Meteorology and Geoscience Australia.

Scope of panel's deliberations by theme

Theme 1: Analysis of the Bradfield Scheme to date

- Consider Bradfield and Bradfield-like assessments (e.g. harvesting, transfer and storage concepts and proposals that connect different subregions/areas) completed to date. Such assessment should consider their limitations at the time as well as the growth in infrastructure within the project area since the original Bradfield proposal.

Theme 2: Economic benefits to regional communities and agricultural production

- Consider the economic benefits to regional communities and agricultural production within the project area, especially through the lens of re-energising the economy following the COVID-19 pandemic and the present economic recession.

Theme 3: Analysis of the project area and its current infrastructure

- Scan and analyse existing bulk water infrastructure, current water demand and whether or not supply is meeting demand within the project area.

Theme 4: Identified opportunities leveraging current infrastructure within the project area

- Assess and provide recommendations concerning where existing bulk water infrastructure can be expanded and connected to support drought-prone regions within the project area.

Theme 5: New opportunities within the project area

- Make recommendations concerning new opportunities where infrastructure does not yet exist.
- Advise on the appropriate staging of opportunities to maximise return on investment to the Queensland community and economy, as well as estimated costings.
- Consider opportunities to leverage complementary infrastructure e.g. hydrogen and hydro-electricity generation that may also benefit the Queensland community.
- Consider the opportunities associated with the Queensland Government's *Hydrogen Industry Strategy 2019–2024*.
- Consider opportunities to integrate with the CopperString Project.

Theme 6: Neighbouring opportunities outside of the project area

- Identify potential bulk water supply infrastructure opportunities that neighbour the project area.

Principles of the assessment

In developing its advice, the panel has explored and considered a wide range of disciplines including, but not limited to, economic and financial assessment, engineering, cost estimation, agronomy, market assessment, environment impacts, hydrology, and social and cultural impacts, including those specific to Aboriginal and Torres Strait Islander peoples. The panel was also guided by the Queensland Government's objectives for bulk water supply, which are to:

- ensure the safety and reliability of dams and urban water supplies
- use existing water resources more efficiently
- develop bulk water infrastructure that provides a commercial return to bulk water providers
- consider projects that will provide regional economic benefits.

When assessing and comparing concepts or proposals, the panel considered:

- the impacts of climate change e.g. improving water security for entitlement holders or communities under a scarce water future, as well as the impact of diverting water from natural ecosystems
- the effect on the health of the region's two world heritage areas: the Wet Tropics of Queensland and the Great Barrier Reef. This included considering the impacts of diverting flows from these two natural assets as well as the effect on reef-dependent economies, such as fisheries and tourism
- Aboriginal and Torres Strait Islander peoples' connection to water, including how proposed infrastructure might affect them as well as cultural connection.

Stakeholder engagement approach

The panel engaged with key stakeholders including regional councils and industry to understand their needs and the potential benefits water development could bring. However, in line with the terms of reference, full public consultation was not undertaken.

Aim

It was important to the panel to make purposeful contact with stakeholders to create a level of trust and confidence in its investigative process and to listen to and understand stakeholders' passions and issues of concern.

Wherever possible and at an early stage, the panel collaboratively tested assumptions, ideas and potential scenarios with relevant stakeholders. From the panel's perspective, it is anticipated this work will help to lay the foundation for prompt movement of policy, planning and investment opportunities.

Process

The panel engaged with stakeholders through:

- briefings from government agencies and external experts
- meetings with key stakeholders
- submissions or letters from members of the public with an interest in or passion for the Bradfield Scheme.

The panel received extensive briefings from government and external experts on matters relevant to its terms of reference.

Briefings included:

- departmental experts on water resource planning and bulk water opportunities and costs
- government experts on climate change and associated modelling
- government and academic experts on the science behind the ecological impacts of water developments on northern Queensland's water resources
- various government and external experts on the value of agriculture
- government experts on the State's energy policies and strategy
- multiple presentations from CSIRO on their assessment of the 1938 and 1942 Bradfield concepts
- the National Water Grid Authority
- presentations from proponents of alternative Bradfield-like concepts
- government water bodies in other jurisdictions.

The panel met with a range of stakeholders to understand the passions and interests associated with water and water-related development. These meetings also helped to inform the panel about the stakeholders' aspirations and expectations. Conversations were held with regional councils, Indigenous organisations, environmental organisations and peak bodies from a range of sectors including:

- irrigation
- agriculture
- water infrastructure
- conservation
- resource
- finance
- energy.

The panel had planned visits to regional areas so they could meet with stakeholders and local councils in person. Unfortunately, these visits were curtailed by COVID-19 lockdowns and restrictions. In response, virtual meetings and Google Earth flyovers were used as an alternate to in-person meetings and site inspections.

The panel also received submissions and letters from members of the public. These submissions often articulated the authors' support for, or opposition to, the Bradfield Scheme. The panel reviewed these submissions and provided a written response.

Overview of conversations

Bradfield's scheme has captured the imagination of Australians ever since it was first proposed in 1938. In their conversations with stakeholders, the panel found there were many divergent views from equally passionate people. These views included:

- supporting the Bradfield scheme in its entirety
- supporting smaller or alternate versions
- opposing the scheme on economic, ecological, regional, engineering or cultural grounds.

The information gathered through the stakeholder engagement process proved beneficial for the panel's overall deliberations and depth of understanding of historical and contemporary views on the Bradfield schemes and Bradfield-like concepts.

Published terms of reference

Introduction

The Bradfield Regional Assessment and Development Panel (the panel) is an independent assessment panel made up of respected experts. The panel will report a set of recommendations to the Minister for Natural Resources, Mines and Energy (the department) for consideration by the Queensland Government. The final report will embody the independent assessments of the panel.

The panel has been established to support the government in assessing the viability of opportunities that a Bradfield Scheme concept present. This may not be of the same magnitude or scale as what was originally envisioned by Sir John Bradfield, or subsequent advocates of the scheme; however, the Palaszczuk Government is willing to progress water infrastructure projects that deliver for irrigators and Queenslanders.

The Queensland Government is ready to have a conversation with the Australian Government and its new National Water Grid Authority on a range of water infrastructure proposals, including the opportunity for increasing regional connectivity where it makes sense.

Purpose

The purpose of the panel is to present a report to the Minister, outlining the results of an assessment of the financial, economic, environmental, social and technical viability of a Bradfield Scheme, or 'Bradfield-like' concepts, as well as a set of recommendations for any further assessment.

The final report will consider the Queensland Government's requirements for the strategic assessment of infrastructure projects as outlined in the Project Assessment Framework and Building Queensland Business Case Development Framework. The Department of Natural Resources, Mines and Energy will supply the panel members supporting information relating to these frameworks.

The final report is due to the Minister for Natural Resources, Mines and Energy 12 months from engagement of the panel.

While there is no defined project area, the project area that the panel will focus on is the geographic area that allows for the diversion of flows from the Wet Tropics to the Burdekin and as far south as the Queensland Murray-Darling Basin.

The recommendations provided to the Minister will address each key theme (as outlined below) and will be included as part of the overall report. The panel's expertise, local knowledge, experience and insights will inform the recommendations provided to the Minister and will be valuable in informing the overall strategy.

Themes

Theme 1: Analysis of the Bradfield Scheme to date

- Consider Bradfield and Bradfield-like assessments (e.g. harvesting, transfer and storage concepts and proposals that connect different subregions/areas) completed to date and their limitations at the time, as well as the growth in infrastructure within the project area since the original Bradfield proposal.

Theme 2: Economic benefits to regional communities and agricultural production

- Consider the economic benefits to regional communities and agricultural production within the project area; especially through the lens of re-energising the economy following the COVID-19 pandemic and the current economic recession.

Theme 3: Analysis of the project area and its current infrastructure

- Scan and analyse existing bulk water infrastructure, current water demand and whether supply is meeting demand within the project area.

Theme 4: Identified opportunities leveraging current infrastructure within the project area

- Assess and provide recommendations concerning where existing bulk water infrastructure can be expanded and connected to support drought-prone regions within the project area.

Theme 5: New opportunities within the project area

- Make recommendations concerning new opportunities, where infrastructure does not yet exist.
- Advise on appropriate staging of opportunities to maximise return on investment to the Queensland community and economy, as well as estimated costings.

- Further, consider opportunities to leverage complementary infrastructure e.g. hydrogen and hydro-electricity generation that may also benefit the Queensland community.
- Consider within the context of opportunities associated with the Queensland Government's Hydrogen Industry Strategy 2019–2024. By 2030, the Queensland Government's vision is to be at the forefront of renewable hydrogen production in Australia, supplying an established domestic market and export partners with a safe, sustainable and reliable supply of hydrogen.
- Consider opportunities to integrate with the CopperString Project

Theme 6: Neighbouring opportunities outside of the project area

- Identify potential bulk water supply infrastructure opportunities that neighbour the project area.

In developing their advice, the panel will be required to explore and consider a wide range of disciplines including, but not limited to, economic and financial assessment, engineering, cost estimation, agronomy, market assessment, environment impacts, hydrology, and social and cultural impacts specific to Aboriginal peoples and Torres Strait Islander peoples.

The panel is an advisory body only and not a decision-making body.

The panel will not undertake any public consultation during the process but will engage with key stakeholders. The panel will consult with regional councils to understand their needs and potential benefits to their local communities.

Principles

The panel will be guided by the Queensland Government's objectives for bulk water supply, which are:

- Ensure the safety and reliability of dams and urban water supplies.
- Use existing water resources more efficiently.
- Support development of bulk water infrastructure that provides a commercial return to bulk water providers.
- Consider projects that will provide regional economic benefits.

The panel will also complete their assessments with consideration to the state's strategic statement and principles for bulk water supply.

When assessing and comparing concepts or proposals, the panel will also consider such things including, but not limited to:

- the impact with regards to climate change, e.g. improving water security for entitlement holders/communities under a scarce water future, as well as the impact on natural ecosystems having water diverted away from them
- the impact on the health of the Great Barrier Reef from diverting natural flows as well as, reef dependent economies, e.g. fisheries and tourism
- Aboriginal peoples and Torres Strait Islander peoples' connection to water, including physical spatial impacts of proposed infrastructure as well as cultural connection.

Traditionally, Queensland only provides recommendations that align the need for bulk water infrastructure clearly with the state's strategies for regional economic development. The panel is provided with freedoms to not only do this, but also go beyond and provide a vision of what future bulk water supply may look like in northern and western Queensland.

Membership

The panel's membership is comprised of:

- Prof Ross Garnaut (Chair)
- Dr Georgina Davis
- Prof Allan Dale.

Any change in membership requires approval by the Minister.

Meetings

Virtual meetings are to be used in the first instance. Technology to support virtual meetings will be approved and made available by the department. Face-to-face meetings may be arranged where appropriate and as agreed by the panel Chair and the department.

COVID-19

Face-to-face meetings will be held consistent with COVID-19 safety requirements to ensure the safe operation of the panel. A Health Plan will be developed to support this.

Panel members

The panel will meet as required online (or in person) at a time determined by the Chair. Any member of the panel may also request that a meeting be held. Meetings will be conducted on a formal basis and be minuted. A quorum consists of all members being in attendance.

Proxy

The use of proxies is not allowed within these terms of reference.

Observers

Proposals for an observer to attend meetings with a panel member need to be made to the Chair two days prior to the meeting. The Chair will decide if an observer may participate in discussion.

Urgent business

The Chair may decide that members may be consulted in writing (including by email) outside formal meeting arrangements, when business arises external to a meeting.

Disclosure of interests

Actual, perceived or potential conflicts of interest need to be identified, disclosed and managed in an open and transparent way. Panel members must declare any interests that they or their immediate family may hold which may impact on their duties as a member of the panel:

- at the time of being invited to sit on a panel meeting
- in the meeting, should any additional interests emerge
- at any time when requested by the department.

The department is responsible for assessing if an actual, perceived or potential conflict of interest exists. Such matters are treated in the strictest confidence.

Management strategies for panel members where a conflict of interest will be determined. As way of example, this might include where an interest is identified by a selected member related to a matter under consideration at a panel meeting. In this case, that member will be excused from the meeting for any discussion about the particular submission or application.

Confidentiality and media

All matters brought before the panel are to be treated as confidential. In addition, the panel must not discuss matters relevant to its business with the media, except with prior written endorsement of the Chair and the Department.

Acknowledgements

We would like to express our thanks and appreciation for the time taken by the many people who have shared their experiences and knowledge. We remain grateful and humbled by the level of effort and thought that so many provided in the numerous correspondence and proposals received.

We also wish to acknowledge the time and insight provided by the numerous and varied stakeholders that we met either in person or virtually, who shared their visions and wisdom for their regions and the land. This particularly includes several mayors, irrigation industry and community leaders and Phil Rist of Girringun Aboriginal Corporation.

Thank you, too, to the National Water Grid Authority, and to CSIRO for allowing us to access their 2021 report and permission to refer to it.

We are extremely grateful to those who organised, cajoled and supported us through our deliberations and authoring of the report.

Thanks to the many members of the Department of Regional Development, Manufacturing and Water, particularly those of the Secretariat from Water Policy, and to representatives from the Department of Environment and Science.

We are also grateful for the meticulous editing and design skills of those from New Word Order, particularly Suzanne Oxford.

We also acknowledge Professor Mike Sandiford, Susannah Powell and Nadia Cusano from the Chair's office for their support.

Finally, we extend our gratitude to all who provided detailed information, science and data to aid our inquiry, recognising the importance and ownership that so many of the proposals and visions have to individuals across the regions. Some have devoted much personal time, energy and knowledge in the public interest to the Bradfield vision. Here we thank especially Sir Leo Hielscher, Sir Frank Moore and Detlef Sulzer, from whom we learned much that is reflected in our analysis and conclusions, even if we were unable to support their particular vision for the use of water in the west of Queensland.

Ross Garnaut
Allan Dale
Georgina Davis

November 24, 2021



02

Appendix 2

Water planning and availability

Water planning and availability

Introduction

In the early 1990s, the Council of Australian Governments adopted a national strategic framework for water management[1]. This Commonwealth–state framework and subsequent intergovernmental agreements set a high-level, long-term national vision for water resource governance and provided guidance to states and territories for market-based reforms aimed at achieving efficient and sustainable water use[2]. State and territory governments retained discretion around how to implement the broad-based water reforms, leading to diverse approaches to water governance, management and administration[3].

The reforms that commenced in the 1990s eventually blended 'top-down' regulation with 'bottom-up' catchment planning, all linked together through stakeholder consultation.

Based on an *Intergovernmental Agreement on a National Water Initiative*[4] (NWI), the state governments developed state-based water management regulation and planning instruments. Queensland has enshrined its NWI obligations into the *Water Act 2000 (Qld)* and presently has 23 water plans. Each water plan is subordinate legislation and provides laws applying to surface water and, in some areas, groundwater. The design and adoption of approaches are guided by the Water Act and tailored to the water catchment. They must take into account existing water rights, environmental water needs, expected climate change impacts, the level of development around the water resource and the type of water supply system (for example, groundwater or surface water; connected or non-connected system). Where possible, water plans reserve a sustainable volume of unallocated water to support future demands in a catchment. At the catchment scale, water plans recognise the social, economic, cultural and environmental value of water.

The Water Act also provides a framework for a trade-off between environmental flows and cultural values versus consumer use. As a general principle, water for critical human needs and minimum environmental flow conditions are met before other consumer uses, including agriculture. Over time, changes in water resource availability may require water users to adapt or reconsider water for either environmental or human needs. For example, if water availability declines due to climate change, the relative balance of how water is used may need to be explored with stakeholders. Understanding the costs, benefits and appropriate pathways for balancing different needs must be informed by the best available science[5].

This appendix provides an analysis of the water availability within the Tully, Herbert and Upper Burdekin catchments and how they relate to the Bradfield scenarios.

Water management in Queensland

Through the Water Act, Queensland has a well-established water planning framework in place to sustainably manage water resources to meet the state's current and future water needs. The Water Act covers surface and groundwater use in Queensland, including regulating major water infrastructure (such as dams and weirs) and water extracted for consumptive purposes.

Water plans have been developed for most of Queensland's catchments and set out the rules for accessing and trading surface water, overland flow and underground water. They balance the needs of water users (e.g. towns, agriculture and industries) as well as consider and establish outcomes for social, economic, cultural and environmental water needs within the defined plan area.

Water plans enable economic growth by establishing water markets and reserving volumes of unallocated water, which are set aside to meet future demands. The Water Act framework provides the Queensland Government with the tools necessary to make water available for community needs and industry development while still protecting the environment.

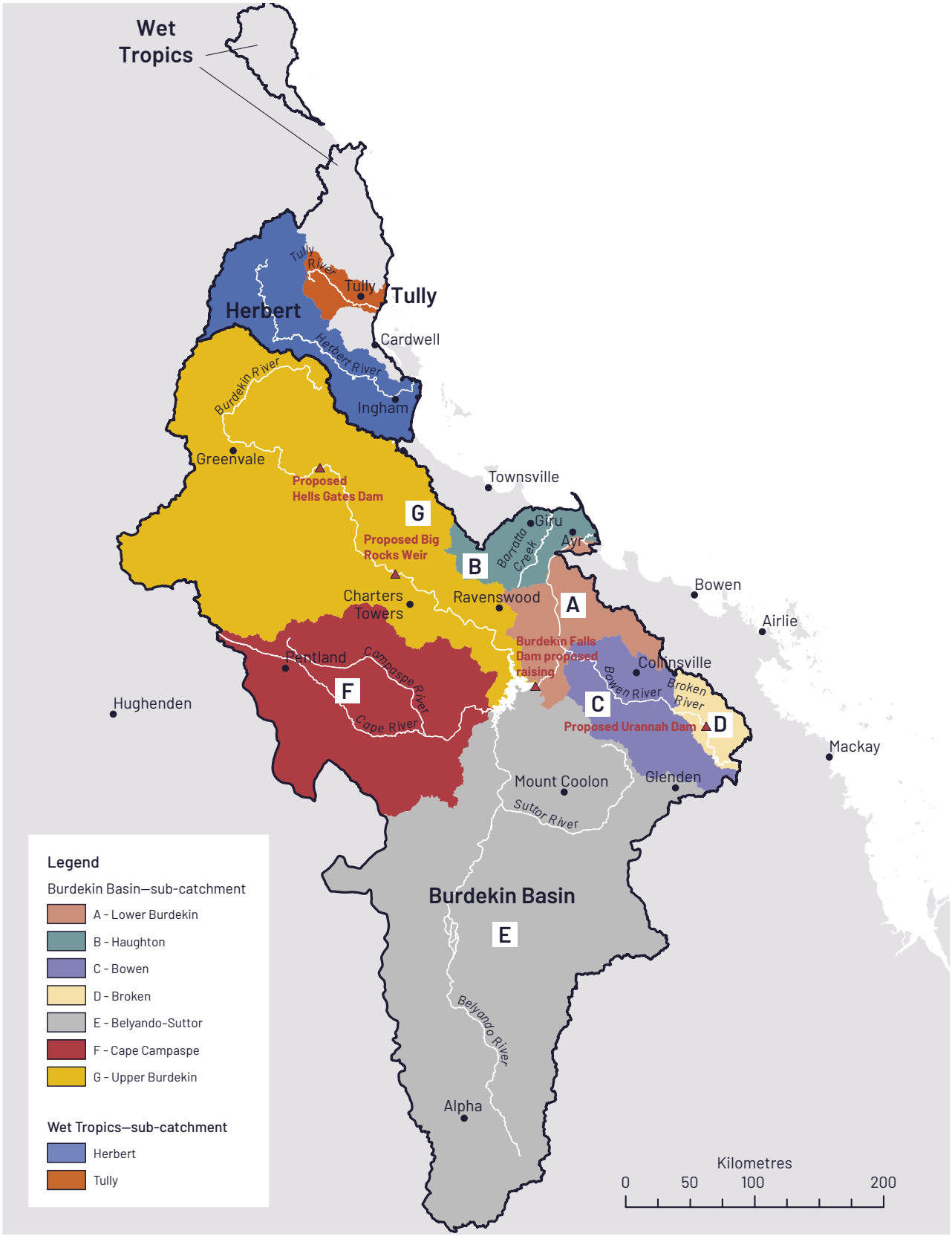
The role of hydrological modelling

Many of the strategies and rules set out in a water plan are underpinned by hydrological models that help decision-making. These models are based on historical observed data about rainfall, runoff and streamflows. In many instances the record from which the data are drawn includes more than 100 years of climate data, showing Queensland's naturally variable climate, including droughts and floods. Rainfall data is sourced from the Bureau of Meteorology while the department manages a network of monitoring stations to measure flows at different locations within each catchment.

Each model also includes information about what Queensland water officials call 'consumptive water use'. Consumptive use includes water drawn through water infrastructure for irrigation and other purposes, metered for use in towns, stock and households, and covered by water entitlements. Note the official language uses the term 'consumptive' for all of these uses.

When all of this information is compiled and calibrated, the computer model forms a connected representation of the movement of water from the headwaters to the end of the systems for streams and rivers within a catchment or basin.

One of the main benefits of compiling a hydrological model is that it enables scenario testing. One of the first scenarios tested is to 'switch off' all water users in the model.



Map A2-1: Modelling scenarios to assess impacts for catchment areas.

This scenario represents the natural flows in the catchment prior to any water resource development. This pre-development scenario is often used as a reference point for testing impacts on environmental flows.

Other scenarios test management decisions and include testing water trades, water sharing rules and environmental management rules. Climate change scenarios for different management options are also considered as a way of understanding how climate uncertainty may affect water availability and environmental flows. These scenarios are used to inform water plan objectives that balance how water is shared between different water users and the environment.

Accessing water

In Queensland's catchments, most of the water is accessed under either a water allocation or water licence. These are collectively referred to as water entitlements. This regulated access supports established industries including agriculture and mining as well as towns and communities.

There are two main types of water entitlements in Queensland: supplemented and unsupplemented water. Supplemented water entitlements are those supplied by water infrastructure (a water supply scheme) and are divided into priority groups. Typically, councils hold high-priority allocations, as the higher security of this category of entitlement is suitable for town water supplies, which require a minimum flow every day of the year. High-priority water is very reliable and more expensive. High-value irrigated crops (especially from trees that produce crops of high value for many years that would be damaged by any failure of steady water supply) and industrial water users may also purchase high-priority water, as they may also attach high value to secure water supply. Medium-priority allocations are typically used for irrigation where water users can adjust their use and their production to the water available.

Water users with unsupplemented water entitlements rely on river flows. Most rivers and streams in Queensland are ephemeral, meaning they flow only some of the time and in response to rainfall. Water users invest in their own infrastructure to take and store the water. Unsupplemented water entitlements often place conditions on when water can be accessed. This may be when a flow exceeds a particular height at a local gauging station. These conditions recognise and protect environmental water needs and the rights of other water users. Because water access is event-based, water users adopt a more opportunistic approach to water-related business decisions. They may use water for an annual crop.

Medium to high flows are important for unsupplemented water users. Unsupplemented water users may prepare their strategy for taking water in advance. Following a large flood, they may wish to plant quickly and maximise their cropping. However, extended periods between flows may undermine the viability of irrigating for some purposes. There are some perennial crops that will yield more when more water is available but survive when water is scarce. Some of these are being tested now in Queensland because of their value in the zero-carbon economy.

Uncertainty about access to water also reduces its value to business. Some uncertainty about the availability of water is inevitable, given Queensland's variable climate and ephemeral river flows. The value of water is increased if uncertainty is reduced whenever it can be done at low cost (e.g. by establishing stable regulatory systems). One of the roles of a water plan is to protect entitlement holders' access to water from decisions that might affect it. Water entitlements are a property right. For example, water allocations are a title that is separate to land and can be bought and sold independently, just like land. This enables water allocation holders to buy a water entitlement to expand their operations or sell a water entitlement they do not need. A water licence on the other hand does attach to the land and its value is embodied in that of the land to which it is attached.

Water plans adopt water allocation security objectives (WASOs) to provide certainty and security to the water allocation holders. WASOs are testable benchmarks. They prevent management decisions that would erode historical, modelled access to allocated water. WASOs are a measure of what access could be expected under the water plan's hydrological model assumptions.

Management decisions are tested against WASOs using the hydrological model. Decisions tested include changing water sharing or environmental management rules or releasing unallocated water reserves for specified purposes.

WASOs also inform the market about the relative historical reliability and value of a water allocation. Understanding the performance and security of a water allocation gives greater confidence for water users to make water-related business decisions.

Maintaining river health and natural flow variability

Water plans acknowledge that the natural state of watercourses has changed due to historical water development. To ensure healthy and productive river systems, each water plan sets environmental flow objectives (EFOs) that aim to mitigate changes to, or maintain, environmental flows, including the natural variability of flows. Environmental flows describe the volume, timing and duration of flows necessary to sustain aquatic ecosystems. The process of setting EFOs is based on establishing a benchmark that would mitigate risk to the health of an aquatic ecosystem as a result of altering flows. These

EFOs have been enshrined in law to ensure the sustainability of Queensland's rivers and streams.

Each part of the flow regime has an important role in maintaining river health. Water plans establish EFOs for low, medium and high flow. Managing periods of low flows are important for mitigating risks associated with droughts. Extended periods of low flows place stress on aquatic ecosystems. Food sources become scarce and aquatic fauna retreat to waterholes and wait for the next flow.

Medium to high flows connect rivers with floodplains, which is important for delivering nutrients. This replenishes food sources and underpins food webs. Medium to high flows are often important life cycle triggers for many aquatic species including for migration and reproduction. Medium to high flows mobilise sediment and are responsible for river-forming processes and freshwater flows to estuaries and nearshore environments linked to fisheries production. Changes to the medium to high flows could significantly alter the dependent ecosystems and affect biodiversity, riverine morphology and food webs.

It is the combination of low, medium and high EFOs stated in a water plan that is needed to sustain a river system's aquatic fauna and ecological processes that underpin healthy and productive rivers.

Unallocated water

Unallocated water is a volume of water that is reserved under water planning instruments and can be made available for future use without compromising the security of existing users or the environmental values within a catchment.

Broadly, the main types of unallocated water and the purposes for which they can be made available include:

- general and high flow reserves: any purpose
- strategic reserve: for projects considered to be of regional significance or for a coordinated project under the *State Development and Public Works Organisation Act 1971*
- strategic water infrastructure: for the development of particular water infrastructure projects e.g. new dams
- Indigenous reserve: for advancing the social and economic aspirations of Aboriginal peoples and Torres Strait Islander peoples.

Water management in the Tully and Herbert rivers, and Burdekin Basin

Water in the Tully and Herbert catchments is managed under the Wet Tropics Water Plan (2013). Approximately 66 per cent of the Tully River catchment and 15 per cent of the Herbert River is within the Wet Tropics World Heritage Area. The Wet Tropics World Heritage Area is the largest expanse of rainforest and supports the highest level of biodiversity of any region in Australia. Many livelihoods and economies in the Wet Tropics depend on healthy natural systems.

Water in the Upper Burdekin sub-catchment is managed under the Burdekin Basin Water Plan (2007). Table A2-1 provides a description of the hydrological modelling scenarios that supports the Wet Tropics and Burdekin Basin water plans.

Accessing water under existing entitlements

All water in the Tully and Herbert River catchments is unsupplemented. There are approximately 64 gigalitres and 74 gigalitres of water entitlements in the Tully River and Herbert River catchments respectively (figures A2-1 and A2-2).

Table A2-1: Description of hydrological modelling scenarios used for the Tully and Herbert River catchments and Burdekin Basin.

Water Plan Scenario	Case name	Scenario description
Tully River catchment	WT_TM08i	Full use of entitlements and unallocated water reserves as specified for the Tully River catchment
Herbert River catchment	WT_HB27_T0	Full use of entitlements and unallocated water reserves as specified for the Herbert River catchment
Burdekin Basin	BH020R-A	Full use of entitlements including latest amendment to the Burdekin Basin Water Plan in 2019 and unallocated water reserves as specified in the water plan

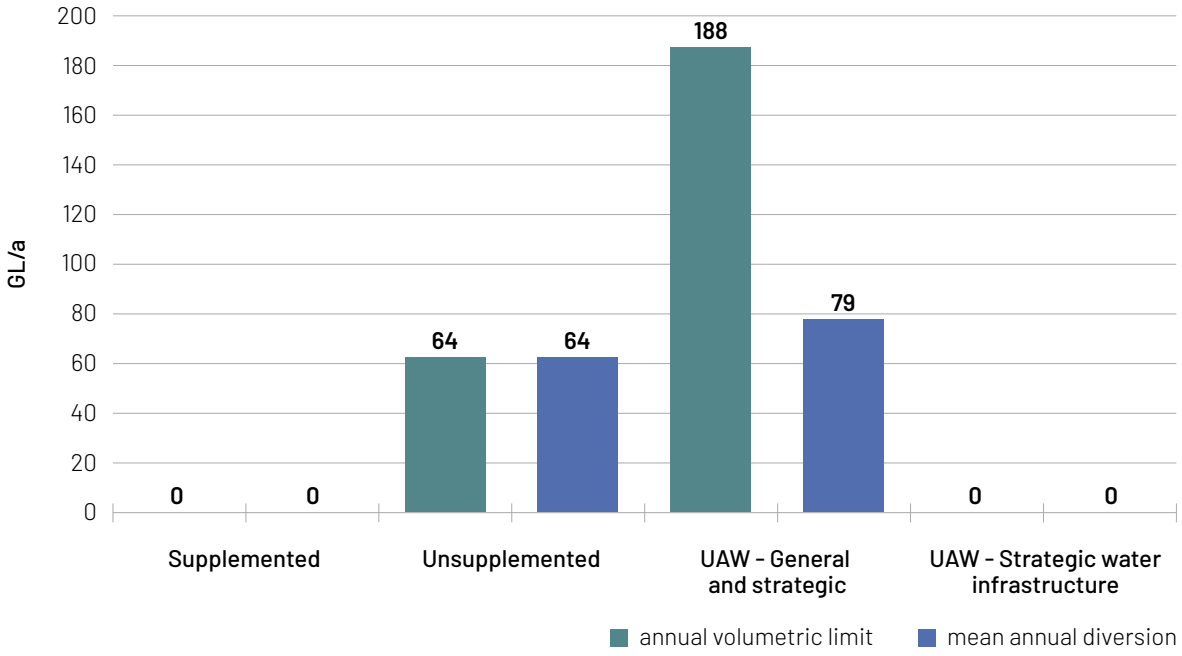


Figure A2-1: Water availability in the Tully River (based on Wet Tropics scenario WT_TM08i).

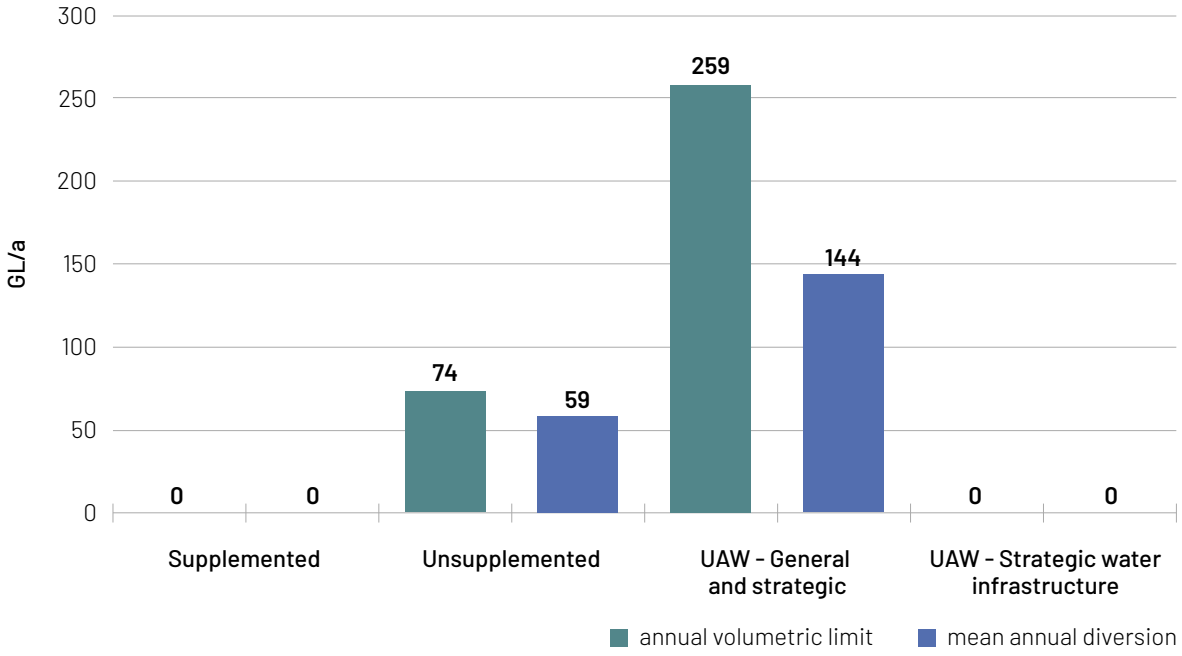


Figure A2-2: Water availability in the Herbert River (based on Wet Tropics IQQM scenario WT_HB27_T0).

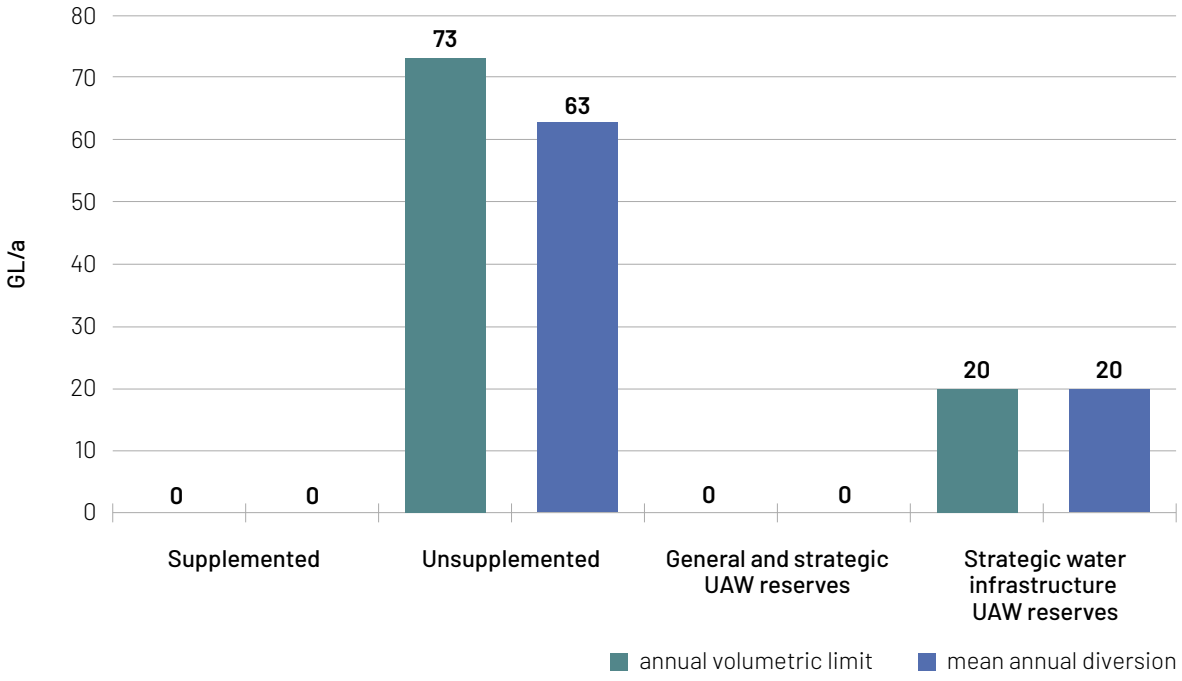


Figure A2-3: Water availability in the Upper Burdekin sub-catchment (based on Burdekin Water Plan IQQM scenario BH020R-A).

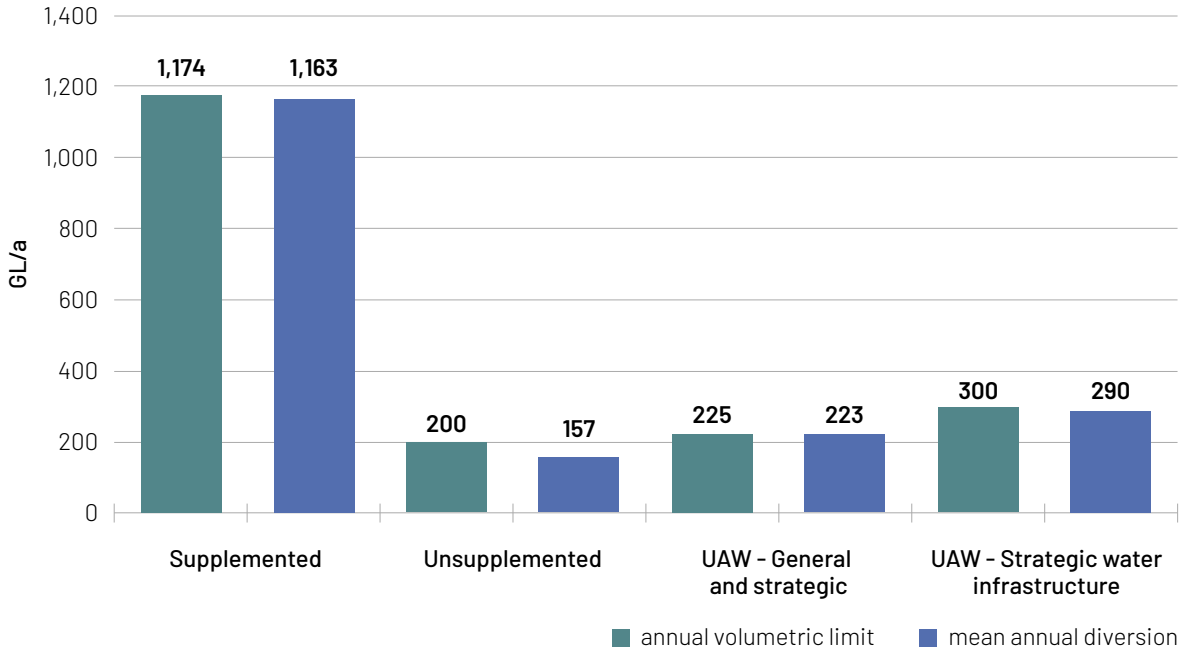


Figure A2-4: Water availability in Burdekin Basin Water Plan (based on Burdekin Water Plan IQQM scenario BH020R-A).

Under the Wet Tropics Water Plan, it is estimated that, on average, existing water users would be able to access 64 gigalitres in the Tully River catchment and 59 gigalitres in the Herbert River catchment.

The only major water storage in the Tully River is Koombooloomba Dam. The dam stores water to supply the Kareeya hydro-electric station (owned by Stanwell Corporation Limited) further downstream.

All water entitlements in the Upper Burdekin sub-catchment are unsupplemented. There are approximately 73 gigalitres of entitlement in the sub-catchment which, on average, could extract a combined 63 gigalitres per year (Figure A2-3). Charters Towers' primary water supply is sourced from Charters Towers Weir in the Upper Burdekin. The weir is small and relies on seasonal filling cycles and continuous inflows from the Burdekin River. While the weir will overflow for six months of the year, extended periods of low flow will quickly reduce the weir's water levels.

Including the Upper Burdekin sub-catchment, there is a total of 161 gigalitres of unsupplemented water entitlement across the entire Burdekin Basin (Figure A2-4) which, on average, could extract 111 gigalitres per year

There are two water supply schemes in the Burdekin Basin, which provide 1,174 gigalitres of supplemented water allocations (Figure A2-4). The Burdekin–Haughton Water Supply Scheme is located at the confluence of the Burdekin River with the Belyando and Suttor catchments. This water supply scheme supports a well-developed agricultural sector in the Lower Burdekin and Haughton sub-catchments with 1,135 gigalitres of water allocation. The scheme also provides high-priority water for the Townsville water supply. On average, supplemented water users will have access to 1,125 per year of the 1,135 gigalitres of water allocation. The Bowen–Broken water supply scheme is located in the Bowen–Broken sub-catchment and predominantly supplies high-priority water for irrigation and mining. It also supplies water for the coal-mining towns of Collinsville, Glenden and Moranbah.

Unallocated water

The Wet Tropics Water Plan establishes reserves of unallocated water for the Tully and Herbert river catchments (Table A2-2 and Figure A2-1). The plan identifies two types of unallocated water reserves that can be released for any purpose: general and high flow.

High flow reserve in the catchments include 180 gigalitres in the Tully River and 245 gigalitres available in the Herbert River. This water is only able to be accessed during flood events. This is important as the water plan specifically protects low flows from further development. On average, the high flow reserve unallocated water in the Tully and Herbert rivers is 71 and 132 gigalitres respectively.

There have been no unallocated water releases in the Tully or Herbert River catchments since the Wet Tropics Water Plan began.

There is no unallocated water for strategic water infrastructure in the Tully or Herbert rivers.

The Burdekin Basin Water Plan establishes unallocated water reserves across the basin to support demand and growth (Table A2-3). In the Upper Burdekin, 10 gigalitres of general reserve and 10 gigalitres of strategic reserve are available. This reserve could be combined to satisfy the requirements for water infrastructure.

Other strategic water infrastructure reserves in the Burdekin Basin include:

- 150 gigalitres in a strategic water infrastructure reserve specifically for raising the Burdekin Falls Dam by up to two metres
- 150 gigalitres in a strategic water infrastructure reserve identified in the Bowen–Broken sub-catchment. Accessing this water would require infrastructure in the Bowen-Broken sub-catchment.

Table A2-2: Unallocated water reserve specified in the Tully and Herbert rivers.

Sub-catchment	General (GL)	High flow (GL)	Strategic water infrastructure (GL)	Strategic (GL)	Indigenous purposes (GL)	Total (GL)
Tully	7	180	0	1	0.5	188.5
Herbert	1.75	245	0	12.45	1	260.2

There are 150 gigalitres of general reserve in the Belyando–Suttor sub-catchment. While this water has not been released, there is significant interest from both the irrigation and mining sector in accessing this water resource. Recent amendments to the Burdekin Basin Water Plan to introduce water trading were aimed at meeting this demand. There have been no water trades in the Belyando–Suttor catchment since the introduction of water trading rules in 2019.

In 2016, 10.8 gigalitres of unallocated water was granted from the 20 gigalitres of strategic reserve for a State purpose related to a Galilee Basin coal project in the Belyando–Suttor sub-catchment, and 9.2 gigalitres remain in that reserve. On conclusion of the mining activity, the unallocated water will return to the state.

Maintaining river health and natural flow variability

In the Tully and Herbert River catchments, the Wet Tropics Water Plan requires that 94 per cent and 97 per cent respectively of the pre-development mean annual flows are maintained. In the Tully River, the pre-development mean annual flow at the end of the system is approximately 2,991 gigalitres while, in the Herbert River, the pre-development mean annual flow at the end of the system is approximately 3,381 gigalitres (Figure A2-5).

Under current water resource development, including releasing all unallocated water reserves, it is estimated that the mean annual flows at the end of the Tully and Herbert river systems would be 2895 gigalitres and 3187 gigalitres respectively. This is about 83 gigalitres and 42 gigalitres above the target set in the water plan. Alongside mean annual flows, there are three other EFOs in the water plan that represent different low and medium to high flows targets in the Tully and Herbert river catchments.

The EFOs for the Tully and Herbert river catchments are set at levels to protect the natural environment in these catchments. The Tully floodplain wetlands are of high ecological importance due to their biodiversity and habitat value. Floodplain lagoons have been found to contain early life-history stages of 15 native fish species, including four that require saline habitat for larval development. Two species that have conservation significance were found in larval stage, demonstrating the importance of these wetlands as nursery habitats. Overbank flooding is critical for maintaining the biodiversity of these wetlands.

Approximately 25 per cent of the Herbert River catchment is protected national parks and includes the Girrigun, Kirrama, Koombooloomba and Paluma national parks. The catchment contains several wetlands that are listed on the National Directory of Important Wetlands. These include:

- Bambaroo Coastal Aggregation
- Blencoe Falls (Blencoe Creek)
- Herbert River Floodplain
- Herbert River Gorge.

There are three declared fish habitat areas in the catchment at Cattle-Palm Creek, Halifax and Hinchinbrook. Hinchinbrook estuary extends to the tidal limit of the Herbert River.

Table A2-3: Unallocated water reserve specified in the Burdekin Basin Water Plan.

Sub-catchment	General (GL)	Strategic water infrastructure (GL)	Strategic (GL)	Indigenous purposes (GL)
Lower Burdekin	50	150		0
Haughton	5			
Bowen	0	150		
Broken	0			
Belyando–Suttor	130		9.2*	
Cape Campaspe	5		5	
Upper Burdekin	10		10	

*An additional 10.8 gigalitres will return to this reserve on conclusion of the project.

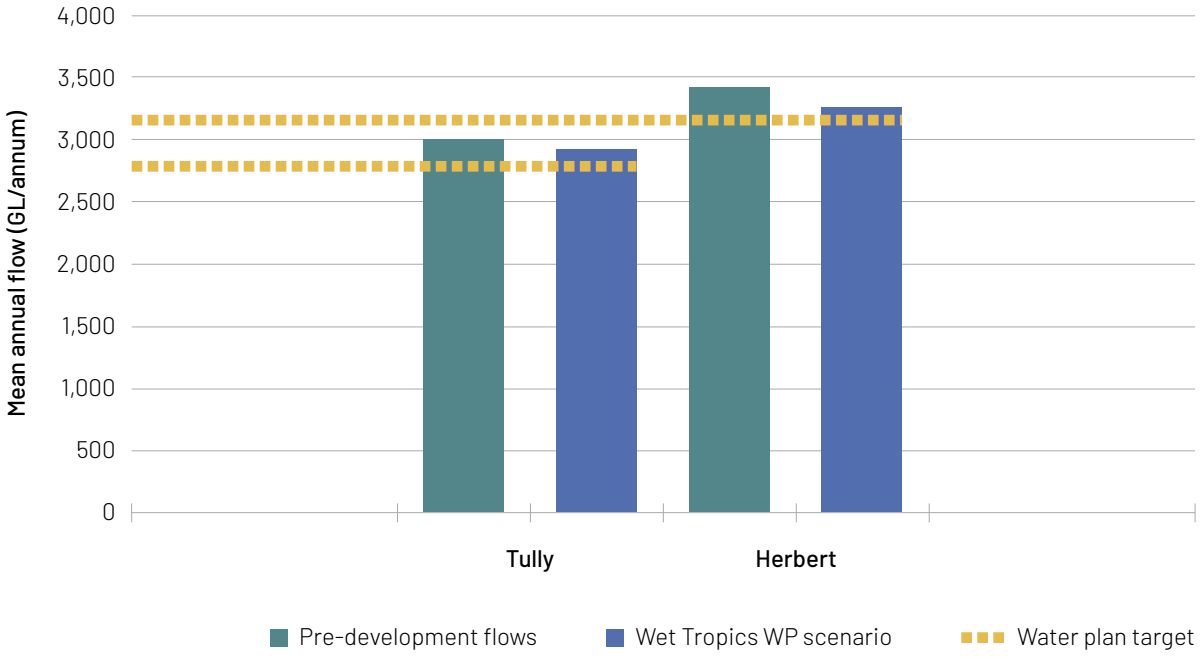


Figure A2-5: Mean annual flows in the Tully and Herbert River catchments
(based on Wet Tropics scenarios WT_TM08i and WT_HB27_T0).

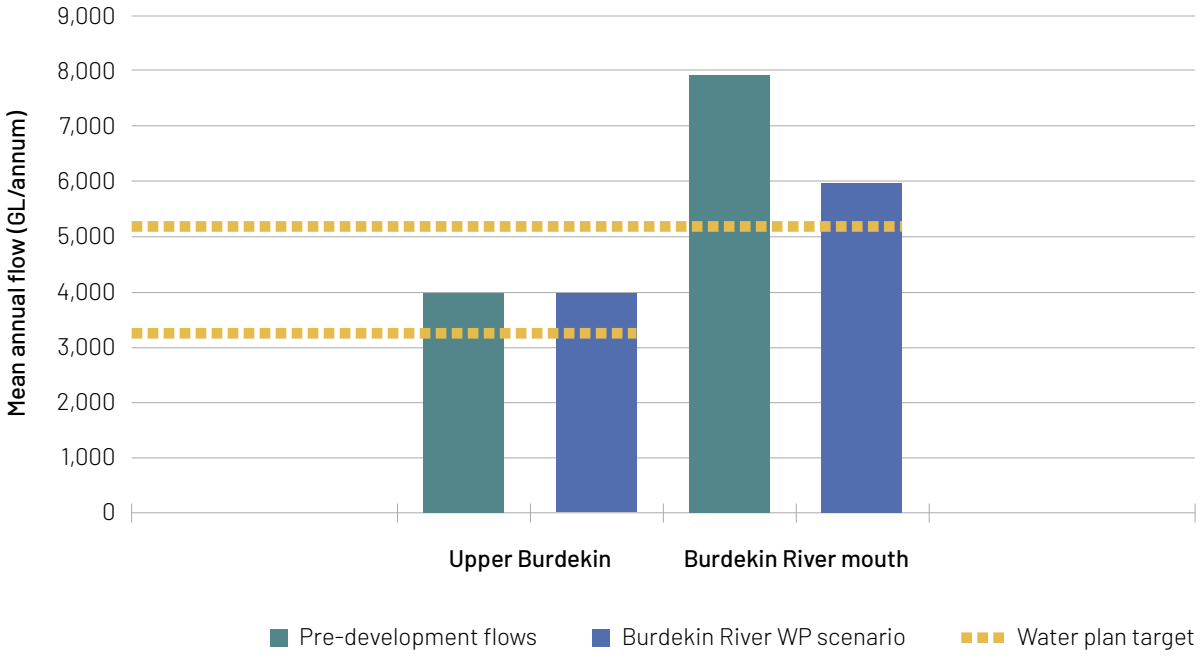


Figure A2-6: Mean annual flows in the Upper Burdekin and Burdekin rivers
(based on Burdekin Water Plan I00M scenario BH020R-A).

The estuary extends further than the mangrove and salt communities and includes vegetation types that are more freshwater environments. Hinchinbrook estuary has a range of unique habitats including seagrass communities and intricate mangrove root systems.

In the Upper Burdekin River sub-catchment, the Burdekin Basin Water Plan requires that 97 per cent of pre-development mean annual flows are maintained. Further down the catchment, at the mouth of the Burdekin River, the plan requires that 75 per cent of the pre-development flows be maintained (Figure A2-6). The pre-development mean annual flow for the Upper Burdekin catchment is 4,035 gigalitres, while the pre-development mean annual flow at the mouth of the Burdekin River is 7,881 gigalitres.

Under current levels of development, including releasing all unallocated water reserves in the Burdekin Basin Water Plan, it is estimated the mean annual flow for the Upper Burdekin catchment would be 3,952 gigalitres, while the mean annual flow at the Burdekin River mouth is 5,909 gigalitres. Alongside mean annual flows, there are 15 other EFOs in the water plan that represent different low and medium to high flow targets at different locations in the basin.

Medium to high flows in the Burdekin Basin are important for providing connectivity of streams and rivers with floodplains in the Lower Burdekin and the internationally recognised wetlands at Cape Bowling Green. These flows deliver coarse sediments to the Great Barrier Reef lagoon, which are important for stabilising beaches at Cape Bowling Green. Medium and high flows are important for forming and maintaining rivers and streams and supplying water and sediment important for estuaries and fisheries. Changes to the medium to high flows associated with strategic water infrastructure reserves are predicted to further impact natural water quality and slightly reduce fisheries production linked to freshwater outflows. High and medium flows provide connectivity between fish populations, particularly in the Upper Burdekin where overtopping of the Charters Towers weir facilitates fish migration.

Assessment of scenarios

The following sections present the findings of three scenarios that have been assessed against the Wet Tropics and Burdekin Basin water plans:

- Bradfield 1942
- CSIRO contemporary Bradfield[6]
- The Queensland Great Dividing Range Scheme[7].

The scenarios estimate the volume of water that could be extracted under each proposal and the impacts of the extraction on existing water users and the environment. Table A2-4 provides an overview of the hydrological modelling scenarios that were developed for this assessment.

Bradfield 1942

Scenario

Bradfield's original proposal was to divert flows in the Upper Tully River into the Upper Herbert and then diverting the combined water from the Upper Tully and Herbert rivers near Herbert River Falls into the Upper Burdekin. A 122-metre high dam wall at Hells Gates would store flows from Upper Tully, Upper Herbert and Upper Burdekin, which would then be diverted to the Flinders River and onto the Thomson.

Bradfield's 1942 variation involved the construction of a much larger dam (152 metres high) at Hells Gates with water diverted to Webb's Lake at the head of Amelia Creek.

CSIRO's review of the Bradfield proposals noted that Bradfield's proposals did not account for the construction of Koombooloomba Dam on the Tully River. Using this existing infrastructure is considered the cheapest option for diverting water to the Herbert catchment.

For the purposes of analysing Bradfield's 1942 proposal, the following infrastructure scenario has been developed:

- **Diversion of water from the Tully River at Koombooloomba Dam:** Storage capacity of 205 gigalitres with a maximum daily diversion limit of 1.2 gigalitres per day (14 cubic metres per second). Water is released into Nitchaga Dam.
- **Nitchaga Dam:** New infrastructure on Nitchaga Creek, it has a storage capacity of 65 gigalitres with a daily diversion limit of 1.2 gigalitres per day (14 cubic metres per second). Water is released into Sunday Creek.
- **Diversion of water from Herbert River Falls Dam:** New infrastructure on Herbert River, it has a storage capacity of 1,485 gigalitres and a daily diversion limit of 5.6 gigalitres per day (65 cubic metres per second). Water is released into the Upper Burdekin River.
- **Diversion of water from Hells Gates Dam:** New infrastructure on the Upper Burdekin River, it has a storage capacity of 142,355 gigalitres and a daily diversion limit of 16.9 gigalitres per day (195 cubic metres per second).

The following additional assumptions were made:

- All unallocated water reserves in the Tully and Herbert river catchments and Burdekin Basin are set to zero.
- No downstream releases are made to meet downstream water users or environmental flow requirements.

As the purpose of this scenario is to understand the impacts of extracting water from the Tully, Herbert and Burdekin rivers, the destination of extracting water from Hells Gates Dam was not necessary to the analysis.

Table A2-4: Description of hydrological scenarios used for the Tully and Herbert river catchments and Burdekin Basin.

Scenario	Case name	Scenario description
Bradfield 1942	WT_TM08i_b1	Full use of entitlements, no unallocated water reserves and maximum diversion of 440 GL per year from Tully River
	WT_HB27_T0_b1	Full use of entitlements, no unallocated water reserves and maximum diversion of 2,040 GL per year from Herbert River at Herbert River Falls (including diversions from Tully River)
	BH020R-b1	Full use of entitlements, no unallocated water reserves and maximum diversion of 6,170 GL per year from Upper Burdekin at Hells Gates Dam (including diversions from Tully and Herbert Rivers)
CSIRO contemporary Bradfield scenario (CSIRO 2021)	WT_TM08i_b2	Full use of entitlements, no high flow unallocated water reserves and diversion of 180 GL per year from Tully River
	WT_HB27_T0_b2	Full use of entitlements, no high flow unallocated water reserves and maximum diversion of 2,040 GL per year from Herbert River at Herbert River Falls (including diversions from Tully River)
	BH020R-C_b2	Full use of entitlements, no unallocated water reserves in the Upper Burdekin and maximum diversion of 6,170 GL per year from Upper Burdekin at Hells Gates Dam (including diversions from Tully and Herbert Rivers)
The Queensland Great Dividing Range Scheme (2021)	WT_HB27_T0_b3	Full use of entitlements, no unallocated water reserves and maximum diversion of 6,000 GL per year from Herbert River at Herbert River Falls
	BH020R-C_b3	Full use of entitlements, no high flow unallocated water reserves in Herbert River and no unallocated water reserves in the Upper Burdekin. Maximum diversion of 14,000 GL per year from Upper Burdekin at Hells Gates Dam (including diversions from Herbert Rivers)

Water extractions

The Bradfield 1942 scenario estimated a mean annual diversion from Hells Gates Dam of 2,466 gigalitres (Table A2-5). CSIRO's assessment of the Bradfield proposals estimated that 2,272 gigalitres per year could be diverted from Hells Gates Dam. Both the estimate derived by CSIRO and from this assessment are less than half of Bradfield's estimate of 5,362 gigalitres per year.

Table A2-5: Mean annual diversion from Tully, Herbert and Upper Burdekin rivers for the Bradfield 1942 scenario.

Location	Storages (GL)	IQQM Scenario	Bradfield 1942 scenario	
			Diversion capacity (GL/a)	MAD (GL/a)
Tully River	Koombooloomba (205) Nitchaga Creek Dam (65)	WT_TM08i_B1	441	360
Herbert River	Herbert River Falls (1,484)	HB27_T0_B1	2,050	1,294
Upper Burdekin	Hells Gates Dam (142,355)	BH020R_B1	6,149	2,466

Scenario 1: Bradfield Scheme 1942 concept

Upper Burdekin River (Burdekin Basin)

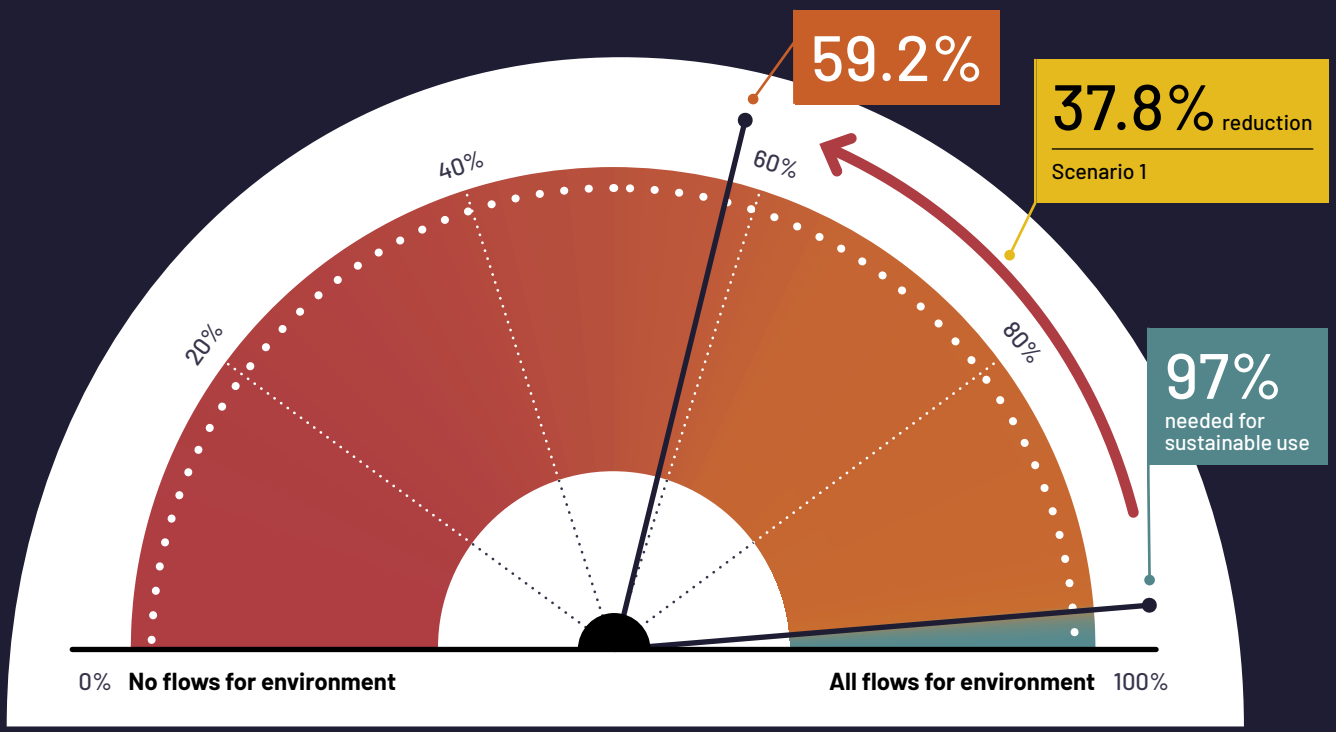
Case reference BH020R_b1

Total unsupplemented extraction		Water extracted for Bradfield Scheme at Hells Gates Dam. Includes diversion from Tully and Herbert rivers	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
73	57	6,149	2,466

Average annual flows upstream of Burdekin Falls Dam (GL/a) (59.2% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (37.8% of pre-development)	Average annual flows required for environment at end of system (97% of pre-development)	Average annual flows for pre-development scenario (100%)
2,388	1,526	**3,914**	4,035

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Scenario 1: Bradfield Scheme 1942 concept

Lower Burdekin and Haughton rivers (Burdekin Basin)

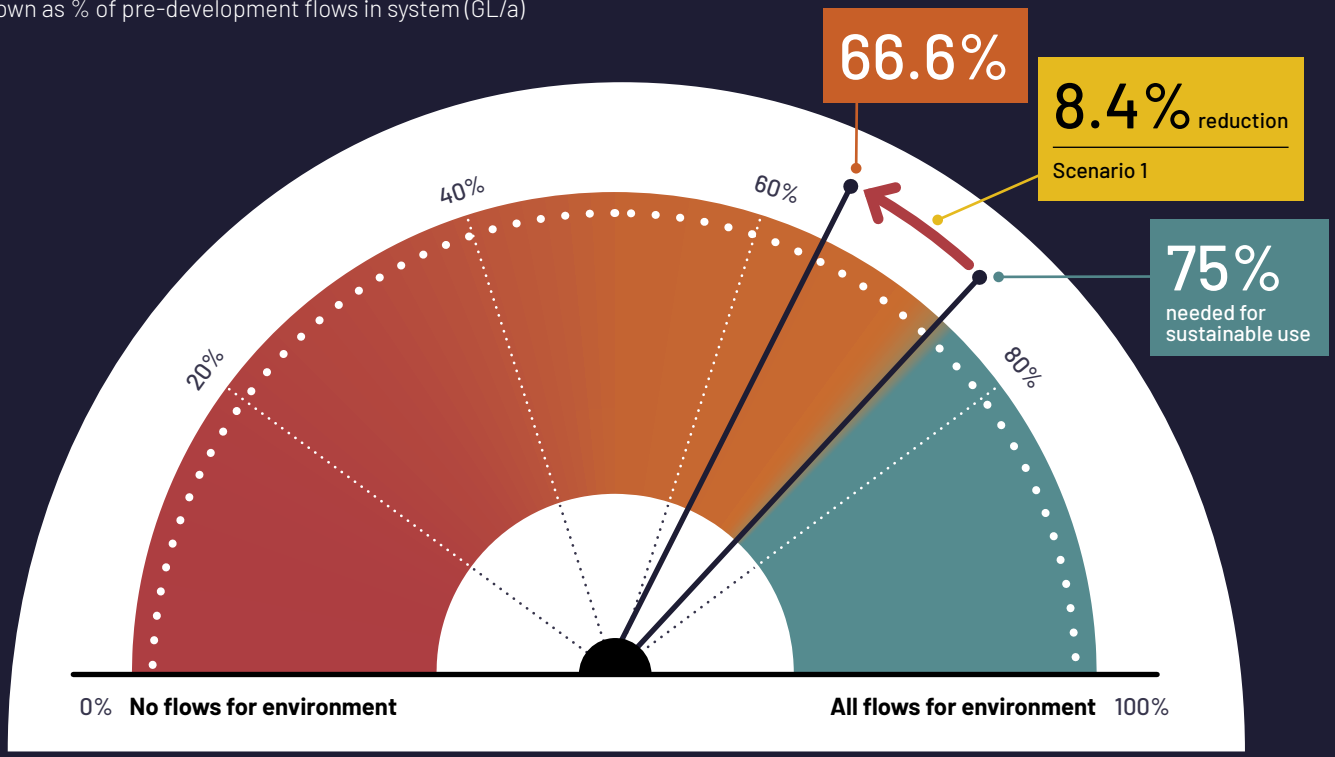
Case reference BH020R_b1

Total unsupplemented extraction		Total supplemented extraction in Burdekin–Haughton water supply scheme	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
59	46	1,135	1,105

Average annual flows at end of Burdekin system (GL/a) (66.6% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (8.4% of pre-development)	Average annual flows for environment requirement at end of Burdekin system (75% of pre-development)	Average annual flows for pre-development scenario (100%)
5,246	664	**5,910**	7,881

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Scenario 1: Bradfield Scheme 1942 concept

Tully River (Wet Tropics)

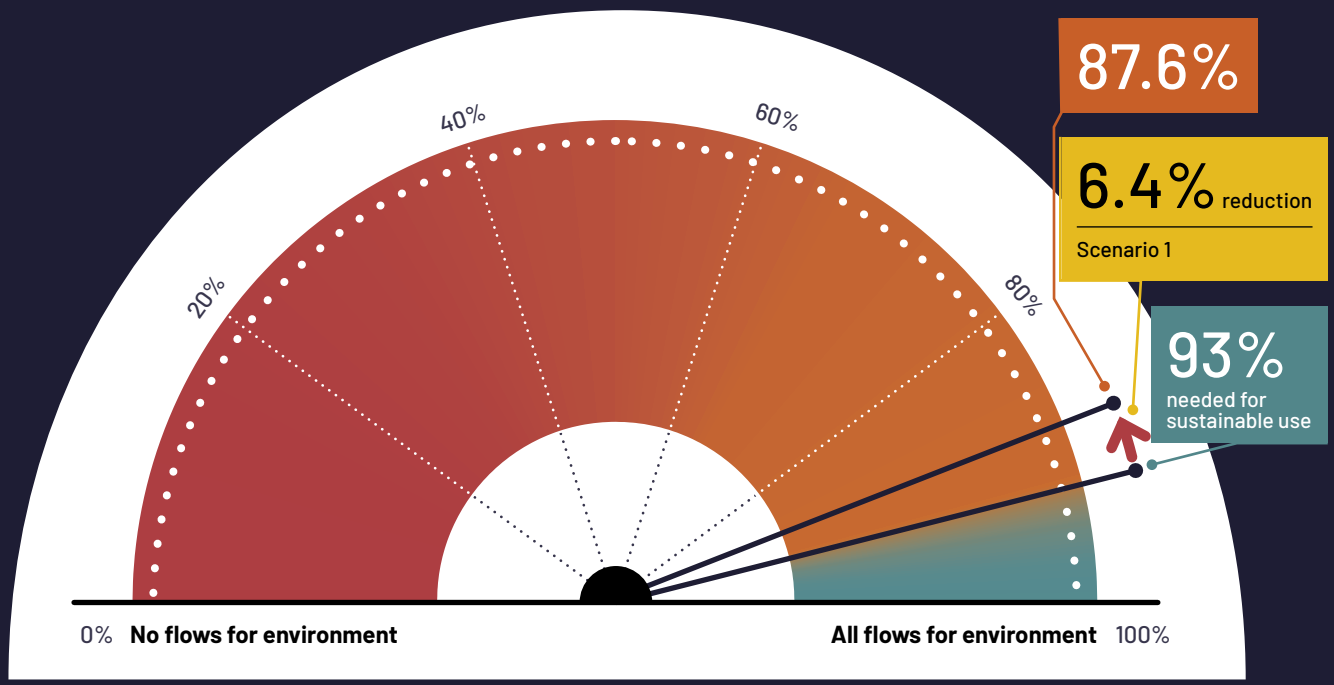
Case reference WT_TM08i_b1

Total unsupplemented extraction		Water extracted for Bradfield Scheme at Koombooloomba and Nitchaga Creek Dam	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
64	63	441	360

Average annual flows at end of system (GL/a) (87.6% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (6.4% of pre-development	Average annual flows required for environment at end of system (93% of pre-development)	Average annual flows for the pre-development scenario (100%)
2,620	191	**2,811**	2,991

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Scenario 1: Bradfield Scheme 1942 concept

Herbert River (Wet Tropics)

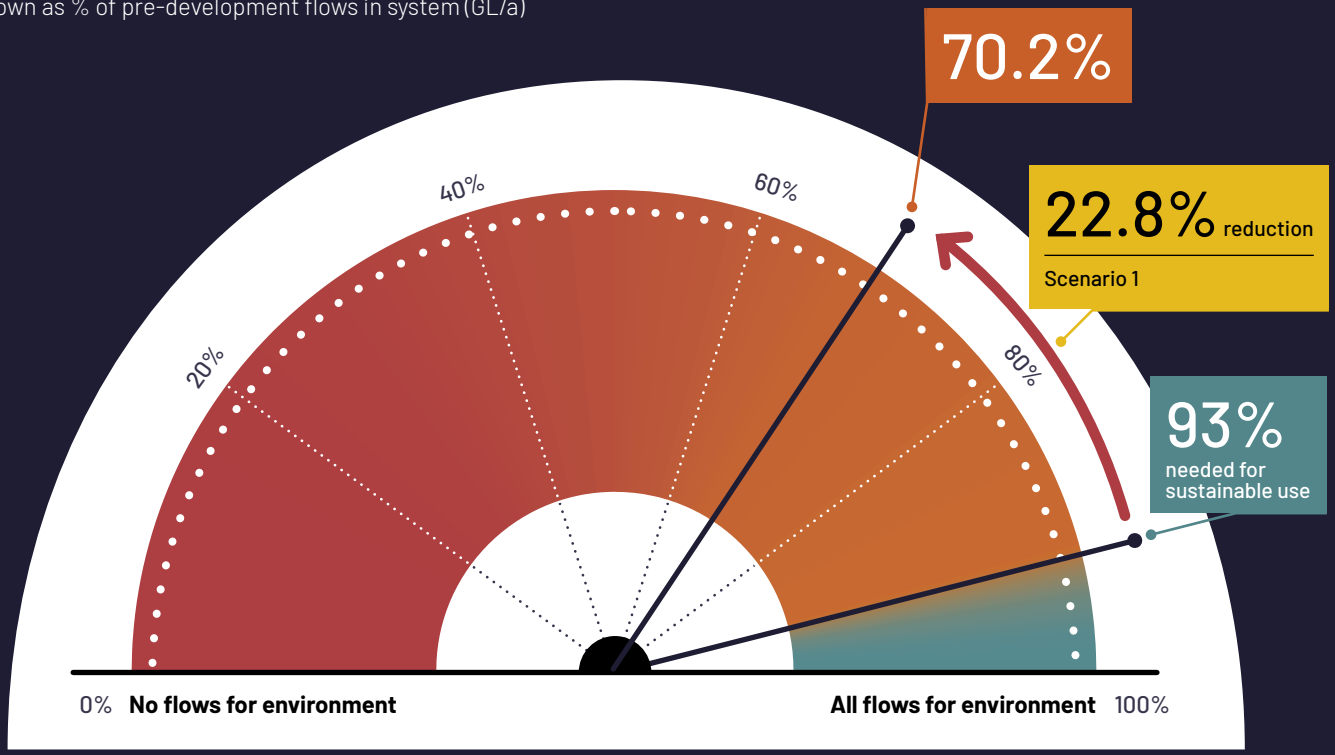
Case reference WT_HB27_T0_b1

Total unsupplemented extraction		Water extracted from Bradfield Scheme at Herbert River Falls Dam, includes diversion from Tully River	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
74	59	2,050	1,294

Average annual flows at end of system (GL/a) (70.2% of pre-development	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (22.8% of pre-development)	Average annual flows required for environment at end of system (93% of pre-development)	Average annual flows for the pre-development scenario (100%)
2,373	771	**3,145**	3,381

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



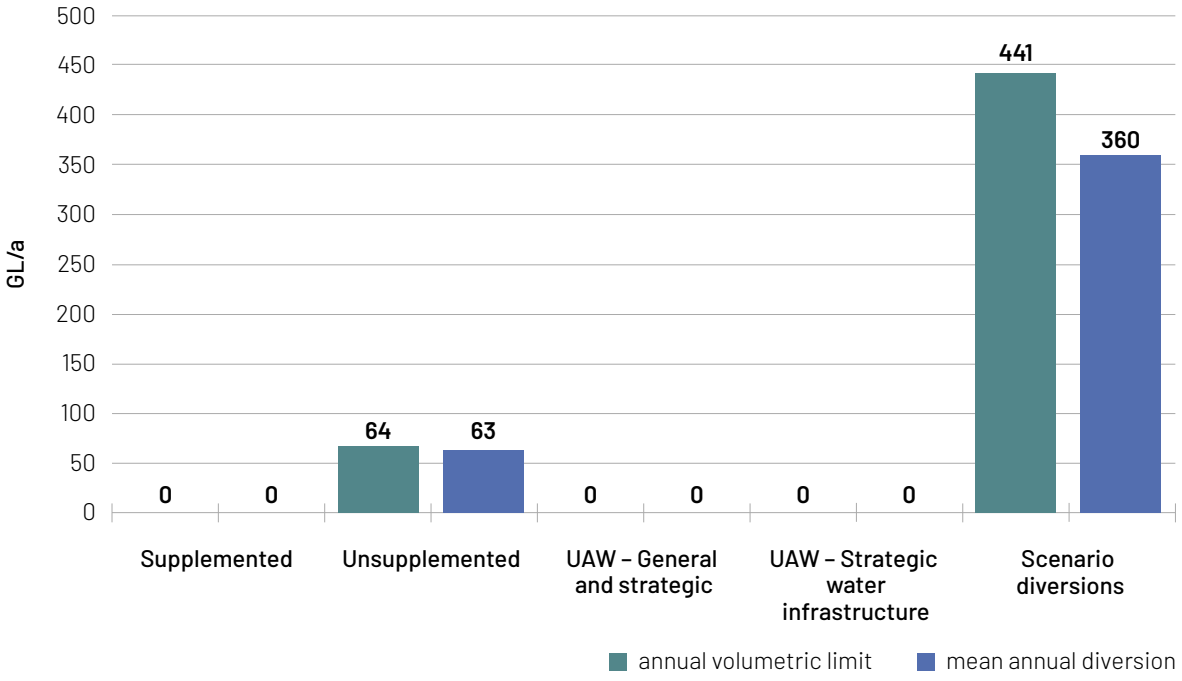


Figure A2-7: Diversions in the Tully River for Bradfield 1942 scenario (scenario WT_TM08i_b1).

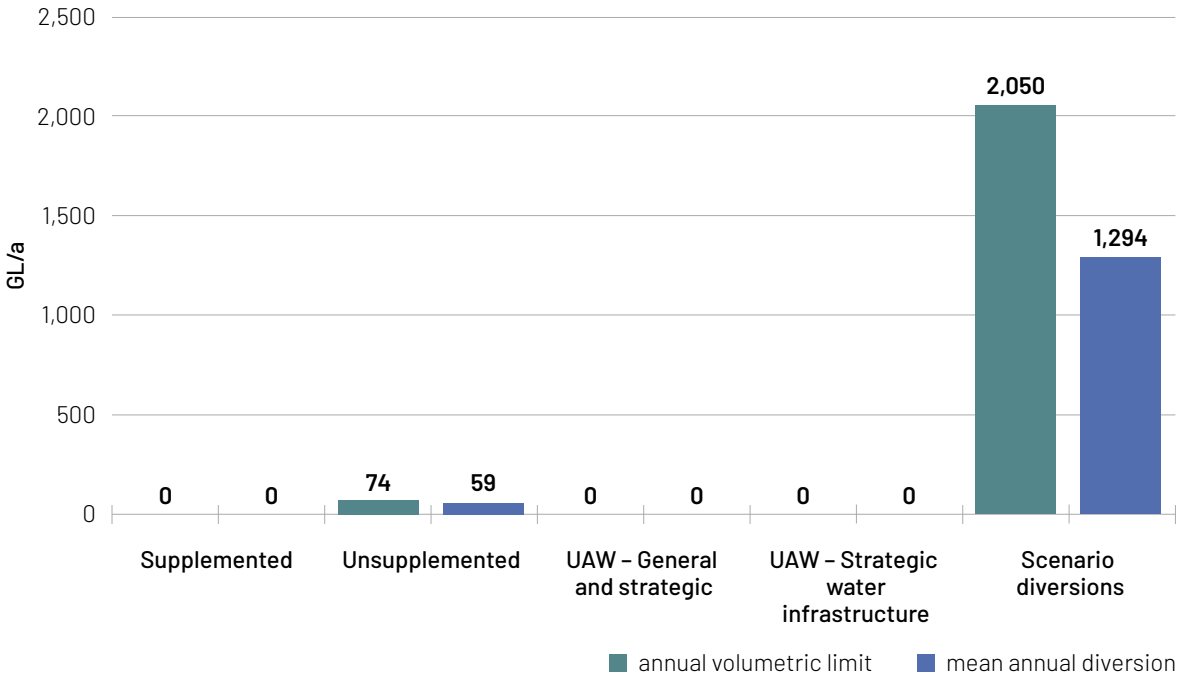


Figure A2-8: Diversions in the Herbert River for Bradfield 1942 scenario (scenario WT_HB27_T0_b1).

* includes diversions from Tully River.

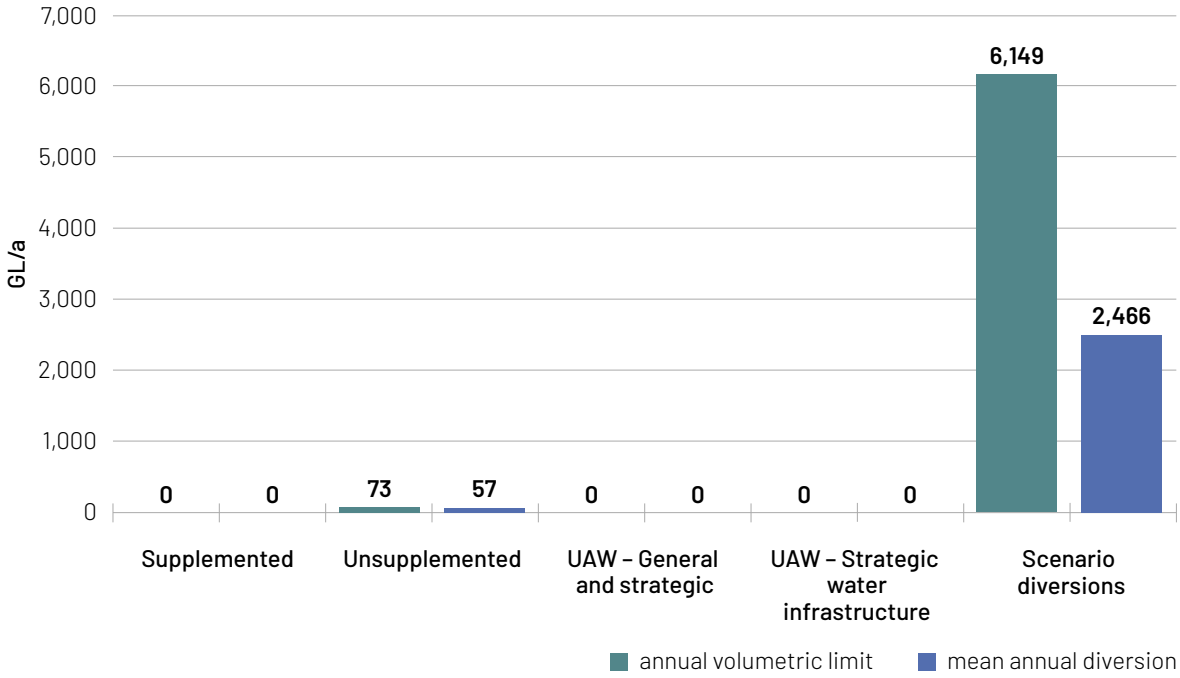


Figure A2-9: Diversions in the Upper Burdekin for Bradfield 1942 scenario (scenario BH020R_B1).

* includes diversions from Tully and Herbert rivers.

Impacts on existing water users

For the Tully and Herbert River catchments, the Bradfield 1942 scenario had a negative impact on unsupplemented water users. However, unsupplemented water users in the Upper Burdekin collectively could, on average, access six gigalitres less water annually. This impact was as much as 25 per cent of mean annual diversion, depending on the location of the water users in the catchment.

The water security of supplemented water users in the Burdekin–Haughton Water Supply Scheme was also affected. The Bradfield scheme reduced the number of years that supplemented water users accessed their full entitlement from 90 per cent to 83 per cent. This is below the 90 per cent benchmark set in the Burdekin Basin Water Plan for this water allocation security objective.

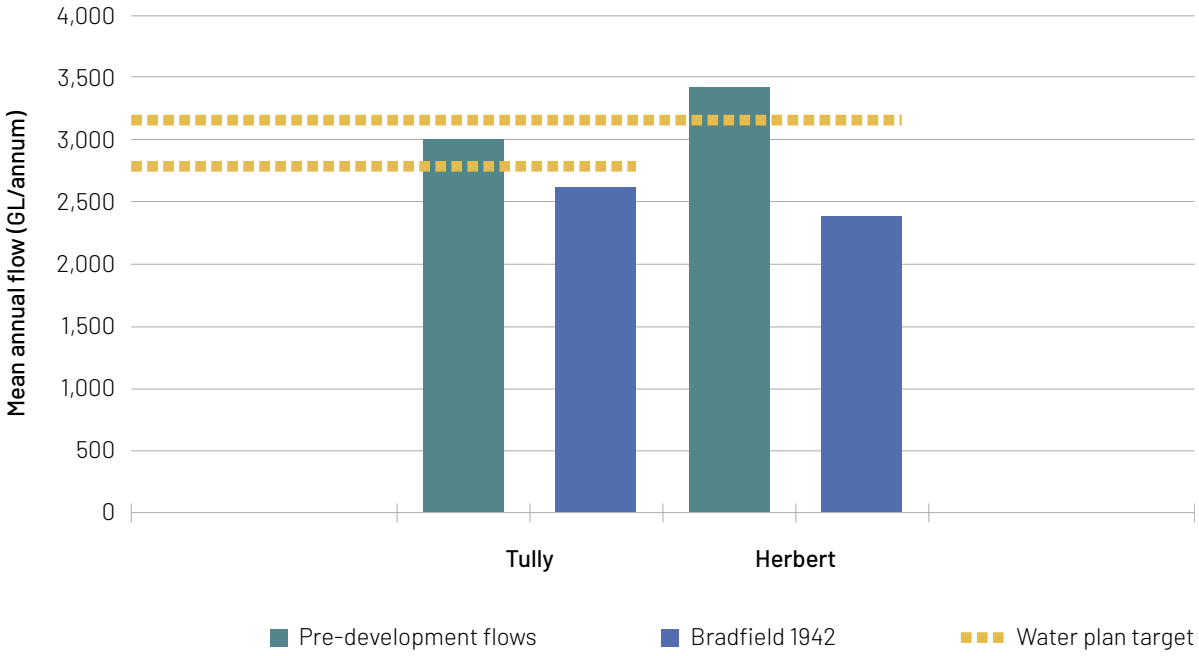


Figure A2-10: Mean annual flows at the end of the Tully and Herbert rivers for Bradfield 1942 scenario.

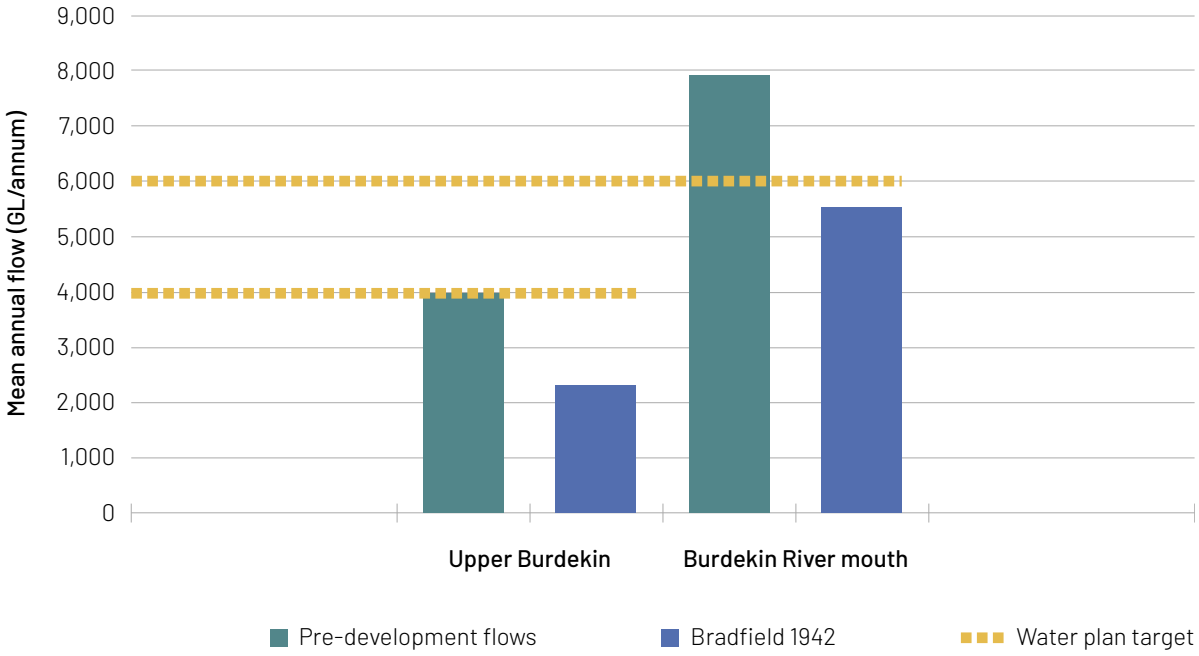


Figure A2-11: Mean annual flows for the Upper Burdekin and Burdekin River mouth for Bradfield 1942 scenario.

Impacts on environmental flows

The scenario affected the mean annual flow for each sub-catchment. In the Tully River, mean annual flow at the end of the system was reduced to 87.6 per cent of pre-development flows. This is 6.4 per cent below the target set in the Wet Tropics Water Plan and is 191 gigalitres less than the plan's requirements (Figure A2-10). The scenario failed three of four EFOs specified in the plan.

In the Herbert River, the mean annual flow at the end of the system was 70.2 per cent of pre-development flows. This is 22.8 per cent below the target in the Wet Tropics Water Plan and is 771 gigalitres less than the plan requirements. The scenario failed all four EFOs specified in the plan.

In the Upper Burdekin catchment, the mean annual flow at Burdekin Falls Dam was 59 per cent. This is 38 per cent below the target in the Burdekin Basin Water Plan and 1,526 gigalitres less than the plan requirements (Figure A2-11). The scenario failed five out of nine low flow objectives and all six medium- to high-flow objectives specified in the Burdekin plan.

The mean annual flow at the mouth of the Burdekin River was 67 per cent of pre-development flows. This is eight per cent below the target in the Burdekin Basin Water Plan and is 664 gigalitres less than the plan requirements. The scenario failed five of nine low flow objectives and four out of six medium- to high-flow objectives specified in the plan.

Conclusion

Analysis of the Bradfield 1942 scenario found that if water was diverted from the Tully, Herbert and Upper Burdekin catchments, it would amount to less than half of the volume estimated by Bradfield in 1942 with a mean annual diversion of 2,466 gigalitres from Hells Gates Dam.

Diverting this water would affect unsupplemented water allocation in the Upper Burdekin and medium-priority water allocation in the Burdekin–Haughton Water Supply Scheme, collectively reducing existing water users' annual access to water by 25 gigalitres. These results fail the Burdekin Basin Water Plan WASOs established to protect existing water allocation holders' access to water. A decrease in access could significantly undermine confidence in water supply and affect business decisions.

Environmental flows in each of the catchments would also be impacted. Collectively, the mean annual flows at the end of system for the Tully and Herbert river catchments and the Upper Burdekin catchment would be reduced by 2,452 gigalitres per annum. These impacts would affect all parts of the flow regime, from low flows to medium and high flows. Additional assessments and detailed scientific investigation would need to be undertaken to understand the full extent of the impacts of these reduced flows to the environment and the ecosystems that rely on them.

Finally, in testing the diversion volumes proposed by Bradfield, all of the unallocated water reserves in the Tully and Herbert River catchments and the Burdekin Basin disappear. This extinguishes any opportunities to develop water resources to meet future demands in these catchments.

CSIRO Contemporary Bradfield Scheme Scenario (2021)

Scenario

In this scenario, CSIRO has adapted Bradfield's 1938 and 1942 proposals to reflect a more modern understanding of water availability and water resource management in the Tully, Herbert and Burdekin rivers. CSIRO has undertaken its own assessment of streamflows and water availability in the catchments' modern catchment runoff modelling calibrated against observed streamflows. It considered the location of existing infrastructure, existing irrigated agriculture and, to a limited extent, the requirements of the Wet Tropics and Burdekin Basin water plans.

For the purposes of analysing CSIRO's work, the following scenario has been developed:

- **Koombooloomba/Tully Falls Weir:** Storage capacity of 205 gigalitres with a maximum daily diversion limit of 0.5 gigalitres per day (5.7 cubic metres per second) from Tully Falls Weir. Releases are made from Tully Falls Weir to meet downstream water users' requirements.
- **Herbert River Falls Dam:** New infrastructure on Herbert River, it has a storage capacity of 1,485 gigalitres and a daily diversion limit of 5.6 gigalitres per day (65 cubic metres per second). No releases are made to meet downstream water users' requirements, and no releases are made to meet environmental flow requirements. Water is released into the Upper Burdekin River.
- **Hells Gates Dam:** New infrastructure on the Upper Burdekin River, it has a storage capacity of 2,280 gigalitres and a daily diversion limit of 8.4 gigalitres per day (97 cubic metres per second).

In line with the CSIRO contemporary Bradfield scenario, the following additional assumptions were made:

- **Unallocated water reserves**
  - General and high-flow unallocated water reserves in the Tully and Herbert are set to zero.
  - Unallocated reserves for strategic and Indigenous purposes in the Tully and Herbert are maintained.
  - General and strategic unallocated water reserves in the Upper Burdekin are set to zero.
  - Unallocated water reserves in sub-catchments other than the Upper Burdekin are maintained.
- No releases are made to meet downstream water users' requirements from Herbert River Falls Dam or Hells Gates Dam.
- No releases are made to meet environmental flow requirements.

As the interest of this scenario was to understand the impacts of extracting water from the Tully, Herbert and Burdekin rivers, the destination of extracting water from Hells Gates Dam was not necessary to the analysis.

Scenario 2: Contemporary Bradfield concept (CSIRO 2021)

Tully River (Wet Tropics)

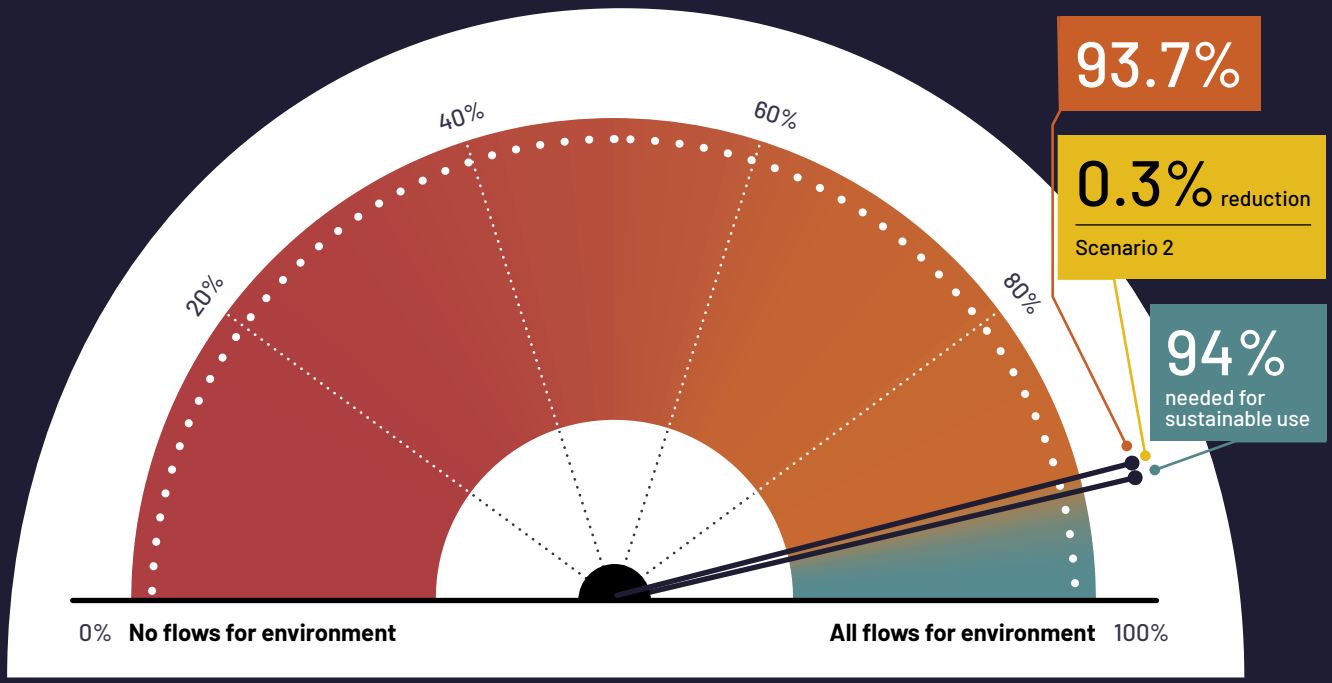
Case reference WT_TM08i_b2

Total unsupplemented extraction		Water extracted for Bradfield Scheme at Koombooloomba and Nitchaga Creek Dam	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
64	63.5	180	156

Average annual flows at end of system (GL/a) (93.7% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (0.3% of pre-development)	Average annual flows required for requirement at end of system (94% of pre-development)	Average annual flows for pre-development scenario (100%)
2,802	9	**2,811**	2,991

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Scenario 2: Contemporary Bradfield concept (CSIRO 2021)

Herbert River (Wet Tropics)

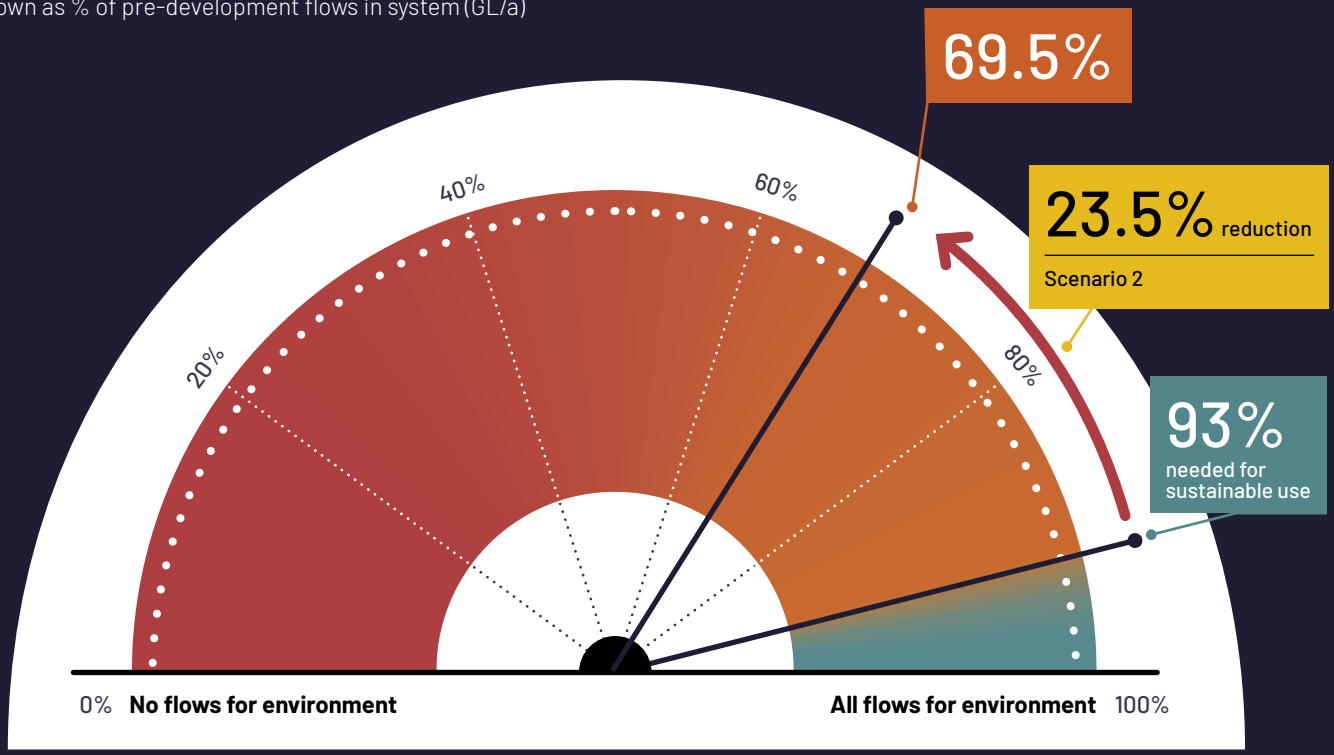
Case reference WT_HB27_T0_b2

Total unsupplemented extraction		Water extracted from Bradfield Scheme at Herbert River Falls Dam, includes diversion from Tully River	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
74	59	2,050	1,106

Average annual flows at end of system (GL/a) (69.5% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (23.5% of pre-development)	Average annual flows required for environment at end of system (93% of pre-development)	Average annual flows for pre-development scenario (100%)
2,350	795	**3,145**	3,381

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Scenario 2: Contemporary Bradfield concept (CSIRO 2021)

Upper Burdekin River (Burdekin Basin)

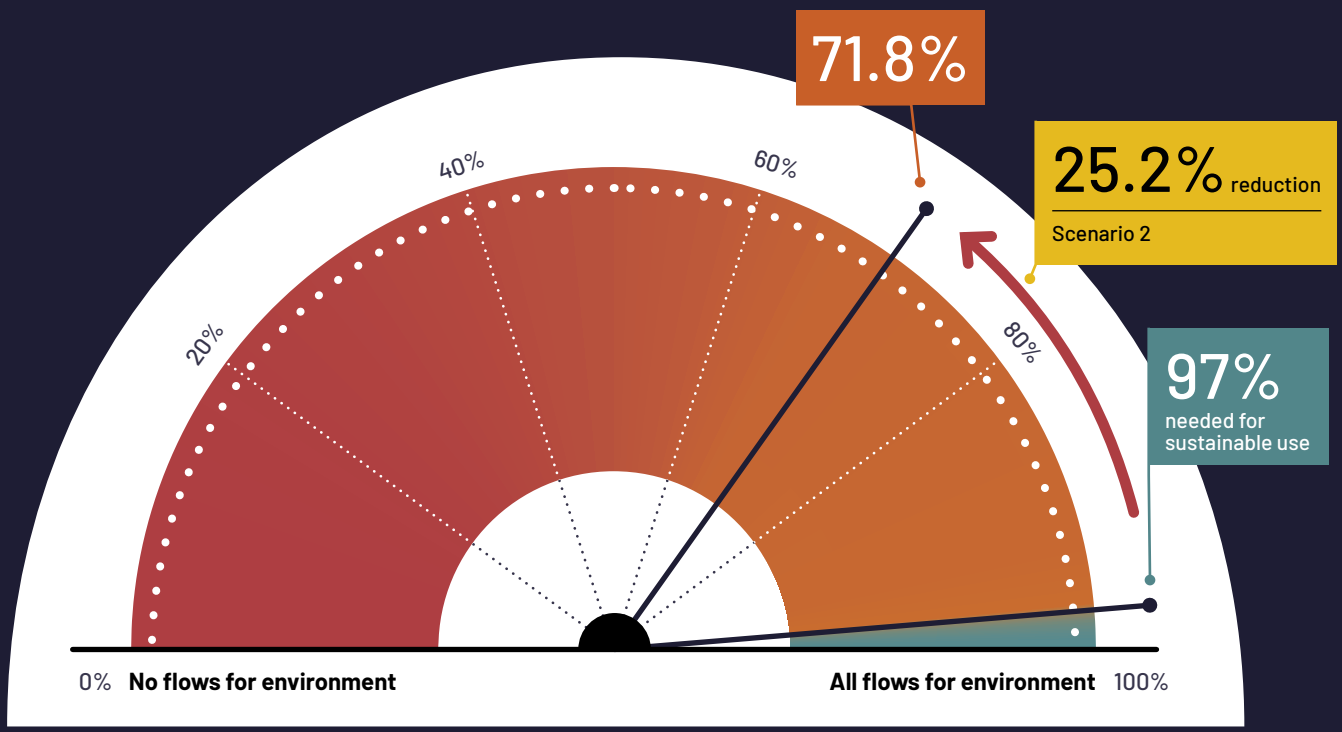
Case reference BH020R_b2

Total unsupplemented extraction		Water extracted for Bradfield Scheme at Hells Gates Dam, includes diversion from Tully and Herbert rivers	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
73	57	3,036	1,792

Average annual flows at Burdekin Falls Dam (GL/a) (71.8% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (25.2% of pre-development)	Average annual flows required for environment at end of system (97% of pre-development)	Average annual flows for pre-development scenario (100%)
2,897	1,017	**3,914**	4,035

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Scenario 2: Contemporary Bradfield concept (CSIRO 2021)

Lower Burdekin and Haughton rivers (Burdekin Basin)

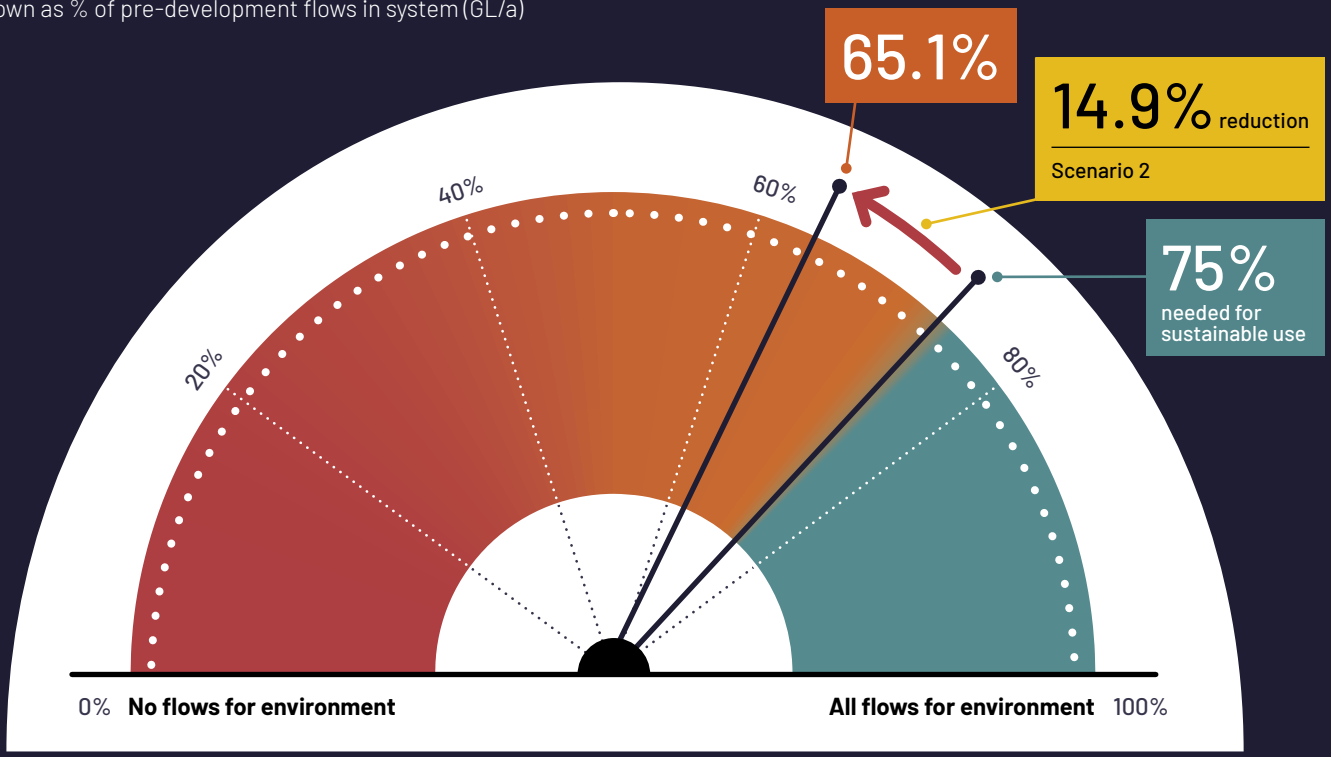
Case reference BH020R_b2

Total unsupplemented extraction		Total supplemented extraction in Burdekin–Haughton water supply scheme	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
59	46	1,135	1,104

Average annual flows at end of Burdekin system (GL/a) (65.1 % of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (14.9% of pre-development)	Average annual flows required for environment at end of Burdekin system (75% of pre-development)	Average annual flows for pre-development scenario (100%)
5,122	787	**5,910**	7,881

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Water extractions

This analysis of the CSIRO contemporary Bradfield scenario estimated a mean annual diversion from Hells Gates Dam of 1,792 gigalitres (Table A2-6). CSIRO's own assessment estimated that 1,881, gigalitres per year could be diverted from Hells Gates Dam.

The scenario also has a mean annual diversion 265 gigalitres per year less than the Bradfield 1942 scenario. The main difference between the Bradfield 1942 and the CSIRO contemporary Bradfield scenario is that the annual volume that can be diverted from the Tully River was limited to 180 gigalitres per year in the CSIRO scenario. This resulted in a mean annual diversion from the Tully River of 155 gigalitres per year for the CSIRO contemporary Bradfield scenario compared to a mean annual diversion of 265 gigalitres per year in the Bradfield 1942 scenario.

Impacts on existing water users

In terms of impacts on existing water users, the CSIRO contemporary Bradfield scenario had similar results to the Bradfield 1942 scenario. For the Tully and Herbert River catchments, the CSIRO scenario did not have a negative impact on unsupplemented water users. However, unsupplemented water users in the Upper Burdekin sub-catchment collectively, on average, accessed five gigalitres less water annually. This impact was as much as 25 per cent of mean annual diversion of a water allocation, depending on the location of the water users in the catchment.

The water security of supplemented water users in the Burdekin–Haughton Water Supply Scheme was also affected. The CSIRO contemporary Bradfield scenario reduced the number of years that medium-priority supplemented water users had access to their full entitlement from 90 per cent to 82 per cent of years. Again, this is below the 90 per cent water security benchmark set in the Burdekin Basin Water Plan.

Impacts on environmental flows

The scenario demonstrated an impact on environmental flows for each sub-catchment. In the Tully River, the mean annual flow at the end of the system was reduced to 93.7 per cent of pre-development flows. This is 0.3 per cent below the target set in the Wet Tropics Water Plan and nine gigalitres less than the plan requirements (Figure A2-15). The scenario failed one of four EFOs specified in the Wet Tropics Water Plan at the end of the system.

In the Herbert River, the impact on environmental flows was more significant. For this scenario, mean annual flow at the end of the system was 69.5 per cent of pre-development flows. This is 23.5 per cent below the target in the Wet Tropics Water Plan and is 795 gigalitres less than the plan requirements. The scenario failed all four of the EFOs specified in the plan.

In the Upper Burdekin catchment, the mean annual flow at Burdekin Falls Dam was 72 per cent. This is 25 per cent below the target in the Burdekin Basin Water Plan and 1,017 gigalitres per year less than the plan requirements (Figure A2-16). The scenario also failed five out of the nine low-flow objectives and five out of the six high-flow objectives specified in the plan for the Upper Burdekin sub-catchment.

At the mouth of the Burdekin River, the CSIRO contemporary Bradfield scenario impacted all aspects of the flow regime. The mean annual flow was reduced to 65 per cent of pre-development flows. This is 10 per cent below the target in the Burdekin Basin water plan and 787 gigalitres less than the plan requirements. The CSIRO contemporary Bradfield scenario also failed 14 of the 15 EFOs at the end of the system.

Table A2-6: Mean annual diversion from Tully, Herbert and Upper Burdekin rivers for the CSIRO contemporary Bradfield scenario.

Location	Storages (GL)	IQQM scenario	CSIRO contemporary Bradfield scenario	
			Diversion capacity (GL/a)	MAD (GL/a)
Tully River	Koombooloomba (205)	WT_TM08i_B2	180	155
Herbert River	Herbert River Falls (1,484)	HB27_T0_B2	2,050	1,106
Upper Burdekin	Hells Gates Dam (2,280)	BH020R_B2	3,036	1,792

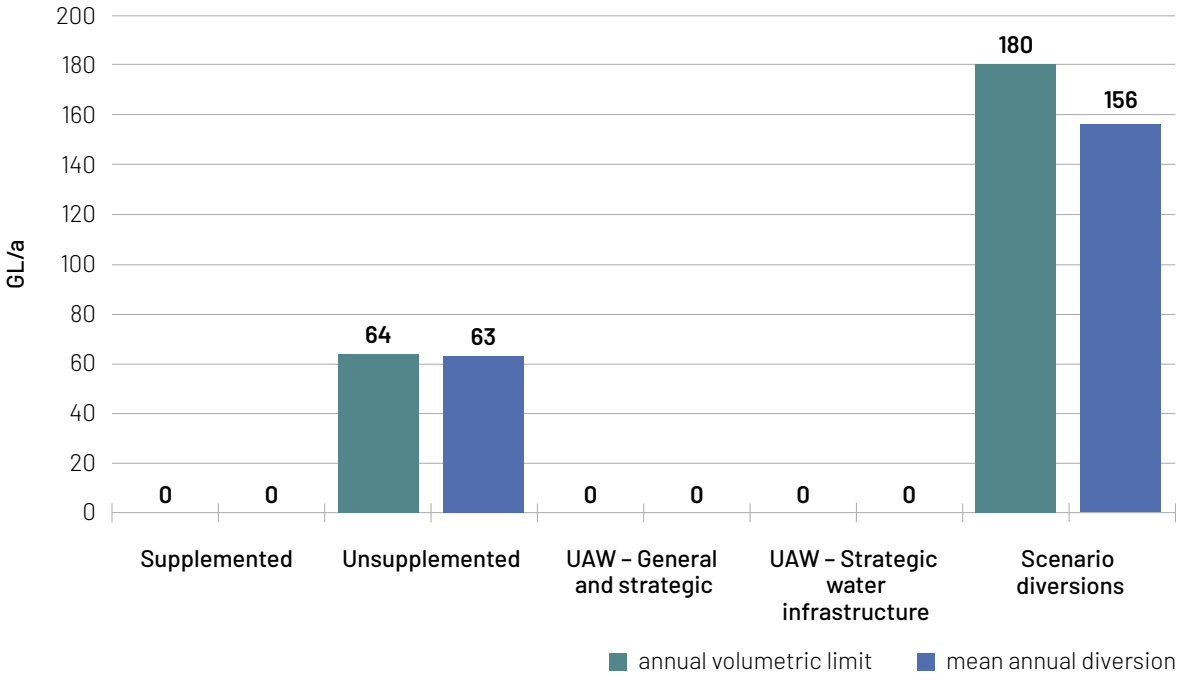


Figure A2-12: Diversions in the Tully River for CSIRO contemporary Bradfield scenario (scenario WT_TM08i_b2).

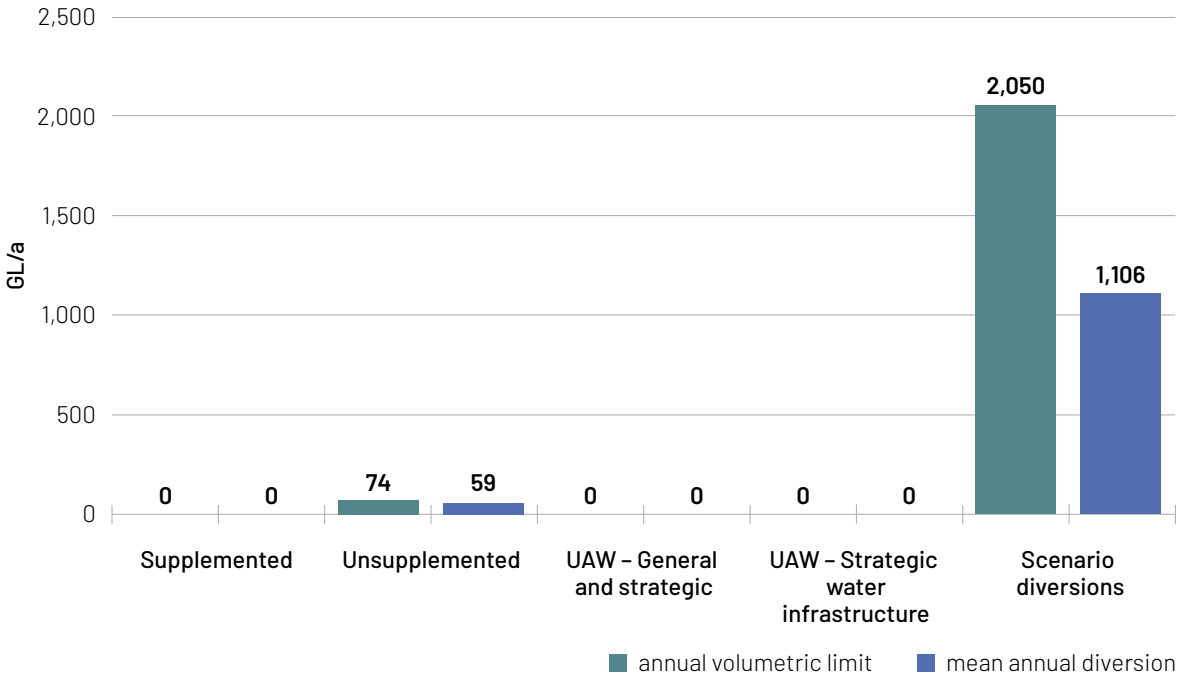


Figure A2-13: Diversions in the Herbert River for CSIRO contemporary Bradfield scenario (scenario WT_HB27_T0_2).

* includes diversions from Tully River.

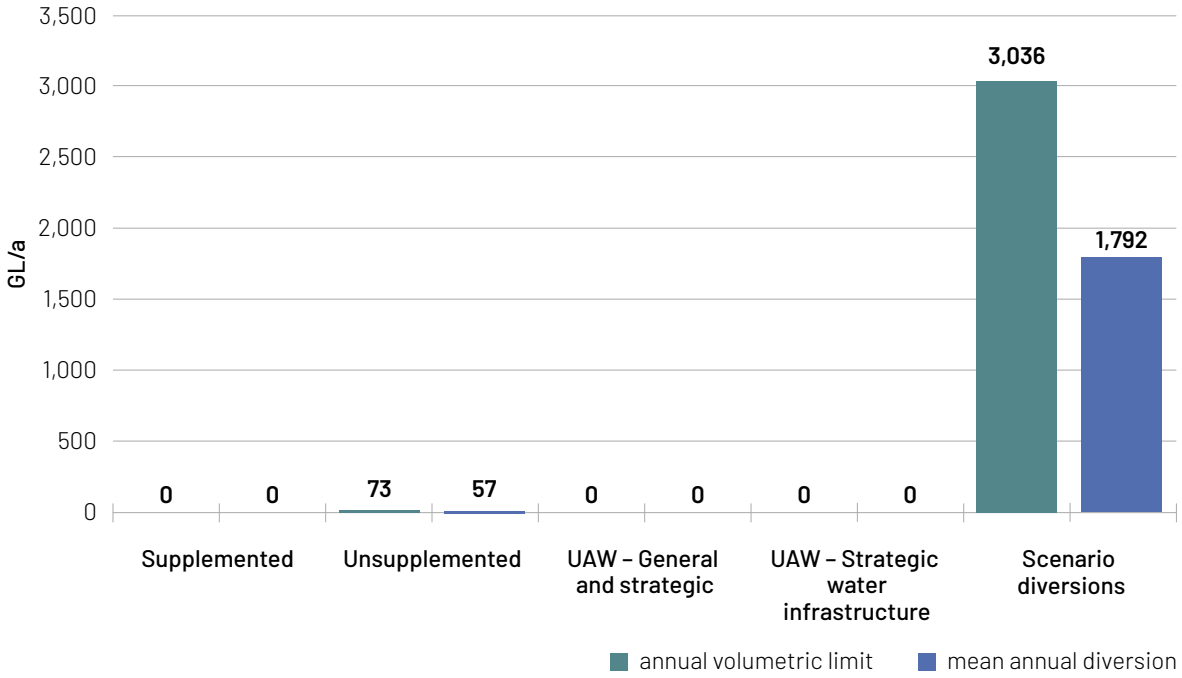


Figure A2-14: Diversions in the Upper Burdekin for contemporary Bradfield scenario (scenario BH020R-C b2).

* includes diversions from Tully and Herbert rivers.

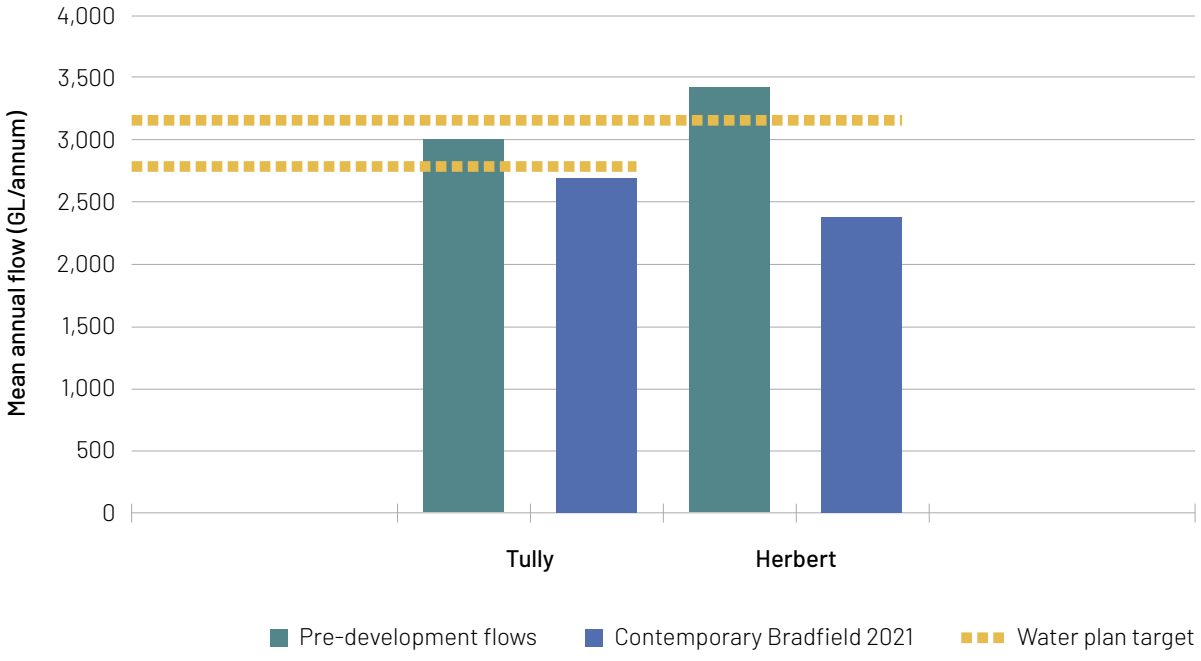


Figure A2-15: Mean annual flows at the end of the Tully and Herbert rivers for CSIRO contemporary Bradfield scenario.

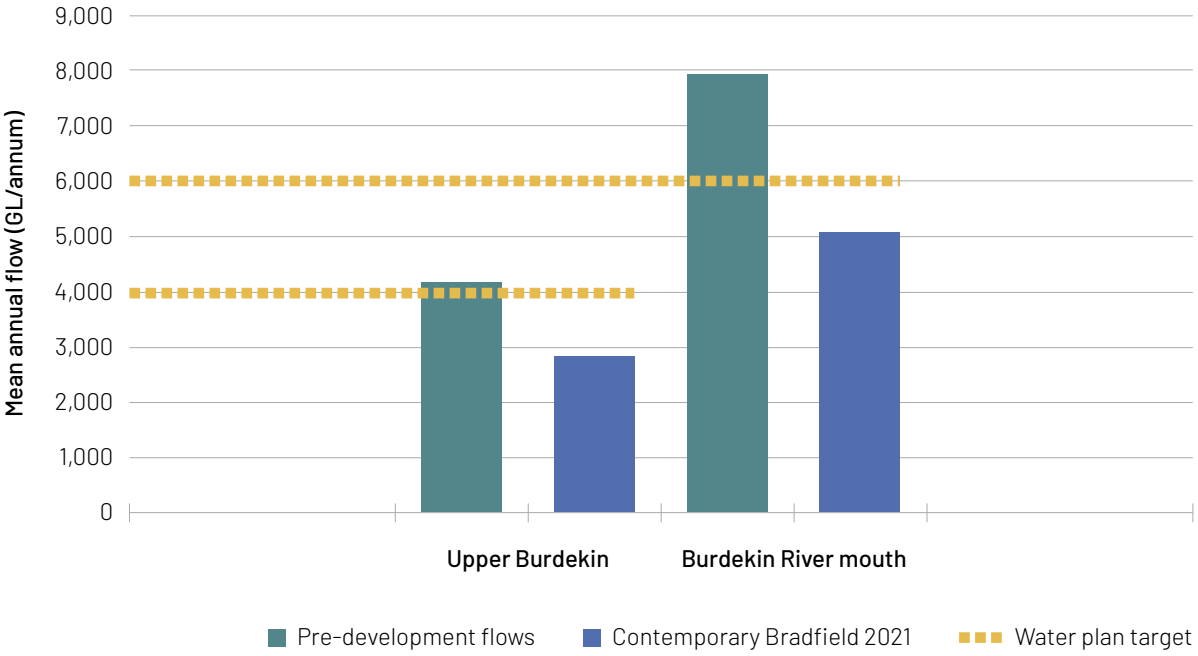


Figure A2-16: Mean annual flows for the Upper Burdekin and Burdekin River mouth rivers for the CSIRO contemporary Bradfield scenario.

Conclusions

While the CSIRO contemporary Bradfield scenario is an attempt to put forward a proposal that would fit within the Wet Tropics and Burdekin Basin water plans, this assessment identifies that the proposal would have significant impacts, particularly on water users in the Burdekin–Haughton Water Supply Scheme and environmental flows in the Herbert and Burdekin rivers.

This assessment found that the mean annual diversion from Hells Gates Dam for the contemporary Bradfield scenario would be 1,792 gigalitres, which is 89 gigalitres less than the mean annual diversion found in CSIRO's own assessment of this scenario.

The efforts to meet plan requirements was evident in the Tully River, where the annual volumetric limit was restricted to 180 gigalitres in line with the high-flow unallocated water reserves in the Wet Tropics Water Plan. This scenario failed the EFO for the mean annual flow in the Tully River by only 0.3 per cent, or nine gigalitres per year.

In the Herbert and Burdekin rivers, the environmental impacts were more notable, with the mean annual flow at the mouth of the Herbert River failing the Wet Tropics Water Plan objective by 23.5 per cent, which resulted in 1,017 gigalitres per year less water than the plan requirements.

For the Burdekin River, the contemporary Bradfield scenario failed 14 of the 15 Burdekin Basin Water Plan's EFOs at the end of the system. The mean annual flow at the mouth of the Burdekin River is 65 per cent of pre-development flows: 10 per cent below the requirement of 75 per cent set in the Burdekin Basin Water Plan. CSIRO estimated the scenario would reduce mean annual flow at the Burdekin River mouth by approximately 18 per cent. Additional assessments and detailed scientific investigation would be needed to understand the full extent of the impacts of these reduced flows to the environment and the ecosystems that rely on them.

This assessment of the contemporary Bradfield scenario demonstrated that it is not possible to divert large volumes of water from the Upper Burdekin and proceed with proposed water infrastructure projects in other parts of the basin without significantly affecting environmental flows. Water resources in the Burdekin Basin are already well developed. Additional extraction over and above the volumes provided in the water plan are likely to threaten the long-term sustainability of the system.

The Queensland Great Dividing Range Scheme (2021)

Scenario

The Queensland Great Dividing Range Scheme proposes diverting water from the Herbert River to Hells Gates Dam in the Upper Burdekin River to provide 14,000 gigalitres of water inland for irrigated agriculture along the Flinders and Thomson rivers. It would provide an additional 50,000 hectares of irrigated agriculture in the Upper Burdekin as well as water security for Townsville and Charters Towers and a hydro-power station that would produce 2,000 megawatts of power.

There is limited detail about exactly how this proposal would extract water from the Herbert River and deliver the water to the Upper Burdekin. Estimation of streamflows and potential extraction is based on rainfall runoff estimates using Bureau of Meteorology rainfall data. These estimates have not been compared to observed streamflows.

For the purposes of analysing the scheme, the following infrastructure scenario has been developed:

- **Herbert River Falls Dam:** New infrastructure on the Herbert River based on the CSIRO 2021 proposal, with a storage capacity of 10,800 gigalitres and an annual diversion limit of 6,000 gigalitres (16.4 gigalitres per day). Water is released into the Upper Burdekin River.
- **Hells Gates Dam:** New infrastructure on the Upper Burdekin River, it has storage capacity of 32,000 gigalitres and an annual diversion limit of 14,000 gigalitres per day (38.4 gigalitres per day).

Additional assumptions include:

- **Unallocated water reserves:** All unallocated water in the Herbert River catchments and Burdekin Basin are set to zero.
- No releases are made to meet downstream water users or environmental flow requirements.

Water extractions

This analysis of the Great Dividing Range scenario estimated a mean annual diversion from Hells Gates Dam of 2,495 gigalitres (Table A2-6). This is 11,505 gigalitres less than the proposal's estimated mean annual diversion of 14,000 gigalitres.

Table A2-6: Mean annual diversion from Tully, Herbert and Upper Burdekin rivers for The Queensland Great Dividing Range scenario.

Location	Storages (GL)	IQQM Scenario	The Queensland Great Dividing Range Scheme	
			Diversion capacity (GL/a)	MAD (GL/a)
Herbert River	Herbert River Falls Dam (10,800)	HB27_T0_B2	6,000	1,075
Upper Burdekin	Hells Gates Dam (32,000)	BH020R_B2	14,000	2,495

Impacts on existing water users

The Great Dividing Range scenario affected unsupplemented water users.

Unsupplemented water users in the Upper Burdekin collectively, on average, had access to six gigalitres less water annually. This impact was as much as 25 per cent of mean annual diversion, depending on the location of the water users in the catchment.

The water security of supplemented water users in the Burdekin–Haughton Water Supply Scheme was also affected. The scenario reduced the years that supplemented water users had access to their full entitlement to 82 per cent. This is eight per cent below the 90 per cent water security benchmark set in the Burdekin Basin Water Plan.

Scenario 3: Great Dividing Range concept 2021

Herbert River (Wet Tropics)

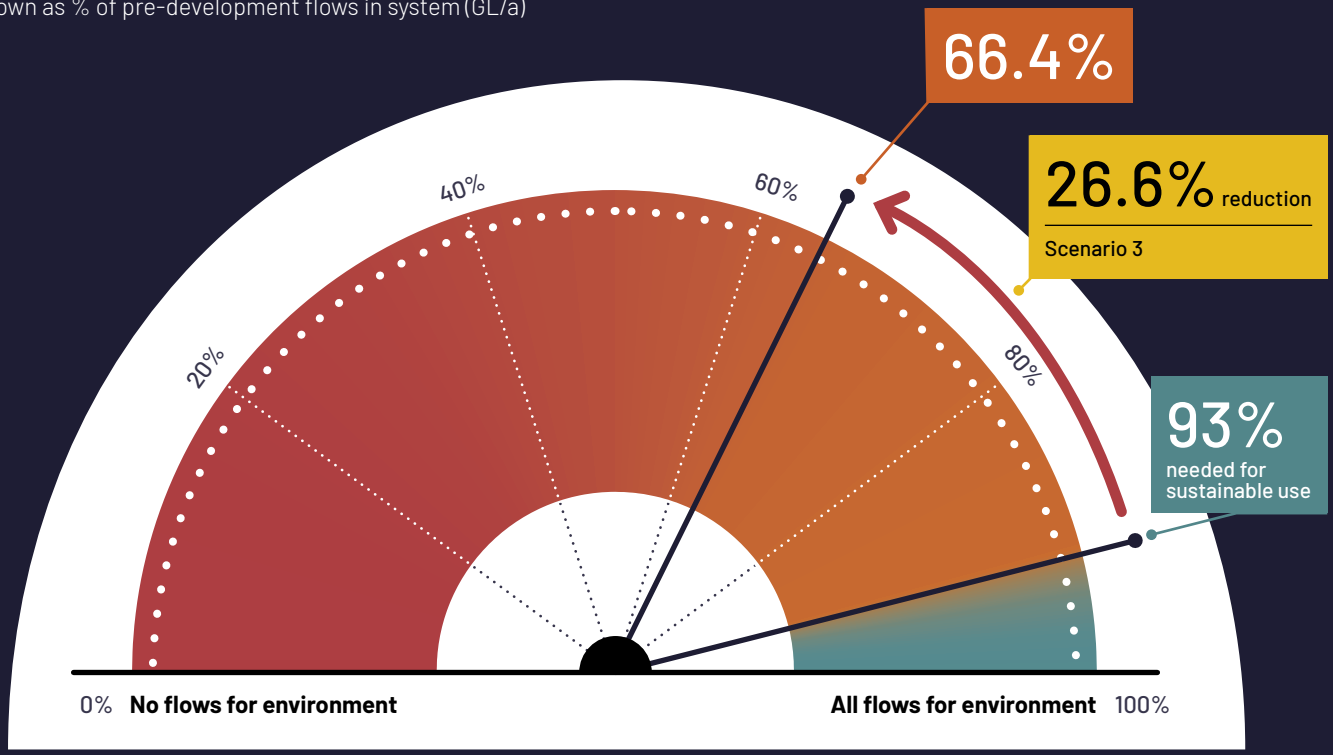
Case reference WT_HB27_T0_b3

Total unsupplemented extraction		Water extracted at Herbert River Falls Dam	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
74	58	6,000	1,075

Average annual flows at end of system (GL/a) (66.4% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (26.6% of pre-development)	Average annual flows required for environment at end of system (93% of pre-development)	Average annual flows for pre-development scenario (100%)
2,089	1,056	**3,145**	3,381

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Scenario 3: Great Dividing Range concept 2021

Upper Burdekin River (Burdekin Basin)

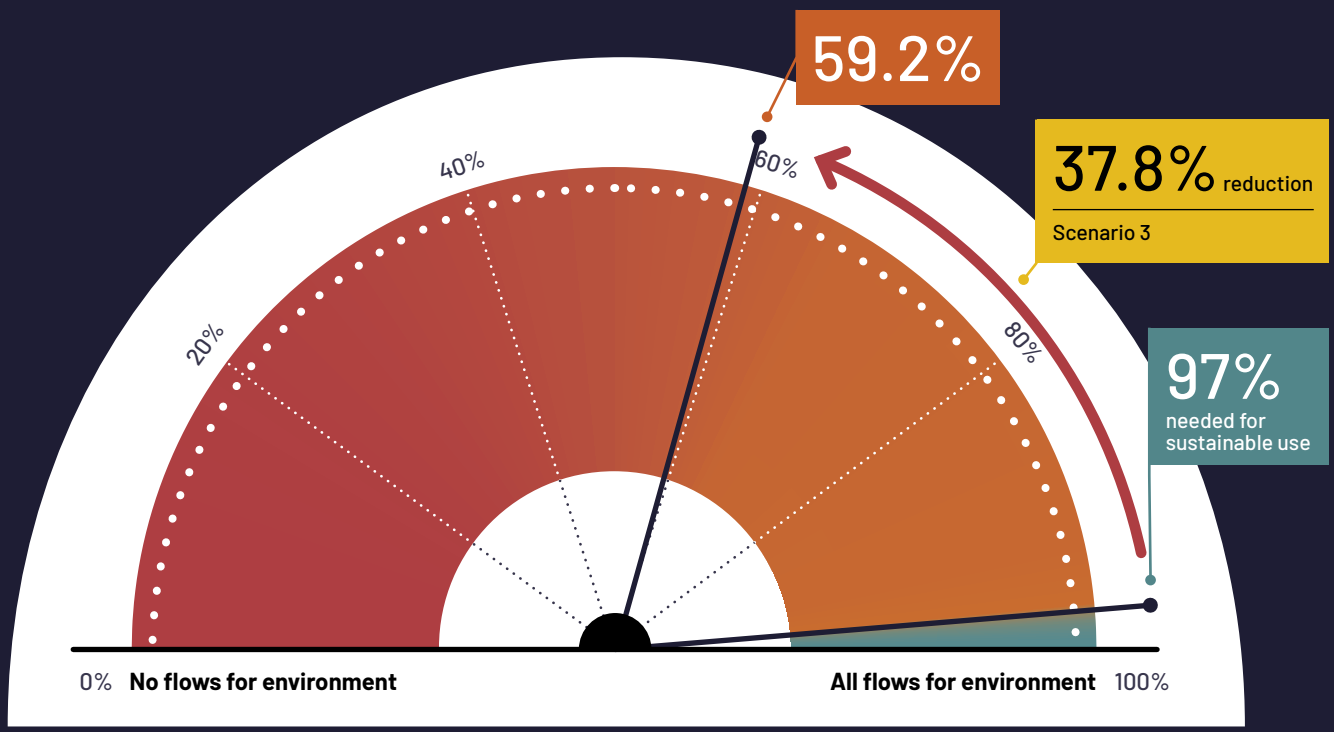
Case reference BH020R-C_b3

Total unsupplemented extraction		Water extracted at Hells Gates Dam, includes diversion from Herbert River	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
73	57	14,000	2,495

Average annual flows at Burdekin Falls Dam (GL/a) (59.2% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (37.8% of pre-development)	Average annual flows required for environment at end of system (97% of pre-development)	Average annual flows for pre-development scenario (100%)
2,388	1,526	**3,914**	4,035

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



Scenario 3: Great Dividing Range concept 2021

Lower Burdekin and Haughton rivers (Burdekin Basin)

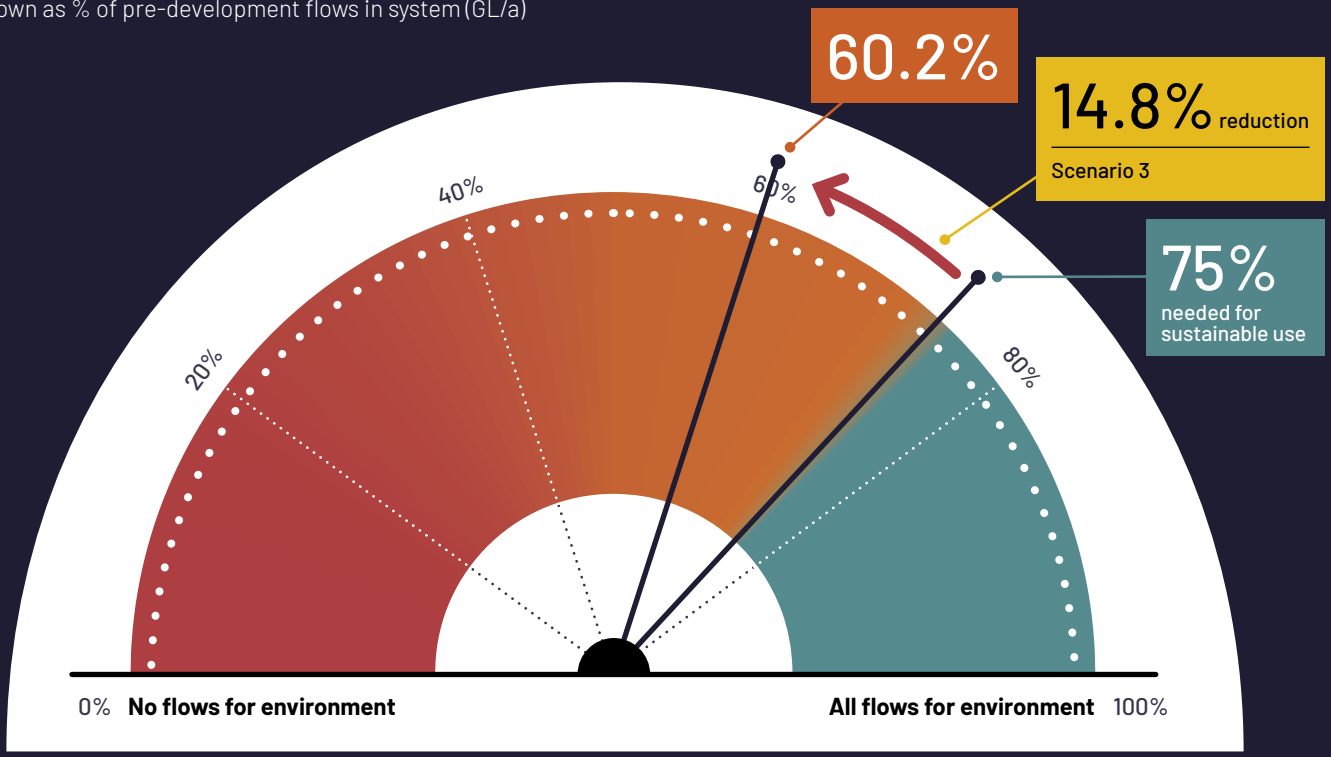
Case reference BH020R-C_b3

Total unsupplemented extraction		Total supplemented extraction in Burdekin–Haughton water supply scheme	
AVL (GL/a)	MAD (GL/a)	AVL (GL/a)	MAD (GL/a)
59	46	1,135	1,082

Average annual flows at end of Burdekin system (GL/a) (60.2% of pre-development)	Shortfall in average annual flows to satisfy water plan requirements (GL/a) (14.8% of pre-development)	Average annual flows required for environment at end of Burdekin system (75% of pre-development)	Average annual flows for pre-development scenario (100%)
4,743	1,168	**5,910**	7,881

Impact on environment and flows

Shown as % of pre-development flows in system (GL/a)



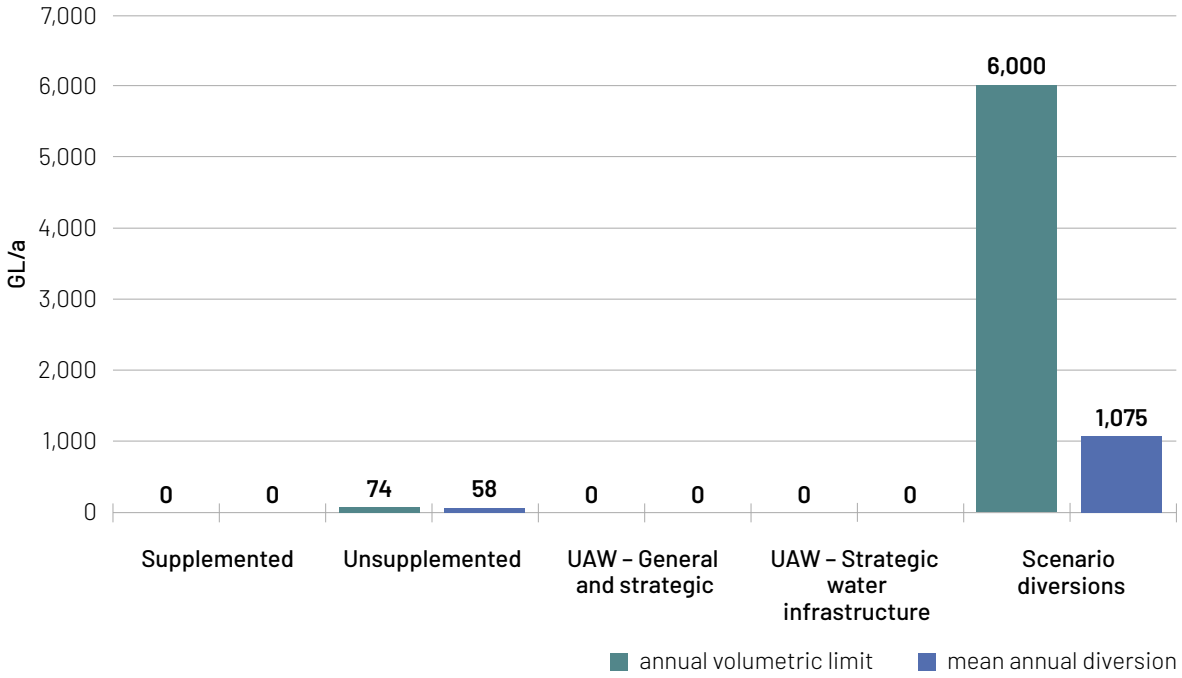


Figure A2-17: Diversions in the Herbert River for Great Dividing Range scenario.

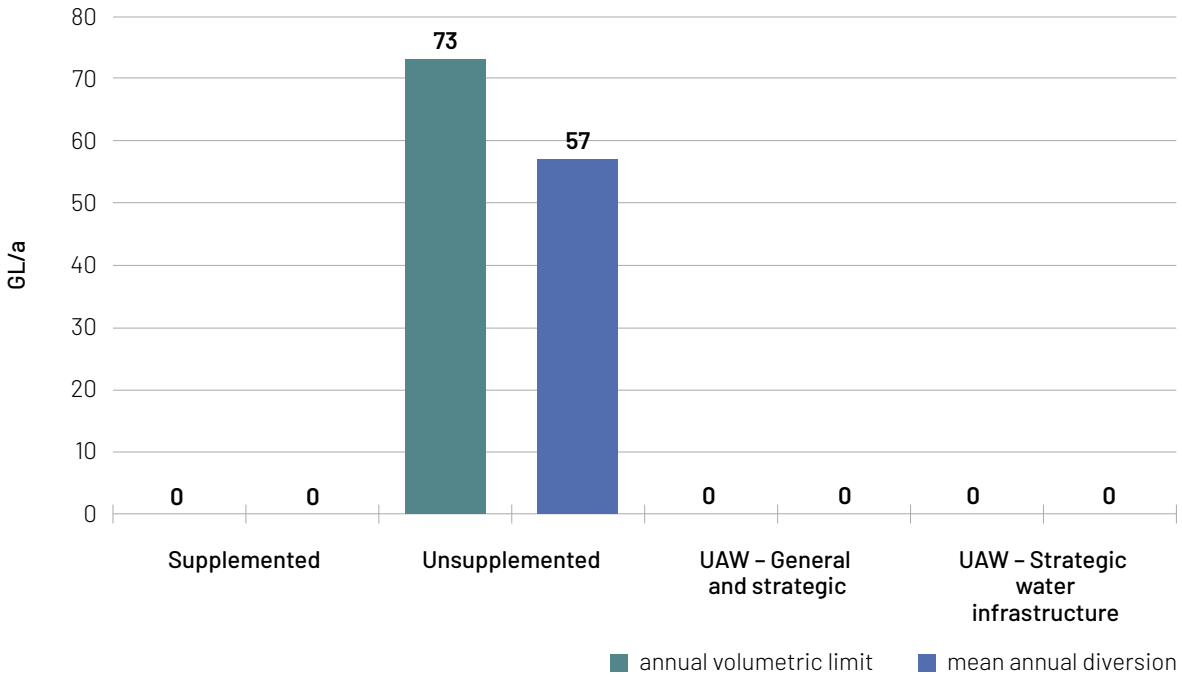


Figure A2-18: Diversions in the Upper Burdekin River for Great Dividing Range scenario.

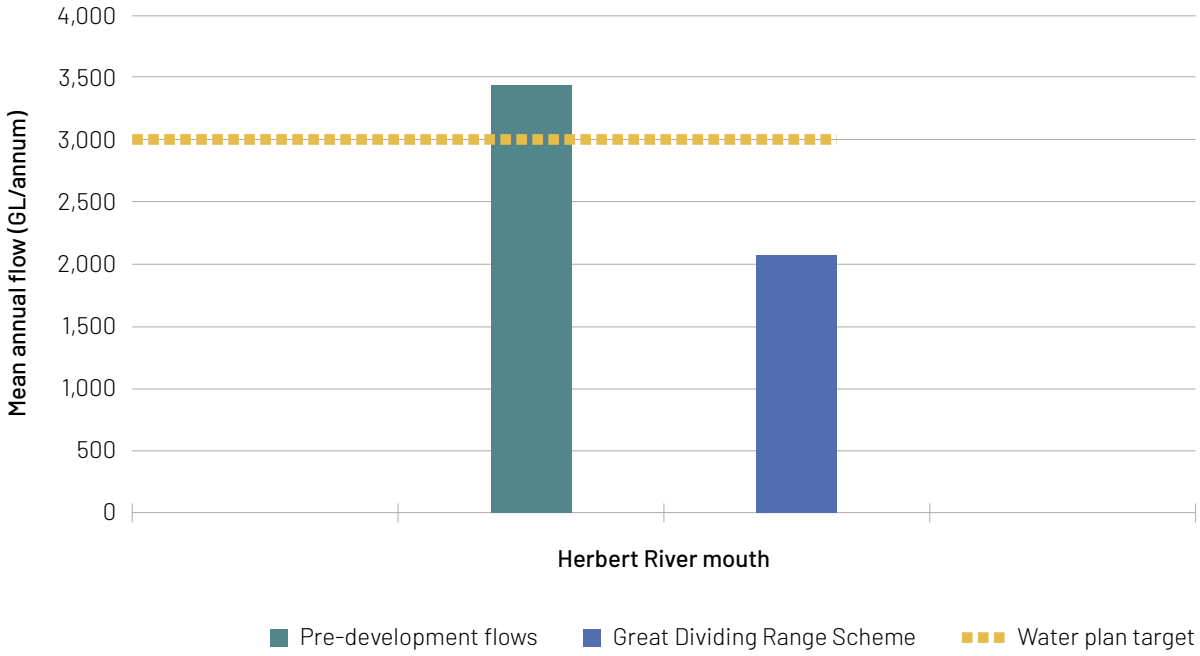


Figure A2-19: Mean annual flows at the end of the Herbert River for Great Dividing Range scenario.

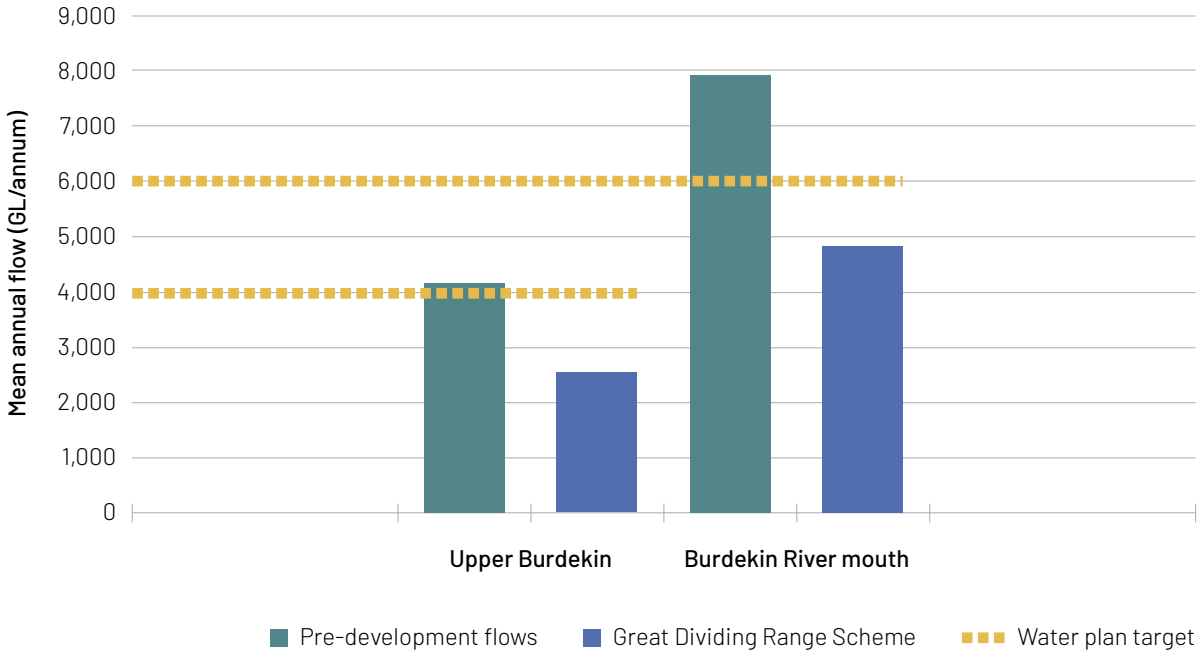


Figure A2-20: Mean annual flows for the Upper Burdekin and Burdekin River mouth rivers for the Great Dividing Range scenario.

Impacts on environmental flows

The scenario affected the mean annual flow for each sub-catchment. In the Herbert River, the mean annual flow at the end of the system was 66 per cent of pre-development flows. This is 28 per cent below the target in the Wet Tropics Water Plan and is 1,056 gigalitres less than the plan's requirements. The scenario failed all four of the plan's EFOs for the Herbert River.

In the Upper Burdekin catchment, the mean annual flow at Burdekin Falls Dam was 59 per cent of pre-development flows. This is 35 per cent below the target in the Burdekin Basin Water Plan and 1,526 gigalitres less than the plan requirements.

The mean annual flow at the mouth of the Burdekin River was 60 per cent of pre-development flows. This is 15 per cent below the target in the Burdekin Basin Water Plan and 1,168 gigalitres less than the plan's requirements. The Great Dividing Range scenario also failed 14 of the 15 EFOs at the end of the system.

Conclusions

Analysis of the Great Dividing Range scenario found that, if water was diverted from the Herbert and Burdekin catchments, this would amount to less than 20 per cent of the volume estimated in the proposal for the Great Dividing Range Scheme with a mean annual diversion of 2,495 gigalitres from Hells Gates Dam. Part of the reason for this large discrepancy between the estimate of the Great Dividing Range Scheme and this assessment relates to the estimation of streamflows. The Great Dividing Range Scheme estimated streamflows based on estimates of average rainfall–runoff relationship across the Upper Herbert and Upper Burdekin catchments.

Water plan hydrological models are underpinned by data for rainfall, streamflows and water use. Models are developed using accepted industry practices for estimating rainfall runoff and are calibrated against observed streamflow data. The models are also peer reviewed. The department collects streamflow data at multiple locations in both the Herbert and Burdekin river systems. In some instance, there are more than 70 years of data, with good high-flow ratings downstream of Herbert Falls. In the case of the Burdekin River, alongside ratings near Hells Gates Dam, the department has more than 40 years of continuous streamflow records at Selheim and Burdekin Falls Dam below Hells Gates Dam, which correlate with the data recorded at Hells Gates Dam.

Diverting water for the Great Dividing Range Scheme under this scenario would impact existing water users in the Upper Burdekin and Burdekin–Haughton Water Supply Scheme, collectively reducing existing water users' average annual access to water by 46 gigalitres. These results fail the Burdekin Basin Water Plan's WASOs established to protect existing water entitlement holders' access to water. A decrease in access could significantly undermine confidence in water supply and affect business decisions.

Environmental flows in each of the catchments would also be adversely affected. Collectively, the mean annual flows at the end of system for the Herbert River catchments and the Upper Burdekin catchment would be reduced by 2,224 gigalitres per annum. These impacts would affect all parts of the flow regime: from low flows to medium and high flows. For the Herbert River, the impact on the flow regime would be so severe that it would transform the Herbert River from a system that has significant environmental value to one that would experience significant stress. Additional assessments would need to be undertaken to understand the implications of these reduced flows to the environment.

Finally, in testing the diversion volumes proposed by the Great Dividing Range Scheme, all of the unallocated water reserves in the Herbert River and Burdekin Basin disappear. This extinguishes any opportunities to develop water resources to meet future demands in these catchments.

Opportunities

Progress in making the Great Artesian Basin watertight

The Great Artesian Basin (GAB) is one of the largest underground freshwater resources in the world. It stores more than 64.9 million gigalitres of water and underlies more than 22 per cent of Australia (1.7 million square kilometres) beneath arid and semi-arid parts of Queensland, New South Wales, South Australia and the Northern Territory. The GAB supports more than AUD$12.8 billion per year of production including agriculture, mining and gas. Its waters sustain significant springs and groundwater-dependent ecosystems, many of which are nationally listed as endangered and are culturally and spiritually significant to Aboriginal peoples.

Groundwater in the GAB, although substantial, is finite. While the annual extraction and free-flowing discharge from the basin is relatively small, extraction can have a significant and rapid impact on water pressure and availability. If the pressure were to drop too far, this would adversely affect industry and the communities who rely on the GAB as their only source of water.

Reducing water waste from free-flowing bores and bore drains is a major way of improving local water pressure and water resources in the basin. When the basin was originally accessed, the quality of materials used meant the flow of water from bores could not be controlled. Bores often developed large pools around the bore head and most bores discharged at rates well in excess of the owners' requirements. Over the past 28 years, Queensland has been involved in rehabilitating 727 bores. They now have taps that can turn the water flow down or off and 432 of the bores now have water delivered through piping instead of more than 14,000 kilometres of open-bore drains.

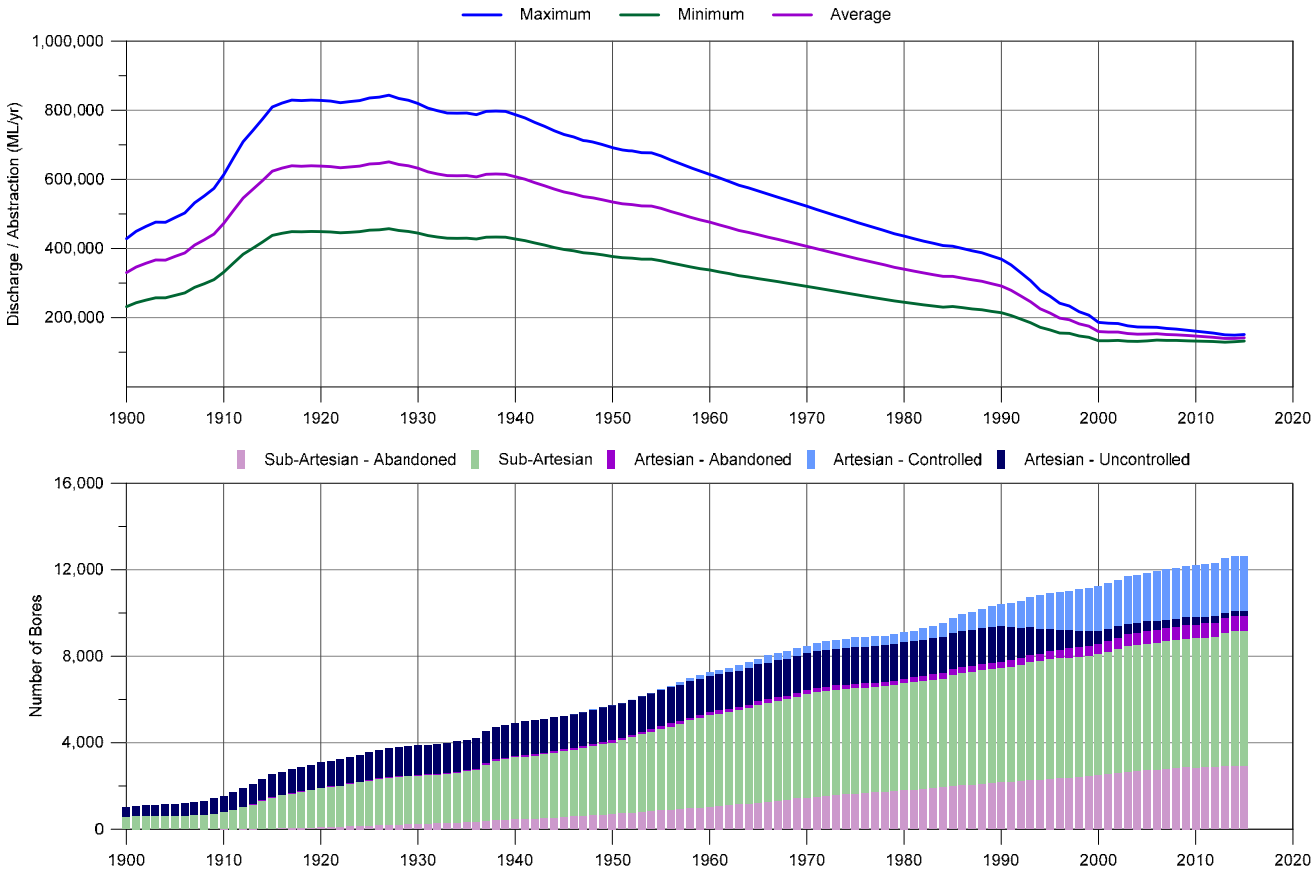


Figure A2-21: Water use and growth in number of bores over time in northern Eromanga.

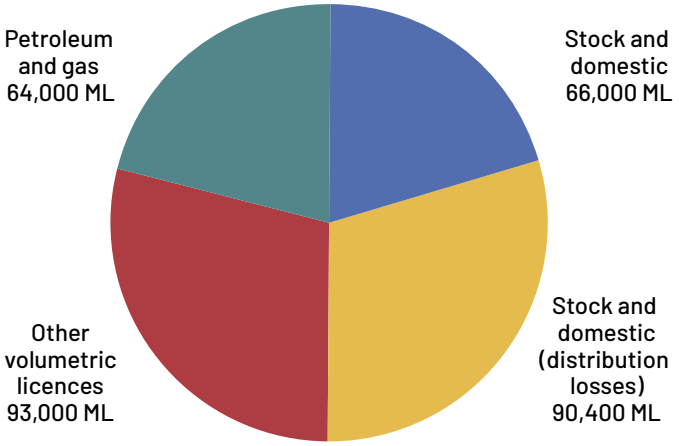


Figure A2-22: Breakdown of water use in the GAB by type.

Note:
Other volumetric licences includes:
- agriculture
- industrial uses
- mining
- irrigation
- town water supplies.

A total of $226 million has been invested in this work by the Commonwealth, state and landholders in Queensland since 1989. This is a value for money rate of $1,036 per megalitre saved for total funds or $735 per megalitre for government funding.

The upshot of this investment is that water use in the GAB is substantially more efficient in 2021 than since it was first used for settler economic activity. Queensland and Commonwealth Government-funded programs have led to almost 215 gigalitres that would have been released now remaining in the basin per year. An unknown amount saved by landholders who have self-funded piping and capping works is on top of this.

An example of the change in water use is demonstrated in the northern Eromanga part of the basin, the part of the state that still has the greatest number of free-flowing bores. The upper graph shows water use over time from water bores in the northern Eromanga. This is a water use estimate with a low, medium and high range provided. The data shows current water extraction, at 103 gigalitres per annum, is half of the estimated discharge in 1900, and is one-sixth of what it was in the 1920s and 1930s.

The lower graph shows the growth in bore numbers in the same area over time. Despite the increase in the number of active artesian bores (currently 1,512), a significant change has occurred from having only a low number of uncontrolled bores (dark blue—170) compared to mostly controlled bores (light blue—878). Decreased water take has resulted in the pressure stabilising in most GAB aquifers except the Surat, where gas production has made large demands on the resource. This improves water security for all basin water users and improves the health and flow to important natural spring ecosystems. Improved artesian pressure enables continued allocation of water to new industries as state or general reserve in the basin plan in most GAB aquifers.

The ongoing problem, and the reason for the Great Artesian Basin and Other Regional Aquifers (GABORA) Plan's 2027 sunset clause in licenses, is the remaining distribution losses are still a significant component of the 313 gigalitres of water used from the basin each year. Figure A2-22 shows the breakdown of water use by type. More than half of the water used is for stock and domestic purposes and, despite the investment to date, almost 30 per cent of the total water used from the basin in Queensland flows from free-flowing bores and bore drains. Most is lost to evaporation or seepage.

How many uncontrolled bores remain?

In 2018–19, the Queensland Government completed a census of bores in the GAB. The census confirmed that, although a large percentage of bores and drains had already been controlled across the state, work remains on bores and, more importantly, on bore drains.

Addressing the remaining water losses can result in significant water savings (Table A2-8), with the Flinders Zone responsible for more than half of the water to be saved. Bore drains were estimated to run more than 34,000 kilometres in the 1960s. This has been reduced to fewer than 4,000 kilometres of open bore drains. However, drains are still the source of most water losses and many watertight bores still run bore drains as this was permitted under previous funding programs.

Breakdown of known remaining projects

The 2019 census data has been updated by removing projects completed under the recent Improving Great Artesian Basin Drought Resilience Program (IGABDR) and Interim Great Artesian Basin Infrastructure Investment Program 2018–2020 (IGABIIP) and analysed in more detail.

Table A2-7: Bore census in the GAB 2018–2019.

GAB Zone	Controlled and pipe	Controlled bores	Uncontrolled bores	Bores with bore drains	Length of bore drains
Barcaldine Zone	16	88	50	110	927
Central Zone	2	4	7	8	32
Eastern Recharge Zone	-	-	1	1	2
Flinders Zone	34	138	65	144	1,840
Gulf Zone	4	7	3	4	4
North West Zone	60	82	10	18	76
Surat Zone	4	13	6	13	158
Warrego Zone	17	79	37	79	947
Western Zone	-	-	-	-	0
Totals	**137**	**412**	**179**	**377**	**3,986**

Table A2-8: Estimated water wastage per GAB zone.

GAB Zone	Estimate water wastage (ML/annum)
Barcaldine Zone	20,990
Central Zone	1,470
Eastern Recharge Zone	12
Flinders Zone	42,787
Gulf Zone	188
North West Zone	3,700
Surat Zone	2,951
Warrego Zone	17,198
Western Zone	0
Total estimated water saving	**89,296**

Table note: *The estimated water savings are for the current status of the bores and bore drains and do not take into account previous water savings.

Table A2-9: Remaining bore and drain rehabilitation needed.

	Landowners	Number of bores	Number of bores and drains	Number of drains only	Number of projects
Landowners with 1 bore project	75	20	55	-	75
Landowners with 1 drain	68	-	-	68	68
Landowners with 2-4 bore/drains	70	19	52	107	175
Landowners with more than 5 bore/drains	2	2	9	15	26
State government	2	3	1	18	22
Local government	2	0	2	2	4
Landowners with work to do	**219**	**44**	**119**	**210**	**360**

Table A2-10: Estimated cost of making the basin watertight.

High-level item	Quantity of items	Average estimate per item	Estimate of costing* (excl. GST)
Bore sealing < 800 m depth**	161	$137,500	$22.116,500
Bore sealing > 800 m delth**	18	$201,500-	$3,627,500
Bore replacement – Non corrosion area	135	$255,500	$34,492,000
Bore replacement – Corrosion area	44	$247,000	$10,873,000
Pipelines, tanks and troughs (bores with drains)	343	$168,000	$57,588,500
Cooling ponds and copper tube grids	93***	$67,000	$6,255,500
TOTAL (excluding GST)			**$134,953,000**

Note: *All values have been rounded to the nearest $500, ** Costs for bore sealing include mobilisation/demobilisation costs, ***Thirty bores with recorded water temperatures equall to 55^{a}C.

Under this analysis, Table A2-9 shows that not all landholders and rehabilitation projects are the same across the basin. Most of the remaining work is to occur on properties with a single bore, bore and drain, or just a drain to be made watertight.

Almost 70 per cent of the landowners (143), have only one bore or drain to rehabilitate. Seventy landowners have 2–4 bores or drains to rehabilitate, and these 175 projects make up 47 per cent of the work to be completed. Two landowners have more than 28 projects remaining on their properties.

Additional uncapped bores are being identified as the pressure across the GAB increases.

Issues with meeting the 2027 WaterTight target

Lack of funding

The successful government rehabilitation programs are saving up to 215 gigalitres per year. The value of this water, if costed at the minimum price for unallocated water in the 2015 sale ($1,420 per megalitre) is $305 million. The water still to be saved would be valued at $126 million. Many of the remaining bores are very hot, some have large bore pools and some are very deep. This makes capping more expensive than for those already rehabilitated. The worst-case financial cost of completing this work is $134 million. This does not include any potential savings from combining jobs on the same property or reducing the number of bores on a property by putting in a piped network for water delivery.

The current IGABDR and the Great Artesian Basin Industry Partnership Program (GABIPP) have been allocated a total of $21.1 million over the 2020–2023 period, which is 15 per cent of the funds needed to make the basin watertight.

Other programs that may contribute to completing work are those linked to the Section 53 in the GABORA Plan which allows a licensee to apply for 30 per cent of the water saved if the works do not include government funding. The Department of Regional Development, Manufacturing and Water has had several requests from entities interested in doing this. The department also put in place the GABIPP to streamline this process. Current funding falls well short of what is required to finish the job that has had such substantial success so far.

Reflections

Over the course of the stakeholder consultation process, the panel received some feedback that the water plans were too conservative regarding water availability. Some stakeholders considered that more water is accessible for infrastructure construction than allowed in the current water plans. There were specific concerns that too much water is allocated and committed to strategic reserves or environmental flows and general concerns that the water plan development process is flawed. The panel acknowledges these concerns, and notes that they can be raised within the adaptive review cycle of the plans. The plans are subject to regular review (every five years by the Minister and, upon expiry, every 10 years) and are subject to continuous improvement from new science, improved modelling processes and more in-situ measurement.

The panel also notes that, as water plans are adaptive, they take into account current and historical data as well as the performance of the hydrological system in the review. To date, amendments to the plans (such as designating a groundwater zone) have been based on the poor performance of a hydrological system, after observation of negative impacts.

The Water Act requires the Minister to consider the water-related effects of climate change in making a water plan and changes to the hydrological performance. The panel notes the department's intention to take expectations of impacts from climate change into future reviews.

Taking climate change into account will need to apply the precautionary principle, which underpins the intent of the NWI. Within this agreement, Section 3.5.1 states the precautionary principle as:

"Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and an assessment of the risk-weighted consequences of various options"[8].

[1] Council of Australian Governments Energy Council, 1994

[2] Council of Australian Governments Energy Council, 1994

[3] Holley and Sinclair, 2016

[4] Council of Australian Governments, 2004

[5] Productivity Commission, 2021

[6] Barber et al., 2020

[7] Hielscher et al., 2021

[8] Council of Australian Governments Energy Council, 1994

03

Appendix 3

Climate change and the supply and value of water

Climate change and the supply and value of water

Executive summary

Climate change is already having a large effect on the average amount of rain that falls in central and northern Queensland, the variability of that rainfall within and between years, and the value of water in various uses.

Queensland law now requires climate change to be considered in developing water plans to allocate the water in rivers among possible uses. Much good work is being done within the Queensland Government to take climate change into account. The panel represents the first public disclosure on, and discussion and use of, that work.

Climate change is already increasing average temperatures, which generally increases evaporation and the amount of water crops needed to achieve old levels of output per hectare. Temperatures will continue to increase until net emissions of greenhouse gases in the world as a whole fall to zero. The international community in Paris in December 2015 agreed to bring net emissions to zero early enough to hold temperature increases from pre-industrial levels (about 200 years ago) to less than 2 degrees and as close as possible to 1.5 degrees. That would require net zero by mid-century at the latest, starting now and with steady progress. A slow start requires a faster and earlier finish. After initial doubts, there is now strong commitment to achieving the Paris Agreement goals, and a chance of holding temperature increases below 2 degrees.

Central and northern Queensland will generally experience higher average rainfall in a warmer climate. However, local geography can modify this general effect. The climate models suggest some coastal areas in central and northern Queensland will experience lower rainfall. In the Burdekin and Fitzroy catchments, the evidence so far confirms the models. We should be careful not to base plans for future water use on old historical patterns of rainfall if these plans and policies cannot be reversed quickly and at low cost in response to increasing knowledge about how rainfall is responding to rising temperatures, and before we know the extent of human-induced climate change.

If the world is successful in holding temperature increases close to 1.5 degrees, then we have already experienced most of the climate change that people will ever see. The policy challenge in that case is to make the most of the opportunities created in the zero-carbon world economy.

Rainfall will be more variable in a warmer world. Secure water—with predictable amounts available year after year—will be more expensive, scarce and valuable. Whether this reduces or increases the case for investing in water storage has to be assessed on the facts, case by case.

The exception to increased evaporation with warming is where cloud cover and rainfall increase by large amounts. This is important in some parts of central and northern Queensland.

Movement to zero emissions increases the value of carbon in soils and living plants. It also increases the value of biomass from plants for carbon and hydrocarbon compounds, to provide zero-emissions alternatives to the oil, coal and gas that we now use for many industrial purposes. This can generate great value for farmers using the land and water of central and northern Queensland, and for industrial growth in those regions. Pretend climate change and a global effort to limit damage from it is not happening and resist adjusting to it, and rural and regional development in Australia will go into reverse. Recognise and adapt quickly to new opportunities, and the world's move to zero net emissions can greatly accelerate development in central and northern Queensland.

How the climate is changing

Climate change and the movement towards a zero-carbon world economy are transforming the availability of water, its value and the way it is used. This profoundly affects the optimal use of water in central and northern Queensland. The effects of climate change are recognised in Queensland's *Water Act 2000*. The Productivity Commission's 2021 draft report on national water policy identifies neglect of climate change as one of two major weaknesses requiring correction[1].

The increase in greenhouse gases in the atmosphere from human economic activity over the past two centuries is increasing temperatures and changing rainfall patterns, the amount of moisture removed by evaporation and the value of goods made with water. The changes have accelerated with the industrialisation of developing countries since the 1970s. They have gathered more momentum in the twenty-first century so far.

Warming and changes in rainfall and evaporation will continue in Australia and all over the world until the net additions of greenhouse gases in the atmosphere falls to zero. The international community at the Paris meeting of the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 agreed to reduce carbon emissions to zero soon enough to hold temperature increases to less than 2 degrees and as close as possible to 1.5 degrees. That has been broadly interpreted as requiring net zero global emissions by 2050. Australia has now joined all other developed countries in committing to reducing their net emissions to zero by 2050. Queensland and all other Australian states and territories are committed to net zero by 2050. The Australian Prime Minister has said the nation will move to zero net emissions by an unspecified date and preferably by 2050. China has committed to net zero by 2060. Since President Jo Biden took office as President of the United States in January 2021, momentum has built towards the achievement of the Paris Agreement goals, and this is manifested in preparations for the next meeting of the UNFCCC in Glasgow in November 2021.

Current patterns of human settlement and economic activity in Australia and all over the world have grown around old patterns of rainfall and other aspects of climate. Climate change disrupts those old patterns. It disrupts established patterns of agriculture, reducing productivity in old locations and opening new opportunities in others. In the near term, it reduces supply and raises the prices of commodities that are produced in large quantities in old agricultural areas that are disrupted by climate change. Adaptation to climate change requires changes in the crops we grow, how we grow them and the places in which we grow them.

Carbon dioxide is the most important greenhouse gas driving change, with methane second in impact. Water vapour actually traps more heat than carbon dioxide. However, since its concentrations are driven by temperature, it is a secondary influence, magnifying the effects on climate of the other gases (see Garnaut 2008 for a summary of relevant literature[2]).

Over the past several decades, atmospheric physicists have been developing increasingly sophisticated models of how accumulations of greenhouse gases in the atmosphere can be expected to raise temperatures and change average levels and variability of rainfall in the world as a whole and in different geographic locations. The models have become more soundly based over time but they are still simplifications of complicated realities. They provide only rough approximations of what might happen.

There is great uncertainty around the predictions of any particular model. There are many different models giving different estimates of what might happen to temperatures and rainfall as the concentrations of greenhouse gases in the atmosphere increase. We don't know which of the many models will best predict the future changes in climate. Each of many models and the predictions drawn are the product of high quality research. Any one model—at either end of the range of outcomes, or in the middle—may turn out to have come closest to predicting what eventually emerges. Policy must allow for uncertainty.

The uncertainty is reduced by the passing of time. Time brings steady improvements to the scientific foundations of the models. This can be expected to reduce the range of predicted outcomes. Year by year, time will also allow observations of actual temperature and rainfall as they reflect increasing concentrations of greenhouse gases in the atmosphere to replace the predictions of scientific models.

Uncertainty leads some people to conclude that, since we can't be sure what will happen if we allow the concentrations of greenhouse gases to increase, then we have no basis for action. That is a big mistake. All of the models predict considerable warming with increases in greenhouse gases, and big changes in rainfall. It is a mistake not to start from the position that the present is very different from the past, and the future will be different from the present. The differences are immensely important to decisions on the best use we can make of water. We have to extract every insight that is available from the observation of changes as they occur and from scientific models of how climate will change in future.

The scientific models give us insights about future change—with wide ranges. We know that as the concentrations of greenhouse gases have increased substantially over the past half-century and most rapidly of all the past two decades, temperatures have increased on average over the earth's surface. They have now increased by about 1.1 degrees above pre-industrial times. There are variations across the earth's surface. On average, the temperature over Australian land has increased by a bit more than over the earth as a whole, by about 1.4 degrees[3].

We know there have already been large changes in rainfall in various locations—increases in some and reductions in others. The ranges in rainfall vary much more across locations than those for temperature. In the world as a whole, higher temperatures increase the amount of water absorbed into the atmosphere and the amount that falls to earth as rain. But the changes in rainfall are unevenly distributed across the earth. Average rainfall is tending to decline in the latitudes of southern Australia and to increase in tropical regions. At the same time, rainfall is tending to become more variable, with higher proportions falling in intense climatic events.

We know from observation there have been marked changes in rainfall patterns away from historical norms across Australia over the past half-century and especially the past two decades, and the nature of the changes varies greatly from region to region. There has been a marked fall in average annual rainfall in the south of the country, especially in the southeast and southwest—in the temperate latitudes that have accounted so far for most of the value of Australian agricultural production. There has been increased rainfall across most of the north of Australia, but some decline in some coastal areas of central and northern Queensland.

Higher temperatures mean greater evaporation. As a result, the same amount of rainfall generally leads to reduced runoff into streams and rivers. The combination of falling rainfall and higher temperatures has radically reduced the amount of water flowing into dams in southern Australia. There is no comparable reduction in northern Australia. The general tendency is towards a small reduction in coastal central and northern Queensland as far north as Townsville, and some increase further west.

In this appendix, we draw as much knowledge as we can from observations of changes so far in temperature, rainfall and streamflow in central and northern Queensland. We present projections from models being developed by the Queensland

Government for water planning in accordance with the requirements of the *Water Act 2000* in seeking to anticipate future changes. These models have not yet been applied to assessing water available for use in water plans. The panel's work is the first application of the analysis to advice on water use.

If the international community succeeds in the Paris Agreement objective of holding increases in temperature below 2 degrees and as close as possible to 1.5 degrees in the world as a whole, a majority of the climate change that will occur has already happened. On the other hand, if the international community fails to achieve the Paris objectives, there will be much larger increases in temperature and changes in rainfall. On rainfall in some Queensland regions, there is uncertainty about the direction of change as well as its magnitude.

The international community's efforts to contain damage from climate change by reducing and then removing net additions to greenhouse gases in the atmosphere are having large effects on the value of water in various uses. These effects will grow as the world moves towards zero net emissions. Using water to grow plants contributes large new sources of value when storing carbon and removing emissions is taken into account. The absorption of carbon into plants and soils is a large new source of value. In the zero-carbon world economy in which substitutes must be found for the oil, coal and gas that is currently used for industrial production, there will be deep global markets for biomass as a source of inputs into plastics, chemical manufactures, liquid fuels and stationary energy. Some of the plants that can contribute high value in the zero-carbon economy are currently unimportant commercially but are well-adapted to northern Australia's variable rainfall and high temperatures and can use water efficiently. Research, development and commercialisation on and of new plants are important in establishing new industries. In addition, Australia has great opportunities to expand its production and export of energy-intensive goods including hydrogen and processed minerals. These require large amounts of water and water-connected energy generation and storage. This appendix ends with a brief discussion of how climate change and policies to contain it are changing the value of using water.

Modelling climate change impacts

Section overview

This section outlines:

- how observed climate has changed across Australia
- how climate change is modelled for consideration in Queensland's water plans and uncertainty associated with modelling
- how climate change models are used to understand the potential impacts of climate change on future water availability
- use of surrogate information such as rainfall and evaporation to understand potential impacts on water availability
- how modelling continuously improves over time.

Australia-wide observed historical climate variables for selected periods

Figures A3-1a, A3-1b, and A3-1c present Australia-wide average daily temperature, average annual rainfall and average annual potential evapotranspiration (PET) respectively, for the periods 1889–1969, 1970–1999 and 2000–2020. Differences between the latter periods and 1889–1969 are also shown. The state was divided into grids defining squares of 10 kilometres by 10 kilometres to present data. Data for this grid is drawn from Commonwealth Bureau of Meteorology and state daily data from gauges. The resulting gridded data source is called Daily SILO. Daily data are aggregated to annual using a water year starting 1 July. This water year is appropriate for northern Australia, but less so for southern Australia.

Higher temperatures are observed in recent decades over nearly all of Australia. In Queensland they are greatest in the west, especially the southwest.

Higher rainfall is observed in recent decades across most of northern Australia, with local exceptions that are important to the panel's work along parts of the coast of central and northern Queensland.

Lower rainfall is observed in recent decades in:

- New South Wales coastal areas
- Victoria
- Southeast and coastal Central Queensland
- Southwest Western Australia
- Southeast South Australia
- Tasmania.

Higher rainfall is observed across most of northern Australia. In Queensland, higher rainfall is observed only away from the east coast.

PET is the amount of water that falls as rain but is not available in streams and rivers because it is absorbed into the atmosphere from evaporation and the respiration of plants. PET has increased over most of Australia and most of Queensland but fallen in northern Queensland.

A complex combination of influences has led to these changes in PET. Overall, there is a positive correlation between PET and temperature. However, other factors including solar radiation, wind speed and humidity also affect evaporation. PET is generally lower when rainfall is higher and vice versa.

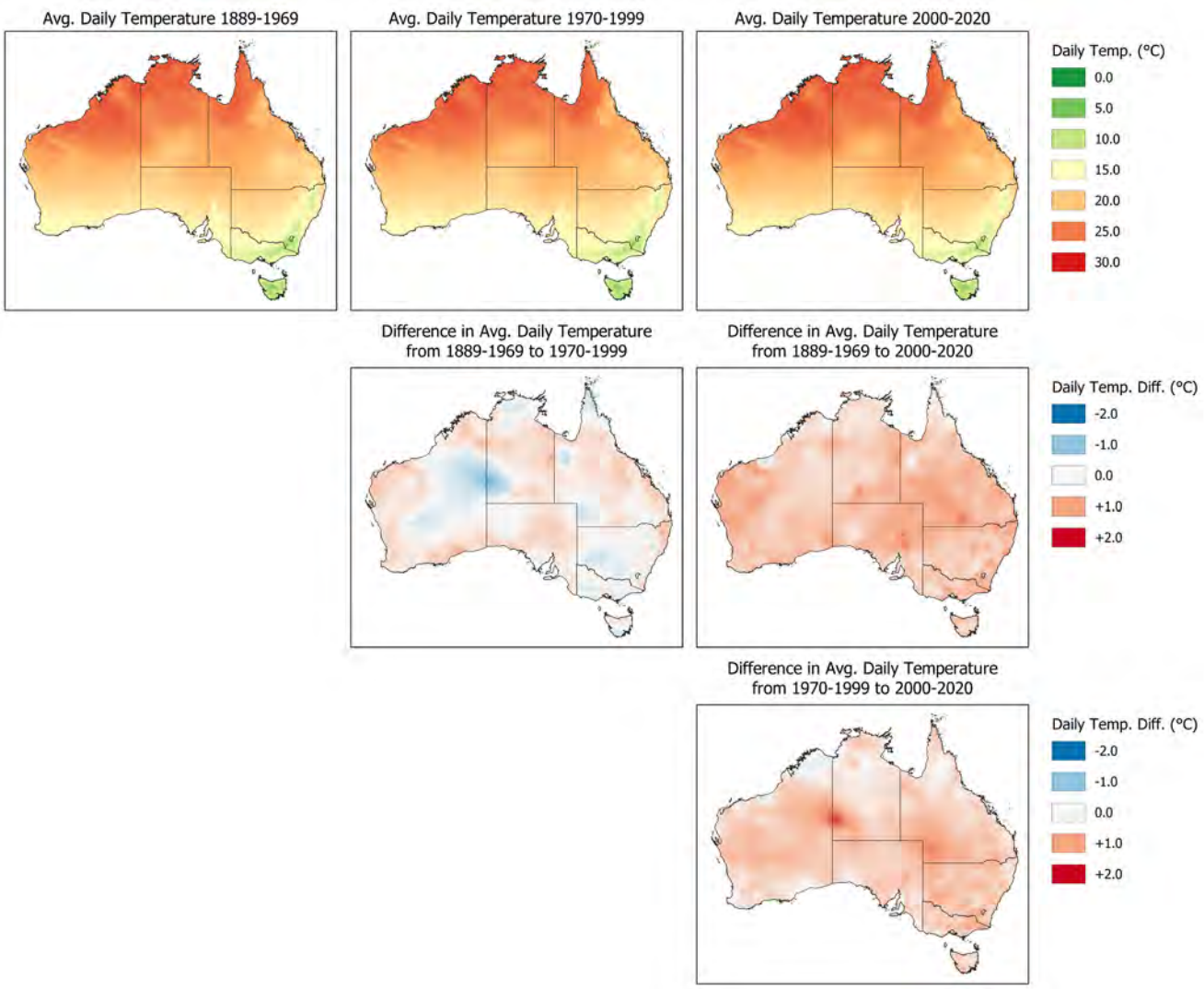


Figure A3-1a: SILO average annual daily temperature for selected periods.

Note: Water years begin 1 July. This means the 2020 water year is from 1 July 2020 to 30 June 2021.

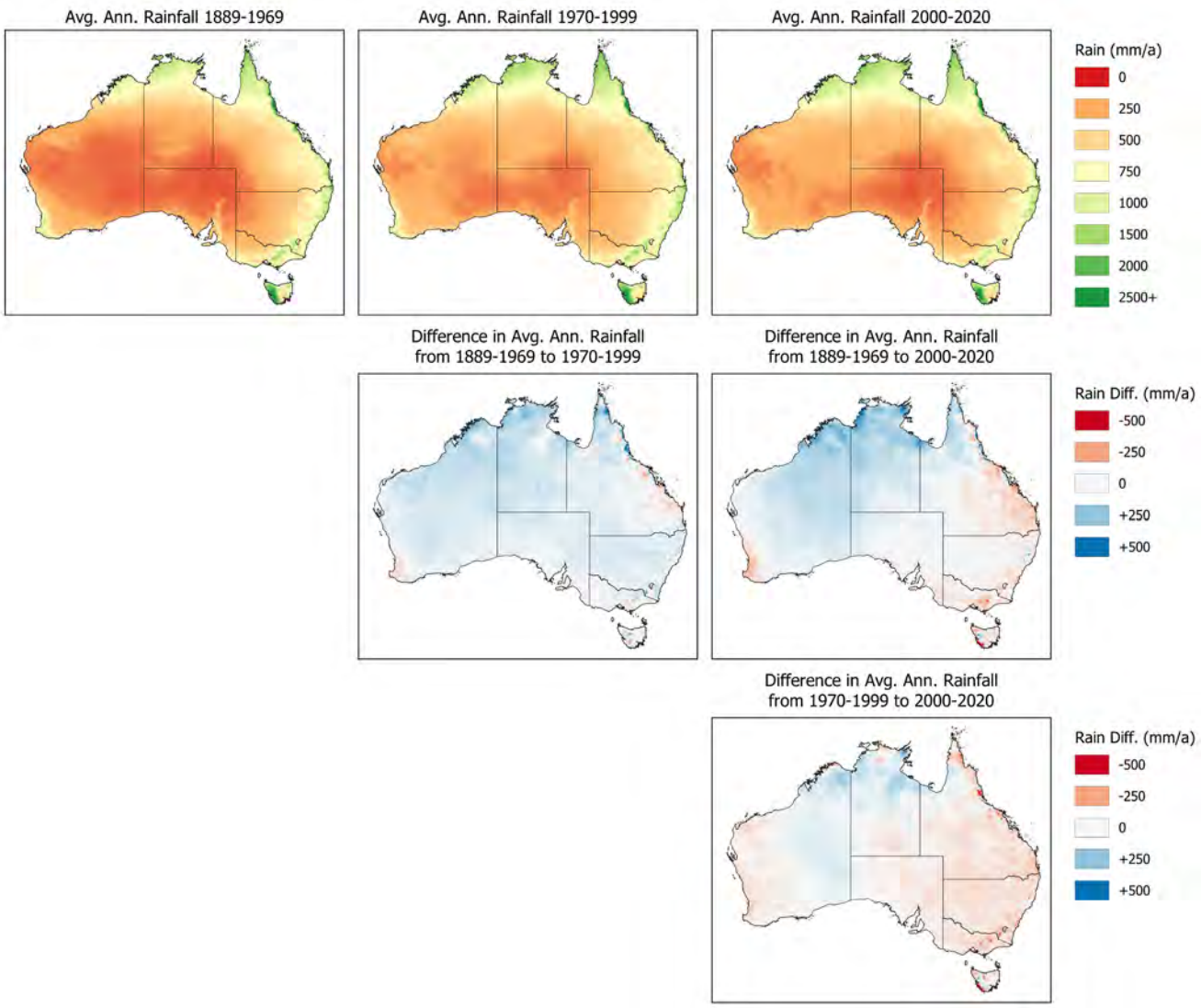


Figure A3-1b: SILO average annual rainfall for selected periods.

Note: Water years begin 1 July. This means the 2020 water year is from 1 July 2020 to 30 June 2021.

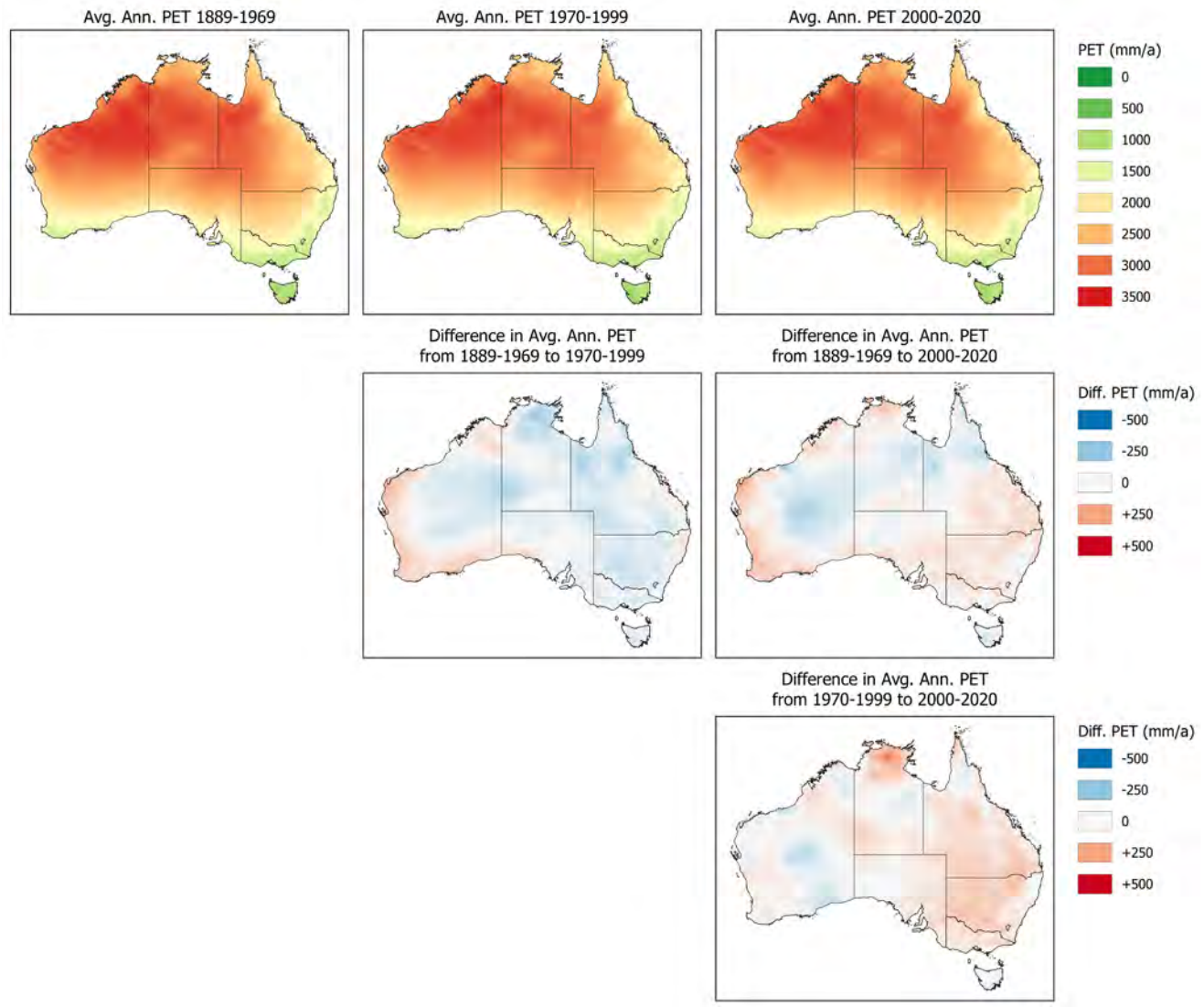


Figure A3-1c: SILO average annual potential evapotranspiration (PET) for selected periods.

Notes: 1. Water years begin 1 July. This means the 2020 water year is from 1 July 2020 to 30 June 2021. 2. PET is not an observable variable. It is calculated from subsidiary observed climate variables using Morton's approach.

This is demonstrated across Queensland. On average, falls in rainfall and corresponding increases in evaporation have been experienced in central to southern Queensland including the coast. The opposite tendency has been present in North Queensland and Far North Queensland. Increased cloud cover and increased humidity may affect this outcome. More research into the relationship is required.

Figure A3-2 (from the Queensland Government's Long Paddock website) shows year by year differences in rainfall from long-term averages. Large variations from average have always been common. The chart at the bottom shows fluctuations in the Southern Oscillation Index, which drives alternating El Nino and La Nina periods. El Nino years are shown in red, with dry conditions often extending over much of Australia, while La Nina (shown in blue) often brings wet conditions over much of the country. There is much for us still to learn about the inter-relationship between global warming and the frequency and timing of El Nino and La Nina events.

Overview of modelling approach

The United Nations' Intergovernmental Panel on Climate Change (IPCC) has overseen the development of pathways that future greenhouse gas emissions might take. These pathways allow the research and outputs of climate models being developed by groups of scientists across the world to be compared. The Queensland Government uses these pathways to understand the possible future effects of increasing concentrations of greenhouse gases on the climate. For Queensland, projections from the climate change models are available at a regional scale for Representative Concentration Pathways (RCP) 8.5 and 4.5. Another concentration pathway, RCP 2.6, comes closest to representing emissions with the Paris Agreement successfully implemented but the Queensland Government did not have access to a downscaled version of RCP 2.6 at the time of the panel's work.

The RCPs were used in the Fifth Assessment Report of the IPCC in 2014 as a basis for the report's findings. The RCP 4.5 scenario generates about 2.6 degrees of warming above pre-industrial levels by 2050. This is significantly beyond the Paris Agreement's target range but is roughly the result if the national commitments presented by members of the United Nations at the time of the Paris Agreement were all implemented[4].

It is in Australia's interest that the world does much better than RCP 4.5, and the international community is committed to doing so.

RCP 8.5 represents serious failure to achieve the Paris Agreement goals—with a resulting global temperature increase of around 3.7 degrees Celsius (Figure A3-1) above 1985–2005 levels (which were then well above pre-industrial levels) by the last two decades of this century. Prior to COVID-19, the replacement of President Trump by President Biden in the United States and an intensification of international climate mitigation efforts through later 2020 and 2021, the world seemed to be on a path that looked something closer to RCP 8.5 than RCP 4.5. Recent developments increase the chances of implementing the Paris Agreement—keeping increases in greenhouse gas concentrations and in temperature well below those presented in RCP 4.5.

The two scenarios are considered in this appendix to exemplify how climate is likely to behave with moderate failure in progress towards the Paris Agreement targets (4.5), and with comprehensive failure (8.5). The panel is aware that planning for effective water use if the international mitigation fails comprehensively is problematic, since water management and policy would be overwhelmed by wider problems of international and domestic disorder. Note that temperature increases in Figure A3-1a are from a base (1986–2005) that already embodies an increase of 1.1 degrees Celsius from pre-industrial levels.

The Queensland Government uses climate change data from the online Queensland Future Climate Dashboard in developing water plans. These data have been used to inform other strategic Queensland Government initiatives such as the:

- *Queensland Climate Adaptation Strategy*
- *Queensland Bulk Water Opportunities Statement*
- *Agriculture Sector Adaptation Plan*
- regional water supply security assessments.

Of the many global circulation models (GCMs) developed in institutions undertaking research in atmospheric physics around the world, results from the 11 models that were judged by officials to represent Queensland's climate better than others have been chosen for use in official hydrological modelling.

An overview of the assessment approach using hydrological modelling is provided in Figure A3-3 and in the text below.

Step 1

The Queensland Government draws on climate change data and modelling available, as discussed above.

Step 2

GCMs generate climate projections at a very large scale. They make predictions about future rainfall and temperature for large parts of the state but do not represent local weather patterns well. These models provide a foundational input into projections of future climate. The current methodology applies two of these RCPs for Queensland. Outcomes with temperature increases lower than RCP 4.5 are possible and desirable. Outcomes with larger temperature increases than RCP 8.5 are possible. These are catastrophic consequences.

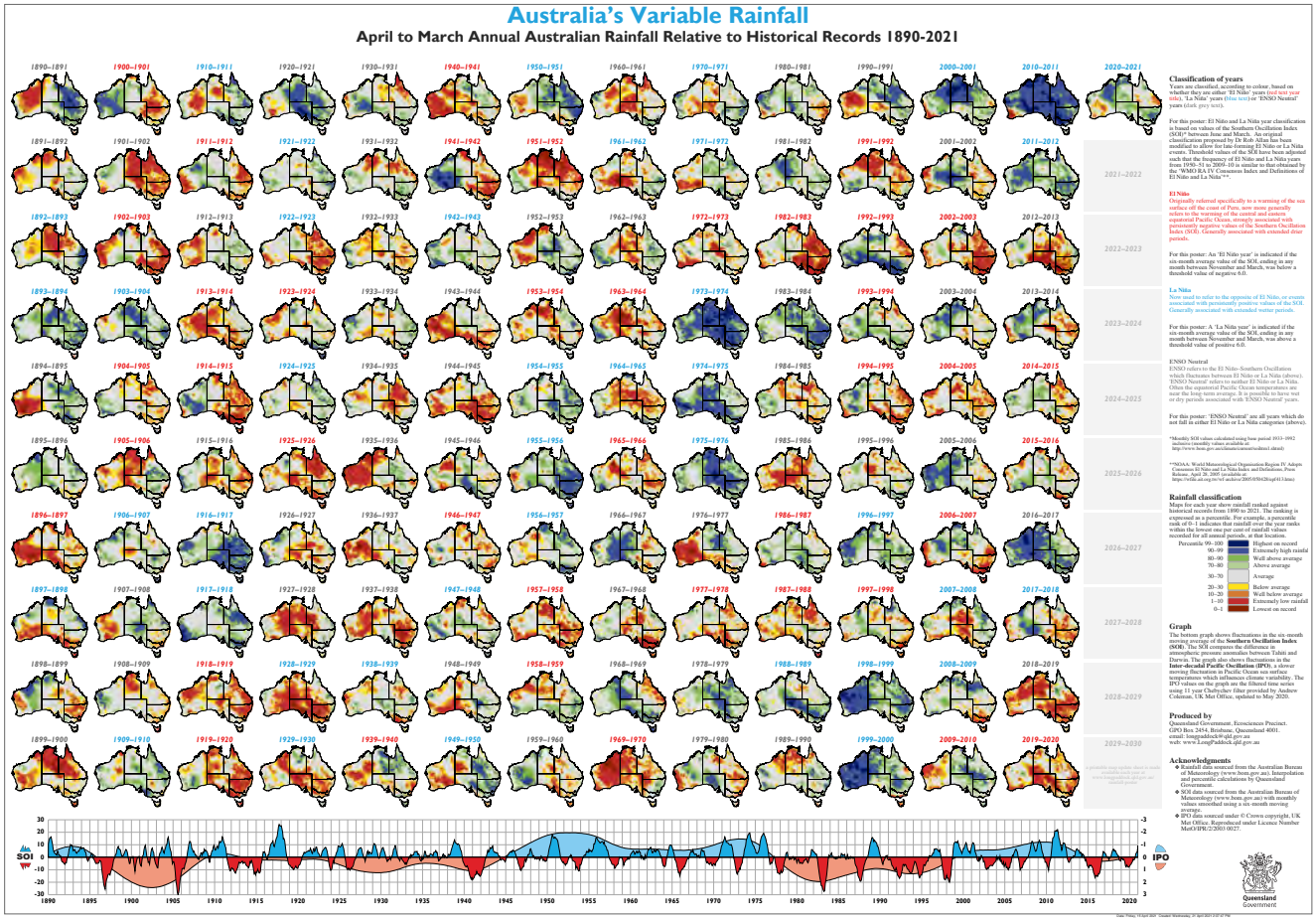


Figure A3-2: Australia rainfall poster 1890–2021.

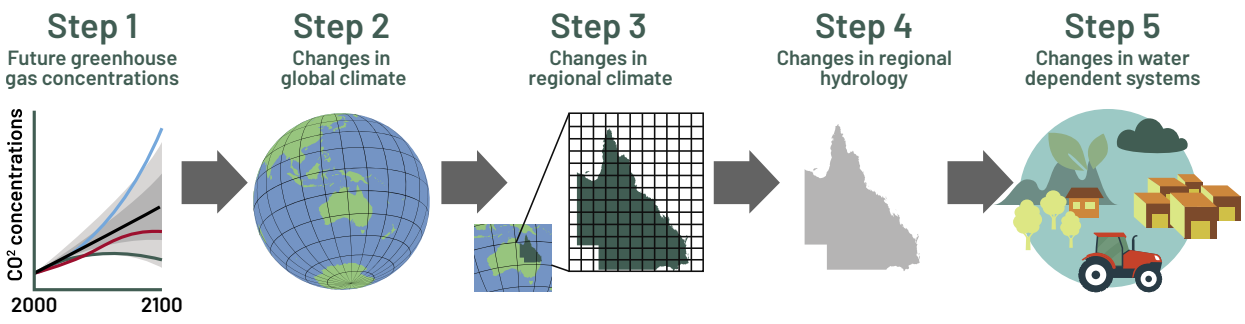


Figure A3-3: The process for incorporating the predictions from climate change models into Queensland water plans.

Step 3

Regional climate models (RCMs) and other downscaling techniques use the projections from GCMs and work out what these changes mean at a local scale. RCMs seek to simulate the local climate systems that affect different parts of the state. This dynamical downscaling has produced climate projection data on a grid measuring 10 kilometres by 10 kilometres across all of Queensland. Some states use downscaling techniques that rely on statistical deduction rather than RCMs, as they are simpler and easier to use and may be as reliable. The presence of significant local features that influence rainfall, such as coastal details, mountains, vegetation and soil characteristics, strengthens the case for using RCMs.

Weather systems of interest for water availability in Queensland are:

- smaller scale convective storms over the coastal ranges that make them wetter than nearby lowland areas
- larger scale tropical systems like monsoon troughs and cyclones that bring widespread rain to northern regions in the warm season
- cold fronts that bring rainfall to the southern regions in the cool season.

The Conformal Cubic Atmospheric Model (CCAM) has been developed by CSIRO for Australian conditions. It is used to downscale the outputs from coarse resolution GCMs. The CCAM is only one of many RCMs that exist or are under development.

Step 4

Regional climate projections are an input to hydrological models that indicate what is likely to happen to flow in rivers or aquifers as the climate changes. From more than a century of records, the model uses rainfall, evaporation and daily streamflow data to develop relationships between rainfall and runoff in a process called calibration. Calibration works by running the model many times using different values of the parameters and choosing the values with which the model would have predicted most closely past patterns of runoff. The values chosen are those that would have generated the smallest divergence between daily flow measured at gauges and the daily flow predicted by the model. The model and parameters of best fit are then used to project the total amount of runoff entering streams in a future that is affected by climate change.

The parameters from the calibration are used to run the model again, this time using the rainfall and evaporation outputs from the CCAM to project what streamflow would be if the climate changed.

Step 5

The final step is to use a water resource (or hydrological) model that tells us how different water needs are likely to be affected by the flow changes. This model includes dams and major pipelines and embodies the water plan rules. It compares how much water is available to different users and how much flow remains in the river using the current time series of streamflow and the projected time series of streamflow. This last step requires more detailed modelling to understand how changes in water availability at a regional scale affect the amount available for economic activity and other uses at a local scale in future. This is still work in progress for most of the state. Once completed, the work will need to be continually updated as models improve and as real data emerges on how climate has changed.

Types of assessments

The Queensland Government is continually improving the hydrological assessment approach in response to the latest information available globally from the IPCC and in response to best practice and peer reviews of the approach.

Results for three main types of assessments will be discussed in the following sections, all of them based on this five-step assessment methodology.

1. **State-wide summary of projected climate impacts:** Using downscaled data across the state with emissions scenarios RCP 4.5 and RCP 8.5, this assessment shows projected changes in rainfall and evaporation at 2050. This represents modelling up to step 3 in Figure A3-3.
2. **Modelling for selected catchments:** Some more detailed modelling has been completed for the Barron, Burnett, Burdekin and Fitzroy, considering emissions scenarios RCP 8.5 and 4.5. This represents modelling up to step 4 in Figure A3-2.
3. **Model outputs against climate change impacts:** This third assessment checks model outputs against the climate change impacts experienced so far.

The panel has had access to the Queensland Government's climate assessment work for water planning. This work has commenced in response to requirement of the amended Water Act in 2018 to consider climate change in all new water plans. This access has allowed us to take account of the effects of climate change on water availability in our own recommendations.

State-wide summary of projected climate impacts

Section overview

This section outlines:

- an overview of projected climate impacts for Queensland
- projected trends in temperature, rainfall and evaporation across the state under model future climate scenarios.

Overview of projected climate impacts across the state

All of the GCMs project an increase in temperature and evaporation in Queensland, with the effect increasing over time until after net emissions have been reduced to zero. The likely trend in rainfall is less certain, with some models projecting an increase and others projecting a decrease. The direction of change varies across the state. Most models project rainfall to decrease in winter over much of Queensland when rainfall and streamflow are already low.

Changes in average rainfall are expected to be very different across regions. On the other hand, the models clearly predict increased variability of rainfall, with the intensity of extreme rainfall events increasing. Tropical cyclones are likely to become rarer but more intense and to reach further south. Large-scale monsoon troughs that provide most of the rainfall in northern and inland areas may also become rarer and more intense.

Small-scale convective storms that provide much of the rainfall to coastal mountains in the wet tropics are likely to decrease, especially in the cooler months. Cool season rainfall from cold fronts that cross southern Queensland is also likely to decrease. Dry spells are likely to become longer.

These changes have the potential to significantly alter the frequency, magnitude and duration of streamflows as well as groundwater levels through changes in aquifer recharge. This has implications for water security and availability for water users and the environment across the state. The frequency and severity of extreme droughts is also likely to increase.

In the past few decades, Queensland has experienced reduced rainfall over much of the coast as far north as Townsville, substantially lower average rainfall across the south, and increased rainfall over much of the north, all with important local variations (see Figure A3-1b). Queensland has not experienced the generally declining trend in annual rainfall that has been recorded in southern Australia. While there are large differences in changes in average rainfall across Queensland, the variability of rainfall has generally increased.

Temperature summary

The models' projections of changes in temperature across the state for 2050 and 2090 for both RCP 4.5 and 8.5 emissions scenarios are shown in Figure A3-4. These increases are from a 1986–2005 base, which already incorporates an increase of about 0.8 degrees in global temperatures from pre-industrial levels.

At 2050, the increases are large everywhere and do not vary greatly across the state. The highest increases are predicted in inland areas, particularly in the southwest. Under RCP 4.5, projected mean temperature increases above 1986–2005 are around 1.7 degrees inland, moving to 1.4 degrees eastwards and northwards. Similar patterns are projected under RCP 8.5, with southwest catchments showing an increase in mean temperature of around 2.2 degrees, far north coastal areas around 1.4 degrees and around 1.9 degrees across most of the rest of the state. There is only moderate temperature difference between the RCM 4.5 and RCM 8.5 emissions scenarios.

However, the differences are large by 2090. Recent research undertaken in the Queensland Murray–Darling catchments has shown water temperatures in refuge waterhole habitats during the summer months may frequently exceed the thermal tolerance of several native fish species under projected climate change scenarios. Increased water temperatures also influence dissolved oxygen concentrations, favouring exotic species like the European Carp over native species that are more sensitive to oxygen stress.

Table A3-1 shows the lowest, median and highest projections for temperature change by decade for RCP 4.5 and RCP 8.5 for catchment areas in which we have contemplated Regional Water Grids developments. The range of predictions comes from the 11 models chosen that were judged by the Queensland Government to be most representative of Queensland. By 2050 under RCP 4.5, an increase in the median temperature is projected across all catchments of 1.1–1.6 degrees Celsius, relative to the reference period. Under RCP 8.5 the increases are between 1.5 and 1.9 degrees for the same catchments at 2050.

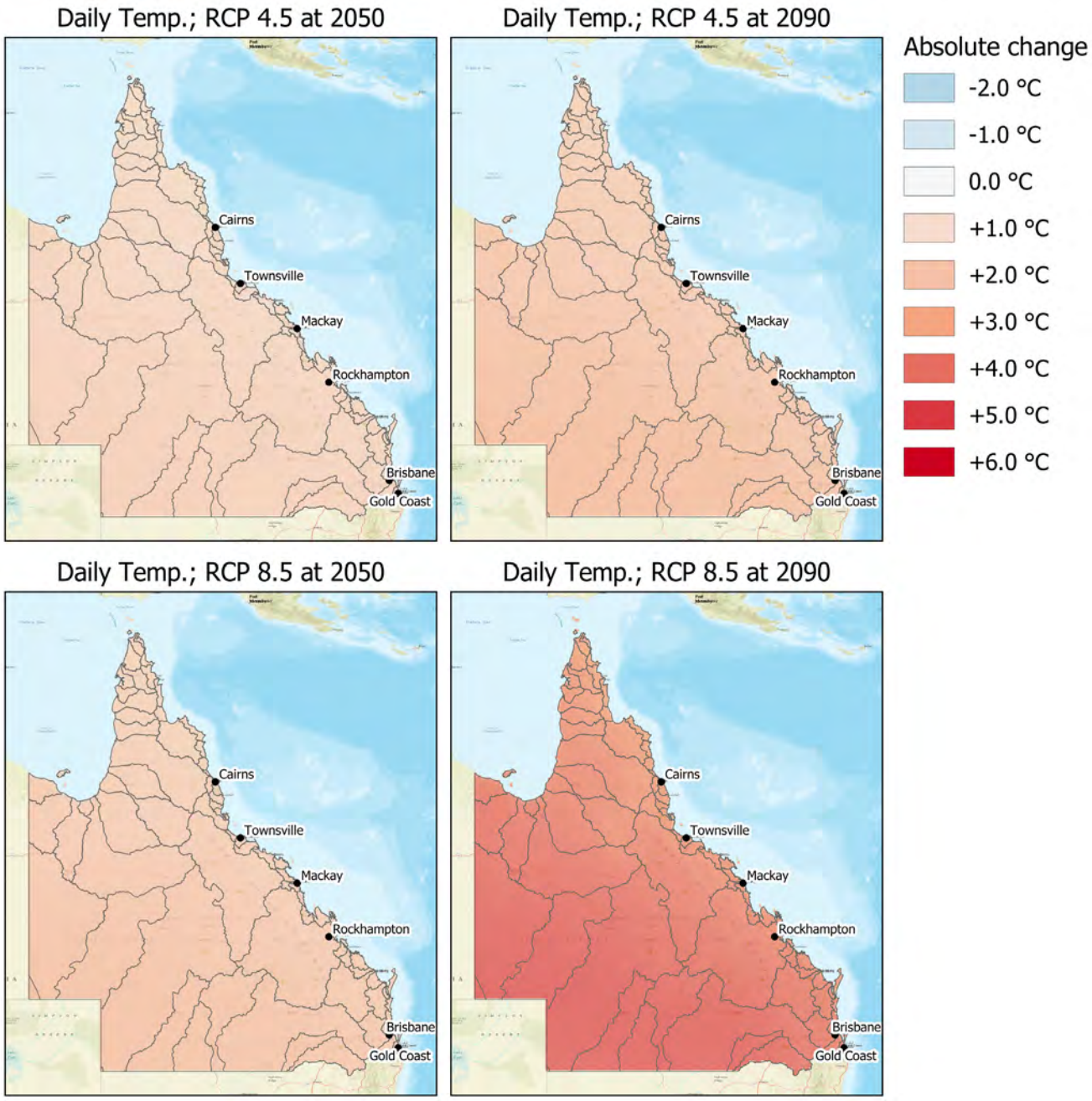


Figure A3-4: Projected change in mean daily temperature (°C) at 2050 and 2090 for emissions scenarios RCPs 4.5 and 8.5 at relative to reference period (1986–2005).

Source: Queensland Future Climate Dashboard (longpaddock.qld.gov.au/qld-future-climate/dashboard/)

Table A3-1: Predicted average daily temperature change (°C) relative to the reference period 1986–2005, based on the emissions scenarios RCP 4.5 and RCP 8.5 for Barron, Burdekin, Burnett and Fitzroy. Under each scenario, P10 is the lowest projected change, P50 is the median projected change and P90 is the highest projected change.

Catchment	Year	RCP 4.5			RCP 8.5		
		P10	P50	P90	P10	P50	P90
Barron	2030	0.5	0.8	0.9	0.6	0.9	1.1
	2040	0.7	1.0	1.2	0.8	1.1	1.5
	2050	0.9	1.1	1.4	1.2	1.5	1.9
	2060	1.0	1.3	1.6	1.5	2.0	2.4
	2070	1.0	1.6	1.7	1.9	2.4	3.0
	2080	1.2	1.6	1.9	2.3	2.9	3.5
	2090	1.3	1.7	1.9	2.7	3.4	4.0
Burdekin	2030	0.5	0.9	1.4	0.4	1.1	1.4
	2040	0.7	1.1	1.7	0.7	1.4	1.7
	2050	0.9	1.4	1.9	1.2	1.9	2.3
	2060	1.0	1.6	2.2	1.6	2.3	3.0
	2070	1.2	1.8	2.3	1.9	2.8	3.5
	2080	1.4	2.1	2.5	2.4	3.4	4.2
	2090	1.3	2.1	2.7	3.0	4.0	5.1
Burnett	2030	0.6	0.9	1.4	0.5	1.0	1.3
	2040	0.8	1.2	1.5	0.9	1.5	1.6
	2050	0.9	1.6	1.8	1.4	1.8	2.4
	2060	1.1	1.6	2.2	1.9	2.3	3.1
	2070	1.3	1.9	2.4	2.2	2.9	3.8
	2080	1.4	2.1	2.5	2.6	3.5	4.4
	2090	1.4	2.2	2.8	3.1	4.1	5.2
Fitzroy	2030	0.6	0.9	1.4	0.6	1.0	1.4
	2040	0.7	1.2	1.6	0.8	1.5	1.7
	2050	0.9	1.6	1.9	1.3	1.8	2.4
	2060	1.0	1.7	2.3	1.7	2.4	3.1
	2070	1.3	1.9	2.4	2.0	3.0	3.8
	2080	1.4	2.2	2.6	2.5	3.5	4.4
	2090	1.5	2.2	2.9	3.1	4.1	5.3

Evaporation summary

Figure A3-5 compares pan evaporation in millimetres per day at 2050 and 2090 for RCP 4.5 and RCP 8.5 downscaled to square grids of 10 kilometres by 10 kilometres. This is not the evapotranspiration referred to earlier, which is closely and directly relevant to river and stream flows. Pan evaporation relates to losses from exposed water surfaces, for example in dams. These maps show long-term changes in evaporation relative to the reference period (1986–2005).

At RCP 4.5 at 2050, the increase in evaporation across Queensland is less than one millimetre per day, reaching up to one millimetre per day in the west (Figure A3-5). At RCP 8.5 in 2050, it is around 1.6 millimetres per day in the Diamantina shire, 1.3 millimetres per day in much of western Queensland and less than one millimetre a day along the coast (Figure A3-6).

The increased temperatures in southern and inland areas of Queensland are projected to be accompanied by a greater increase in annual evaporation. Higher evaporation leads to greater losses of water from river systems, lakes, dams and storages and water available for economic and other uses, particularly during drier times. Crop water requirements may increase. Plant water stress may affect fodder availability for stock in some areas. Given most of Queensland's river network is considered ephemeral, it is likely watercourses will be drier more often and for longer, placing pressure on persistent waterholes. 'No flow spell periods' will increase in frequency and duration, increasing the importance of waterholes as critical refuge habitats. The persistence of refuge waterholes is also likely to be affected by increased evaporation at the waterhole surface and evapotranspiration by riparian vegetation. The quality of refuge habitat will decrease due to frequent heat waves that result in rapid water temperature increases and dissolved oxygen concentration decreases to levels that do not sustain aquatic life. These are inevitable environmental consequences of climate change, which increase the importance of maintaining environmental flows of water.

Table A3-2 shows the lowest, median and highest projections for changes in annual PET by decade for RCP 4.5 and RCP 8.5 for the catchments of the proposed Regional Water Grids. Note the range of projections arises from the uncertainty in the projections across the various GCMs, which use the 11 models most representative of Queensland. Median PET increases for these catchments range from 8–11 per cent under RCP 4.5 and 10–16 per cent under RCP 8.5 at 2050. The anticipated increases in evapotranspiration across Queensland will substantially reduce water availability. It will also affect losses in open storages and increase the amount of water required to achieve given amounts of plant growth. In areas of declining rainfall, such as coastal Central Queensland, it will exacerbate the decline in water availability. In areas of increasing rainfall, it will reduce the effective increase in the availability of water. All of these effects will be much greater with failure of the global effort to achieve zero net emissions at an early date. Higher water availability in areas of increased rainfall will increase the value of strategies to reduce losses from evaporation, including judicious plant selection and covering of water storages. In some locations, this may include floating solar electricity generation systems.

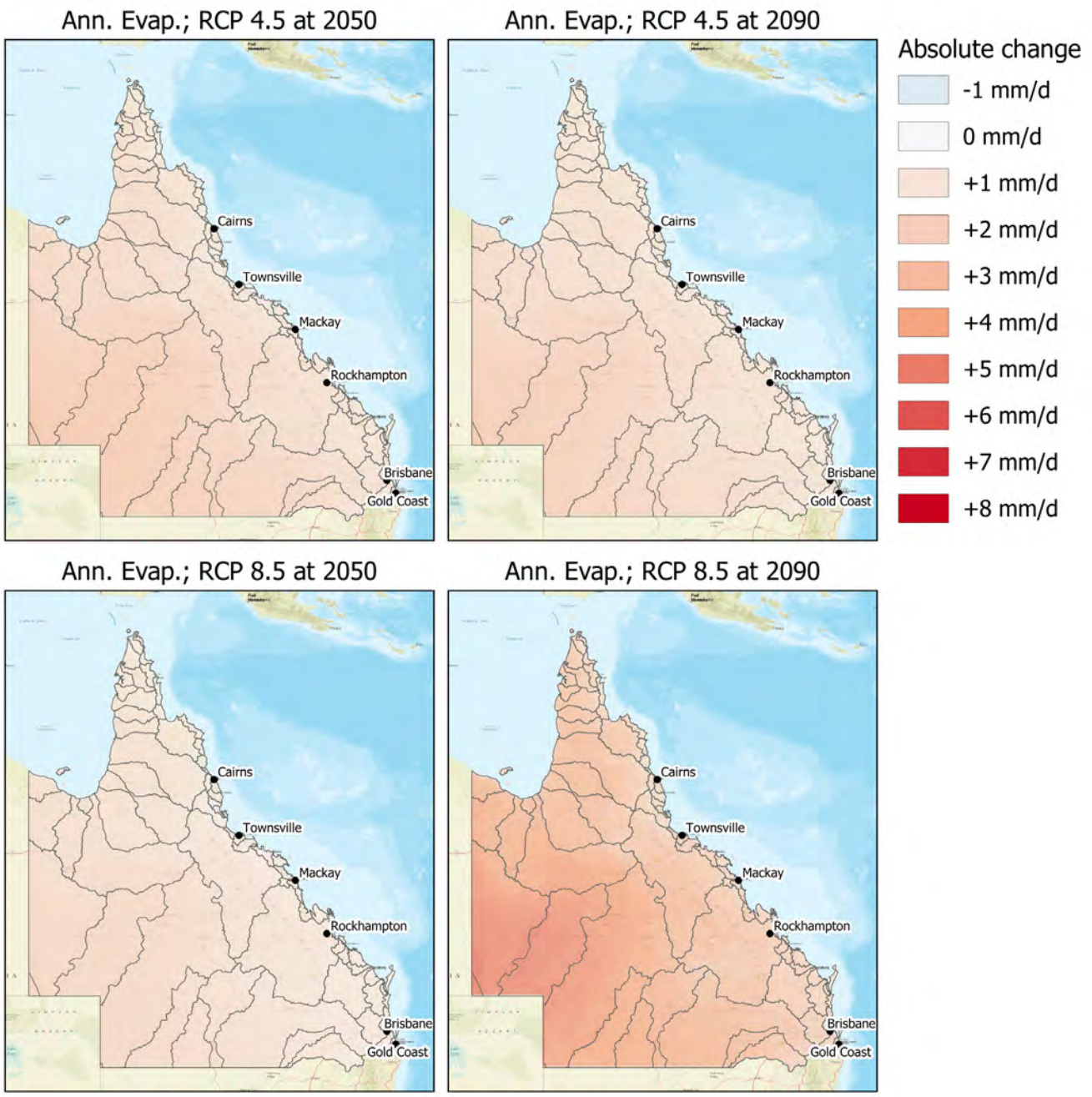


Figure A3-5: Projected change in average daily pan evaporation (mm/d) at 2050 and 2090 for emissions scenarios RCPs 4.5 and 8.5 at relative to reference period (1986–2005).

Source: Queensland Future Climate Dashboard (longpaddock.qld.gov.au/qld-future-climate/dashboard/)

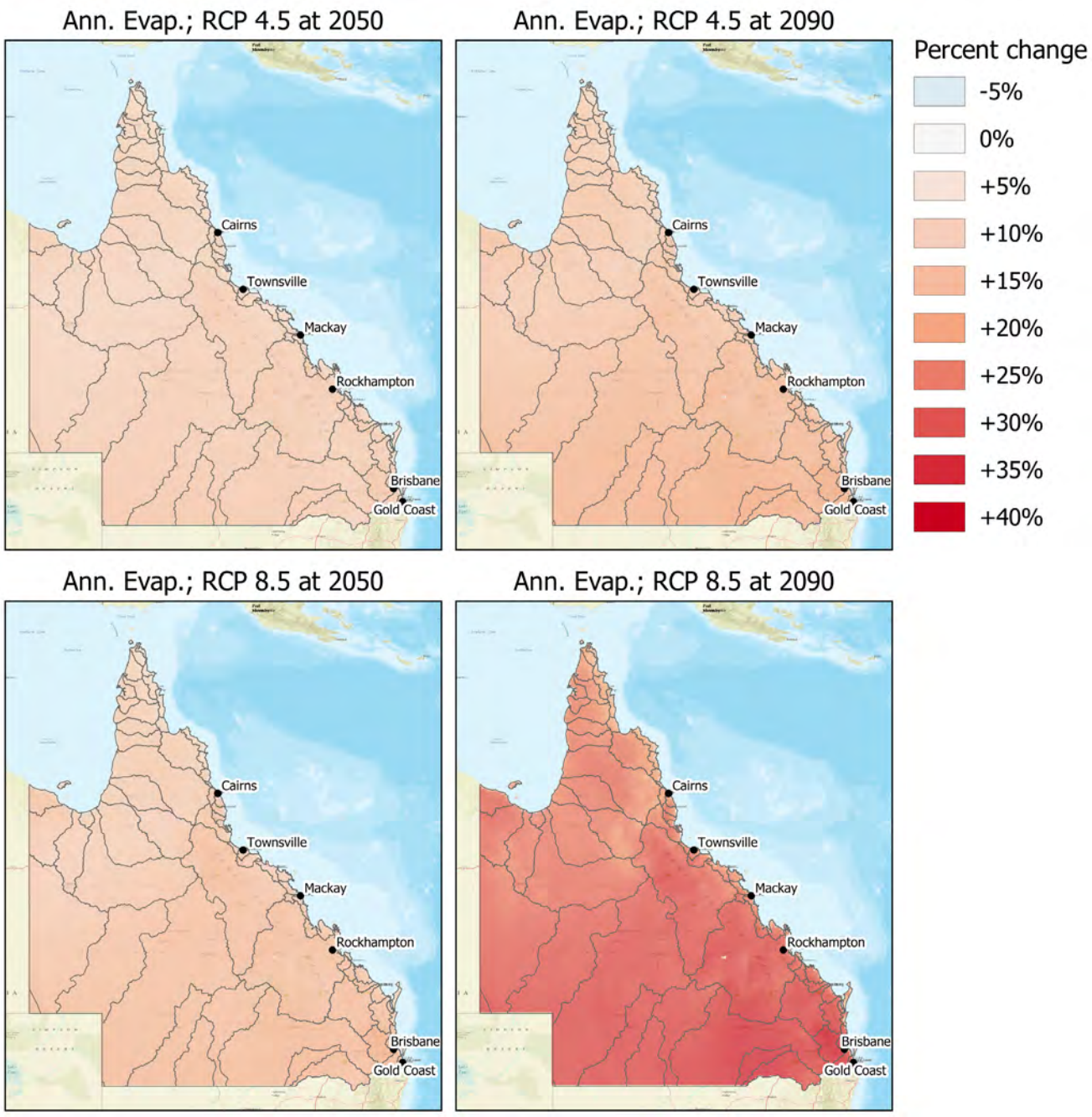


Figure A3-6: Projected percentage change in average daily pan evaporation (%) at 2050 and 2090 for emissions scenarios RCPs 4.5 and 8.5 at relative to reference period (1986–2005).

Source: Queensland Future Climate Dashboard (longpaddock.qld.gov.au/qld-future-climate/dashboard/)

Table A3-2: Projected change in average annual PET (millimetres per year) relative to the reference period 1986–2005, based on the emissions scenario RCP 4.5 and RCP 8.5 for Barron, Burdekin, Burnett and Fitzroy. Under each scenario, P10 is the lowest projected change, P50 is the median projected change and P90 is the highest projected change.

Catchment	Year	RCP 4.5			RCP 8.5		
		P10	P50	P90	P10	P50	P90
Barron	2030	+44	+110	+190	+48	+130	+210
	2040	+25	+130	+190	+82	+170	+280
	2050	+70	+170	+260	+150	+200	+330
	2060	+100	+170	+280	+160	+240	+350
	2070	+140	+170	+260	+210	+280	+410
	2080	+100	+210	+280	+220	+350	+500
	2090	+110	+210	+300	+210	+430	+650
Burdekin	2030	+39	+160	+320	+73	+140	+300
	2040	+20	+160	+400	+130	+260	+320
	2050	+31	+260	+490	+230	+390	+480
	2060	+150	+310	+570	+250	+500	+710
	2070	+250	+280	+570	+300	+600	+820
	2080	+110	+320	+580	+400	+720	+900
	2090	+62	+350	+590	+460	+790	+1100
Burnett	2030	+48	+100	+280	+57	+120	+250
	2040	+61	+140	+310	+110	+210	+260
	2050	+94	+230	+360	+190	+330	+400
	2060	+160	+300	+460	+210	+410	+590
	2070	+230	+270	+440	+250	+500	+670
	2080	+170	+310	+540	+330	+600	+740
	2090	+180	+320	+580	+390	+660	+910
Fitzroy	2030	+50	+130	+310	+31	+170	+260
	2040	+38	+160	+370	+67	+260	+320
	2050	+59	+270	+490	+160	+390	+460
	2060	+150	+320	+550	+220	+490	+690
	2070	+230	+310	+560	+190	+550	+780
	2080	+130	+340	+610	+300	+670	+830
	2090	+120	+370	+670	+360	+710	+1100

Rainfall summary

Figure A3-7 compares mean daily rainfall in millimetres per day at 2050 and 2090 for RCP 4.5 and RCP 8.5 downscaled to square grids of 10 kilometres by 10 kilometres. These maps show changes in mean daily rainfall relative to the reference period (1986–2005). Although the projected trend in rainfall varies across the state, climate models suggest the intensity of extreme rainfall events is likely to increase. Tropical storms and cyclones may occur less frequently in the future but are likely to be more intense. Figure A3-7 shows rainfall is projected to increase west of the Great Divide in the central and northern parts of the state. It is projected to decline elsewhere in Queensland, especially along the east coast and in the southwest. In many areas of the state, little change in annual rainfall is projected. Figure A3-8 shows these changes as percentages. The rainfall increases in central and northern Queensland west of the Great Divide are very large under RCP 8.5, while the reductions in rainfall in the northern coastal region and the Burdekin catchment are large.

At 2050 there is little difference between the two emissions scenarios. The differences are generally much larger by 2090.

Table A3-3 shows the lowest, median and highest projections for the projected changes in annual rainfall by decade for RCP 4.5 and RCP 8.5 for the proposed Regional Water Grids catchments. For all catchments, the median results from the 11 models show small negative changes. They are largest in the Barron. The range from the models includes positive effects as well as negatives across all catchments. The model that shows the largest decline in Burdekin rainfall suggests very large falls.

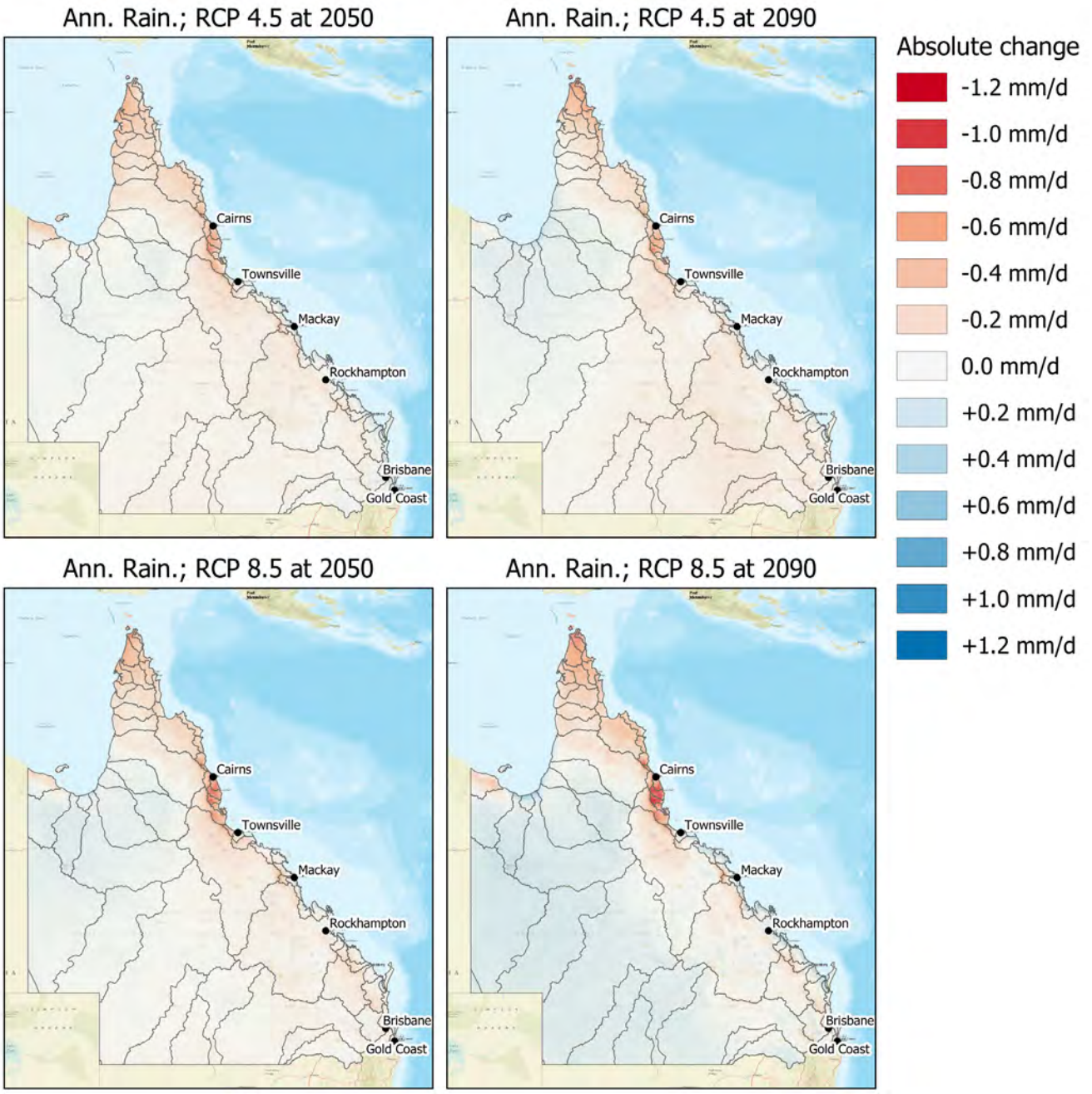


Figure A3-7: Projected change in mean daily rainfall (mm/d) at 2050 and 2090 for emissions scenarios RCPs 4.5 and 8.5 at relative to reference period (1986–2005).

Source: Queensland Future Climate Dashboard (longpaddock.qld.gov.au/qld-future-climate/dashboard/)

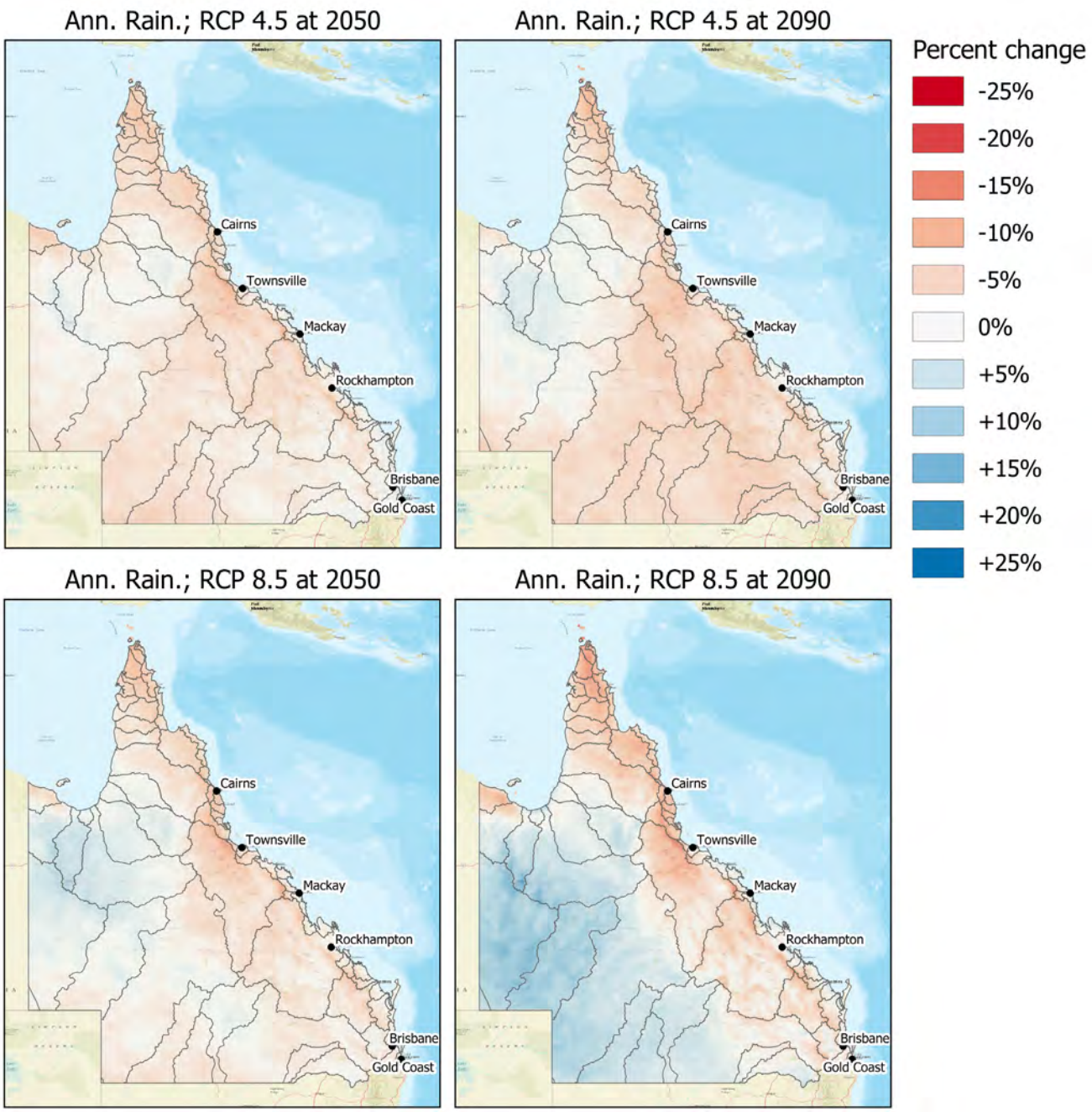


Figure A3-8: Projected change in mean daily rainfall (%) at 2050 and 2090 for emissions scenarios RCPs 4.5 and 8.5 at relative to reference period (1986–2005).

Source: Queensland Future Climate Dashboard (longpaddock.qld.gov.au/qld-future-climate/dashboard/)

Table A3-3: Predicted annual rainfall change (%) relative to the reference period 1986–2005, based on the emissions scenario RCP 4.5 and RCP 8.5 for Barron, Burdekin, Burnett and Fitzroy. Under each scenario, P10 is the lowest projected change, P50 is the median projected change and P90 is the highest projected change.

Catchment	Year	RCP 4.5			RCP 8.5		
		P10	P50	P90	P10	P50	P90
Barron	2030	-16%	-8%	2%	-14%	-8%	-1%
	2040	-15%	-4%	6%	-18%	-7%	2%
	2050	-21%	-7%	2%	-17%	-9%	-1%
	2060	-19%	-3%	4%	-13%	-7%	-2%
	2070	-14%	-7%	7%	-15%	-5%	-2%
	2080	-12%	-6%	1%	-20%	-5%	1%
	2090	-12%	-5%	3%	-25%	-9%	5%
Burdekin	2030	-17%	-2%	7%	-9%	-5%	2%
	2040	-13%	2%	6%	-12%	-2%	4%
	2050	-17%	-4%	5%	-14%	-6%	3%
	2060	-22%	-1%	6%	-16%	-6%	7%
	2070	-24%	-4%	1%	-19%	-5%	9%
	2080	-16%	-6%	5%	-29%	-1%	8%
	2090	-19%	-6%	10%	-35%	-1%	13%
Burnett	2030	-14%	-2%	8%	-10%	-2%	10%
	2040	-8%	-2%	6%	-9%	-5%	8%
	2050	-8%	-2%	3%	-10%	-3%	3%
	2060	-10%	-2%	4%	-15%	-2%	6%
	2070	-9%	-3%	2%	-9%	-2%	6%
	2080	-17%	1%	5%	-7%	-3%	4%
	2090	-21%	-2%	5%	-10%	-3%	6%
Fitzroy	2030	-10%	-3%	6%	-9%	2%	6%
	2040	-9%	1%	7%	-9%	-1%	6%
	2050	-13%	-5%	6%	-11%	-3%	4%
	2060	-16%	-2%	7%	-12%	-3%	7%
	2070	-16%	-3%	1%	-10%	-3%	8%
	2080	-19%	-1%	1%	-12%	0%	7%
	2090	-25%	-3%	10%	-16%	0%	9%

Modelling for selected catchments

Section overview

This section outlines:

- the results of applying more detailed modelling of future climate to the Regional Water Grids areas of Barron, Burdekin, Fitzroy, and Burnett
- historical temperature, rainfall and evaporation records and comparison with the climate models' predictions for each of the Regional Water Grids areas
- some implications of future changes in climate on the amount of water available for new economic activity.

Taking climate change into account avoids costly mistakes in allocating access to water for various uses. Failure to do so can lead to wasteful underuse of a potentially valuable resource or to crisis when the water is not available to meet expectations. Failure to take climate change into account is an important cause of the crisis in water management in the Murray–Darling Basin.

The Commonwealth and state governments have agreed in the National Water Initiative to consider climate change in water planning and allocation. The Queensland Parliament has passed laws requiring the honouring of these commitments. The Queensland Government has in recent years made major efforts to consider climate change when assessing the availability of water for allocation to various uses. The panel accepts the approach adopted by the department as being reasonable, although it has not previously been made public, and has not yet been applied to water plans. The panel makes references to that work in its own suggestions for water infrastructure investment. The Queensland Government, and the panel, recognise we are in the early stages of taking climate change into account in water planning. In particular, we are at an early stage in using observation of how the climate has actually changed over recent decades to recalibrate the models to reflect climate change as it is actually emerging.

The Queensland Government database (called SILO) provides climate data from January 1889 until yesterday. These data are created from Bureau of Meteorology gauging stations, state gauging stations and other sources. Some of the data from other sources are estimations. The water resource models, in this case the Integrated Quantity and Quality Model (IQQM), are calibrated to be consistent with the observed historical data. These models are updated and recalibrated periodically, typically every 10 years.

The ways in which the future climate will respond to increases in concentrations of greenhouse gases are inherently uncertain. The climate is naturally variable—as observed in the historical data. There are uncertainties about the extent to which the international community succeeds in meeting its agreed climate goals. The data represent significant progress and substantial failure in the RCP 4.5 and 8.5 scenarios. Each of the global climate models used by the Queensland Government project a range of possible outcomes rather than a single point. And the 11 different global climate models project a different range of future climate outcomes from the same increases in greenhouse gas concentrations. These 11 models are themselves selected by Queensland officials from a much larger set, and the panel has not exercised its separate judgement over the selection process.

For a particular emission scenario at a particular projection year, 11 different estimates of future climate are created, one for each climate model (GCM). Then the water resource model is run for each future climate estimate. This results in a set of estimates of temperature, evaporation, rainfall and eventually streamflows, all affecting the availability of water. This set of estimates represents a range of future outcomes. The Queensland Government's approach is to take the median of the set of projected outcomes as the best representation of what may happen in future. This is a reasonable approach—although we do not have a scientific basis for saying that all of the models are equally likely to accurately predict the future. For policy-makers, this is an area of what has been called radical uncertainty[5]. We do not know which of the models is inherently superior. We will only know when the future climate reveals itself.

In recognition of the uncertainty, we also present data on the 10th and 90th percentiles of the set of data from the model—model outcomes close to the outer limits of the range of projected climate outcomes. Each of the climate models has its own probability distribution around the central estimate.

Overview

For the Burdekin, Fitzroy, Barron and Burnett, additional modelling has been completed to look at:

- how climate change may affect average daily temperatures, average annual evaporation and average annual rainfall at RCP 4.5 and RCP 8.5 emissions scenarios
- how climate change may affect river flows and the availability of water for economic uses.

The implications from the models for changes in temperature, evaporation and rainfall are shown in this section. The data presented are catchment averages over 20-year windows. Each window is centred on the projection year. For example, the projection at 2040 uses the period January 2030 to December 2049.

The reference period from which the change is calculated is January 1986 to December 2005.

Looking at the historical record, average temperatures have increased in all catchments. These are largest for the most recent period, from 1990 onwards. There is no doubt about it: these regions, like the world as a whole, are getting hotter. Global warming is real, and we can feel it and see it in the data. The difference between temperature and evaporation projections in emissions scenarios RCP 4.5 and RCP 8.5 is fairly small in 2050 and much larger in 2090.

The effects of rising greenhouse gas concentrations on rainfall is not so straightforward. Neither is the difference between projections for 2050 and 2090 so simple. They are different across the four Regional Water Grids catchments.

The charts show changes in the amount of water available for diversion for economic uses from the streams and rivers that are predicted by taking the averages of the models. 'Total losses/gains for diversions' does not consider the current volume of underutilisation in a scheme.

The results from the median of the 11 GCM outputs have been shown, as well as the variability as represented by the 90th and 10th percentiles (80 per cent confidence interval). The historical simulation periods used for each model are shown.

- **Barron catchment:** 1 January 1913 to 31 December 1995
- **Burnett catchment:** 1 January 1890 to 30 June 2008
- **Burdekin catchment:** 1 July 1890 to 30 June 1998
- **Fitzroy catchment:** 1 January 1889 to 31 December 2007

Barron

Impact of climate change on streamflows and water available for diversion for economic uses in the Barron

The net impact of using the models for assessing water available for diversion from the Barron is summarised in Table A3-4.

The models suggest that by 2050 there will be around 21 gigalitres per annum or 12 per cent less water available for irrigation diversion in the Mareeba–Dimbulah Water Supply Scheme than would have been expected if historical patterns continued. This may be attributed to the impact of evaporation and reduced inflows on the volume of water held in storage. Medium-priority users are affected, while high-priority users are not. Water sharing arrangements in dry times supply high-priority in preference to medium-priority water allocation. High-priority water allocations represent the smaller proportion of the total scheme's entitlement.

When this information is considered alongside the water allocated in Queensland's water plans, it should be kept in mind that the analysis does not consider the current volume of underutilisation in a scheme. It does not consider increases in demand from established users of water as temperature increases.

There has been no assessment of potential impacts to the aquatic ecology in the Barron under this climate change assessment, including whether environmental flow requirements are affected. Neither has there been any reassessment of distribution losses for the scheme.

Historical temperature, evaporation and rainfall

Let us now examine how the actual experience of climate change in recent decades compares with projections from the models.

Figure A3-9 shows the long-term average daily temperature records for the Barron catchment. The bars are the annual average temperatures. The red line shows the five-year running average (the mean). The horizontal lines (blue for 1890–1969; green for 1970–1999; orange for 2000–2019) show averages over three long periods. The three decades from 1970 had somewhat higher average temperatures than the first eight decades covered by the record. The last two decades had substantially higher average temperatures than earlier periods. Within the past two decades of much higher average temperatures, the second decade was much warmer than the first.

Figure A3-10 shows the equivalent sets of data from the evaporation records for the Barron catchment. The records show evaporation in the last three decades of last century was substantially lower than in the preceding 80 years. Evaporation so far this century has also been lower than in those first eight decades of records, but higher than late last century. This contrasts with expectations of increases in evaporation from the median of the models.

Figure A3-11 shows the long-term annual rainfall totals for the Barron catchment, as well as the five-year running mean and means for each period. Average rainfall was not noticeably different in the last three decades of last century or in the first two decades of this century than in the first 80 years of the historical record.

Figures A3-9 to A3-11 present real data. We can compare these with projections from the models. As we gather more real data, we will gradually learn which of the climate models most accurately reflects real influences on climate. However, we are in the early stages of applying climate models and of observing the real effects of growing greenhouse gas concentrations on the climate. When what has been happening diverges from the predictions of the future formed by using the median of 11 models, we can start to think about whether that median is giving us the most reliable indications of future climate.

Looking ahead, by 2050, the median of the models suggests if emissions follow the RCP 8.5 scenario (substantial failure of global mitigation), temperature will be 1.5 degrees above the reference period (1986–2005). Note that the reference period already embodies substantial warming. If emissions growth follows the RCP 4.5 scenario (substantial progress towards but falling short of achievement of the Paris global mitigation goals), the average of the models anticipates a further increase of 1.1 degrees above the reference period.

Nothing in the Barron catchment projections is challenged by the emerging temperature record.

Looking at projected evaporation changes at 2050 (Table A3-2), average annual evaporation is projected to increase by 8–10 per cent in comparison to the reference period (1986–2005), with little difference between the median values under either scenario (4.5 or 8.5 RCP) by 2050. The observations of change over the past two decades are not pointing to the increases suggested by the models. It is early days. This is something to watch. Continuation of a flat trend in evaporation would raise questions about whether use of the median from the models is giving us the most reliable guide to the future.

The median of the projected rainfall changes from the models in Table A3-3 predicts a reduction in rainfall between seven per cent (moderate failure to implement the Paris Agreement) and nine per cent (comprehensive failure) between late last century (the reference period 1986–2005) and 2050.

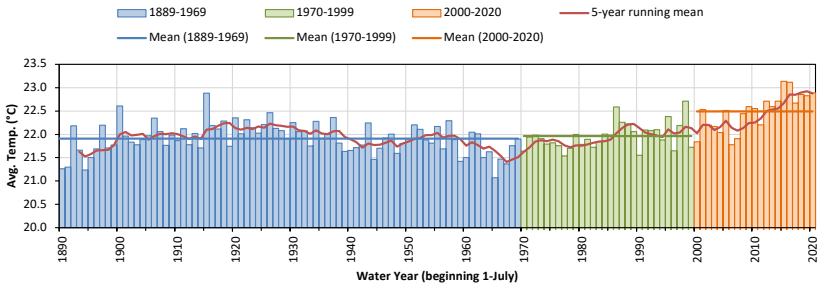


Figure A3-9: Annual average historical daily temperature records and trends: Barron catchment.

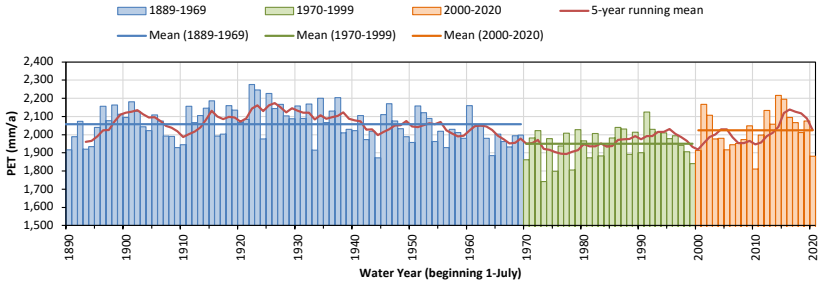


Figure A3-10: Annual historical potential evaporation records and trends: Barron catchment.

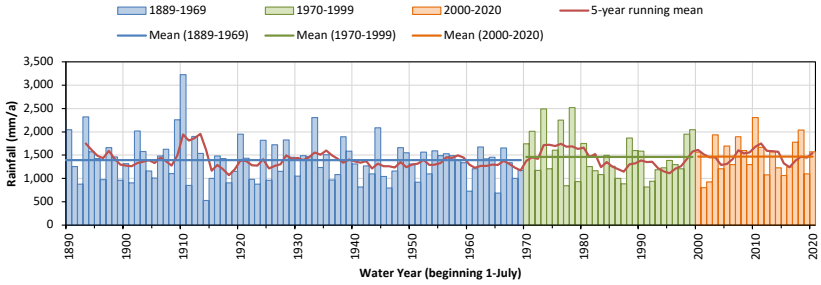


Figure A3-11: Historical annual rainfall records (mm per annum): Barron catchment.

Table A3-4: Modelled historical diversions and diversions under climate change (RCP 4.5 at 2050) using median output of climate models: Barron catchment.

Supplemented water use group	Historical (GL/a)	Median RCP 4.5; 2050 (GL/a)	Difference (GL/a)	Difference (%)* *rounding applied
Total high-priority water use	13.6	13.5	0	0
Total medium-priority water use	18.8	161.0	-20.9	-12
Total high-priority and medium-priority water use			**-20.9**	

Again, the absence of any fall in mean rainfall so far gives us something to watch for evidence of whether the median of the models is the best guide to the future.

Overall, the models point to significantly less water being available for economic use in the Barron as a result of climate change. This possibility should be taken seriously, and care should be taken not to make firm commitments for use of the water that would have been available on average in the first 80 years of observation. However, actual observations are not pointing to reduced availability of water. We should be alert to the possibility that projected reductions in average rainfall and increases in PET may not occur.

Burnett

Impact of climate change on streamflows and diversions for economic uses in the Burnett

The models' anticipation of the impact of climate change on water available for economic use in the Burnett is summarised in Table A3-5. Very little change is anticipated with the small reduction concentrated on medium-priority water. There is a larger reduction in medium-priority allocations. Water sharing rules give priority access to high-priority water allocations in dry times. There is less high-priority than medium-priority demand in the Burnett catchment. High-priority water is more expensive and is used for high-value crops that require reliable flows of water. At present, these are mainly high-value horticultural crops. The analysis does not take into account the reality that not all water currently allocated is used—it does not provide for future increases in water for new economic uses out of current allocations that are not used. Demand for water in current uses could be expected to increase in a drier and warmer climate. There has been no assessment of potential impacts to the aquatic ecology in the Burnett under the projected climatic conditions, including whether environmental flow requirements are affected. Similarly, assumptions affecting distribution losses for the scheme have not been revisited. Hotter and drier climatic conditions would be likely to increase losses in distributing water to users.

Historical temperature, evaporation and rainfall

Here we present data for the Burnett in a manner that follows that used for the Barron.

Figure A3-12 shows the long-term annual average daily temperature records for the Burnett catchment, as well as the five-year running mean (red) and means for each period. The graph shows higher temperatures in recent decades, with the period 2000–2019 showing a significantly higher mean than the previous periods of record.

Figure A3-13 shows the long-term annual potential evaporation records for the Burnett catchment, as well as the five-year running mean, and means for the same three historical periods used in presentation of the Barron data. The records show lower average evaporation in the last three decades of the twentieth century, and a lift back to earlier historical levels so far this century. As in the Barron, large increases in average temperatures have not so far been associated with substantial increases in evaporation.

Looking at the models' indications of future changes to evaporation

Table A3-2 shows average annual evaporation at 2050 is projected to increase above the reference period (1986–2005) by 11 per cent under RCP 4.5 and 16 per cent under RCP 8.5. Again, the absence of the strong tendency for observed evaporation to rise is in line with the projections from the models. The early apparent divergence between observations and median model predictions is weaker for the Burnett than the Barron.

Figure A3-14 shows the long-term annual rainfall totals for the Burnett catchment, as well as the five-year running mean and means for each period. There was little change over earlier historical experience (a small reduction in 2000–2019).

The median of the models had projected increases in evaporation and reductions in rainfall in the Burnett. This is not yet showing up in the observational record. Water planners should take care in presuming reductions in rainfall until there is stronger evidence that projected changes are actually occurring.

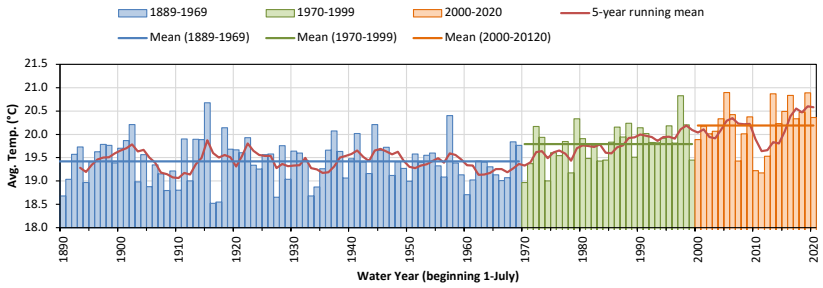


Figure A3-12: Annual average historical daily temperature records and trends: Burnett catchment.

Note: Nothing in the observed record challenges the projections of temperature from the models.

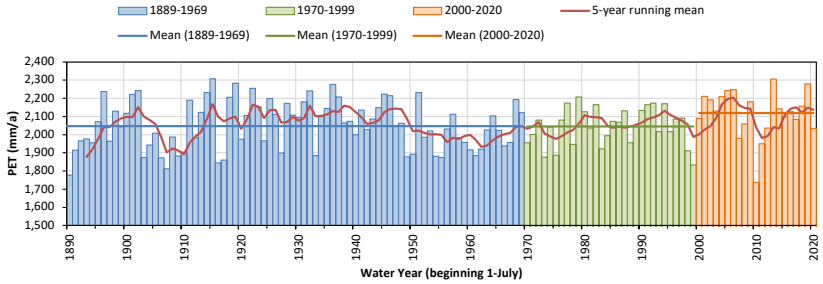


Figure A3-13: Annual historical potential evaporation records and trends: Burnett catchment.

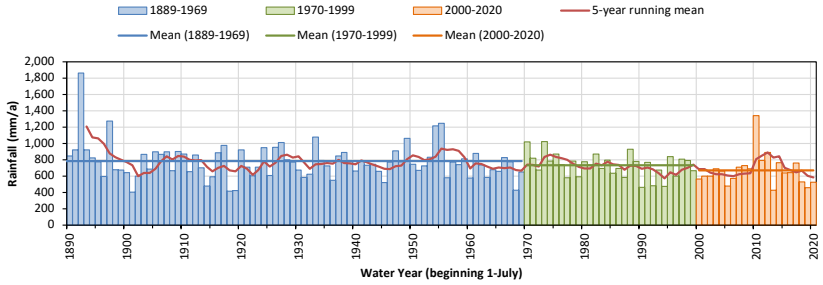


Figure A3-14: Historical annual rainfall records (mm per annum): Burnett catchment.

Table A3-5: Modelled historical diversions and diversions under climate change (RCP 4.5 at 2050) using median output of climate models: Burnett catchment.

Supplemented water use group	Historical (GL/a)	Median RCP 4.5; 2050 (GL/a)	Difference (GL/a)	Difference (%)* *rounding applied
Total high-priority water use	82.6	82.8	+0.2	0
Total medium-priority water use	430.7	427.0	-3.7	-2
Total high-priority and medium-priority water use			**-3.7**	

Burdekin

Historical temperature, evaporation and rainfall

Figure A3-15 shows increases in the long-term annual average daily temperature records for the Burdekin catchment, as well as the five-year running mean and means for each period.

Actual recorded temperatures have increased recent decades in the Burdekin, much as they have in the Barron and Burnett.

The models suggest increases of 1.9 degrees over the reference period by 2050 under RCP 8.5, and 1.4 degrees under RCP 4.5—much the same as the other catchments (Table A3-1). Nothing in the recent observational record challenges that projection.

Figure A3-16 presents the historical record for evaporation. There was no change in the last three decades of last century but a step up over the twenty-first century so far.

The models project an increase in evaporation between the average of the reference period and 2050, by 10 per cent under RCP 4.5 and 16 per cent under RCP 8.5. That is broadly consistent with the observational record over recent decades.

Figure A3-17 shows a small reduction in average rainfall between the first 80 years of observation and the last three decades of the twentieth century, and another small step down over the past two decades.

The models predict reductions in projected rainfall between four per cent and six per cent by 2050, from the reference period of 1986–2005 (Table A3-3). Nothing in the observational record so far challenges this projection. It would seem prudent to allow for the likelihood that average rainfall in the Burdekin will be lower and average losses from evaporation higher in future than in the past.

Impact of climate change on streamflows and diversions in the Burdekin

The climate change scenario models for the Burdekin suggest the likelihood of a substantial decline in annual streamflow at the end of the system by 2050 but a wide range of possible outcomes. The median change for RCP 4.5 is a reduction from a mean of 5,450 gigalitres per annum to 4,780 gigalitres per annum.

The net impact on water available for economic use in the Burdekin ('supplemented water diversions' in the official language of the water plans) is summarised in Table A3-6.

The modelled effects of climate change by 2050 for emissions scenario RCP 4.5 are relatively minor for users with secure rights to water ('high-priority users') in the Bowen–Broken Water Supply Scheme (a reduction of almost two per cent). High-priority users in the Burdekin–Haughton Water Supply Scheme are not affected. The models project a reduction of around five per cent for medium-priority users. This may be attributed to the impact of evaporation and reduced inflows on the volume of water held in storage, together with water sharing arrangements that give priority to high-priority water allocations in dry times. High-priority water allocations represent the smaller proportion of total scheme entitlement in both schemes.

In total, the models project a small reduction in water available for new economic uses from managed schemes ('supplemented water' in the official language)—a reduction of about 38 gigalitres per annum in the Burdekin catchment, proportionately larger in the Bowen–Broken catchment. The analysis is based on assumptions that users utilise the whole of the allocations to them. It does not consider the considerable present underutilisation of allocations in a scheme. As with the other catchments, this modelling of water available for new economic uses doesn't take into account the impacts of climate change on environmental flows or the effects of warming and drying on demand from existing users of water.

The confirmation in the recent observational record of the models' projections of moderately lower rainfall and higher evaporation suggests it would be wise not to allocate as much water indelibly to future uses as would have been available previously.

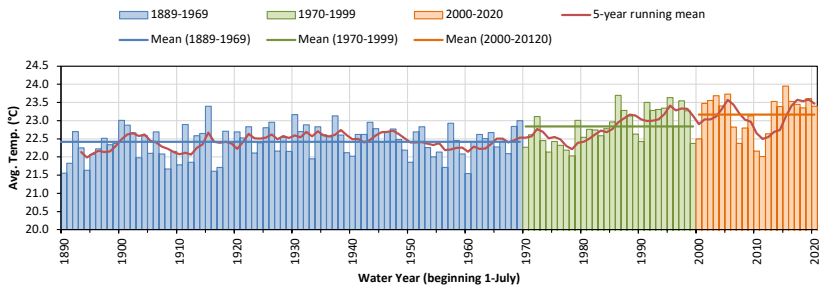


Figure A3-15: Annual average historical daily temperature records and trends: Burdekin catchment.

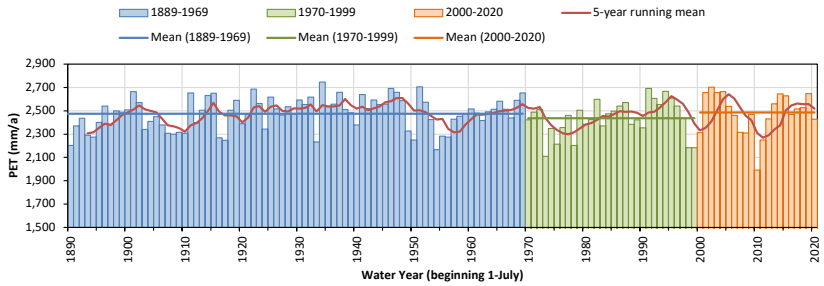


Figure A3-16: Annual historical potential evaporation records and trends: Burdekin catchment.

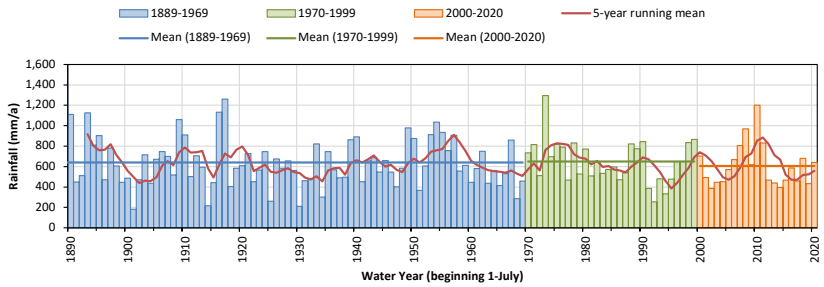


Figure A3-17: Historical annual rainfall records (mm per annum): Burdekin catchment.

Table A3-6: Modelled historical diversions and diversions under climate change (RCP 4.5 at 2050) using median output of climate models: Burdekin catchment.

Supplemented water user group	Historical (GL/a)	Median RCP 4.5; 2050 (GL/a)	Difference (GL/a)	Difference (%)* *rounding applied
Burdekin–Haughton Water Supply Scheme				
High-priority group	26.8	26.8	0	0
Medium-priority group	1,233.9	1,207.6	-26.3	-2
Losses/gains			**-26.3**	
Bowen–Broken Water Supply Scheme				
High-priority group	33.0	32.3	-0.7	-2
Medium-priority group	145.5	134.0	-11.5	-8
Losses / gains			**-12.2**	
Total losses/gains for Burdekin diversions (ML/annum)			**-38.5**	

Fitzroy

Historical temperature, evaporation and rainfall

Figure A3-18 shows the usual large increases in temperature in the Fitzroy catchment over the past half-century, accelerating over the past two decades. The models project similar increases in temperature under both scenarios to those for other catchments (Table A3-1).

By 2050, for emissions scenario RCP 8.5, an increase in temperature of 1.8 degrees is projected in comparison to the reference period (1986–2005). In comparison, an increase in temperature of 1.6 degrees is projected under the emissions scenario RCP 4.5 (Table A3-1).

Figure A3-19 shows a fairly consistent evapotranspiration rate through the later decades of last century, and some increase over the past two decades.

The average of the models points to an increase in annual average evaporation by 2050 from the reference years, by 11 per cent under RCP 4.5 and 16 per cent under RCP 8.5 (Table A3-2). There is no outstanding contradiction between the output from the median of the models and the record of observation so far.

Figure A3-20 shows average annual rainfall late last century similar to that in the earlier historical record, and a fall so far this century.

The models anticipate small reductions in rainfall under both the RCP 4.5 and RCP 8.5 scenarios (five per cent and three per cent respectively; Table A3-3). The observational record so far does not challenge the output of the models. It would be prudent to allow for small reductions in future rainfall below historical averages.

Impact of climate change on streamflows and diversions in the Fitzroy

The climate change scenario models suggest little impact of climate change on streamflow at the end of the Fitzroy system in the median case (5,030 gigalitres per annum compared with a historical mean), but large reductions (to 3,610 gigalitres per annum) in the lowest case and increases (to 11,900 gigalitres per annum) in the highest case.

Overall, the net impact on existing supplemented diversions in the Fitzroy is summarised in Table A3-7. In total, a reduction in 29 gigalitres per annum is projected in water available for diversion to new economic uses, mainly in medium-priority water. This modelling of water available for diversions is subject to the same caveats introduced in discussion of the other catchments.

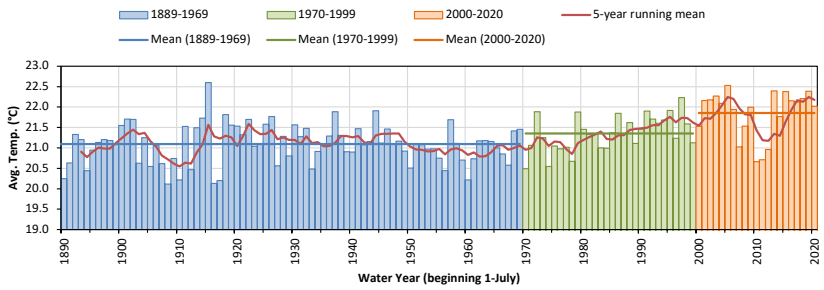


Figure A3-18: Annual average historical daily temperature records and trends: Fitzroy catchment.

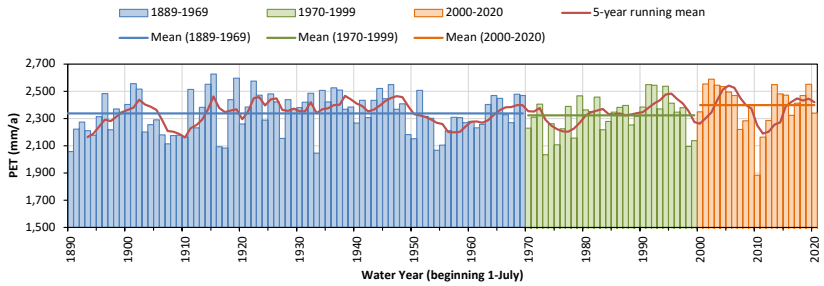


Figure A3-19: Annual historical potential evaporation records and trends: Fitzroy catchment.

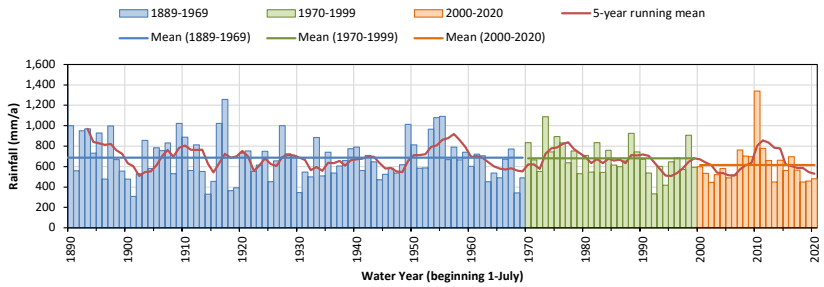


Figure A3-20: Historical annual rainfall records (mm per annum): Fitzroy catchment.

Table A3-7: Modelled historical diversions and diversions under climate change (RCP 4.5 at 2050) using median output of climate models: Fitzroy catchment.

Supplemented water user group	Historical (GL/a)	Median RCP 4.5; 2050 (GL/a)	Difference (GL/a)	Difference (%*) *rounding applied
Dawson Valley Water Supply Scheme				
High-priority water	100.7	99.9	-0.8	-1
Medium-priority water	58.4	52.0	-6.4	-11
Losses / gains (ML/annum)			**-7.2**	
Nogoa–Mackenzie Water Supply Scheme				
High-priority water	263.2	260.5	-2.7	-1
Medium-priority water	162.2	143.4	-18.8	-12
Losses/gains (ML/annum)			**-21.5**	
Total losses/gains for Fitzroy diversions (ML/annum)			**-28.7**	

Comparison of observed and projected climate variables for selected catchments

This appendix has presented projections of climate change affecting water availability from a range of climate models. It has lined these up against changes observed so far. To conclude the appendix, we describe graphically how actual climate outcomes are unfolding alongside projections from the models.

We compare median projections from the models, and variations from the median, with actual observations in each of the Regional Water Grids catchments. The focus is successively on observed and projected average daily temperature, annual PET and annual rainfall. The projected data are created by the same method as was used in the detailed hydrological water resource modelling.

The blue in each chart represents conditions in the century before climate change began to exert a strong influence in about 1990. The orange in each chart represents conditions beyond that time. Distributions of projections (orange) are not continuous. Each decadal projection represents a 20-year window (e.g. a projection at 2050 uses climate from January 2040 to December 2059). The modelling outputs for each system are:

- Barron system: Table A3-7
- Burdekin system: Table A3-8
- Burnett system: Table A3-9
- Fitzroy System: Table A3-10.

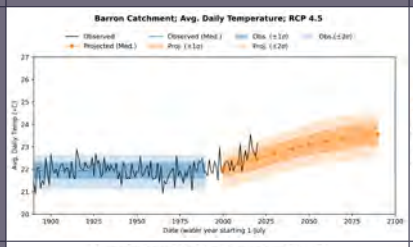
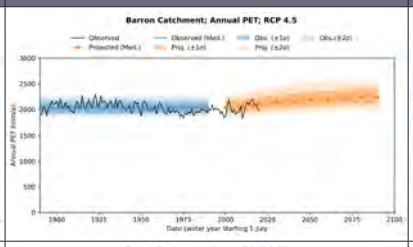
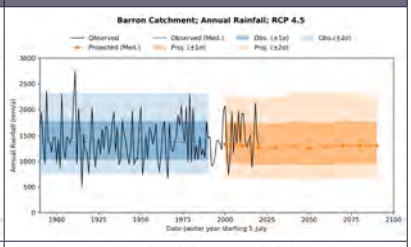
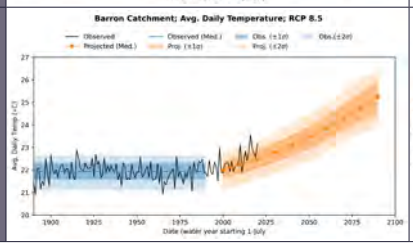
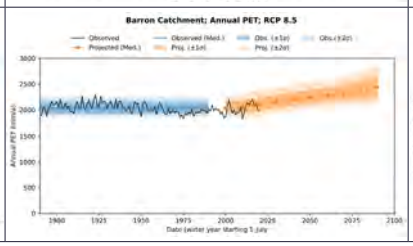
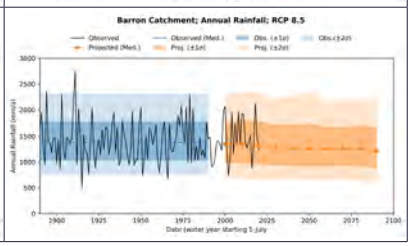
The continuous black lines represent actual observations in each year. The continuous blue lines represent the average of the past record; the continuous orange lines the moving 20-year average of actual and, for the future, projected outcomes. The shaded areas around the solid blue and orange lines give an idea of the variability of the measurement. The dark blue and dark orange shaded areas contain the range within which two-thirds of observations can be found. The lighter blue and lighter orange areas contain 95 per cent of observed (for the past) and projected (for the future) outcomes.

Table A3-8 shows that, in the Barron catchment, temperatures since 1990 have been tracking closely expectations from the model—if anything, a bit on the high side. Evaporation was expected to increase a bit, and generally has been unfolding as expected. Rainfall was expected to fall slightly. So far, it has been higher than anticipated.

In the Burdekin, evaporation was expected to increase moderately. So far it has been tracking within expectations. Rainfall was expected to fall moderately. So far it has been tracking within expectations—with extreme volatility.

Evaporation in the Fitzroy was expected to increase a little. Observations on the downside have been larger than anticipated. Rainfall was expected to fall a little. Observations are generally consistent with that, although the average has been bent upwards by extremely high levels in one year.

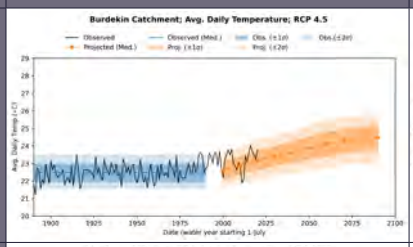
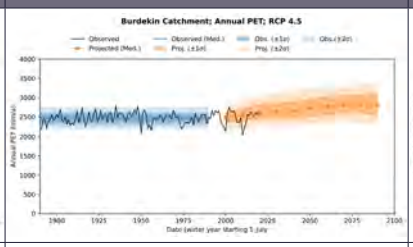
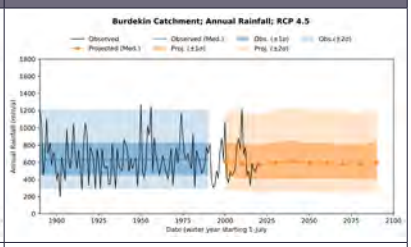
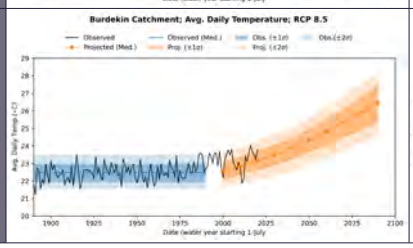
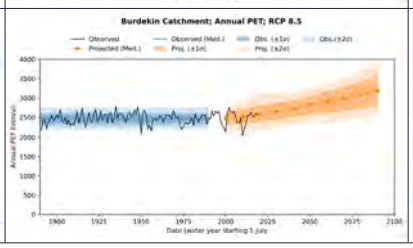
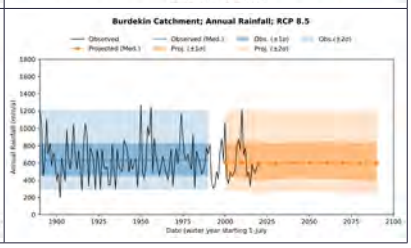
Table A3-8: Observed and projected average daily temperature, annual potential evaporation and annual rainfall projections: Barron catchment (RCP4.5).

Scenario	Average daily temperature	Annual potential evaporation	Annual rainfall
RCP 4.5			
RCP 8.5			

Notes:

- Statistical period for observed data is 1890 to 1990.
- Projections are decadal. They are not continuous.
- Variability is presented as shaded percentiles in standard deviations, e.g. ±1σ contains ~68 per cent and ±2σ contains ~95 per cent of variability.

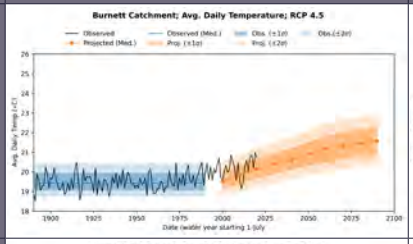
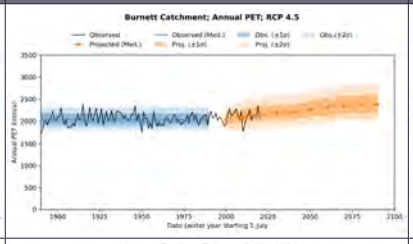
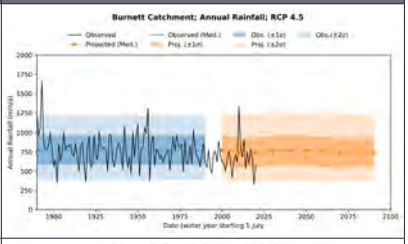
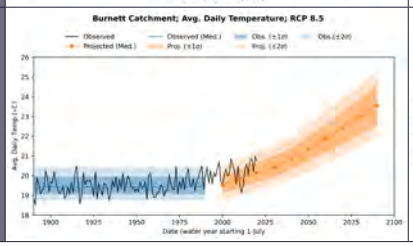
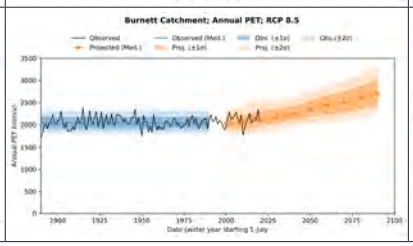
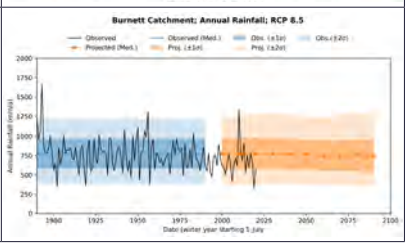
Table A3-9: Observed and projected average daily temperature, annual potential evaporation and annual rainfall projections: Burdekin catchment.

Scenario	Average daily temperature	Annual potential evaporation	Annual rainfall
RCP 4.5			
RCP 8.5			

Notes:

- Statistical period for observed data is 1890 to 1990.
- Projections are decadal. They are not continuous.
- Variability is presented as shaded percentiles in standard deviations, e.g. ±1σ contains ~68 per cent and ±2σ contains ~95 per cent of variability.

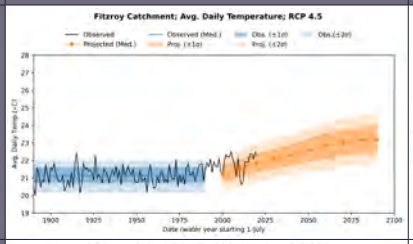
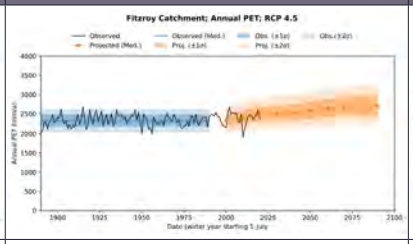
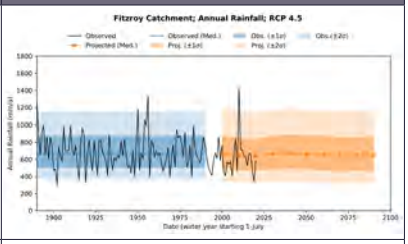
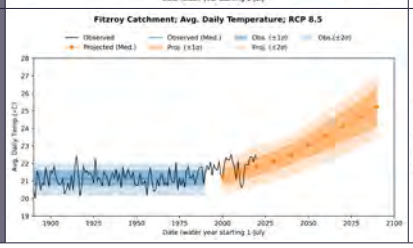
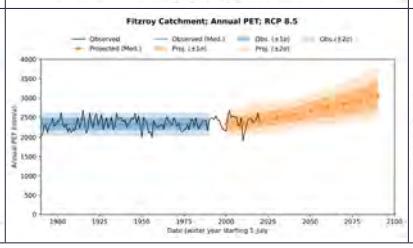
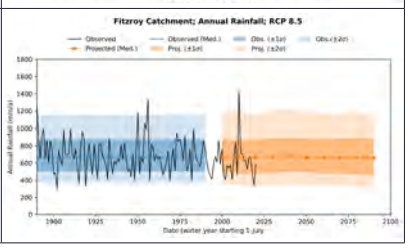
Table A3-10: Observed and projected average daily temperature, annual potential evaporation and annual rainfall projections: Burnett catchment.

Scenario	Average daily temperature	Annual potential evaporation	Annual rainfall
RCP 4.5			
RCP 8.5			

Notes:

- Statistical period for observed data is 1890 to 1990.
- Projections are decadal. They are not continuous.
- Variability is presented as shaded percentiles in standard deviations, e.g. ±1σ contains ~68 per cent and ±2σ contains ~95 per cent of variability.

Table A3-11: Observed and projected average daily temperature, annual potential evaporation and annual rainfall projections: Fitzroy catchment.

Scenario	Average daily temperature	Annual potential evaporation	Annual rainfall
RCP 4.5			
RCP 8.5			

Notes:

- Statistical period for observed data is 1890 to 1990.
- Projections are decadal. They are not continuous.
- Variability is presented as shaded percentiles in standard deviations, e.g. ±1σ contains ~68 per cent and ±2σ contains ~95 per cent of variability.

Some implications

Section overview

The science of atmospheric physics tells us increasing concentrations of greenhouse emissions will raise temperatures everywhere, increase evaporation in most places, increase rainfall in some places and reduce it in others, and cause a higher proportion of rainfall to arrive in occasional intense events. The changes will grow until the whole world has reduced net emissions to zero. The international community of nations has agreed to work together to achieve zero net emissions in time to hold temperature increases below 2 degrees and as close as possible to 1.5 degrees above pre-industrial levels. We may or may not succeed in that goal. Success would see us living with substantial but limited increases in temperature and changes in patterns of rainfall on top of what has already occurred: most of the change that humans will ever experience has already happened by 2021. Failure would see temperatures increase and other dimensions of climate change in ways far outside previous human experience, with damaging and probably catastrophic consequences.

All of these changes have important implications for the use of water and investment in water infrastructure. There are important implications even if we succeed in the goal of holding temperature increases close to 1.5 degrees (which would represent much earlier achievement of zero net emissions than embodied in RCM 4.5). Australians have been slow systematically to take climate change into account in managing water. This has contributed to the large problems of over-allocation of water in the Murray-Darling river system, to an extent that is greatly damaging established patterns of life in many communities.

Central and North Queensland, which are the subject of the panel's work, are not in the Murray-Darling situation. The Queensland Government and Parliament have taken steps to ensure it stays that way. The government is required by law to consider climate change in decisions on water allocations and therefore in decisions on investment in water infrastructure. Much good work has been undertaken to meet this legal requirement. The panel has had access to that work and commends it.

Taking future climate change into account is easier said than done. Atmospheric physics is seeking to understand an immensely complex natural system. The defining feature of human-induced climate change is an increase in temperature. Models that seek to predict the change in temperature as greenhouse gas concentrations increase are now all pointing in the same direction, and the range of estimates of temperature increases that come with any specified level of greenhouse gas concentrations becomes narrower with steady improvements in the science. This is clear in the projections from the models used by Queensland officials and reported in this appendix. Observed temperature increases in central and northern Queensland are close to (a bit above) the median projections from the models.

The determinants of average levels and fluctuations in rainfall are more complex. The models all recognise that, as the atmosphere warms, average global rainfall increases and a higher proportion of the rain falls in intense events. A warmer atmosphere absorbs more moisture from evaporation and so charges the atmosphere for greater release of water in rain events. But the amount of rain that falls on a particular region depends on how increased temperature affects winds and how local topography interacts with wind to induce precipitation. Less rain will fall in many areas—notably in the southern latitudes, which historically provided a high proportion of Australian agricultural production. More rain will fall in others—most of northern Australia, and in central and northern Queensland except for some areas near the coast.

The complexity causes different scientifically based models to project very different effects of warming on rainfall in particular regions. As we have seen, in some catchments of central and northern Queensland, some sound models project increases and others project reductions in rainfall in the same catchments. We do not have a basis for thinking one model more likely to predict the future more closely than others. Taking a median of selected models, as the Queensland Government does, is one way of forcing a choice among them. That gives us some guide to the way the future may unfold. But we should recognise that one of the outlying projections—the model showing the largest reduction or increase—may turn out to be a better guide than the median. We can build decisions on the median but should remain aware that the upper or lower bounds of the range of models may turn out to be more accurate guides to the future. We should use climate models to guide policy in full knowledge that we are making decisions under uncertainty. This means taking decisions that make the best sense in the light of the full range of outcomes—that add the most expected value when we take into account the whole range of possible outcomes and the chances that each of the projected outcomes will become future reality. And it means taking every chance to improve our models, by continually upgrading them as science advances and by continually recalibrating them as the unfolding of climate history tells us directly which models have been closest to predicting change. The decadal recalibrations of the models against the data that are undertaken by the Queensland Government are critically important—and we should always be ready to reassess at

shorter intervals if data emerges that is inconsistent with the projections from the models.

The median of the projections of future rainfall from the models used by Queensland officials predicts substantial increases in evaporation and decreases in rainfall in the four catchments subject to detailed analysis. This is good reason to avoid allocating firm rights to water and building water infrastructure that would only work with old historical (the 80 years to about 1970) levels of rainfall. It is good reason for cautious approaches to allocation. The median of the projections also points to increases in rainfall in central and especially northern Queensland away from the east coast. This is reason to be ready to make good use of extra water if the unfolding of climate reality confirms the projections.

At the same time, we should recognise that some credible models predict substantial increases in rainfall in each of the catchments. This is good reason to be ready to make good use of extra water if the unfolding of reality confirms that reality is delivering the wetter possibilities.

Changes in rainfall as greenhouse gas concentrations have increased over the past half-century reveal a moderate reduction of rainfall in the Fitzroy and Burdekin catchments (as projected by the median of the models) but not in the Barron or the Burnett. This should cause us to look closely at the emerging data from and the models for the Barron and Burnett, to see whether the median of the models is providing a reliable guide to the future. It should not yet cause us to make large investments in water infrastructure on the presumption that the wetter outcomes will continue. But continued observations of rainfall above the median expectations from the model would, at some point, support upward adjustment of our expectations for water planning purposes.

We did not look as closely at projections and outcomes further west from the four catchments in northern Queensland that are the focus of the Regional Water Grids. Here the models projected significant increases in rainfall and the observational record so far confirms those expectations. We should not jump quickly to decisions that indelibly use that extra water. We should, however, commence now the research and planning that allow us to make use of increased water if a wetter future reveals itself in the years ahead.

We would waste resources on a large scale and create large problems for communities in future if we allocated rights to water now that turned out to exceed the availability of water as climate change forces changes in rainfall and evaporation. There is a case for prudence and caution in allocations and investment in water infrastructure.

Both the models of climate change used by the Queensland Government and the observation of reality over recent decades show substantial increases in rainfall in northern and, to a lesser extent, central Queensland away from the coast.

The extra rain is arriving in more concentrated episodes. This creates an opportunity to undertake research and planning to productively use increased water if it becomes available across regions, especially in the north—the same areas once seen as beneficiaries of a classic Bradfield scheme.

The certainty of change in climate and uncertainty about its precise effect on rainfall argue for allocative and investment decisions that can adjust at low cost to increased knowledge about the availability of water. They argue for a higher proportion of allocation to be contingent on the availability of water, rather than be guaranteed to particular users. And they argue for avoiding irreversible, large decisions on investment that depend on availability of water until we have the full knowledge to confidently support the decisions.

The increased variability of rainfall and water supply that is likely to accompany continued global warming requires a similar response. There are likely to be times when water is available in great abundance, interspersed with deeper and longer dry periods. Sound water planning will have to be able to put rushes of water to good use while avoiding patterns of investment and development that turn out to be wasteful through the complete cycles of wet and dry times.

Rich new economic opportunities are emerging in the low-carbon world economy for the products of land and water that do not depend on large, steady supplies of water, and which can take advantage of variable supplies. Knowledge that the future availability of water year by year is even less certain than in old times of drought and flooding rains must play a role in selecting and managing crops. It must also play a role in decisions on infrastructure investment, giving greater value to assets that can be used flexibly as availability of water deviates from expectations.

To make optimal use of immense new opportunities for using central and northern Queensland for productive regional development requires us to manage land and water and other inputs into development in different ways. It requires public commitments into research on new development opportunities—just as early development of the established Australian agricultural and pastoral industries required extensive support from public sector-supported research. We need research into new plants, new processing technologies, new ways of providing water to crops and new patterns of providing infrastructure to support regional development.

The Productivity Commission's draft report on the National Water Initiative identifies climate change as a significant risk to the future security of Australia's water resources. It recommends that undeveloped and developing water systems set economic activity and environmental shares of available water in a way that manages the risk of future water resource reductions. For highly developed systems, the Productivity Commission's draft report advocates developing triggers for

rebalancing economic and other uses in response to water availability and future climate risk. This is one dimension of the policy development that is necessary to underpin Queensland regional development at a time of climate change.

This appendix does not cover in detail how climate change may affect the amount of water required in river systems to meet environmental flow requirements. Nor does it discuss in detail the volume of distribution loss from water allocations required to deliver water to customers under warmer and drier climatic conditions. Greater investment in assessments is required to understand the potential impact of future climate risk for proposed new water infrastructure.

The panel reads the models to suggest a strong possibility of significant decline in average water availability in the four eastern catchments and of some increase in the central and especially northern inland. The models suggest the biggest decline will be in the Barron. The models say we will have much more variability in water—a factor which is, in itself, difficult to model.

If the world succeeds with the Paris Agreement targets, we have already had two-thirds of the warming we will get—but there is much more to come if we fail.

The observational data so far tend to confirm a reduction in the availability of water so far from the Fitzroy and Burdekin but do not so far confirm the reduction in average availability in the Barron and the Burnett. They tend to confirm a large increase in average availability in the northern regions west of the Great Divide.

We are still learning. We should be careful not to allocate indelibly all of the water the historical data says would be available in the eastern catchments if the future repeated the past, especially the Burdekin and the Fitzroy. We should be ready to allocate to non-indelible uses increased water when it is available, either because the average is turning out to be higher than the median of the 11 selected models suggests, or because we are getting more high rainfall events.

One practical implication is that a higher proportion of water use should be in nurturing plants that do not depend on a high degree of certainty that a specified minimum level of water will always be available. This is a new consideration and requires us to undertake more research and development on plants that have these characteristics.

Another practical implication is that highly secure water will be more scarce and have higher value than before. That means there will be more value in investing in it than before—when increments of increased security can be achieved at reasonable cost. In some circumstances, it may be the basis for analysis that justifies higher levels of capital expenditure to increase the proportion of water that can be committed with confidence for all or most years.

At the same time, climate change in Australia and the world is increasing the value of the products (carbon sequestration, food and industrial biomass) from plants that do relatively well with variable rainfall and water availability. Again, this is new, requiring new research and development on new uses of water and land.

Central and northern Australia's high rainfall and the likelihood that it will be substantially maintained in most cases and substantially enhanced in others is a valuable asset in regional development. Climate change in Australia and the world has increased the value of this asset and the contribution it can make to regional development. The judicious use of this asset can underpin regional development in these important areas of Queensland. Judicious use requires investment in climate research and research, development and commercialisation of new systems of agriculture and silviculture, and of industrial processes that use the products of these activities. It requires investing in careful regional planning, integrating State powers and funding with Commonwealth funding, and engaging a wide range of affected people in local communities who are affected when water is used in new ways.

On balance, taking climate change into account increases the prospects for development in central and northern Queensland. It strengthens the reasons for introducing improved practices into regional development policy—and for making sure we manage well the abundance of water that is increasingly scarce and valuable in Australia.

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1 Productivity Commission, 2021

2 Garnaut, 2008

3 Masson-Delmotte et al., 2021

4 Intergovernmental Panel on Climate Change, 2021; United Nations Framework Convention on Climate Change, 2021

5 Kay and King, 2020



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Appendix 4

Indigenous interests in water development

Indigenous interests in water development

Introduction

For Queensland's Aboriginal and Torres Strait Islander peoples, water is part of a single connected system that includes the land, people, history and all living things. In this context, the waters of central and northern Queensland have spiritual, cultural, social, economic and environmental value to Indigenous individuals, families, clans, tribes and institutions[1]. International obligations and the *Human Rights Act 2019 (Qld)* and *Human Rights Regulation 2020* oblige the State and other parties (to varying degrees) to engage these interests in decision-making. More specifically, Queensland's Traditional Owners have well-defined and significant tenure, cultural heritage, and other rights and interests in land and water resources that may be affected by or influence water allocation and water development (i.e. the modification of water catchments to achieve societal needs). Indigenous peoples also have knowledge and perspectives that need to be engaged to achieve more sustainable and culturally appropriate water management.

Despite these obligations and interests, Aboriginal and Torres Strait Islander peoples across Queensland often have not been fully engaged as genuine partners in water infrastructure planning and development. This is particularly true of water allocation planning, development assessment and approval processes[2].

The introduction of Queensland's *Human Rights Act 2019* has recently solidified the need to comprehensively engage with Aboriginal and Torres Strait Islander peoples in resource use planning and development. This engagement may range from quality consultation to developing equity-based partnerships or supporting Indigenous-led water development. As such, in the panel's assessment of significant but conceptual water development scenarios, considering potential Indigenous interests and rights in water and land is essential.

This appendix explores the broad array of Aboriginal and Torres Strait Islander peoples' interests in water, relevant to the panel's work. Major issues of importance for the assessment process and for implementing panel findings include:

- engaging Indigenous interests in water planning and water development planning and decision-making under the Human Rights Act 2019 and other international, national and Queensland-based policy frameworks
- accounting for Indigenous interests in water allocation planning
- accounting for Indigenous interests in water development planning and project assessment, from catchment scales down to assessing individual water development proposals
- considering the contextual, procedural and cost implications of native title on past and future water infrastructure development.

Foundations for stronger Indigenous engagement in water development

Compelling reasons for change

Past water development in northern and central Queensland has generally marginalised rather than empowered Traditional Owners in achieving their visions and aspirations for development. Only through the past 30 years of operation of the *Native Title Act 1993 (Cth)* and Queensland's *Aboriginal Land Act 1991* and *Torres Strait Islander Land Act 1991* has the prospect of a well-defined, significant and tangible Traditional Owner estate started to emerge. This has also been bolstered by other Commonwealth and state-based redistributive programs such as those delivered by the Indigenous Land and Sea Council (ILSC). Consequently, Traditional Owners now have increasingly defined rights and interests across some 78 per cent of the landscape[3]. This transformation in rights is quickly changing past approaches that marginalised Traditional Owners in water development decision-making.

These increased rights and interests in land and water have introduced a need for proponents of development to negotiate with Traditional Owners. Other national and state policy frameworks also seek to address systemic economic and social disadvantage in northern and central Queensland's Indigenous population. Two nationally significant pieces of work describe the continuing gap between the economic and social wellbeing of Aboriginal and Torres Strait Islander Queenslanders and the balance of the Australian and Queensland populations.

1. Relevant statistics are regularly monitored through the Australian Government's Closing the Gap reporting framework[4]. The Commonwealth–State Closing the Gap policy process began in response to a call for governments to commit to achieving equality for Aboriginal and Torres Strait Islander peoples in health and life expectancy within a generation.
2. More recently, through a growing understanding of the importance of integrating Aboriginal and Torres Strait Islander peoples' interests in Australia's Developing Northern Australia agenda, the National Indigenous Australians Agency (NIAA) has drawn inspiration from both the UN's Sustainable Development Goals (the SDGs) and the Organisation for Economic Cooperation and Development (OECD). The NIAA's work has aimed to explore the current economic status of Indigenous peoples in the north[5]. The social justice implications of failure to close the economic gap in northern Australia, including in Queensland, will become an increasingly prominent national and international concern.

These considerations are why any major new water development in central and northern Queensland needs to

substantively improve the economic wellbeing of Indigenous peoples over the next 30 years and beyond. Indeed, recent work undertaken by the Commonwealth increasingly shows the agricultural development opportunity in the emerging Indigenous estate. This work, by the Department of Agriculture, Water and the Environment[6], shows:

- the importance of the standing Indigenous workforce in northern Queensland
- the significance of Indigenous land ownership and interests
- declining Indigenous economic participation across the north
- lower levels of Indigenous business ownership
- the national economic and employment value of activating the Indigenous estate through Indigenous-led approaches.

Finally, within the context of a range of political processes in Australia across the past decade, including the *Uluru Statement from the Heart*, constitutional recognition discussions and the Voice to Parliament debates, it seems clear there is a growing national sentiment for new approaches and reconciliation addressing Aboriginal and Torres Strait Islander peoples' disadvantage. These sentiments will also be considered in the context of Queensland's Path to Treaty processes. Aboriginal and Torres Strait Islander communities and groups across northern and central Queensland have their own clear development aspirations. In this context, Traditional Owners generally seek, and increasingly have the capacity, to be equity partners or development partners in major water infrastructure as well as agricultural and other development opportunities.

International and national obligations and policy settings

Aboriginal and Torres Strait Islander peoples' rights, interests and aspirations in water planning and development need to be considered, defined and negotiated. The requirements to address these broad aspirations are reconciled through international conventions, national conventions, policy settings and policy regulations. This section outlines these policy and program arrangements briefly to ensure the panel considers them in its deliberations. The various international and national arrangements outlined here are of significance.

At the global scale, the UN *Declaration on the Rights of Indigenous People* is relevant as it establishes a universal framework of minimum standards for the survival, dignity and wellbeing of Indigenous peoples. It also elaborates on existing human rights standards and freedoms as they apply to Indigenous peoples. The Australian Human Rights Commission mobilises the declaration's national standing.

Globally, over recent decades, many Indigenous peoples have asserted their rights to determine their own economic destinies and have developed innovative partnerships to promote regional development. These efforts show vibrant Indigenous economies are fundamental to self-determination. Recently, the OECD[7] reported recommendations of interest to Australia across four main areas to strengthen the enabling environment for Indigenous economies:

- improve Indigenous statistics and data governance
- create an enabling environment for Indigenous entrepreneurship and small business development at regional and local levels
- improve the Indigenous land tenure system to facilitate opportunities for economic development
- adapt policies and governance to implement place-based economic development that improves policy coherence and empowers communities.

Australia has obligations arising from these international conventions and arrangements. National processes that draw policy relevance from these include:

- emerging Voice to Parliament considerations
- the National Closing the Gap Policy Framework. Under this framework, the Council of Australian Governments (COAG) has a strong, regularly monitored framework for developing policies, strategies, program and project delivery, and monitoring of progress towards socio-economic equality for Indigenous peoples across Australia through targets compared to broader Australian society
- the Northern Australian Indigenous Accord, developed through initiatives in the recent white paper on developing northern Australia[8] with a particular focus on OECD[9] policy targets
- various national regional development policies and programs seeking to achieve regional development outcomes inclusive of Indigenous interests
- the Indigenous Advancement Strategy, a national grants-based program hosted by the NIAA, seeking to secure economic and social outcomes for Indigenous peoples
- strategies that seek to achieve performance-based outcomes for involving Indigenous businesses in Commonwealth procurement
- long-standing land and business institutions and programs, including two national groups seeking land return and Indigenous equity in economic development ventures: the ILSC and Indigenous Business Australia.

These frameworks are complemented at the Queensland level of government.

Queensland's *Human Rights Act 2019* and other policy settings

Respectful engagement of Aboriginal and Torres Strait Islander communities in future water planning and development is

essential. The planning process for partnering with Aboriginal peoples and Torres Strait Islander peoples in the formation of water planning activities varies across the state. These broad obligations, however, are now well-articulated through the *Human Rights Act 2019*.

At the heart of any engagement under the *Human Rights Act 2019* is the consideration of Aboriginal and Torres Strait Islander peoples' rights to free, prior and informed consent. This concept has been recognised by intergovernmental organisations, international bodies, conventions and international human rights law to varying degrees, and increasingly, within the laws of the state. Free, prior and informed consent is a manifestation of Indigenous peoples' right to self-determine their political, social, economic and cultural priorities. It contains three interrelated and cumulative rights of importance:

- the right to be consulted
- the right to participate
- the right of people to their lands, territories and resources[10].

Beyond the *Human Rights Act 2019*, policy frameworks and program settings of importance to the panel's deliberations include:

- Queensland's Path to Treaty process
- the Queensland Government's Thriving Communities Partnership, which aims to build more resilient communities and stronger organisations
- the *Gurra Gurra Framework 2020–2026*, which supports the Department of Environment and Sciences to meet a wide range of existing and emerging international and legislative obligations and commitments.

Indigenous interests in water planning

Subsidiary to many of these policy and program settings, Queensland's water planning framework itself requires the consideration of Indigenous rights and interests, particularly in the sense that:

- Australia's National Water Initiative (NWI) provides a framework to enable Aboriginal and Torres Strait Islander peoples' input into water allocation planning[11]. The recent Productivity Commission report into NWI progress has made calls for strengthening this engagement
- under the *Water Act 2000 (Qld),* Queensland's water planning framework provides a foundation for Indigenous engagement at catchment scale (see Appendix 2)
- changes to the Water Act in 2018 enhanced the opportunity to further explore cultural outcomes in water allocation planning. Newly developed and reconstituted water plans must now unequivocally recognise, through explicitly stated cultural outcomes, the importance of water resources to Aboriginal and Torres Strait Islander peoples, including their strong spiritual connection to water.

Based on these frameworks, several specific interests require careful integration into water allocation decision-making processes. Currently, the process for partnering with Aboriginal and Torres Strait Islander peoples in forming or reconstituting water plans varies across the state and depends on the complexity of the issues and their potential impact. The processes adopted are informed by operational protocols for consultation, such as those published by the Queensland Department of Seniors, Disability Services and Aboriginal and Torres Strait Islander Partnerships. Consequently, a one-size-fits-all approach cannot be applied across the northern and central Queensland landscapes under consideration by the panel.

Accounting for cultural values and outcomes in water allocation

Cultural values and outcomes may be identified under a water plan where cultural matters important to Aboriginal and Torres Strait Islander peoples are identified and can be linked to flows. In this context, there is frequently a strong link between the values identified in planning for environmental flows as well as cultural values[12]. For Aboriginal peoples in the Queensland Murray–Darling Basin, for example, as part of the Water Connections consultation, yellowbelly (a species of native fish) was identified as being important to Aboriginal values and uses of water. Figure A4-1 shows the range of economic, social and cultural values attributable to yellowbelly by local Aboriginal peoples. Consequently, in the water planning process, any threats to the viability of yellowbelly via poor water quality would affect a wide array of Indigenous values.

Another example of new approaches to considering cultural values and outcomes involves Queensland Government working closely with Aboriginal peoples in the Queensland Murray–Darling catchments to improve the way water resources are managed. As a result, the Condamine–Balonne, Border Rivers and Moonie water plans include new cultural outcomes that consider cultural values, Indigenous uses of water, and objectives and outcomes for water management. The Department of Environment and Science, for example, has coordinated several Aboriginal waterway assessments with the Aboriginal nations of the Queensland Murray–Darling Basin. The information gained has been considered and included in the development of environmental values and water quality objectives under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*.

In this planning context, an Indigenous sense of place and identity underpins the sustainability and resilience of communities, and place-based approaches to water planning are important.

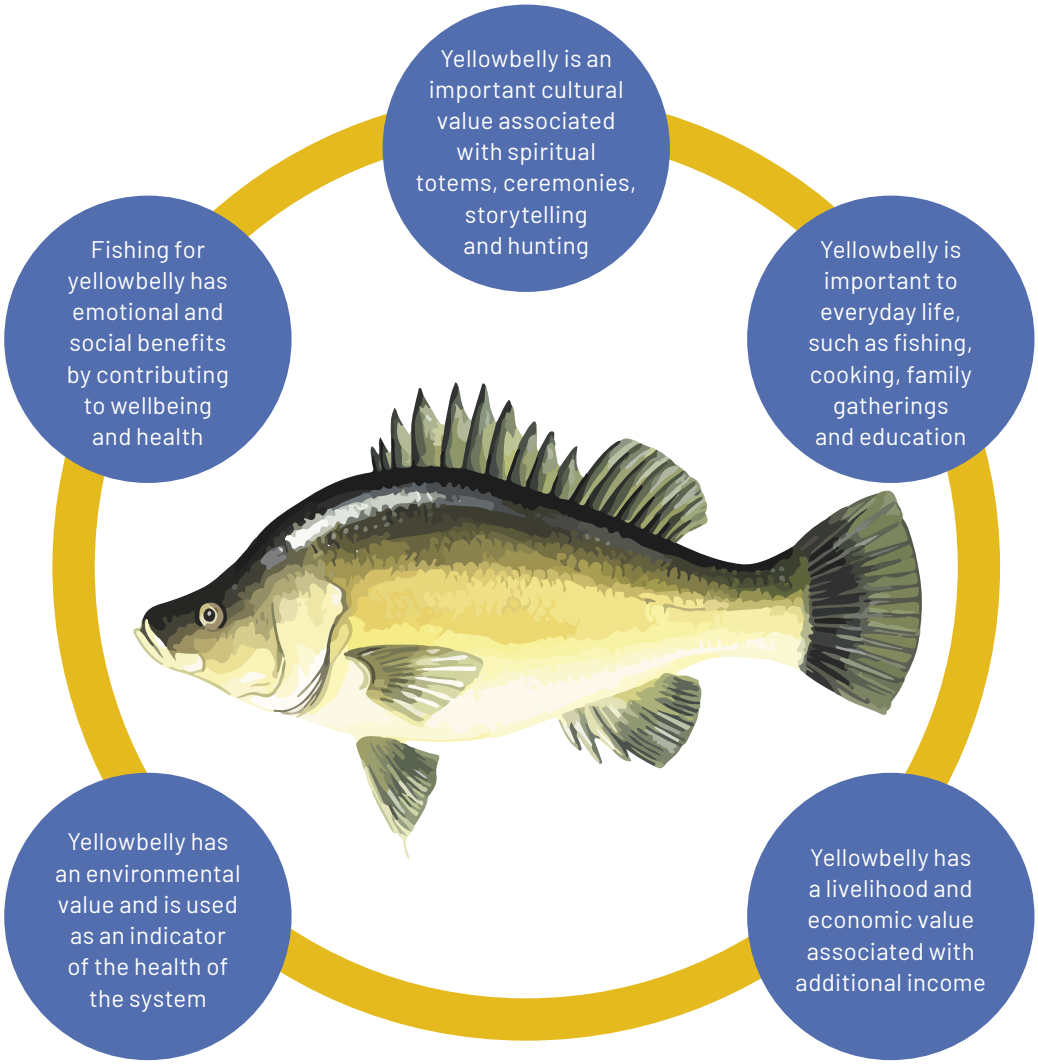


Figure A4-1: Yellowbelly as an example species with a range of values and uses.

Water connections: Aboriginal peoples' water needs in Queensland

The Queensland Government has worked closely with Aboriginal peoples in the Queensland Murray–Darling catchments to improve the way water resources are managed. From this engagement process, a guide to inform water plan development in the Condamine–Balonne, Border Rivers and Moonie catchments has been created. There is now a deeper appreciation of Aboriginal peoples' connection to water and their desire to influence how water is managed in the catchments in the future. The new water plans for the Murray–Darling catchments include new cultural outcomes taking account of cultural values and uses of water. Cultural outcomes in several plans across Queensland include:

- maintaining flows in a river to support cultural, recreational or community values identified as important to Aboriginal and Torres Strait Islander peoples (e.g. flows that support a particular plant or animal species valued for ceremonial or storytelling purposes or used as a traditional food source)
- protection of groundwater levels from overuse in order to maintain culturally significant springs
- providing water to support Aboriginal and Torres Strait Islander peoples' enterprises that are reliant on water. A number of water plans reserve a specific volume of unallocated water for Indigenous purposes. The release of unallocated water in remote communities and to Aboriginal peoples and Torres Strait Islander peoples is likely to promote jobs and boost local economies.

As water plans are developed or reviewed in Queensland, cultural outcomes together with strategies and measures to achieve the outcomes and monitoring and reporting obligations will need to be included.

A sense of place is often derived from landscape features: the hills, valleys, plains, waterways and seascapes that have formed over millions of years. Heritage and cultural value are attributable to both tangible elements and objects and intangible expressions of spiritual, aesthetic, social, historic, symbolic and authenticity value[13]. Indigenous communities across the globe have demonstrated a long-term cultural relationship with land and water. Key values and perspectives of water in Indigenous cultures can include[14]:

- water as a living being and water bodies having specific powers
- water as a life source
- land and water as an integrated whole
- physical and spiritual wellbeing of humans as being connected with water
- water forming a part of people's identity.

Consequently, for Aboriginal and Torres Strait Islander peoples, as the world's oldest living continuous culture, water is part of one connected system that includes the land, people and all living things. It has spiritual, cultural, social, economic and environmental value. Water is vital for many aspects of Aboriginal and Torres Strait Islander life, such as fishing, hunting, swimming, storytelling, family gatherings, ceremonies and other sacred activities. Aboriginal and Torres Strait Islander peoples also have knowledge and perspectives that are vital if sustainable water management is to be achieved. These perspectives have increasingly been formally captured in water planning processes through engagement with local Aboriginal peoples.

Given supporting legislation is relatively new, the practice of including these cultural values in water planning is in its infancy. Contemporary water resource plans (e.g. in Cape York, the Gulf and the Wet Tropics) have incorporated these values better than older plans (e.g. the Fitzroy). Consequently, the rights and interests of Aboriginal and Torres Strait Islander peoples in water resource management will vary across Queensland according to the allocations of water already committed

Indigenous water reserves in the *Cape York Water Plan (2019)*

Cape York has large areas of relatively undisturbed landscape and high biodiversity value, with Traditional Owners maintaining strong ties and connections to land and water. The *Cape Water Plan* recognises Aboriginal and Torres Strait Islander peoples' close cultural connection with the land and water resources.

The plan empowers Traditional Owners to make decisions about the region's water resources to meet the economic, social and cultural needs of Aboriginal and Torres Strait Islander peoples, consistent with the objectives of the *Cape York Peninsula Heritage Act 2007*. It allows for a Cape York Peninsula Heritage Area-based unallocated water reserve to be established that enables the granting of water licences to eligible people at zero cost per megalitre, free from water licence fees and charges. The water management protocol defines the volumes of unallocated water held in each catchment as either Cape York Peninsula Heritage Area (CYPHA) reserve, strategic reserve or general reserve.

The CYPHA reserve of unallocated water, comprising 485,300 megalitres (from a total unallocated water reserve of 516,350 megalitres), can be made available under an established process to help Aboriginal or Torres Strait Islander communities in the Cape York Peninsula Region achieve their economic and social aspirations. There is additional capacity for Aboriginal and Torres Strait Islander communities to access the strategic reserves set aside within the water plan, although no process has yet been established for this release.

The plan will work with other regulatory proposals to ensure that the allocation of water is sustainable and the application and use of that water is compatible with best management practices. This includes considering ecological outcomes and water allocation and management strategies that support and maintain the condition of ecological assets in the plan area, as well as supporting good water quality outcomes.

Unallocated water is water reserved under a water plan that can be made available for future use without compromising the security of existing users or environmental values. The volumes proposed for each catchment in the Cape have been set to maintain at least 97.5 per cent of median annual freshwater flows, inclusive of the protection of cultural values. In catchments where current entitlement volumes exceeded 2.5 per cent of median annual freshwater flows, no additional water has been set aside under the CYPHA or general reserves. This approach was considered to yield a conservative estimate of the proportion of flows that could be taken for consumptive use with minimal impact on environmental flows, cultural needs and existing entitlements.

in water plans to cultural and socio-economic uses. As a comparison, 94 per cent of volumes in the Cape York Water Plan area—a less developed catchment—is potentially available for uses that contribute to cultural outcomes. In the heavily developed and fully allocated Murray–Darling Basin, only about 0.5 per cent of water plan volumes are available for cultural outcomes after existing allocations. As water plans expire and are renewed across Queensland, they must incorporate provisions for cultural outcomes that better recognise the rights and interests of Aboriginal peoples and Torres Strait Islander peoples.

Indigenous domestic use and strategic Indigenous reserves

Discrete Aboriginal communities (e.g. Woorabinda, Yarrabah, Aurukun, etc.) have rights to water for domestic purposes. While these rights are not widely recognised, they are normally well catered for through water allocations for domestic consumption within most water plans. The need for such water must be well analysed and integrated into all water plan reviews in northern and central Queensland.

Starting with the Wet Tropics Water Plan, an Indigenous strategic reserve (available to Aboriginal and Torres Strait Islander peoples for commercial use or trade) has increasingly been negotiated into the unallocated water reserve. The negotiation of an Indigenous strategic reserve in water plans enables Aboriginal and Torres Strait Islander peoples to participate in the economic use of water and participation in water markets. For example, such reserves (although limited) have now been embedded in the Gulf Water Plan. A more expansive approach has been applied in the Cape York Water Plan (see page 186). However, there are few examples of Indigenous communities mobilising economic and commercial value from these reserves, suggesting a clear strategy to support participation by Aboriginal and Torres Strait Islander peoples is needed.

The rights and interests of Aboriginal and Torres Strait Islander peoples in water resource management across Queensland will vary according to water already committed in water plans to non-cultural uses. For example, the majority of unallocated reserves are set aside for Traditional Owners in Cape York, while small Indigenous strategic reserves have been set aside in the Fitzroy. Future updates to water plans must incorporate provisions for a more equitable assignment of the rights and interests of Aboriginal and Torres Strait Islander peoples in water across the state, as distinct from water set aside to meet cultural values.

Indigenous interests in water development at scale

Incorporating the interests of Aboriginal and Torres Strait Islander peoples is important in water development planning processes at catchment scale, right down to local water project planning. In this context, distinct from water allocation planning, there are often different interests, policies and delivery processes at play. While Aboriginal and Torres Strait Islander peoples' involvement in water allocation planning is evolving, Queensland has a much deeper history of engaging Indigenous concerns in project development than in broad catchment-based water development assessment and planning activities that are not a standardised part of Queensland's land use and infrastructure planning systems.

There are growing examples of good practice at the wider water development planning scale, but generally they focus on catchment-scale consideration of Indigenous cultural, social and economic values and aspirations. Examples of work undertaken in this field include by the CSIRO in the Flinders and Gilbert Agricultural Resource Assessment, covering broad analysis of water development options in the Flinders and Gilbert catchments[15], and more recently in the Northern Australia Water Resource Assessment studies focused on the Mitchell Catchment[16]. Beyond these more theoretical assessment processes, there is still little formalised engagement with Aboriginal and Torres Strait Islander peoples in such planning within northern and central Queensland.

At the project scale, practices of Indigenous engagement in the state's project planning and impact assessment processes have steadily improved. Many of these improvements started with the Queensland Government forming a formal Social Impact Assessment Unit within its planning and impact assessment system following the Fitzgerald Inquiry into the future of Fraser Island[17]. While Indigenous engagement and involvement is a feature of most water project development and assessment processes, the quality varies widely. At the more innovative end of the spectrum, project proponents often start by seeing local Traditional Owners as equity partners in the project development process. In these cases, formalised and long-term governance processes for engagement are established, and equity investment, enterprise and employment targets are set and achieved. Other cultural and social impacts are also rigorously identified, with solutions negotiated locally.

Accounting for cultural issues in water development

Queensland has foundational laws to protect Aboriginal and Torres Strait Islander peoples' cultural heritage, including property, land, sea and water rights that must be integrated into decision-making for new water infrastructure developments. These laws include the *Aboriginal Cultural Heritage Act 2003 (Qld)* and the *Torres Strait Islander Cultural Heritage Act 2003 (Qld)*. Both Acts provide a framework for protecting Indigenous cultural heritage in the landscape. The main mechanism through which each Act operates is the cultural heritage duty of care. This requires a person carrying out an activity to take all reasonable and practicable measures to ensure the activity does not harm cultural heritage.

The duty of care applies to any activity involving Aboriginal or Torres Strait Islander cultural heritage. This includes cultural heritage located on freehold land and regardless of whether or not it has been identified or recorded in a database.

Queensland's Aboriginal and Torres Strait Islander cultural heritage legislation encourages direct agreement-making between land users and Aboriginal or Torres Strait Islander peoples. Consultation with Aboriginal or Torres Strait Islander peoples for an area may be necessary if there is a high risk that the activity could harm Aboriginal or Torres Strait Islander cultural heritage.

The Commonwealth's *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* also protects significant Indigenous areas and declared objects[18]. Broad-scale legislation of importance to development in Cape York Peninsula is covered under Queensland's *Cape York Heritage Act 2007*.

Good practice cultural heritage assessment and management in water project development should remain embedded in well-governed relationships between project proponents and affected Indigenous communities, as distinct from stand-alone consultation activities.

Social and economic impact assessment

Several pieces of legislation require the consideration of social and economic impact issues (particularly for Indigenous and other interests) in development planning and impact assessment processes. These include:

- the *Environmental Protection and Biodiversity Conservation Act 1999 (Cth)*
- the *Planning Act 2016 (Qld)* and *Regional Planning Interests Act 2014 (Qld)*
- the *State Development and Public Works Organisation Act 1971 (Qld)*.

Again, social and economic impact assessment of Aboriginal and Torres Strait Islander interests is best embedded in well-governed approaches to project development and engagement. These should include longer-term (whole-of-project-life) approaches that identify, avoid, mitigate or manage major social and economic impact opportunities and issues, such as:

- opportunities for economic partnership and equity in the development process
- longer-term employment and training opportunities
- Indigenous enterprise and employment opportunities through project procurement
- compensation and royalty issues associated with impaired tenure rights
- improvements in local health and human services care and delivery.

Strong and stable socio-economic impact management plans and agreements can be negotiated under these sorts of well-governed and engaged processes, ensuring real accountability is established and maintained.

Native title implications for land and water development

The resolution of native title (and other relevant tenure issues) should be fundamentally integrated into the processes for engagement and impact assessment for water assessment and development planning and approval. While case law is still evolving across Australia, native title represents a fixed set of rights and interests for Traditional Owners in the northern and central Queensland landscape. Because of its complexity and significance, this section of this Appendix deals with native title and other tenure-related interests in their own right. These interests, however, need to be fully engaged through free, prior and informed consent principles in water allocation and water development planning and impact assessment processes.

Background to the *Native Title Act 1993*

National, state and territory-based land and resource use rights policy and delivery have, until now, been focused on the orderly resolution of rights under various Commonwealth (e.g. the *Native Title Act 1993*) and state legislation (e.g. Queensland's *Aboriginal and Torres Strait Islander Land Holding Act 2013*, the *Aboriginal Land Act 1991* and the *Torres Strait Islander Land Act 1991*). This rights-focused agenda has not yet fully envisaged the policy and legislative base required for long-term management of these rights in a post-determination environment. As claims-based activity under the *Native Title Act 1993* and other Commonwealth and state-based legislation finishes, an entirely new policy focus will be required that empowers Traditional Owners to advance their social, cultural and economic aspirations.

The Commonwealth *Native Title Act 1993* recognises the rights and interests of Aboriginal and Torres Strait Islander peoples in land and waters according to their traditional laws and customs. The purpose of the Act is "to provide a national system for the recognition and protection of native title and for its co-existence with the national land management system". The Act sets up processes to determine where native title exists, how future activity affecting native title may be undertaken (e.g. through Indigenous Land Use Agreements) and to provide compensation where native title is impaired or extinguished. The Act also gives Indigenous Australians who hold native title rights and interests the right to be consulted and to participate in decisions about activities proposed to be undertaken on the land. Aboriginal and Torres Strait Islander peoples have been able to negotiate benefits for their communities, including employment opportunities and heritage protection. Importantly, the Act also establishes a framework to recognise and operate representative bodies that provide services to native title claimants and native title holders. The Australian Government continues to provide significant funding to resolve native title issues in accordance with the Act, including funding to native title representative bodies, registered native title bodies corporate, the National Native Title Tribunal and the Federal Court of Australia[19].

Native title considerations in a post-determination world

In recent years, with increasing national policy attention to Indigenous land rights, the Australian Government has been seeking to improve the efficiency of native title processes, including the need to support Traditional Owners in using these rights and drawing benefit from them, and meeting the new challenges facing Traditional Owners post-determination[20]. In October 2014, COAG announced an urgent "investigation into Indigenous land administration and use, to enable Traditional Owners to readily attract private sector investment and finance to develop their own land with new industries and businesses in order to provide jobs and economic advancement for Indigenous peoples"[21]. Findings included recommendations to support Indigenous peoples' decision-making and the use of their rights in land and waters for economic development. As a result, COAG identified five areas where governments should focus their efforts[22]:

- gaining efficiencies and effectiveness in the process of recognising rights
- supporting bankable interests in land
- improving the way business is done on Indigenous land or land subject to native title
- investing in the building blocks of land administration
- building capable and accountable land holding and representative bodies.

Linked with this work, the COAG Senior Officers Working Group (COAGSOWG)[23] identified several parallel Australian Government processes that could influence this agenda. These included:

- the Australian Law Reform Commission reporting on a two-year inquiry into the connection, joinder and authorisation aspects of the *Native Title Act 1993*[24]
- the Australian Human Rights Commission[25] facilitating an Indigenous leaders roundtable on property rights in Broome and economic development within the Indigenous estate[26]
- the Forrest Review considering improvements to help create parity between Indigenous and other Australians, including through development on Indigenous land and land subject to native title[27]
- a Deloitte Access Economics' Review investigating the roles and functions of native title organisations[28].

Potential future native title interests in water

While significant progress is being made in relation to Aboriginal and Torres Strait Islander native title rights in sea country (e.g. in cases such as Blue Mud Bay and the Torres Strait), native title rights in fresh water resources are relatively untested in case law. The *Native Title Act 1993* defined native title as including rights to water for customary purposes, and courts are yet to recognise a commercial right to water[29]. Informally, negotiation of Indigenous strategic reserves in water allocation planning represents a de facto recognition that Aboriginal and Torres Strait Islander peoples have some form of moral or historical rights to water for the purposes of economic and social development. While these rights remain untested in law, the panel considers it is important to be either generous in the negotiated establishment of Indigenous strategic reserves, or at least water planners need to be conservative in the full allocation of general reserves.

Implications of Timber Creek for existing and new water infrastructure

New developments in native title law are also occurring in compensation—dealing with the impact of past and future impairment of native title rights. A recent area of great importance for the panel's consideration is the decision related to compensation required for past infrastructure development at Timber Creek in the Northern Territory. In the Timber Creek decision, delivered on 13 March 2019, the High Court of Australia determined, for the first time, the approach to be taken to resolving native title compensation claims[30]. This legal case has implications for the cost of compensating for the effects of large-scale infrastructure on Indigenous native title rights. In this decision, the High Court accepted the approach adopted to calculate compensation for the impairment of native title by

past infrastructure. This will have implications for the costings of existing and future water development options if they are to properly acknowledge or account for the costs of water infrastructure development in Queensland. Historically, many large water infrastructure projects have ignored or overlooked these future cost implications.

Summary implications for Bradfield-like development

The following represents a summary of implications arising for the panel in undertaking its role in the wider assessment of water development scenarios and options.

Have Indigenous interests in water allocation planning been resolved?

Even before large-scale water development options can be considered in catchments, water allocation planning needs to deal with the following questions:

- Have strong governance frameworks been established to guide Indigenous engagement arrangements well?
- Are cultural outcomes adequately accounted for?
- Have Indigenous social and economic interests in water been accounted for?
- Have Indigenous domestic water use interests been properly allocated?
- Have appropriate Indigenous strategic reserves been allocated fairly across the entire water planning area?
- Have potential future native title interests in water been considered?

Framing Indigenous interests in water development planning

Before large-scale water development projects can be progressed, catchment-scale water development planning needs to deal with the following questions:

- Have strong engagement frameworks been used in water development planning?
- Have Indigenous domestic water supply project development needs been met?
- Are communities supported to articulate their water development aspirations?
- Are cultural issues accounted for in defining or assessing development options?
- Have Indigenous socio-economic interests and allocations been accounted for?
- Are strategies in place to mobilise Indigenous strategic reserves?
- Have potential future native title interests in water been considered?

Framing Indigenous interests in major project planning, assessment and approval

In project-specific planning, assessment and approvals, considerations include:

- negotiating strong Indigenous partnerships in project engagement, including partnerships related to managing Indigenous knowledge
- ensuring effective recognition, protection and conservation of Aboriginal and Torres Strait Islander cultural heritage through negotiating cultural heritage management plans as described in the *Aboriginal Cultural Heritage Act 2003* and the *Torres Strait Islander Cultural Heritage Act 2003*
- exploring Indigenous interests in project equity
- prosecuting positive cultural, social and economic impact assessment
- strong, adaptive impact-management agreements
- negotiating native title interests in a structured way
- including appropriate costs for native title compensation
- ensuring Indigenous procurement obligations are met.

1 Maclean and Bana Yaralji Bubu Inc., 2011; Maclean et al., 2015
2 North Australian Indigenous Land and Sea Management Alliance Indigenous Water Policy Group, 2013; Hartwig et al., 2020
3 North Australian Indigenous Land and Sea Management Alliance Indigenous Water Policy Group, 2019
4 Department of the Prime Minister and Cabinet, 2020
5 National Indigenous Australians Agency, 2020; Barber et al., 2020
6 Department of Agriculture, Water and Environment, 2021
7 Organisation for Economic Cooperation and Development, 2019
8 Australian Government, 2015
9 Organisation for Economic Cooperation and Development, 2019
10 United Nations Human Rights Council, 2016
11 Maclean et al., 2012; Ayre and Mackenzie, 2012; Jackson, 2006
12 Maclean et al., 2015
13 Throsby, 2016
14 Australian Law Reform Commission, 2015
15 Department of Infrastructure and Regional Development, 2013
16 Lyons and Barber, 2018
17 Dale and Crisp, 2002
18 Caxton Legal Centre, 2020
19 Department of Foreign Affairs and Trade, 2012
20 Council of Australian Governments Senior Officers Working Group, 2015; Dale et al., 2013
21 Council of Australian Governments Senior Officers Working Group, 2015, p1
22 Council of Australian Governments Senior Officers Working Group, 2015
23 Council of Australian Governments Senior Officers Working Group, 2015
24 Australian Law Reform Commission, 2015
25 Australian Human Rights Commission, 2015
26 Australian Human Rights Commission, 2015
27 Forrest, 2014
28 Deloitte Access Economics, 2014
29 Hartwig et al., 2020
30 Abraham and Isdale, 2019



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Appendix 5

Bradfield Scheme assessment and background

Bradfield Scheme assessment and background

Assessment of Bradfield concepts

The panel analysed the Bradfield Scheme proposals and variations to it to make an informed assessment of the financial, economic, environmental, social and technical viability of the scheme and similar Bradfield-like concepts.

This appendix provides details of the Bradfield concepts examined and the results of the assessments undertaken to identify what has been considered, why this is relevant to each proposal and the panel's own deliberations.

The panel examined the following Bradfield concepts:

- original 1938 Bradfield proposal
- subsequent 1942 Bradfield proposal
- variation of the 1942 Bradfield proposal, as described by CSIRO in their 2020–21 report[1] for the National Water Grid Authority (NWGA), aimed at testing the scheme's viability
- Queensland Great Dividing Range Scheme, put forward in 2021 by Sir Leo Hielscher, Sir Frank Moore and Mr Detlef Sulzer.

Technical assessments referenced

The panel's examination of the practical application of these proposals was aided by recent scientific and engineering assessments.

The CSIRO report presented to the panel focuses on a variation to the 1942 Bradfield concept and The Queensland Great Dividing Range Scheme.

A technical assessment was completed with oversight by the Chief Engineer of water and dam safety in Queensland to evaluate the water supply and transport infrastructure required for the proposals. This assessment analyses available hydrology, geology, and topography (i.e. land formations) and provides some design calculations for the proposals based on engineering experience.

Bradfield Scheme concepts reviewed

Table A5-1: A high-level view of the four main Bradfield schemes.

Scheme	Description
1938 Bradfield	• Proposes water diversions from the Tully and Herbert rivers to the headwaters of the Burdekin • Construction of a 122-metre high dam at Hells Gates • Diversion of flows via a 144-kilometre tunnel to west of the Great Dividing Range to the headwaters of the Flinders and Thomson rivers
1942 Bradfield	• Variation on the 1938 scheme • 152-metre high Hells Gates Dam • Approximately 400 kilometres of twin pipes to the headwaters of the Thomson River only
CSIRO 1942 Bradfield variant	• Variation of the 1942 Bradfield proposal • 97.5-metre high dam at Hells Gates • 679-kilometre channel to the Thomson River (near Aramac Creek), replacing the twin pipes proposal outlined in the 1942 proposal
The Queensland Great Dividing Range Scheme	• Variation of the 1938 Bradfield Scheme • Water diversions from the Herbert River only • 108-metre high Hells Gates Dam • 90-kilometre tunnel and extensive excavation at the inlet and outlet of the tunnel, to the west of the Great Dividing Range to the headwaters of the Flinders and Thomson rivers

Considerations for assessing viability questions

In assessing the viability of these Bradfield and Bradfield-like proposals, consideration was given to the following factors:

- availability of water within various catchments across the state, taking into account claims on allocating water for uses including agriculture, industry, urban consumption, the environment and cultural purposes
- recognising the uncertain but potentially large effects of increases in temperature on evaporation average levels and variability of rainfall as a result of increased concentrations of greenhouse gases in the atmosphere
- established legal requirements associated with legislation that underpin the state water plans and the intergovernmental agreements embodied in the National Water Initiative principles
- future market demands and trends for commodities, particularly changes in the value of water associated with climate change and the world's commitment to build a zero-emissions economy. This includes higher prices for agricultural commodities in which Australian and global production has been disrupted by climate change, an increased value of carbon in soils and plants, and an increased value of biomass to replace fossil hydrocarbons in energy and industrial production.

Previous assessments and background

Various assessments have been undertaken in the past of the Bradfield Scheme. Some of these include:

- a review in 1945 by the Chifley Government in the context of post-war reconstruction, where the Snowy Mountains Scheme and the Ord River Scheme were preferred
- a Bureau of Meteorology assessment in 1945, which identified a need for investigation by soil management and engineering experts and queried whether the scheme's contribution to climatic improvement had been 'overestimated'
- investigations by William Nimmo (Chief Engineer of the Stanley River Works Board) in 1947 concluding there were technical deficiencies in Bradfield's analysis including assumptions around ground elevations, and over-estimation of water supply capability and underestimation of costs
- a consortium of engineers led by Cameron McNamara Consultants, which undertook a desktop review of the Bradfield concept
- a 1981 parliamentary sub-committee report (Dr Eric Heidecker, Mr Roy Stainkey and Mr Bob Katter) assessed a Revised Bradfield Scheme, finding that it may enable some million acres of cotton and wheat cultivation and probably 750 megawatts of hydro-electric generating capacity.

Consideration of the 2021 CSIRO study of the Bradfield Scheme

An assessment of the scheme was carried out in 2021 by CSIRO for the NWGA[2]. In instigating this report, the NWGA has stated its intention to use contemporary science to lead a program of work with Australia's science agencies to assess opportunities and challenges posed by an assessment of the historic Bradfield Scheme to divert water inland from northern Queensland.

The technical report presented to the panel provides technical feasibility and financial viability of Bradfield's original schemes. It covers a range of issues relating to the scheme including:

- climatic conditions and their impact upon runoff and reservoir evaporation
- water resource modelling to determine the amount of water that could be taken by the infrastructure in the various systems
- a desktop soil and land suitability analysis along with an assessment of the potential farming enterprises that may be suited for those soils and climate
- an assessment of infrastructure necessary to make the scheme functional, including an analysis of the volumes of water
- an economic assessment of the scheme based on the cost estimates
- the impact such a scheme would have on existing user reliability, environmental flows and Indigenous water values, rights and interests
- a review of the legislative and policy environment that may impact the scheme's development.

This assessment has informed the panel's analysis of the Bradfield Scheme and Bradfield-like concepts, as:

- it provides a more detailed assessment of the scheme than was originally designed by Bradfield
- it relies upon contemporary information and modelling techniques to undertake the assessment, albeit at a scoping study level
- where fundamental flaws were identified in the original Bradfield proposal, CSIRO developed functional solutions
- the CSIRO focused on improving cost effectiveness and scheme value.

The panel notes that, while improving the functionality of the scheme, the changes suggested in the CSIRO study did not deal with the foundational question of water availability within the contemporary constraints.

The CSIRO report builds on past assessments of the Bradfield Scheme to formulate its findings and provides a level of detail to give the panel confidence it can be used as a reference for carrying out a high-level assessment of other variations of the Bradfield Scheme.

The panel questions some aspects of the CSIRO assessment, as discussed later in this appendix.

Chief Engineer's technical assessment report

The Chief Engineer's assessment has provided the panel with additional engineering analysis and technical assessments. At the request of the Chief Engineer for water and dam safety, Water Resources Pty Ltd performed a review of the CSIRO study in parallel with an independent assessment to address specific considerations including:

- what infrastructure might be required to draw water from the Tully and Herbert rivers across to the Burdekin, and how much water can be drawn across
- given the storage sizes at Hells Gates that Bradfield contemplated in his 1938 and 1942 options, if there is a more optimal storage solution
- given the heights of these storages, whether it would be possible to transfer water to the west of the divide via a tunnel as contemplated under the 1938 version, having regard to levels of the Flinders and Thomson rivers
- the feasibility of the twin tunnels from Hells Gates to Webb Lake as contemplated in the 1942 Bradfield option
- what other options exist to transport water to the west of the divide, such as via channels, and what might be the general feasibility or otherwise of such solutions
- typical construction risks associated with dams and long-distance water transportation infrastructure.

Key findings considered from the Chief Engineer's technical assessment

Water transfer from the Tully and Herbert rivers to Burdekin

As identified by CSIRO, Koombooloomba Dam has been constructed on the Tully River since Bradfield proposed his scheme. CSIRO's proposal to use the existing Koombooloomba Dam to divert water by tunnel to a new dam on Nitchaga Creek and then via a diversion tunnel to Sunday Creek (both in the Herbert catchment) would be a more cost-effective solution than that proposed by Bradfield.

While not considered a good dam site, a dam could be constructed at Herbert Falls Dam, which could divert flows to the Upper Burdekin River. CSIRO proposed a 6.5-metre diameter tunnel to achieve this. A hydraulic check conducted by comparing the surface elevations determined by CSIRO (as shown below) to those derived from Google Earth shows a good correlation. A hydraulic grade line (HGL) was developed, which showed the flowrate intended could be achieved.

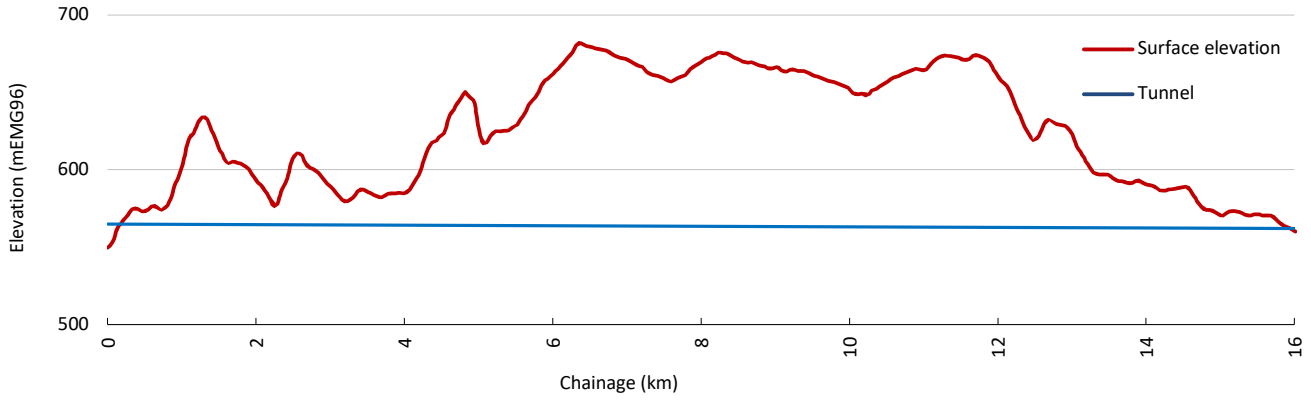


Figure A5-1: Surface elevation along tunnel between Herbert River Falls Dam and the Upper Burdekin River from the CSIRO Report.

Source: Water Resources report p10

Hells Gates Dam

From an engineering perspective, the gorge at Hells Gates is part of a land formation that is a favourable location for a dam. It's also a central feature of the Bradfield Scheme. Bradfield (1938) originally proposed a 122-metre high dam wall with a full supply level (FSL) of 442 metres Australian height datum (AHD) so water could be moved from the Hells Gates reservoir to the Flinders River (122-metre high dam wall option) using gravity. In his 1942 variation, he proposed increasing the dam wall height to 152 metres (FSL 472 metres AHD).

The CSIRO modelling indicates there is likely to be insufficient inflows to fill the extremely large storages for dams of this size (54,950 and 142,350 gigalitres respectively). The CSIRO study also indicates a dam with an FSL of 405 metres AHD is optimal based upon the dual objective of minimising unit capital cost and maximising yield.

The SMEC group has been engaged by Townsville Enterprise Limited (TEL) to complete the reference design for the proposed Hells Gates Dam as part of the detailed business case (DBC) for the Hells Gates Irrigation Scheme. The DBC proposes the dam with a reference design of 372 metres AHD, which is 70 metres and 100 metres lower respectively than the dam heights proposed by Bradfield and 33 metres lower than the dam height proposed by CSIRO. The Chief Engineer's assessment report concludes that even the smallest of these dams proposed would not comply with the objectives of the Burdekin Basin Water Plan.

The reviewed CSIRO study states that for water to flow using gravity from a Hells Gates reservoir to a point on the Flinders River before Skeleton Creek (i.e. Glendower) as proposed by Bradfield, the offtake level would have to be at least 108 metres above the Hells Gates Dam river bed, resulting in an effective 'dead storage' of 42,650 gigalitres.

Increasing the height of the dam wall at Hells Gates to a 128.5-metre high dam (FSL 448.5 metres AHD) increased the 'active storage' by 14,340 gigalitres, and a 10-metre diameter tunnel could result in a mean annual diversion of 600 gigalitres to the Flinders River. CSIRO has determined that further increasing the height of the dam wall would not increase the mean annual diversion to the Flinders River, and further increasing the diameter of the tunnel would marginally increase diversions but substantially increase the cost of the tunnel itself.

Water transfer to the west of the Great Divide

An assessment has been performed to determine whether it would be possible to transfer water to the west of the divide using a tunnel in light of the levels of the Flinders and Thomson rivers. Using modern elevation data it was found by CSIRO that a longer tunnel was required than envisaged by Bradfield, increasing the cost significantly. It was determined by CSIRO that it is not possible to divert water by gravity from a Hells Gates reservoir into the headwaters of the Flinders River catchment higher than about Glendower, which is a location much lower along the Flinders River than proposed by Bradfield.

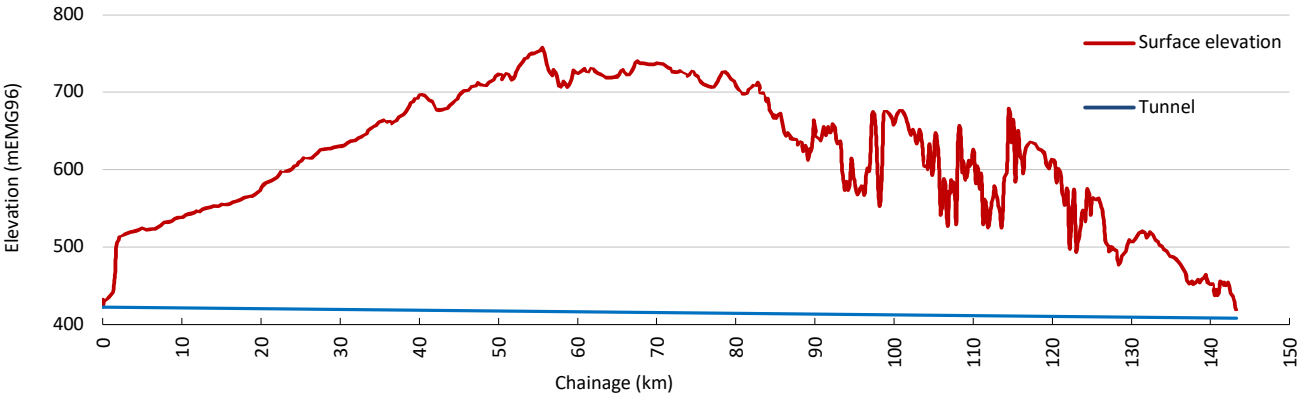


Figure A5-2: Surface elevation along tunnel from Hells Gates Dam to Upper Flinders.

Source: CSIRO Report 2021

The CSIRO determined that a 144-kilometre long, 10-metre diameter diversion tunnel would be required. They had considered this tunnel to be very expensive because the tunnel overburden stresses is very thick, up to 300 metres in places, requiring very deep intermediate access shafts for machinery and workers to build.

A hydraulic check has been completed by comparing the surface elevations determined by CSIRO (as shown below) to those of Google Earth, which showed good correlation. A hydraulic grade line (HGL) was developed which showed the tunnel would need to be at least 144 kilometres to pass an acceptable design flowrate of 157 cubed metres, as shown in the drawings included in the Water Resources technical assessment report.

Taking into account the length and overburden stresses of the tunnel, the expert studies show that a pumped pipeline system combined with channels where the land formation is more suitable would be far more cost-effective to move water to the west of the Divide.

Feasibility of twin tunnels from Hells Gates to Webb Lake

Bradfield proposed twin 25-foot diameter pipes to move water to Webb Lake from Hells Gates Dam. The CSIRO advice says channels are considerably more cost-effective than pipes over gradual slopes and a gravity-driven pipeline between Hells Gates and Lake Buchanan would be more than 20 times as expensive as a gravity channel of equal capacity.

The CSIRO report also indicated a pumping pipeline system would be more than five times as expensive as a gravity channel of equivalent capacity.

An assessment has been completed to check the feasibility of twin tunnels from Hells Gates Dam to Webb Lake. A section was taken as a straight line between Hells Gates Dam reservoir and Webb Lake as shown in Figure A5-3. This analysis indicates that a surface elevation at the start of the pipeline would be very similar to the end of the pipeline (352 metres – 338 metres = 14 metres). A hydraulic check has been completed by developing a HGL calculation, which showed the tunnel would need to be at least 228 kilometres in length.

The HGL shows a gravity pipeline solution along a straight line would not work as the HGL is significantly below the surface elevation over extended lengths. It is considered that, with some realignment (and pipeline extension), a pumped pipeline system could be developed, however the pipeline and pumping stations would be significant. Based on the cost estimating methods used for long-distance large diameter pipelines, it is

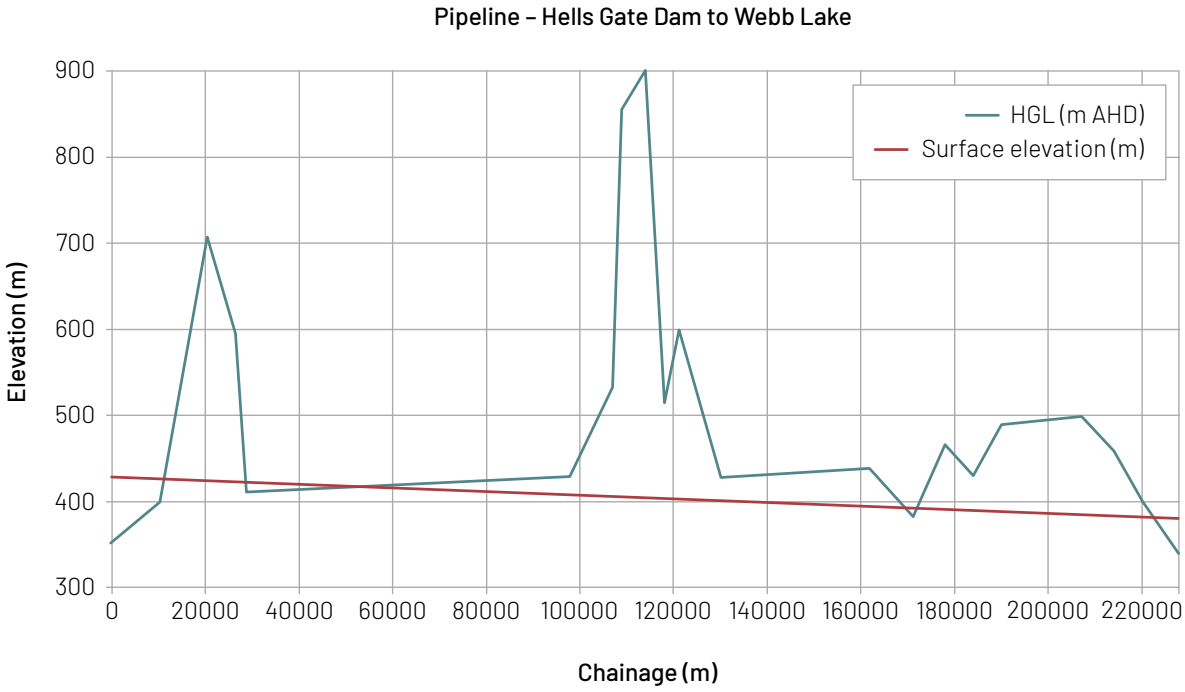


Figure A5-3: Hydraulic grade line (HGL) for gravity pipeline from Hells Gates to Webb Lake.

Source: Water Resources 2021 report

estimated the pipeline would cost in the order of $27 billion. This projection suggests the CSIRO's assertion that a gravity channel would be much more cost-effective is correct.

The Chief Engineer's assessment confirms that the channel cross-section required would create a very large irrigation channel with a bed width of 50 metres with side slopes and a flow depth of 4.4 metres.

Technical assessment of The Queensland Great Dividing Range Scheme (2021)

The Great Dividing Range Scheme is an ambitious proposal. The Chief Engineer's assessment raises many engineering questions for which there are no ready answers. The panel did not go into these issues, because the project relied upon much larger amounts of water than were available. It required much more water than the CSIRO version of the Bradfield Scheme, which faltered at the water availability hurdle.

Limitation of past scoping estimates

Bradfield's original proposal was conceptual with limited specific or technical detail. Hence, CSIRO undertook its own interpretation of the Bradfield concepts to improve their functionality. To address this, some engineering changes were made to make the scheme work or work better.

The cost estimates used for the final infrastructure options assessed by CSIRO were described in their report as being 'scoping-level estimates'. That investigation was based on a desktop analysis and CSIRO stated it expected an order of accuracy for their estimates of -25 per cent to +50 per cent. These estimates also assumed no adverse geological conditions would be encountered, otherwise the costs would be considerably higher. The CSIRO report notes that cost overruns are prevalent for large infrastructure projects, particularly those involving substantial sub-surface excavation. It cites a report[3] that found in Australia "the median and mean cost overrun for large dams to be 40 per cent and 120 per cent respectively", and there were similar findings from international studies[4].

This level of analysis is appropriate at this conceptual stage of the scheme's development.

CSIRO's findings relating to environmental flows and impacts upon existing user reliability require examination. The Queensland water resource planning process incorporates a legal requirement to protect flows within streams and rivers for environmental purposes (this is discussed in greater detail in Appendix 2 of this report). Such flows are directed towards maintaining the ecological health of the rivers and receiving waters, and the volumes and conditions are based on robust, peer-reviewed and contemporary science. These safeguards for healthy river systems protect the environment but also established industries and communities that rely on the natural resource to function. Once determined, these flows may not be available for other uses such as irrigation or industry until such time as rigorous analysis provides a sound reason for changing them.

- The CSIRO report identifies a need for significant quantities of protected flows in the water plans to be preserved for environmental and ecological purposes as well as the flows required to supply existing water entitlement holders. It did not conduct detailed analysis. The Queensland Government's specialist hydrologists and water planners have completed water plan compliance assessments and provided the results in Appendix 2.
- The contemporary Bradfield scenario that CSIRO developed showed that the engineering challenges could be overcome. The proposal failed at a more basic level: the availability of water. If it had cleared the water availability hurdle, it is unlikely that it would have generated economic development benefits as large as alternative uses of water closer to its source.

Limitations of Bradfield's original analysis

The original Bradfield concepts were conceived with limited hydrological and topographical data. At the time, Bradfield relied on what is known as aneroid levels 'without water' (measures of atmospheric pressure from a barometer) to determine elevation levels. CSIRO noted that, despite this limitation, many of the levels used were reasonably accurate. Bradfield's work within the tools of his day can reasonably be described as brilliant in the accuracy of its conclusions. Brilliant, but in some important respects, wrong. The main shortcoming related to the Hells Gates Dam diversion levels, specifically concerning the 1938 Bradfield concept.

For hydrological data, Bradfield used rainfall and runoff relationships established in Germany. For example, this produced mean annual streamflow estimates for the Upper Tully, Herbert, Upper Burdekin and Flinders catchments, which totalled 7,192 gigalitres. These are twice the volumes determined by CSIRO (3,306 gigalitres) based on climate and hydrological data and tools that were unavailable to Bradfield. Queensland's hydrological modelling estimates that the mean annual flow for these catchments prior to any water resource development was 3,267 gigalitres. Given the low level of the development in these catchments, the data reviewed shows there is close similarity between the Queensland Government and the CSIRO hydrology assessments.

Bradfield did not take full account of the extreme variability in flows in rivers of northern Australia. The high variability of streamflows increases the size of dams necessary for a given level of secure water supply. Bradfield did state in his manual

scripts that estimating the quantity of water discharged year by year appeared almost impossible. With modern water modelling calibrated against real data collected over more than 100 years, the Queensland Government is able to determine the quantity of water discharged year by year (see Appendix 2).

There has been significant water resource development and increased human use in the catchment since 1938, and this must be considered in any contemporary analysis of the Bradfield Scheme. Bradfield did not make any allowance for flows for the environment.

Basis for the panel's analysis

In considering the Bradfield Scheme and its variants, the panel identified a range of 'prerequisites for success' that should be met to ensure the viability of a scheme of this nature. These prerequisites are set out in the following table.

Options analysis

Table A5-1 provides a high-level comparison of the four Bradfield options. The following sections describe the panel's assessment of each of these options, along with overarching considerations such as water availability, environmental and ecological impacts, cultural heritage issues and other matters.

Water required for the Bradfield Scheme

In analysing the 1938 and 1942 Bradfield schemes and Bradfield-like variants, the most basic issue upon which everything else depends is the availability of water.

Bradfield's vision entails diverting large volumes of water from the east to the west of the Great Dividing Range, thus opening large tracts of inland Queensland for irrigated agriculture. The Bradfield options need large volumes of water to be available.

The estimated capital expenditure for all options reviewed by the panel would exceed $15 billion. The economic case for the capital expenditure depends on the water being made available by a scheme adding value to total economic activity that exceeds that expenditure. Understanding the amount of water that is available for a Bradfield or Bradfield-like scheme is the starting point of evaluation. Appendix 2 provides insights to the various Bradfield schemes, applying knowledge derived from the sophisticated and robust water planning process required by law in Queensland.

The central feature of the Bradfield Scheme and its variants is the impoundment of water at the Hells Gates Gorge, from both the upper reaches of the Burdekin River and diversions from the headwaters of the Herbert and Tully rivers.

Table A5-2: Prerequisites for viability and success.

Prerequisites for success	Description
Water availability	Sufficient water is available to sustain the scheme after meeting commitments to established economic uses, environmental flows and Indigenous cultural requirements; and taking into account the effects of climate change. Demands on water have to be reconciled with the Queensland's legislated water resource planning process.
Ecological impacts	Impacts upon the ecology or environment as a result of the scheme's construction and operation are rigorously analysed and understood to assess if benefits exceed costs for the community as a whole.
Technical viability	The main elements of the scheme have been assessed for technical viability: the scheme's infrastructure is capable of delivering the stated quantities of water to the points of use or distribution.
Agricultural feasibility	The feasibility assessment takes account of the potential crop types and output and market demand for their products, considering soil suitability and climatic conditions.
Economic viability (including risk analysis)	The scheme provides net economic benefit, weighing appropriately the relative effects on local, state and national economic activity—large enough to outweigh any negative non-economic effects.
Social impacts	Analysis of the scheme covers rigorously net benefits to regional communities.
Cultural and Indigenous impacts	The scheme provides net cultural and economic benefit to Indigenous peoples.

The Queensland Government has assessed the total pre-development mean annual streamflow from the Burdekin River catchment at Hells Gates to be 1,665 gigalitres. This is based on the Burdekin hydrologic model which was developed to support and underpin the current Burdekin Water Plan. That Burdekin hydrologic model was developed in accordance with contemporary modelling processes and methodologies and quality-assured procedures, using model calibration techniques based on historical records where possible. This work has been externally peer reviewed. CSIRO's analysis of the Bradfield Scheme calculated the mean annual streamflow from the Burdekin River catchment at Hells Gates to be 1,603 gigalitres. Bradfield calculated this to be 3,678 gigalitres per annum.

Both the CSIRO and Queensland Government calculated these volumes using hydrological models that have been calibrated against streamflow gauges across the three catchments. The modelled streamflows correlated reasonably well with past studies, in particular the 1982 report on the Bradfield Scheme by Cameron McNamara Consultants.

CSIRO also used a reservoir and diversion water balance model to determine the volumes of water that could be transferred from the Tully and Herbert catchments and taken from an impoundment at Hells Gates. Even though the CSIRO models differ from the Queensland Government models used for water plans, the calculated results are similar.

Environmental flow objectives have been set as required by Queensland's legislation across all three catchments. The water that must be set aside to maintain these objectives accounts for a considerable proportion of the total water available at the Hells Gates Gorge. CSIRO did not limit the volume of water that could be diverted from the Hells Gates Dam to allow for environmental flows. It simply determined the amount of water flowing past Hells Gates Gorge and the capacity of different infrastructure options to transfer the water to the west of the Divide. CSIRO's analysis of the contemporary Bradfield scenario determined that it may be possible to divert 1,881 gigalitres per annum. Bradfield's calculations determined that 5,362 gigalitres per annum could be transferred. The Queensland Government analysed both the CSIRO contemporary Bradfield scenario and Bradfield's original schemes and calculated that 1,792 and 2,466 gigalitres per annum could be transferred respectively. CSIRO then assessed the impact of extracting such flows from the Burdekin, Tully and Herbert rivers on environmental flow objectives and downstream user reliability. CSIRO did not exclude from its assessment the strategic and general reserves that have been set aside for future potential developments in the Burdekin Water Plan (these reserves are discussed in further detail). The water plan is a legal instrument and, once approved, water cannot be accessed or used for purposes other than those nominated in the plans. The plans' allowance for environmental and downstream development reasons are based on analysis and varying them involves loss of value from the uses of water envisaged in the building of the plans. Diverting water from uses envisaged from the plans is possible but involves a cost that has to be taken into account in any assessment of the value of the proposed alternative uses. Both the CSIRO contemporary Bradfield scenario and Bradfield's original schemes violate requirements of water for various purposes that are protected under Queensland law.

Assessing impact of proposed concepts

CSIRO's assessment of the impact of these proposed transfers upon the environmental flow objectives of the Tully, Herbert and Burdekin rivers has two parts[5]:

- upstream of the Burdekin Falls Dam, the mean and median annual flows fall by 39 and 36 per cent respectively
- at the end of the Burdekin River system, the mean and median annual flows fall by 18 and 28 per cent respectively.

Since Bradfield described the original scheme in 1938, there has been considerable water resource development across all three catchments. In the Burdekin River downstream of the Hells Gates Gorge, there are now five weirs plus the Burdekin Falls Dam. These storages collectively provide nearly 100 gigalitres of high-priority water and 1,000 gigalitres of medium-priority water to agriculture, urban and mining users in the region. There are some 90,000 hectares of irrigated agriculture downstream of the Burdekin Falls Dam. There are also a number of small-scale water use allocations that rely on natural runs of the river between the Hells Gates Gorge and the Burdekin Falls Dam.

CSIRO's analysis concludes there would be minimal impact upon user reliability downstream of Hells Gates Dam in a scheme that diverts a total of 2,272 gigalitres to the west of the Great Dividing Range. These impacts for downstream water users were not discussed in the CSIRO report. They need to be considered based on diligent water availability assessments.

CSIRO observes that Bradfield-type diversions of water from the Tully would diminish the operation of the Kareeya Hydro Power Station at the Tully Falls Weir. This cost needs to be considered in assessing the economic effects of the scheme but is small in the scheme of things. It could probably be recouped by upgrading the power capacity to be more suitable for firming intermittent renewables.

Upstream of the Burdekin Falls Dam in the Upper Burdekin River sub-catchment, only 20 gigalitres of water have been reserved under the water plan. A DBC completed by TEL has indicated Big Rocks Weir could make 10–20 gigalitres of water available if constructed and if a decision were made to release the unallocated water identified in the water plan to support its development. The Queensland and Australian governments have committed to provide $3 million each to pre-construction activities to move the Big Rocks Weir project to investment decision. Subject to the outcomes of these activities and

further Queensland Government consideration, the two governments have committed a further $27 million each towards construction.

Confident planning for the use of water requires consideration of the effects of climate change. This is undertaken in Appendix 3. The current evidence suggests climate change will lead to a small decrease in average availability of water in the Burdekin catchment, but there is much uncertainty. Uncertainty argues for caution in committing to full use of the water currently thought to be available in the Upper Burdekin River sub-catchment until more of the climate change future has revealed itself.

Several other proposals are competing for the remaining unallocated water reserves in Burdekin Basin Water Plan Area. These include:

- the raising of the Burdekin Falls Dam to meet the needs of additional demand from agriculture, mining and urban growth requirements in Townsville and Bowen
- the Burdekin to Moranbah Pipeline, which is a proposed duplication of an existing pipeline to meet presumed additional demand from coal mining, but possibly of value for other uses if not required for mining. This would increase demand for water from Burdekin Falls Dam
- a pipeline from Burdekin Falls Dam to the Bowen region for both agriculture and urban use.

TEL sponsored and the Commonwealth Government funded a preliminary business case in 2019 for a version of the Hells Gates Dam that is much smaller than the Bradfield options. This scheme intends to provide some 542 gigalitres per annum of water to adjacent irrigation users, rather than take the water west of the Divide as proposed by Bradfield.

In conclusion, only 20 gigalitres of water is set aside in the Burdekin Water Plan for any development upstream of the Burdekin Falls Dam in the Upper Burdekin River sub-catchment. Of this reserve, 10 gigalitres is likely to be allocated to the Big Rocks Weir development. Hence, there would only be 10 gigalitres of water remaining for any potential development at Hells Gates, in the absence of major diversion from the Herbert and Tully. The diversions from the Tully and the Herbert rivers alone would not be large enough to justify Bradfield-scale infrastructure.

Bradfield 1938

The 1938 version of the Bradfield Scheme involved diverting water from the Tully and Herbert rivers to the headwaters of the Burdekin.

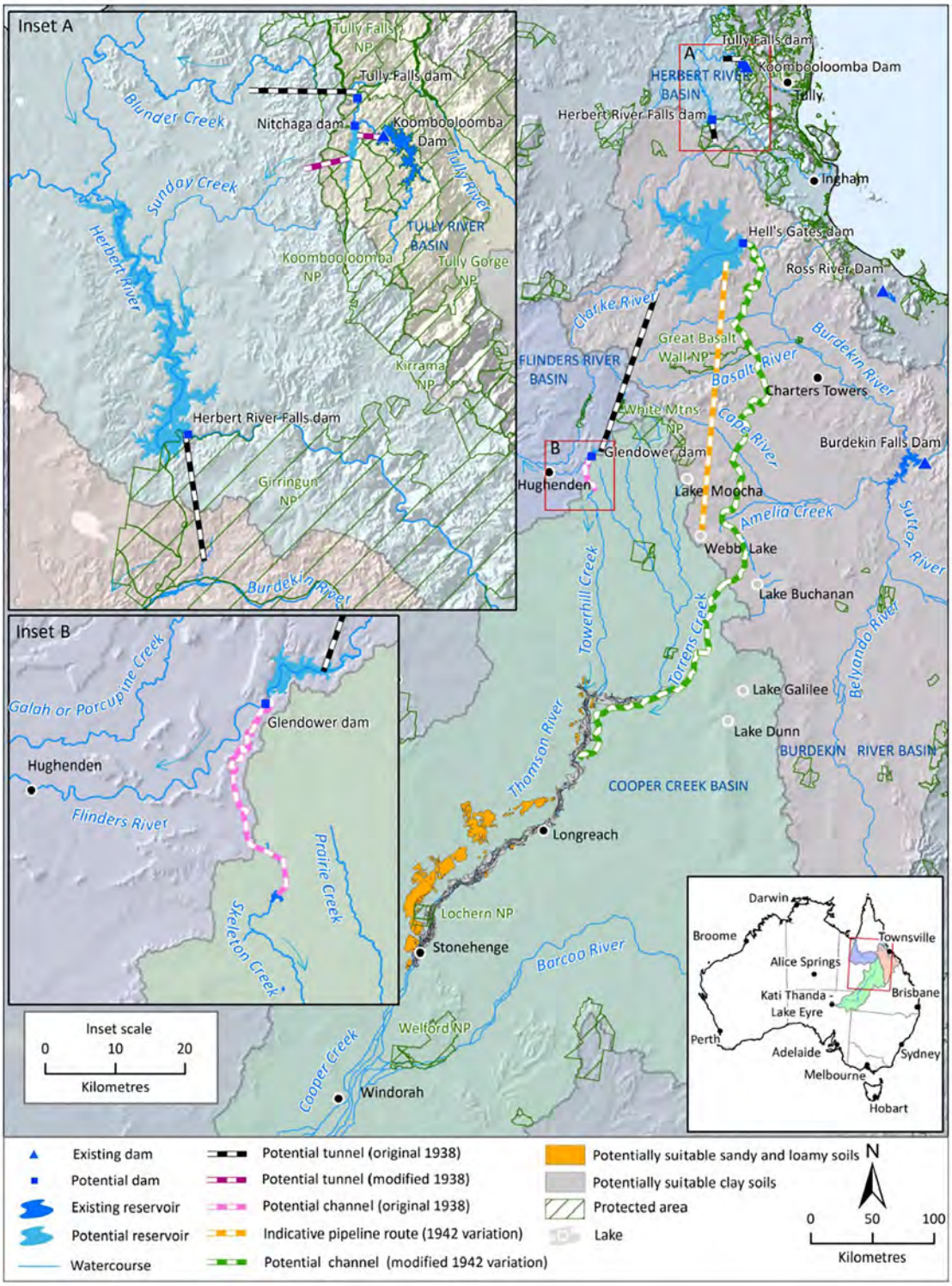
Bradfield's 1938 manual scripts note, "the site chosen for the final impounding of water on the eastern side of the Divide is at 'Hells Gates', a gorge on the Burdekin River". The manual scripts go on to note, "the consequent backing up of water along the Clarke River, a west–east flowing tributary of the Burdekin, would permit the access of Tully, Herbert and Burdekin waters to within a short distance of the Main Dividing Range through which they can be taken by Tunnel. Once through the Divide, the waters would be discharged into the Flinders River or one of its tributaries and a suitable corridor (gorge) dammed, in order to create a large artificial water basin".

While Bradfield proposed a 122-metre high dam at the Hells Gates Gorge on the Burdekin River, CSIRO undertook a screening-level analysis of various dam sites in the Upper Burdekin to assess whether Hells Gates was the best site for such a dam. CSIRO assessed five sites on the eastern side of the Divide and a summary of this assessment is provided in Table A5-3.

From this analysis, CSIRO selected the Hells Gates Dam to form the basis of its scoping studies for its report. Their report did not find any of the alternatives to be clearly better for the purpose of diverting water to the west of the Divide to the Flinders or Thomson rivers.

Once impounded on the east of the Divide, flows were to be transferred west of the range via a tunnel to the headwaters of the Flinders and Thomson rivers. Bradfield proposed damming the headwaters of the Flinders River. CSIRO has consequently developed a concept for the Glendower Dam that would enable distribution of flows by gravity to both the Flinders and Thomson rivers. Bradfield proposed movement of water to the Thomson via a canal to Skeleton Creek, which is a tributary in the headwaters of that river.

The level of the Glendower Dam dictates the inlet level for the tunnel at Hells Gates, which must be at 428 metres earth gravitational model 96 (EGM96). This is only 14 metres below the FSL of the proposed Hells Gates Dam, and some 100 metres above the lowest point in the dam. Hence the dam under this proposal would have large quantities of water that cannot be distributed to west of the Divide without pumping (known as 'dead storage'). Some of that 'dead storage' may be distributed elsewhere under a different scenario (not considered in assessments by CSIRO or Bradfield).



Map A5-1: An assessment of the historic Bradfield Scheme to divert water inland from northern Queensland.

CSIRO consequently assessed the amount of water that could be distributed west of the dividing range to be 598 gigalitres. This is a small fraction of Bradfield's estimate of 5,362 gigalitres. This difference is to a significant extent a result of Bradfield's reliance upon atmospheric pressure from a barometer to determine levels for the scheme.

Bradfield's miscalculation of elevations affecting the diversion of water to the west of the Divide have implications for the length of the required transfer tunnel. This tunnel must now be 144 kilometres in length and up to 300 metres deep under the Great Dividing Range in places. CSIRO estimates the cost of the tunnel alone to be $13.293 billion (the total capital cost of the option is estimated to be $22.495 billion). This correlates with the Chief Engineer's assessment, which estimated the tunnel would cost in the order of $27 billion. To minimise costs, including reducing the time of tunnel construction, CSIRO assessed the use of seven tunnel boring machines (TBMs). This would entail constructing shafts along the route to drop the TBMs into place. These shafts would also be used to extract excavated material and deliver material for the tunnel lining. This must be done in remote locations where access is challenging.

An assessment of this option against the panel's prerequisites for success is provided in Table A5-4.

Table A5-3: Summary of CSIRO assessment.

Impoundment option	Commentary
Lake Lucy	• Highest possible site in the assessment in the Upper Burdekin • Proposed by Nimmo (1947) as an alternative to Hells Gates for conveying water to the Flinders River • Yield is only approximately 15 per cent of Hells Gates due to the smaller catchment (without the Tully and Herbert diversions)
Greenvale	• Lowest modelled capital cost per megalitre of the five sites • Yield approximately 46 per cent of Hells Gates (without the Tully and Herbert diversions)
Mount Fullstop	• Slightly upstream of Hells Gates • Similar yield to Hells Gates with Tully and Herbert diversions and similar unit cost
Hells Gates	• Synonymous with the Bradfield Scheme • Higher yield than the Lake Lucy and Greenvale options • Lower unit cost per megalitre compared with Lake Lucy, Greenvale and Mount Foxton
Mount Foxton	• Downstream of Hells Gates • 17 per cent more yield than Hells Gates due to the larger catchment area • More than 40 per cent more expensive per cost per megalitre than Hells Gates • Lower level would make gravity water diversions west of the Divide difficult

Table A5-4: Assessment of 1938 Bradfield concept against prerequisites for success.

Prerequisites for success	Assessment of 1938 Bradfield concept
Water availability	On the most generous of assumptions, the water available for distribution from a dam at Hells Gates falls well short of that presumed by Bradfield in his 1938 scheme. Once requirements for uses of water established in the post-war period are taken into account, together with assessments of downstream requirements for environmental flows, Indigenous cultural values and firm commitments to new uses, the amounts from the Upper Burdekin itself can be calculated in tens rather than thousands of gigalitres. The certain prospect but uncertain impact on water availability resulting from climate change argues against large, irreversible commitment to use of all water that appears now to be available for future use. Transfers from the Tully and Herbert could add to the water available but in nowhere near the volumes presumed by Bradfield.
Ecological impacts	CSIRO identified a range of potential ecological impacts along the Flinders River that were not identified by Bradfield. There are also the requirements for environmental flows assessed through the Queensland water planning process underpinning the water plans to be taken into account. The immense augmentation of river flows in the Lake Eyre Basin envisaged in the original Bradfield conceptions would be deeply disruptive of established ecological systems in rivers adjusted to intermittent flows.
Technical viability	To ensure the scheme could distribute water to the west of the Divide, a significant reduction in the volume of diversions from the Burdekin was required.
Agricultural feasibility	The smaller volume of water limits the amount of irrigated agriculture that can be developed. CSIRO considered there would be only sufficient water to irrigate along the Flinders River and not the Thomson River. Current assessments of climate change (Appendix 3) suggest there is likely to be a substantial increase in rainfall without corresponding increases in evapotranspiration in the catchments of the Flinders and other rivers flowing into the Gulf of Carpentaria, so it is by no means certain that water would be more scarce and valuable in the Flinders region than in areas adjacent to the Burdekin catchment.
Economic viability (including risk analysis)	The work has not been done to assess the value of water in many of the agricultural uses that are emerging in a carbon constrained world. However, it is not at all clear that the value would be higher at great distance from the Burdekin catchment than closer to it, and it is this difference in value that would have to support investment in infrastructure to transfer water over long distances. The water volumes are simply not large enough to support the capital expenditure (estimated by CSIRO at $22.5 billion) required to build the immense dam envisaged in the Bradfield schemes.
Social impacts	The regions to which water was to be transferred under the Bradfield schemes have been declining in economic activity, employment and population over recent decades. There is high social value in maintaining and modestly expanding employment, incomes and population in these regions. This expansion would require some augmentation of water availability, but not the immense expansions envisaged by the Bradfield schemes. The more modest augmentation of water availability to meet the social objectives that have highest value are better provided under smaller regional development schemes discussed in the panel's main report.
Cultural and Indigenous impacts	Detailed on-ground assessment with Traditional Owners and cultural impacts would be required and have not yet been undertaken.

Bradfield 1942

The 1942 concept had three main variations to the 1938 scheme, namely:

- The height of the Hells Gates Dam was increased from 122 metres to 152 metres.
- Instead of tunnelling under the Great Dividing Range, Bradfield proposed 400 kilometres of twin pipes to distribute the water across the range under gravity. This necessitated selecting a longer route to the south of Hells Gates. Bradfield proposed the twin 25-foot pipes run to Webb's Lake at the head of Amelia Creek, where the gorge in the range is about 1,200 feet (365.76 metres) above sea-level. From here, Bradfield thought the water could probably be passed though the Range without tunnelling to the Torrens Creek and "thence to the Thomson River".
- Consequently, the water could only be distributed to the headwaters of the Thomson River, and so this version of the scheme excludes the Flinders River region for potential irrigation.

CSIRO noted the total grade on this proposed pipeline is tightly controlled by the offtake level at the Hells Gates Dam and the natural level of the Great Dividing Range some 400 kilometres away. CSIRO calculated the cost of the pipelines would be five times greater than a channel of similar capacity. The flat gradient would require pumping, the costs of which were estimated by CSIRO to exceed $300 million per annum. These costs assume failure to use opportunities for the low-cost supply of renewable energy to this region, but the costs of pumping would nevertheless be substantial. The small size of the Torrens Creek and its steepness to the Thomson River would generate substantial erosion of the water course with anything like the proposed scale of augmentation of water flows.

For these reasons, CSIRO did not consider Bradfield's 1942 concept worthy of further consideration. They did develop and consider their own alternative to it, which responded to inherent weaknesses in the classical Bradfield schemes. An assessment of Bradfield's 1942 option against the panel's prerequisites for success is provided in Table A5-5.

Table A5-5: Assessment of 1942 Bradfield option against prerequisites for success.

Prerequisites for success	Assessment of 1942 Bradfield concept
Water availability	There were shortcomings in Bradfield's hydrological modelling to assess the availability of water in the various catchments under consideration.
Ecological impacts	This prerequisite was not assessed by CSIRO as this version did not meet the key prerequisites relating to technical viability and water availability.
Technical viability	This option is not technically feasible as the 152-metre high Hells Gates Dam would never fill due to insufficient inflow and evaporation. Furthermore, the proposed twin pipes and pumping through them would add substantially to costs.
Agricultural feasibility	This prerequisite was not assessed by CSIRO as this version did not meet the key prerequisites relating to technical viability and water availability.
Economic viability (including risk analysis)	The high costs of the twin pipes and pumping make it economically weaker than other options.
Social and cultural impacts	Likely on balance to be less advantageous than smaller scale options which convert decline in employment and population into modest expansion. This prerequisite was not assessed by CSIRO as this version did not meet the key prerequisites relating to technical viability and water availability.
Cultural and Indigenous impacts	The above deficiencies removed the need for substantive cultural impact assessment. Without detailed on-ground assessment with Traditional Owners, cultural impacts could not be substantively assessed.

CSIRO Contemporary Bradfield Scheme Scenario

The CSIRO variant has two main differences to the 1942 Bradfield concept including:

- a 97.5-metre high Hells Gates Dam instead of the 152-metre high option proposed by Bradfield in 1942
- a 679-kilometre channel from Hells Gates to the Thomson River (near Aramac Creek), replacing the twin pipes proposal.

In respect of the dam height, Bradfield never provided an explanation as to why he proposed increasing the height of Hells Gates from 122 metres (1938 option) to 152 metres (1942 option).

CSIRO noted that, by using a channel to divert water west of the range, a lower offtake point could be used to draw water from Hells Gates. This effectively increased the functional capacity of this storage compared with the 1938 tunnel option.

This option allowed CSIRO to optimise the size of the Hells Gates Dam, having regard to several factors including:

- **inflows**
- **storage evaporation:**
  - For example, CSIRO determined that the 152-metre high Hells Gates Dam that formed part of the 1942 Bradfield concept would never fill as evaporation across the significantly increased surface area of the lake would exceed the inflows.
- **cost:**
  - The higher the dam becomes, the more costly it is to build, not only because of the additional height, but the increase in length of saddle dams required to tie back to a point in the valley equivalent to the dam crest level.
  - For example, CSIRO estimated that the 122-metre high dam contemplated in the 1938 Bradfield concept would cost approximately $5.7 billion, compared with $1.814 billion for the 97.5-metre high dam contemplated in this variant.

Table A5-6 summarises the CSIRO's alternative option. It shows the yield of Hells Gates peaks and plateaus with a FSL of 400 metres EGM96 and this coincides with close to the lowest cost per megalitre. Consequently, CSIRO has recommended a storage at Hells Gates with a FSL of 405 metres EGM96 for their variation of the 1942 Bradfield Scheme.

The CSIRO variation to the 1942 Bradfield Scheme introduces a channel to replace the twin pipes to divert the water across the Great Dividing Range. CSIRO analyses a 679-kilometre channel that extends from Hells Gates through to the junction of Aramac Creek with the Thomson River. The channel introduces the additional water into the Thomson River at a point where erosion can be minimised and there are more suitable soils for irrigation. The channel is 50 metres wide and four metres deep. CSIRO analyses a route that enables the flow of water by gravity along the entire length.

A summary of this scheme's characteristics against the panel's prerequisites for success is provided in the following table. At this scoping study stage, this variation appears technically viable. In our assessment, the water is not available for this limited version of the Bradfield Scheme, even with flows from the Tully and the Herbert. There are also large questions about whether this would be the most valuable use of water that is available. Environmental and social impacts would be large, requiring assessment.

Table A5-6: Assessment of CSIRO variant against prerequisites for success.

Prerequisites for success	Assessment of CSIRO variant of the 1942 Bradfield concept
Water availability	The scheme is based on CSIRO hydrological models that have been calibrated to streamflow gauges. The option and assessment does not allow for either environmental flow requirements or existing user requirements as set out in the water plans for the three catchments.
Ecological impacts	There are major environmental flow objective impacts from this scheme. The transformation of the intermittent flows of the Thomson River system would require close analysis and assessment. This impact would likely be large and negative. The effects on environmental flows downstream in the Burdekin may be large and require some limitations on scale of water diversion. Effects on the Tully and the Herbert would be less problematic but require analysis and careful response.
Technical viability	The scoping study determines the scheme is technically capable of diverting some 2,272 gigalitres of water to the west of the Great Dividing Range. More detailed planning, survey, geotechnical studies and design would be required to confirm this.
Agricultural feasibility	A desktop soil suitability study has identified areas adjacent to the Thomson River that are potentially capable of carrying 30,000 hectares of citrus and 150,000 hectares of cotton. CSIRO assesses it is likely cotton would require 40 per cent more water and citrus 25 per cent more water, compared with other regions closer to the source of the water. There may be alternative crops that use water more effectively in a hotter world and generate substantially higher value in a carbon-constrained world, but the research has not been done to assess the contribution they could make.
Economic viability (including risk analysis)	On the CSIRO assumptions, the scheme could support 30,000 hectares of citrus and 150,000 hectares of cotton at a water price of $470 per megalitre. This would only cover 51 per cent of costs over the lifetime of the scheme. CSIRO uses a discount rate of seven per cent in assessing the cost of capital, which is a serious overestimate in contemporary circumstances, leading to overestimates of the cost of water. More economically realistic assessments of the cost of capital may allow costs within the CSIRO framework to be covered. However, this calculation assumes away the fundamental issue: the water is not available to support the transfer of water on this scale. If the water were available, it is not clear that such use would generate higher value than use closer to the source of the water, with more modest interventions contributing to enhancing incomes, employment and population in the catchments of the Lake Eyre Basin that would benefit from the alternative CSIRO scheme.
Social and cultural impacts	CSIRO analysis states the scheme could create up to 15,000 jobs in the vicinity of Longreach during construction and 13,000 full-time equivalent (FTE) if it was fully developed (i.e. all 180,000 hectares). The latter would mostly be contract labour. Expansion of employment and population of more modest scale would be clearly positive for the long-term welfare of the affected communities. Massive transformation on the scale proposed would be more problematic.
Cultural and Indigenous impacts	The CSIRO report notes Aboriginal peoples have secured a range of legally recognised native title and cultural heritage rights (requiring negotiation) in the assessment area and notes Indigenous communities would need to be persuaded that major inter-catchment transfers were compatible with their values and development objectives.

The Queensland Great Dividing Range Scheme

From a technical perspective, this scheme is a variation of the 1938 Bradfield Scheme, with the following differences:

- the scheme assumes diversions from the Herbert River only (i.e. excludes the Tully River)
- the scheme assumes a 108-metre high Hells Gates Dam (compared with 122-metre for the 1938 Bradfield Scheme)
- the scheme assumes a 90-kilometre tunnel from Clarke River to the headwaters of the Flinders River (compared with a 144-kilometre long tunnel for the 1938 Bradfield Scheme). To achieve this, the scheme assumes a 65-kilometre excavation at the inlet and a 50-kilometre excavation at the outlet—to connect with the tunnel.

This proposal, developed by individuals using their own resources and working in the public interest, is impressive in its detail and engineering insights. There are several technical matters that need to be addressed. Firstly, the tunnel proposed under this option is some 40–50 metres deeper than that proposed under the 1938 Bradfield Scheme (as represented by CSIRO). The depth varies across the length of the tunnel, compared with the 1938 option. This has the following implications:

- The tunnel inlet is deeper than the 1938 option and therefore could access more water from the Hells Gates impoundment.
- The deeper tunnel makes the total length of the tunnel plus the associated excavations at the inlet and outlet considerably longer than the 1938 option (205 metres compared with 144 metres).
- The 65-kilometre outlet channel, which extends from the end of the tunnel, would finish some 55 metres lower than the FSL of the proposed Glendower Dam. The Glendower Dam is required to distribute flows to both the Flinders and Thomson rivers. This would compromise the diversion capacity from Hells Gates and only allow distribution to the Flinders River (providing the channel is extended to a point where the water is able to discharge to the river).

In addition, the proposal has extremely deep excavations adjacent to the tunnel, being approximately 200 metres deep at the inlet and 125 metres deep at the outlet. This would require significant stabilisation work and extensive battering to ensure the stability of these slopes during both the construction and operation of the scheme.

The proponents have thought through many of the issues in impressive detail. However, it has the same basic problem of other versions of the Bradfield Scheme: the water is not available to use the infrastructure that is proposed. The concept assumes the annual average streamflow at Hells Gates to be 20,000 gigalitres.

- One feature of the scheme is its inclusion of large-scale hydro-electric power generation from the Hells Gates Dam with a height of 108 metres above the river bed. As the Great Dividing Range scheme designed the hydro-electricity generation, two gigawatts of power of energy are to be generated from the flow of 5,400 gigalitres of water through five hydro-electric turbines. This flow does not in itself necessarily disrupt the use of the water downstream, although detailed work would need to be done on the timing of flows to avoid negative environmental and other impacts. The hydro-electric value of a dam at Hells Gates is potentially very large, with potential to play a major role in firming supply of low-cost solar and wind power to new industrial activities in Townsville and central Queensland. However, the project's water requirements for hydro-electricity far exceed the available water including transfers from the Tully and Herbert. The Great Dividing Range proposal has minimal analysis of environmental, cultural and social costs and benefits of the scheme.

Other relevant considerations

Inability to stage the scheme's delivery

Analysis has drawn attention to major uncertainties relating to the eventual value of the Bradfield Scheme. Neither the Bradfield Scheme nor the variants can be staged. This means work cannot cease at one stage if the unfolding of history reveals there is no longer justification for the project.

Greater uncertainty strengthens the case for governments to make smaller incremental investments that can be extended at small cost or changed in the light of changing circumstances. There is always uncertainty about the outcomes of investment and option value in smaller and flexible commitments. Nevertheless, immense projects sometimes have large value and are warranted despite the risk. This is a time of unusually large uncertainty, as the extent and nature of the effects of climate change on rainfall reveal themselves, and as policies develop in major countries and the world as a whole affecting the value of water used to sequester carbon and grow biomass. The option value of incremental and flexible investments is especially high at this time.

Conclusions from the panel's examination of other Bradfield concepts

The panel considered a number of Bradfield concepts involving different variations and configurations of infrastructure for a Bradfield-type scheme.

All of these variations were considered to be unviable first of all because they required much more water than is available. If water had been available, difficult environmental issues would have to be addressed. If these issues could be managed, the panel can see no reason why water applied to these purposes would contribute more to regional development in Queensland than uses of water closer to its source near the Great Dividing Range.

[1] Barber et al., 2020
[2] Petheram et al., 2021
[3] Petheram and McMahon, 2012
[4] Ansar et al, 2014
[5] Barber et al., 2020

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Appendix 6

Water infrastructure planning and assessment frames

Water infrastructure planning and assessment frames

Introduction

This appendix provides an overview of the planning, assessment, financing, delivery and operational frameworks for significant water infrastructure affecting northern and central Queensland. It explores governance and institutional issues with a bearing on the success or otherwise of Bradfield-like development opportunities. It also explores the institutional preconditions for success for the progression of the panel's work. The appendix concludes with specific observations of relevance to the panel in the development of its analytical findings and recommendations.

Governance frameworks for water infrastructure investment

The process of decision making about water infrastructure in Queensland occurs across three layers of government. It also involves significant decision-making among private sector partners involved in infrastructure development. As with all infrastructure decisions, limited budgets and funds need to be allocated across competing interests. The demands of managing risks and complying with regulations can crowd out focus on objectives and the foundations for success. Sound planning and policy making frameworks guide decision making and the prioritisation of projects in the water sector. Understanding this decision making framework and its strengths and weaknesses has been an important consideration for the panel.

Nationally significant infrastructure

At the national level, the 2004 National Water Initiative (NWI) is centrally important. Agreed by the Commonwealth and state and territory governments, the NWI states "proposals for investment in new or refurbished water infrastructure should be assessed as economically viable and ecologically sustainable, prior to the investment occurring"[1]. Consequently, an interpretation of the NWI is those who use the value of water should pay the full cost of the infrastructure to provide it, and the taxpayer should not have to subsidise water supply. The NWI recognises circumstances in which there can be departures from this overarching principle. Governments can intervene if there is market failure. Subsidies to achieve purposes other than maximising economic value need to be transparent. Over time, there has been increasing national understanding of the need to consider a wider range of decision making objectives (i.e. multiple criteria) including regional development in northern Australia.

Recognising the need for new infrastructure to be economically and environmentally stable, the current redrafting of the NWI seeks to enhance the existing NWI objectives by requiring all infrastructure and non-infrastructure solutions that could meet the investment objective to be considered and assessed. Projects are to be assessed against criteria to demonstrate how they adhere to the NWI requirements of economic and environmental sustainability and cost recovery or sharing between users. In time, a consistent framework should be adopted that includes detailed project assessments, selection processes and institutional arrangements[2]. Frameworks such as the National Water Grid Authority (NWGA) investment policy framework could provide guidance or criteria to prioritise investments that provide the highest net benefit of all options available to increase access to water.

This examination of national investment in regional infrastructure is increasingly being explored through Australia's premier infrastructure agency, Infrastructure Australia (IA). There is also increased consideration of the need to build circular economy principles into infrastructure design and investment[3]. For nationally significant infrastructure, IA sets out the approach used to identify potential infrastructure solutions that address major challenges and opportunities. This work is done as a foundation for project inclusion in the IA Infrastructure Priority List. Queensland's Business Case Development Framework broadly aligns with IA's Assessment Framework to enable it to prioritise and progress initiatives deemed to be of national interest. The IA Infrastructure Priority List guides the decisions of the Australian Government, which then influence bilateral (Commonwealth–State) negotiations on budgetary and program allocations. The scale and scope of Bradfield-like developments would require inclusion in the priority list at some time. This means Commonwealth–State collaboration would be essential from the outset of any planning and delivery processes.

A recent development within the Australian Government in progressing the potential for Commonwealth–State cooperation on water issues is the formation of the NWGA within the Department of Infrastructure, Transport and Regional Development. The NWGA delivers the National Water Grid (the Grid) and the Australian Government's plan for a secure water future[4]. The Grid is a series of region-specific water storage and distribution solutions to secure predictable supplies of water now and in the future. The Grid also helps to provide water infrastructure that is tailored to the needs of the regions, growing agricultural output and building regional resilience. It has a focus on unlocking agriculture in new regions, especially in Australia's north, as well as providing a secure source of water in established agricultural areas.

The NWGA administers the National Water Infrastructure Development Fund, now rebadged as the National Water Grid Fund (NWGF). The NWGF provides funding to accelerate the planning and construction of water infrastructure projects to enhance water security and to help stimulate regional economic growth, including through irrigated agriculture.

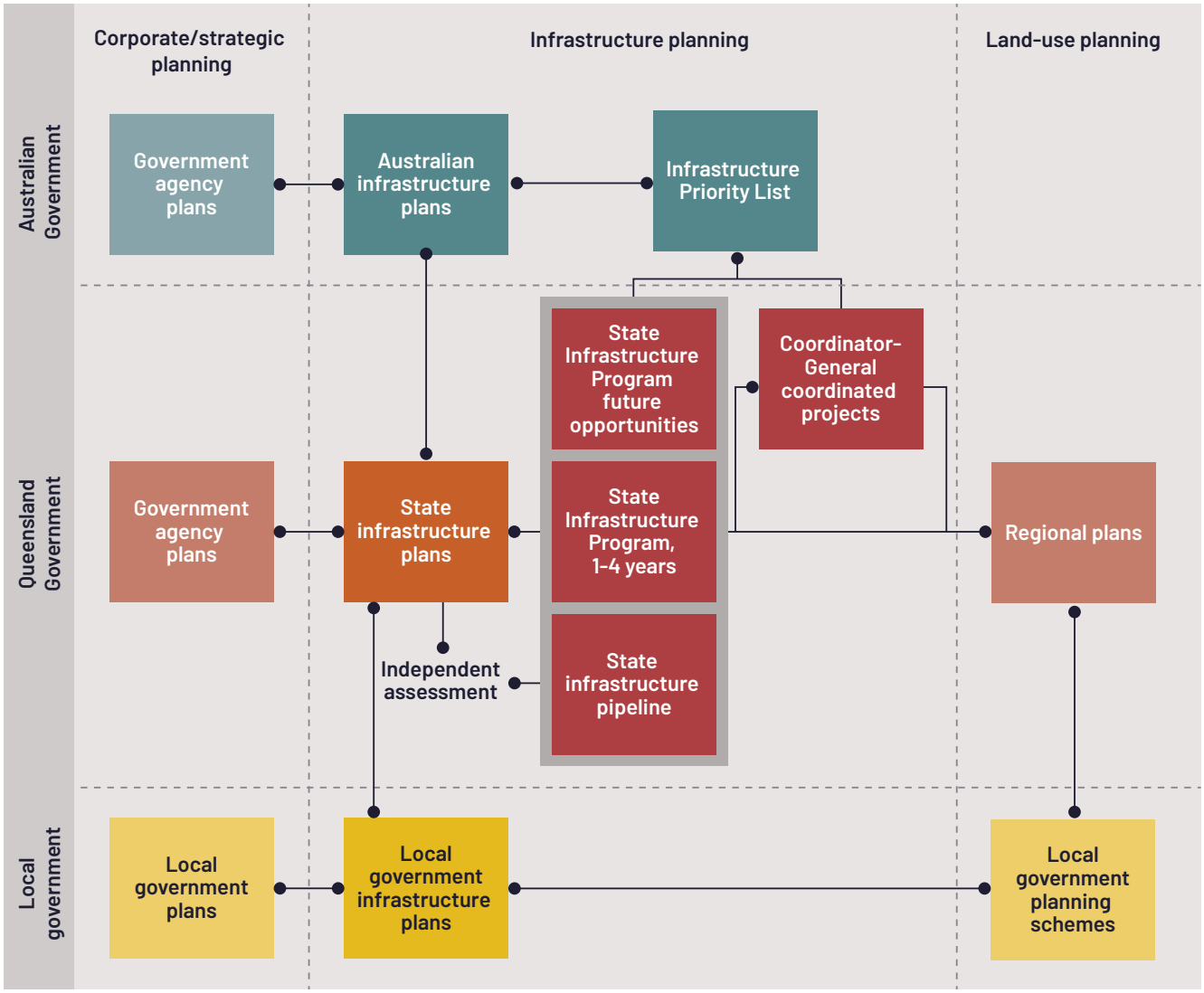


Figure A6-1: The *State Infrastructure Strategy* (SIS) planning alignment framework.

In late 2018 the Commonwealth Government announced additional funds from the NWGF. In Queensland, significant funding arrangements and proponents are now in place and feasibility assessments have started (e.g. Hells Gates Dam and Big Rocks Weir). The Lakelands Irrigation Area business case is developing a full project scope. There have also been capital contributions offered towards the Mareeba–Dimbulah Water Supply Scheme modernisation[5]. Funding offers are subject to establishing the necessary agreements between the Commonwealth and Queensland governments, and subsequent agreements with proponents delivering the projects[6]. More broadly, in the 2021–22 Federal Budget, the Australian Government announced 12 new projects to continue developing the Grid.

In the north, the North Queensland Water Infrastructure Authority (NQWIA) was established in March 2019 to provide strategic planning and coordination of Commonwealth resources to implement the Hughenden Irrigation and the Hells Gates Dam (including Big Rocks Weir) projects. These projects were funded under the NWGF. The NQWIA works collaboratively with stakeholders, local governments and the Queensland Government to progress water infrastructure feasibility and planning, including the development of NWGF-eligible business cases.

The development of Bradfield or Bradfield-like opportunities would require cooperation between the Queensland Government, the NWGA and the NQWIA.

The *State Infrastructure Strategy*

Queensland's *State Infrastructure Strategy* (SIS) outlines how the State Government will guide infrastructure investment across its agencies, ensuring infrastructure planning and delivery integrates with land use planning and economic development plans[7]. Infrastructure planning across the state needs to respond to key drivers that include population growth, changing demographics, current and future pandemics, and rapid technological advancements, as well as the hosting of the 2032 Olympics[8]. These drivers form the basis of state-wide and regional priorities and set pathways to underpin economic recovery, resilience and growth. For this reason, opportunities identified by the panel for significant agricultural development will need to influence the SIS. The SIS Part A (strategy) is updated every five years and a new draft strategy will be delivered in 2021, setting out an agenda that strengthens COVID-19 economic recovery and accounts for considerations of relevance to the recent Intergovernmental Panel on Climate Change Report[9]. The SIS Part B (program) is updated annually. Together, both parts form Queensland's basis for assessing project proposals based on their affordability and their alignment with government priorities and objectives.

The longer term and annual SIS infrastructure program aims to align with infrastructure planning across or within different levels of government. Figure A6-1 shows the relationships between the SIS and underlying corporate, strategic, infrastructure and land use planning activities that take place across other levels of government.

As a result of the SIS process, Queensland's infrastructure program is driven by strategic objectives that guide the development of major projects across the whole infrastructure lifecycle. The infrastructure lifecycle is generally seen to have four phases:

1. Planning: identifying future service needs based on clearly defined problems and opportunities
2. Assessment: developing and analysing options, including progression to an investment decision at the conclusion of this stage
3. Delivery: procuring and constructing solutions
4. Operation: operating and maintaining the infrastructure through its in-service life and withdrawing from service or managing the transition to replacement.

Queensland Treasury decides and assigns funding to water projects as part of the State Government's budget process. All projects are considered within the context of other State Budget priorities and the state's water and resource management objectives and policies. Treasury's Project Assessment Framework (PAF) incorporates commercial principles to manage risk and appropriately respond to real service needs. To successfully secure Queensland Government investment, projects need to demonstrate an economic benefit (in terms of jobs and gross state product) as well as opportunity costs. The PAF is used across government to ensure a common assessment approach. It provides tools and techniques to assess projects throughout their lifecycle, from the strategic assessment of service requirements to the realisation of delivery and benefits. For this reason, The Centre of Policy Studies' modelling of the Regional Water Grids scenario has been important (Appendix 7).

At the more detailed assessment level, section 18 (4) of the Queensland Government's Financial and Performance Management Standard requires line departments, accountable officers and statutory bodies to have regard for the PAF when preparing asset evaluations.

Departmental infrastructure plans and the *State Development Act*

Queensland Government departments are often responsible for progressing and implementing their own infrastructure. For large and complex projects, however, the State's Coordinator-General has wide-ranging powers to plan, deliver and coordinate large-scale projects under the *State Development and Public Works Organisation Act 1971* (the *SDPWO*

Act). The Coordinator-General does this while ensuring the environmental impacts of these projects are managed well. Under the *SDPWO Act*, the Coordinator-General can, among other things of relevance to the panel:

- declare a project to be a coordinated project and lead the environmental impact assessment process
- recommend to the Minister and Governor-in-Council that the declaration of a proposed development should become a prescribed development
- recommend to the Minister and Governor-in-Council to declare part of the state to be a state development area (SDA) for more intensive planning
- oversee development by controlling land use, development assessment and acquiring land in SDAs
- recommend to the Minister and Governor-in-Council that a local body or another person undertake works on behalf of the Coordinator-General
- acquire land or easements for works and provide powers to enable the Coordinator-General to access land and materials to complete works
- undertake investigations, prepare plans, give directions and take any other measures needed to build and regulate important infrastructure developments.

The state's Infrastructure Proposal Development Policy defines the required approach to the assessment and assurance of departmental infrastructure proposals. It is intended to support the guidance provided by the Queensland Government's PAF. This assurance mechanism ensures project analysis and evidence used in investment decisions are robust, and the proposed investments will deliver positive outcomes by addressing a clearly defined problem or opportunity. In defining the problem or opportunity (as well as the possible solutions), infrastructure proposals must consider whole-of-government economic, social and environmental priorities, as well as changing regional and sectoral needs. It is intended that, as government capability matures, infrastructure decisions will shift from traditional agency-by-agency approaches to a more comprehensive and coordinated system-wide approach.

As would be needed by the sorts of proposals being considered by the panel, a systemic view—rather than simply a line agency view—of investment proposals at the early stages of development would further enable coordinated decision making across the state government. Water infrastructure development, for example, would need to be better integrated with energy, transport, communications and other infrastructure. This could ensure agency infrastructure plans align with whole-of-government service delivery objectives, priorities and strategies, including those set out in the SIS and regional infrastructure plans. Queensland's policy approach aims to respond to these needs and relates to the planning and assessment stages of the infrastructure lifecycle. It does not apply to proposals prepared by other entities such as government-owned corporations (GOCs), the Queensland Rail Transit Authority and the Queensland Bulk Water Supply Authority (Seqwater). A special GOC investment guidelines policy confers these investments, whereby GOCs are required to obtain formal proposal approval for investments from their responsible ministers.

GOC investment guidelines policy

As GOCs may need to be involved in major water infrastructure, it is important to note that Investment Guidelines for Government Owned Corporations (2020) sets out the key principles GOCs need to adopt when undertaking investments, ensuring the shareholding ministers' requirements are met while enabling GOCs to pursue commercial opportunities and create shareholder value. The guidelines apply to all GOCs and statutory authorities, except the Queensland Investment Corporation Limited.

Across Australia, a formal assurance process for application across major government investments is applied based on the Gateway Process developed by the United Kingdom's Office of Government Commerce. The Queensland Government has endorsed the use of Gateway for major infrastructure projects. Managed by Queensland Treasury. Gateway reviews are undertaken at key stages or milestones in project development to ensure project proposals and associated investment meet strategic objectives and achieve value for money.

The panel acknowledges other influences affecting investment strategies and decisions within Queensland's GOCs such as bulk water providers or energy networks. These influences include the Australian Energy Regulator's role in setting the amount of revenue that network businesses can recover from customers for using networks, ranging from levels of infrastructure investment through to infrastructure costs (including hard infrastructure and systems costs). Importantly for water infrastructure, this also includes the annuity held by Sunwater for each of its assets, and other factors influencing monopoly service providers.

Market-led proposals

Public funding for infrastructure is subject to competing interests across government to meet community needs and economic and social infrastructure drivers. Private sector funding or co-funding of projects presents the opportunity to progress without a burden on the public sector. Market-led (or unsolicited) proposal frameworks are now in place in every Australian state and territory, including Queensland. Queensland's market-led proposal assessment and approval process involves four stages, affecting proposals from the private sector that seek an exclusive commercial arrangement

with government to deliver a service or infrastructure to meet a community need. They always include a role for the state, such as providing access to government land, assets, information or networks. In return, market-led proposals are expected to provide benefits to the Queensland community. They are suited to projects that can be funded by the private sector and are considered low cost/risk to the Queensland Government.

The Market-Led Proposal Guidelines policy document sets out the process for how the Queensland Government will consider all market-led proposals. Market-led proposals are assessed by a cross-agency team that recommends whether an exclusive mandate should be granted to the proponent to develop a detailed proposal. The team must consider if any proposal addressing the same need, or proposing a similar outcome, is under active consideration by the government. It determines if the proposal is a genuine commercial proposition requiring the support of the government and if it is suited to existing funding mechanisms such as grants or tenders. It provides an assessment report to the market-led proposal panel on next stage progress.

Project appraisal process for water infrastructure

To support Queensland infrastructure decisions, the Queensland Business Case Development Framework guides what a business case analysis should contain and aligns best-practice state and national requirements, including Queensland's PAF and IA's Assessment Framework. These frameworks allow government to assess business cases consistently and to compare competing investment opportunities. It guides business case investment proposals through three stages:

- Stage 1: Strategic assessment (conception)
- Stage 2: Options analysis (generating and analysing options)
- Stage 3: Detailed business case (detailed analysis of the preferred options).

The Queensland Government's approach to infrastructure planning recognises there is typically more than one way to solve a problem. The best solution may be to upgrade or modernise existing infrastructure or consider different ways to meet a service need. Infrastructure is ultimately built to deliver a service, so it is critical to explore various options that involve building infrastructure as well as those involving a change in the way services are delivered. This aligns with the proposed NWI infrastructure approach that all options to meet the objective should be considered. Thus, the future opportunities section in the annual capital program forming part of the SIS articulates infrastructure service gaps and challenges, not solutions. This need has made the panel particularly keen to ensure there is a strong place-based approach to water development planning (either at the basin or catchment scale) to ensure assessment of the widest possible range of interventions.

The strategic assessment stage must provide compelling evidence and clearly articulate the problem or opportunity and the service need. At this stage it is necessary to document the benefits targeted by responding to the service need. A strategic response is a high-level intervention that may include activities that change demand, improve productivity or even change supply arrangements. This phase is supported by investment logic mapping as an early-stage technique to assist in developing and documenting the logic that underpins a potential investment decision.

The options analysis stage acts as the first filter for any infrastructure-related investment decision across government. When developing initiatives at the early planning stage, SIS priorities must be considered. Priority categories (Figure A6-2), from highest to the lowest, are:

- reform
- better use
- improving existing use
- new.

This represents a clear statement from the government that low-cost options that maintain or improve services to Queenslanders will be considered over big-ticket infrastructure projects that achieve similar outcomes. While there is a clear preference towards non-build options, in many situations multiple proposed project options will be required to achieve the desired outcome. A combination of better-use and improve-existing-use approaches can delay the need for new infrastructure, while reform in combination with new could reduce the cost of new infrastructure to the public.

The investment decision stage involves assessing a project business case and different aspects such as financial cost, economic benefits and social benefits. The costs, benefits and risks of proceeding (or not) with a project are considered in this stage and the preferred delivery method is confirmed. For large, complex projects, specific purpose vehicles or statutory authorities may be selected as the appropriate entity to oversee delivery. These delivery options are investigated as part of this stage. An investment decision for a project, however, is not made solely on the outcomes of a business case. The government's financial position and fiscal strategy also influence these decisions, as the government must be accountable for the money it spends. To this end, investment decisions coalesce the state's budget and its infrastructure and servicing needs.

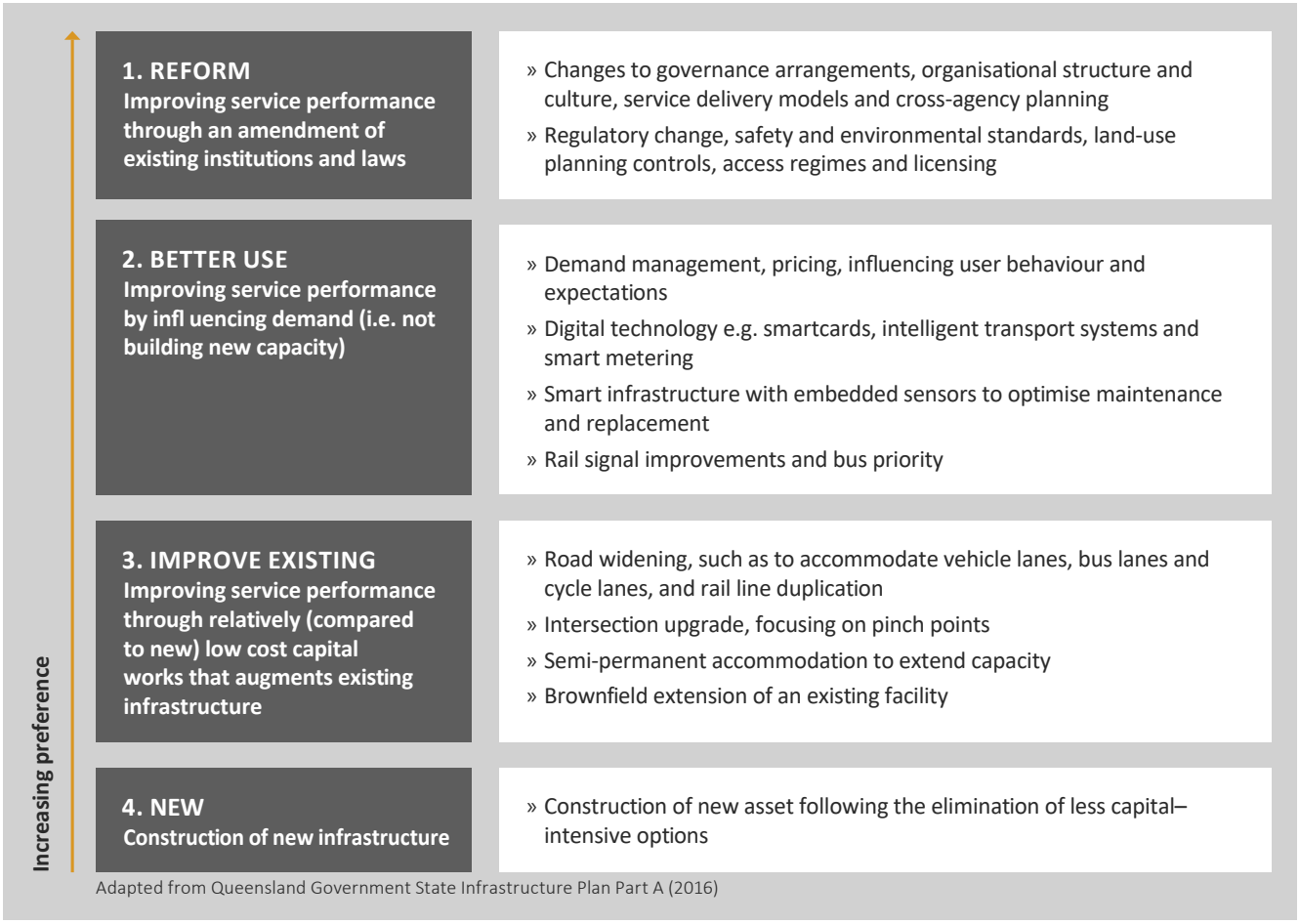


Figure A6-2: The Queensland Government's options assessment process.

The decision-making framework for Queensland water infrastructure

Background

Recent water reform throughout Australia has aimed for more efficient provision of water infrastructure. Queensland's bulk water supply infrastructure and distribution systems are primarily owned by the government-owned bulk water commercial entities Sunwater, Seqwater, the Mount Isa Water Board and the Gladstone Area Water Board. These entities support economic development by supplying bulk water to grow businesses and develop new enterprises. They do this by supplying water from existing sources or from new infrastructure, if required and justified. Queensland Treasury and the Department of Regional Development, Manufacturing and Water jointly monitor the performance of the bulk water entities and the Queensland Competition Authority oversees periodic pricing reviews.

Local governments also own and operate bulk water storages, water treatment facilities and distribution infrastructure which provides water supplies within their areas.

While reform has increasingly considered private investment, traditionally the role of private proponents has remained minimal at best. This general lack of private involvement in bulk water infrastructure can be attributed to factors such as:

- the high-cost capital investment with long lead times for revenue recovery
- the long-term nature of water assets with high ongoing operational costs
- a reliance on assets that are subject to variations in natural resource availability with climatic conditions
- high dam safety and compliance costs to meet public safety requirements as they develop over time.

Private sector involvement in water infrastructure, however, is changing. Recent developments in the provision of water services have included the:

- transfer of government-owned bulk water distribution infrastructure to local private sector entities (under local management arrangements) to own and operate water assets in selected channel irrigation schemes, with risks to the state managed via a rigorous assessment process prior to transfer
- private sector design and construction of the Gold Coast Desalination Plant, and its operation for a fixed term, with risks to the state managed via detailed contract arrangements and the state maintaining ownership of the plant.

This has created an opportunity for greater private sector investment in a broader range of water infrastructure, including the private ownership of bulk water storages. The Queensland policy for bulk water infrastructure currently has a hierarchy of objectives driven by safety and efficiency first, including making the best use of existing available water and then considering the need for further investment in new infrastructure. The recent evolution of Australian Government programs such as the NWGF have also changed the historical norm, with private sector-driven bulk water infrastructure proposals now being developed for Australian and Queensland Government consideration. Also influencing more private sector involvement in the water sector is the increase of extreme events such as floods and droughts, placing increased pressure on bulk water infrastructure for agriculture and mining. With this, however, comes the public perception of risks associated with water infrastructure, with final responsibility ultimately being sheeted home to state governments.

NWI review by the Productivity Commission

As part of the National Competition Policy in Australia, both Commonwealth and Queensland Government leaders have committed to a program of economic reforms. In 1994, the Council of Australian Governments (COAG) adopted a water reform framework informed by this policy. Reforms covered pricing, rural water schemes, water trading, resource management, institutional arrangements and public consultation. COAG eventually agreed to the NWI in 2004 as the blueprint for future water reform.

Following the dissolution of the National Water Commission in 2014, the Productivity Commission, the Australian Government's independent research and advisory body on a range of economic, social and environmental issues, has been charged with undertaking triennial reviews on national water reform progress associated with the NWI. In its National Water Reform 2020 draft report[10], the Commission found Australia was managing its water resources well but identified the need to fully implement entitlement and planning reforms, and to respond to new identified challenges. Of particular note is the recommendation that greater guidance and clarity around infrastructure investment is needed. Specifically, the Commission recommended all options (infrastructure and non-infrastructure) that may meet investment objectives be considered. In this context, criteria are needed for how projects can demonstrate adherence to the NWI requirements of economic and environmental sustainability and cost-sharing between users.

A new framework is also needed for government investment that includes project assessments, selection processes and institutional arrangements. To meet these and other proposed new and enhanced water reform objectives, the National Water Reform Committee was tasked in May 2021 with drafting a renewed NWI which is expected to be delivered by December

2021. Once agreed to, water ministers around Australia will be expected to endorse the new NWI in June 2022, with the new objectives to be implemented from 1 July 2022. Future national water reform inquiries will assess jurisdictional progress in water reform against the intent of the objectives within the new NWI.

In reviewing major infrastructure proposals since 2017, the Commission found not all projects adhered to the NWI principles of economic viability. In the Commission's view, for example, business cases for two projects (Rookwood Weir and Stage 2 of the Haughton Pipeline Project) had benefit-cost ratios of less than one and their construction might cost more than the benefits they would generate for the Australian community. This presumes, however, that cost-benefit ratios are calculated with economically rational discount rates, which is an assumption the panel suggests should be reviewed.

Among this and other issues, the Commission's assessment has concluded that jurisdictions are only partly achieving their commitments under the NWI. There is clearly still more to be done across the jurisdictions to ensure NWI signatories (federal, state and territory governments) abide by the agreement through decision-making processes for new infrastructure. This finding reinforces the Commission's 2017 conclusions. The proposed changes to the NWI will provide greater clarity and guidance to assist jurisdictions in choosing water infrastructure investments that are economically, culturally and environmentally sustainable.

Queensland Bulk Water Obligations Statement: A prioritisation framework

The *Queensland Bulk Water Obligations Statement*[11] (QBWOS) outlines the bulk water security strategy and is a future directions statement for the state. QBWOS identifies the need to coordinate the prioritisation of new water infrastructure proposals for projects that will contribute to the state's economic development, and to consider where government funding may be required for construction. It is the state's strategic infrastructure document for water and a critical element of the SIS. QBWOS includes an annual update focused on bulk water availability across the state, and updates on Queensland's key infrastructure projects, contemporary policy initiatives and opportunities. It outlines the Queensland Government's objectives for bulk water supply (stated in order of priority) as:

1. Provide safe and reliable dams and urban water supplies.
2. Use existing water resources more efficiently.
3. Support infrastructure providing a commercial return to bulk water providers.
4. Consider projects that will provide regional economic benefits.

As set out in QBWOS Part A, state-owned water entities must comply with guidelines and processes when investigating projects. This includes:

- developing business cases consistent with the state's BCDF
- observing the Queensland Treasury PAF regarding government agencies and water entities
- seeking ministerial oversight and approval for projects over certain thresholds.

QBWOS outlines a decision tree that filters the consideration given to economically viable projects as distinct from pathways for commercially viable projects. When integrated with the required PAFs, the decision tree provides key points of consideration to guide relevant agencies assessing commercially viable or economically beneficial projects (see Figure A6-3). The Bulk Water Prioritisation Framework has been developed to ensure new proposals are prioritised based on best available evidence. This includes considering factors such as comparable estimates of capital costs and water yields from proposals and assessing economic opportunities that additional water supply could enable across regional Queensland. An understanding of bulk water infrastructure priorities helps equip the Queensland Government to assess infrastructure projects. This process should help the state understand long-term opportunities in bulk water development and inform future activities such as reviews of water plans in some catchments. It should also help provide the evidence base required to demonstrate why some projects should not proceed and enable the state to concentrate effort and funding on key bulk water infrastructure priorities.

The Bulk Water Prioritisation Project, identified as a priority within QBWOS, is designed to be:

- a source of advice about which projects have merit and can advance, and which projects have significant viability challenges and should not progress
- a repeatable process which can be updated over time
- a method for comparing projects across a range of competing interests.

The QBWOS 2019–2020 Program Update stated "meeting demand will not always require new infrastructure and there are a number of initiatives in development to support better use of existing supplies and infrastructure"[12]. These initiatives include exploring new solutions and technologies, supporting water markets to be more effective, and including better use of latent capacities. Again, this reinforces the panel's view that a more place-based approach to water development planning is essential to ensure new water development delivers good outcomes.

As part of QBWOS, Assessing Demand for Water: Guidance for Project Proponents provides direction for project proponents developing new bulk water infrastructure[13]. A rigorous assessment of demand is key to evaluating an opportunity for sustainable development where it is considered the supply of water may be a constraining factor (see Figure A6-4). The characteristics of the unmet demand must be defined before potential solutions can be identified and assessed. Understanding the scale of the water supply–demand gap at different water price points (along with potential risks to demand) is crucial for assessing solution feasibility, shortlisting options, and business case evaluation. A robust demand assessment is crucial when potential solutions include the construction of expensive, long-life assets such as dams. There is a high level of uncertainty surrounding demand for water over long periods. Additionally, demand assessments tend to be susceptible to optimism bias, leading to overestimated benefits.

Water business cases seeking Queensland Government investment should be developed to provide the government with a high degree of confidence that the service need exists and benefits will be realised. Noting it is not guaranteed the State Government will fund any business case or proposed solution, this document outlines the best-practice approach for developing a water demand profile and reflecting that profile in the business case. Following this approach helps project proponents and business case advisors develop robust business cases that sufficiently address demand-related risks associated with water projects. It also ensures projects are consistent with existing assessment frameworks, including the Queensland Treasury PAF, the BCDF and IA's Assessment Framework.

This guidance informs water demand assessment at all stages of business case development (i.e. throughout the strategic business case, the preliminary business case and the detailed business case). A lack of effective demand assessment has historically been a problem for water infrastructure assessment in Queensland[14]. Now, if project business cases do not include robust demand assessments in line with this guidance, those projects are less likely to be identified as being suitable for more detailed assessment and development. Proponents seeking state investment now typically submit business cases consistent with this guidance before starting more detailed and costly project assessments including, for instance, environmental impact studies.

The QBWOS reports there is currently an estimated 280 gigalitres per annum of uncommitted supplemented water allocations (water that could be yielded with limited investment) and 865 gigalitres of unused committed supplemented water allocations[15]. Potential additional water that could be secured through more efficient water use could be difficult to estimate but is also likely to be substantial.

Options for water infrastructure development

Discussion of the Bradfield Scheme proposal tends to lead thinking about water infrastructure towards the consideration of large storages and diversion pipelines. Consistent with QBWOS and NWI, and as suggested through the panel's various water development scenarios (i.e. the Regional Water Grids and Making Water Work scenarios), a much wider range of water infrastructure development options or alternatives should be on the table for comparative assessment to achieve additional secure and affordable options for development. As noted previously, the BCDF provides a structured process requiring investment logic mapping and options assessments to frame the consideration of a range of interventions to a defined problem before a solution is identified and before an investment decision is made.

The Water Services Association of Australia (WSAA) notes the significant challenges of achieving water security by balancing future supply with future demand, particularly in light of the impacts of climate change[16]. In response, many jurisdictions are looking at diversifying their approach to planning for water development and securing water supplies to manage risks around water security. This section outlines a range of potential solutions accounting for emerging challenges (e.g. climate change, funding limits and regulatory frameworks) and opportunities (such as new technologies). Indeed, a much wider form of physical infrastructure options needs to be considered, alongside social infrastructure options that deliver equivalent outcomes (e.g. water trading, research and development, or extension).

The Bradfield Scheme and recent variations have largely incorporated traditional bulk water storage solutions, with a focus on dams, weirs and barrages. These have been the foundation go-to solutions of bulk water supply schemes throughout Queensland. There are already more than 400 dams, weirs and barrages across the state. Dams provide some benefits in mitigating the impacts of flood events, though only a small number (including the Peter Faust Dam in the Whitsunday region) have been specifically designed to provide flood mitigation as well as water supply. According to WSAA, dams in protected catchments provide a safe, low-cost water supply to urban communities. They also provide the added benefit of storing water in years of high rainfall to supplement years of lower rainfall, backed up by restrictions during drought. Dams have effectively served regional and rural communities for many years, but times of drought have shown reduced streamflows can significantly affect water security. These considerations need to be weighed against safety, environmental and social costs. Some of the wider hard and soft infrastructure options in addition to dams are explored next.

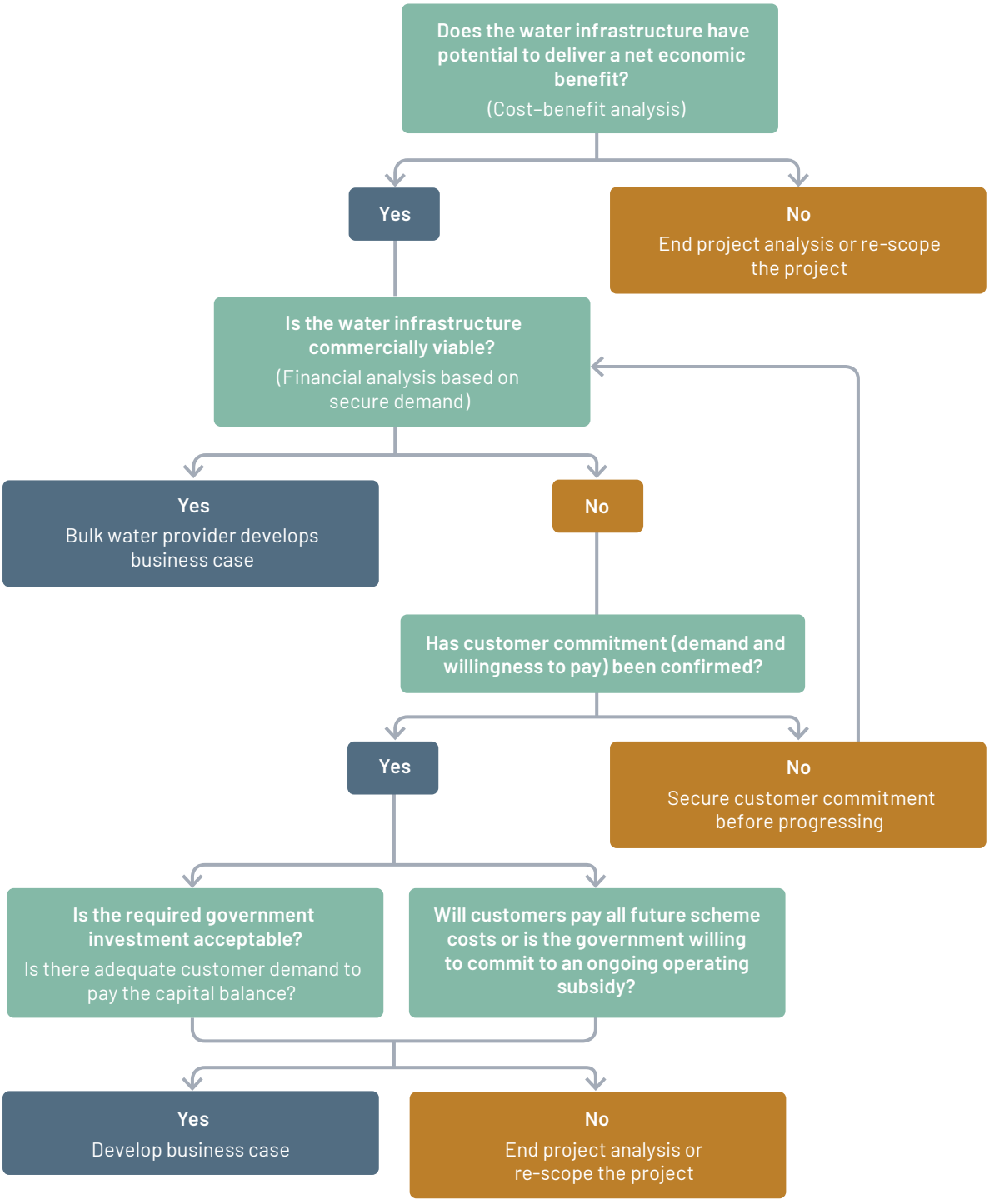


Figure A6-3: Decision tree to support QBWOS investment assessment processes.

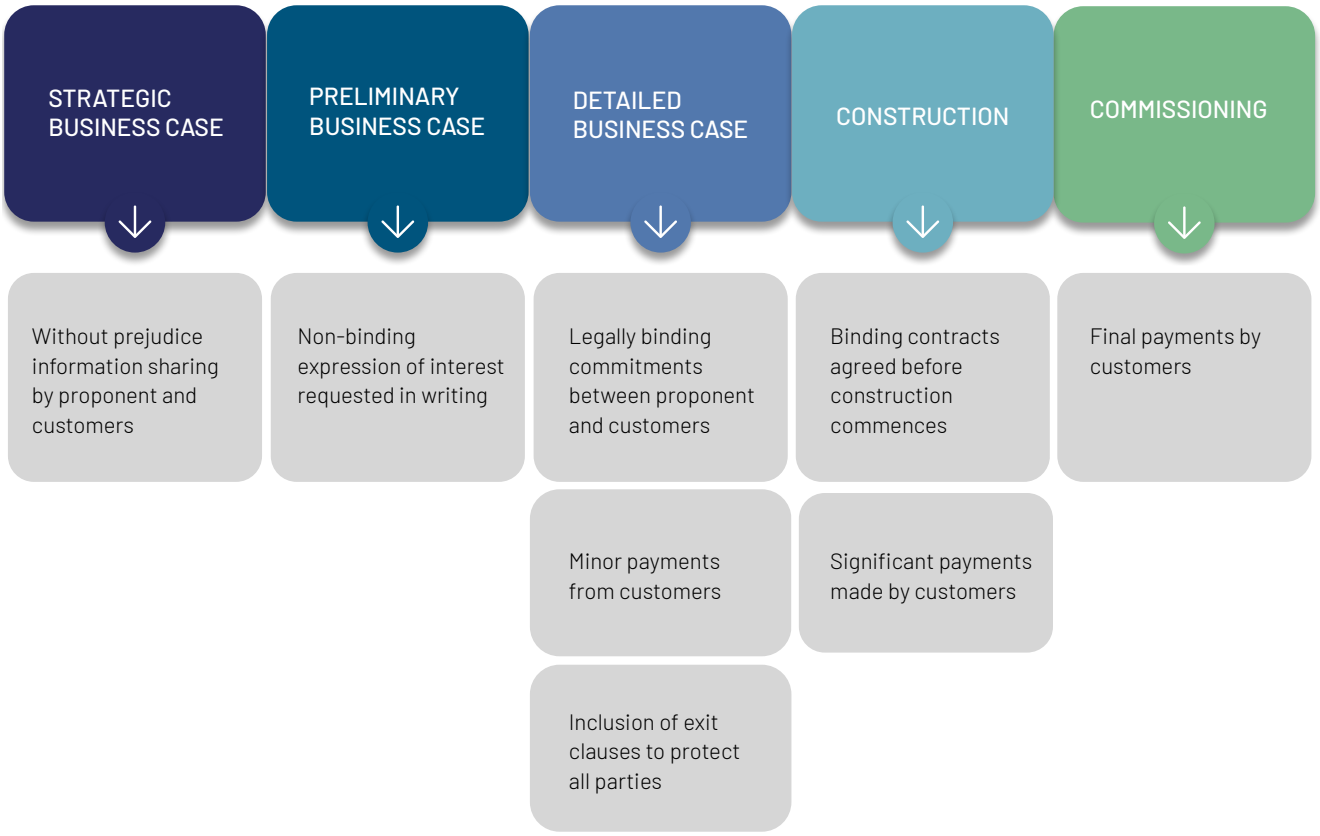


Figure A6-4: The required approach to obtaining an appropriate level of customer commitment at different stages of project development.

Offstream storage options

Surface water can be harvested from watercourses and transferred to strategic offstream storage structures when licence conditions (such as sufficiency of river flows) permit. This opportunistic take recognises the prudence of diverting excessive natural flows in the wet season for beneficial use in the north. For this reason, if suitable technologies can be developed, this option might provide significant potential to capture, store and provide a basis for the transfer of wet season flow allocations set aside in the Wet Tropics Water Plan. While flood harvest storage is a significant part of the irrigation estate in southern Queensland, significant new research—particularly through engineering and cost-benefit trials—is needed in northern and central Queensland for this opportunity to be considered as part of the solution mix. Solving these opportunities is likely to have significant benefits in the Gulf, Mitchell and Cape York regions. Evaporation management of storages will be an important consideration.

Innovative overland flow capture

Overland flow is water that runs across the land after rainfall, either before it enters a watercourse, after it leaves a watercourse as floodwater, or after it rises to the surface naturally from underground. Again, this opportunistic take recognises the prudence of diverting excessive natural flows for beneficial use in the north. Similarly, significant new research is needed in northern and central Queensland and evaporation management needs to be considered.

Targeted groundwater development

Groundwater is an important water source and Queensland already has a framework to sustainably manage it (through water plans), including the potential impacts (quantity and quality issues) of the resource sector (via Queensland's *Environment Protection Act 1994*). The Great Artesian Basin, for example, is a crucial water supply for central western Queensland. Groundwater resources are only partially known and deployed across the state. They are particularly significant in the Lake Eyre Basin region. Again, research, particularly through engineering and cost trials, is needed.

The Queensland Government has released unallocated groundwater from the Western Great Artesian Basin to provide resources to grow their businesses and create new jobs. Water resources, for example, have been released from the western Queensland parts of the Hooray, Cadna-owie, Springbok Walloon and Hutton groundwater formations. The expression of interest covered groundwater made available from parts of the Eromanga and Adori Injune aquifer units underlying western Queensland. All these water resources are subject to the Great Artesian Basin and Other Regional Aquifers Water Plan 2017, and there are limits on where new bores can be located and water licences can be issued. The water accessibility and quality of these aquifers is variable.

Managed aquifer recharge, sand dams and underground weirs

The use of underground water-holding technologies and practices provides opportunities for water users to improve the quantity and reliability of supplies that would otherwise be ephemeral (i.e. available only during short periods near to the wet season). Underground water storage could address the evaporation losses from surface water that are likely to increase in many areas under current climate scenarios. The challenge is to find sites across Queensland suitable as storages that are not already subject to high water extraction but are still in areas of water demand. Some options include:

- sub-surface dams or the use of underground aquifers suitable for water storage and artificial recharge
- sand dams or above-ground dams with an infilled artificial aquifer that is recharged though surface water application over sand
- managed aquifer recharge (MAR).

MAR is the purposeful recharge of water to aquifers for subsequent recovery or environmental benefit. Some key MAR concepts are outlined in Figure A6-5. National guidelines for MAR development and management have been established to help regulators and MAR operators develop schemes. Significant research work is required to progress and explore the potential to develop MAR, sand dams and underground weirs. One known project aims to identify areas in Queensland, including northern Queensland, that show the best potential for further investigation for sub-surface and sand dams.

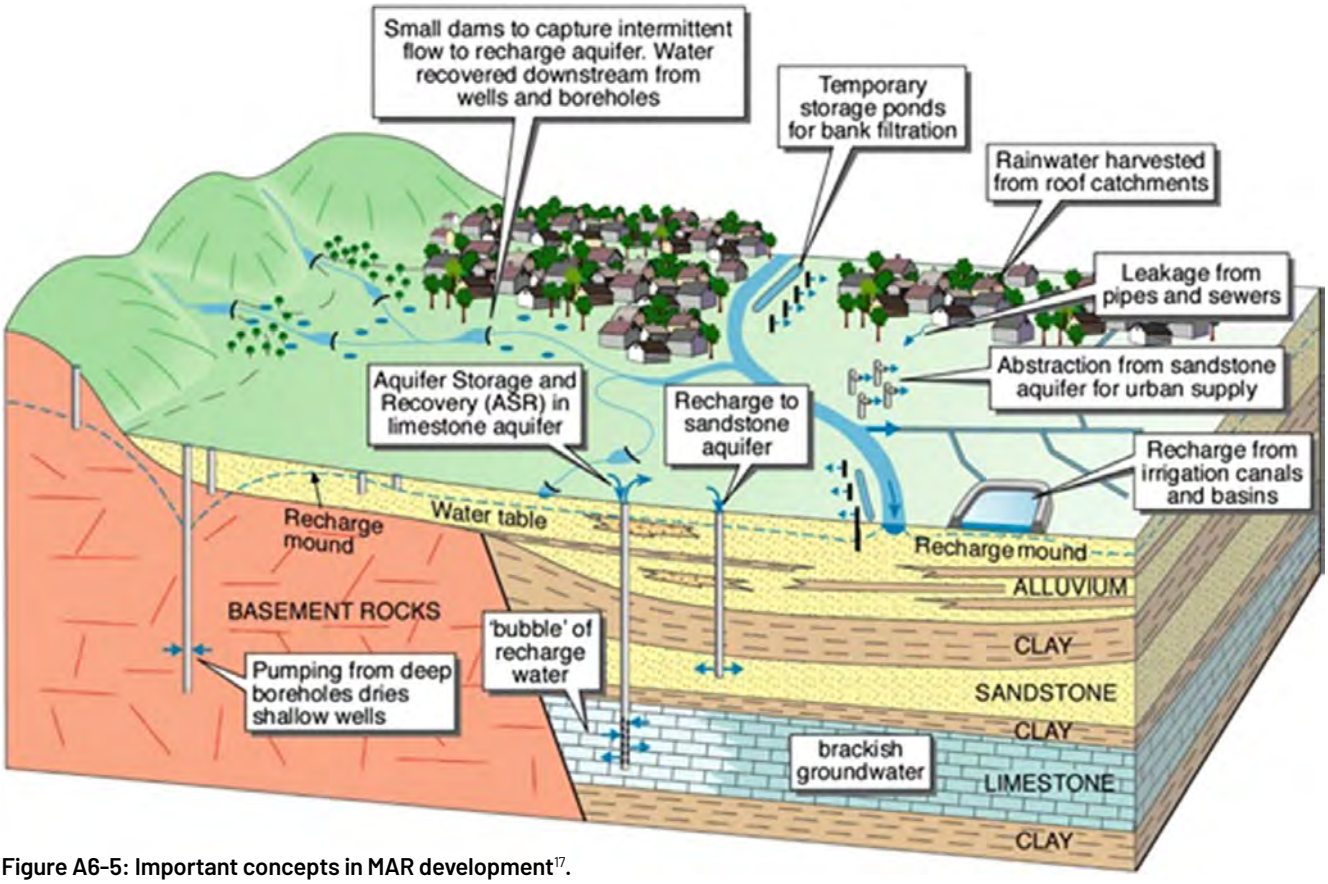


Figure A6-5: Important concepts in MAR development[17].

Wastewater treatment and reuse

Wastewater generated from municipal, industry and agricultural uses can be treated to produce recycled water of different grades for a range of uses. Many Queensland communities already rely on recycled water to irrigate their parks and gardens. Recycled water can also be used directly in industrial and agricultural applications, and indirectly to augment raw water supplies upstream of a town's water treatment plant. Water recycling has particular significance at the farm and sub-catchment scale for agriculture. There will be increasing demands and competition for wastewater, particularly as treatment costs reduce. Queensland's emerging hydrogen sector has identified opportunities for wastewater.

Desalination

Desalination involves removing salt from either seawater or saline groundwater, which can also include water associated with coal seam gas extraction. The processes are energy-intensive but can result in a reliable source of water during drought. Regional deployment of portable desalination plants can augment supplies where groundwater-sourced water quality is not initially fit for purpose. The former Queensland Department of Natural Resources, Mines and Energy reviewed the potential to deploy portable desalination plants in regional Queensland to provide temporary potable water supplies in times of drought or another emergency. They incorporated sample site assessments and costings as well as a scan of portable desalination plant use nationally and internationally. The study assessed production volumes and nominal costs for

plant purchase and hire, transport to site, set-up, connection, operational expenses, decommissioning and transport back to base for six sample sites. Site-specific assessments are needed before deploying portable desalination plants. Disposing of waste products will remain a challenge.

Additional water development options

While not intended to be an extensive list, the panel notes that a much wider range of hard and soft infrastructure options needs to be considered and assessed in place-based approaches to regional water development planning. As a minimum, they include:

- modernising water supply schemes (e.g. the current modernisation scheme in the Mareeba—Dimbulah Irrigation Area)
- using inter-storage transfers to deliver water security in the context of climate risk
- instilling new technologies that lower the cost of pipeline development (now being applied in the Lockyer Valley)
- improving on-farm irrigation efficiency (e.g. Farm Water Futures Program)
- developing hydro and pumped hydro energy
- repurposing existing infrastructure and (mining) voids (e.g. the Kidston Gold Mine Transition pumped hydro example in Box 2)
- lifting agricultural productivity through research, development, extension, education and value-adding (refreshed marketing, processing etc.)
- establishing more innovative water trading processes and platforms[18]
- revising water pricing mechanism adjustments in allocation priorities.

Water development in the regional planning context

While planning for water allocation in Queensland is relatively mature, the past 30 years or so have seen a less cohesive focus on water development planning. Planning for water infrastructure cannot be separated from wider land use and infrastructure planning processes, and particularly those related to energy and transport. This section unpacks the wider regional development planning and impact assessment context and explores the positioning of water in that context.

State development coordination and impact assessment

The SDA provisions of the *State Development and Public Works Organisation Act 1971* can be used for strategic water and agricultural development planning. Additionally, at large project scale, significant agricultural, mining, urban and industrial development projects that the Queensland Minister for State Development considers to be of state significance under the Act can also be called in and managed as a coordinated project (effectively operating like a mini-SDA). This call-in power has often been applied when project proposals have major state or regional significance. Relevant feasibility studies are undertaken and assessed in relation to existing legislation, but the Coordinator-General decides the application of rules and sets relevant conditions. For this reason, the Act is an important part of the regional development planning framework[20].

Kidston Gold Mine transition

The Kidston Gold Mine, 270 kilometres northwest of Townsville, was once one of the largest gold mines in Australia. It ceased operations in 2001. Two open-cut pits that remain will be repurposed to hold water as part of a pumped hydro energy storage facility to produce approximately 250 megawatts (or 2,000 megawatt hours) of dispatchable (baseload) power for export to the electricity grid.

The facility, being developed by Genex, will store energy from a 50-megawatt solar farm that is operating on the site and a planned 150-megawatt wind farm that will begin construction in 2022. Referred to as the K2-Hydro project, the mine pits will be transformed into a giant battery, pumping water into an upper storage reservoir when energy prices are low, then releasing it through reversible turbines into the lower reservoir to generate power when demand for electricity is high.

Construction is expected to be completed in 2024. A 187-kilometre transmission line, supported by the state and Genex, will connect the Kidston Renewable Energy Hub to the National Energy Market. The transmission line is also expected to facilitate the connection of further renewable generation projects in the region.

The project is the first pumped hydro project in Australia since 1984 and will be the first to be used solely for energy storage and generation with no reliance on existing water storages.[19]

While not inexpensive, the process offers a cohesive level of state support in major water development project assessment and approval. Under the Act, a place-based or specific project-based environmental impact statement (EIS) can be prepared under terms of reference set by the Queensland Government. An EIS explores the environment of the project area, potential impacts, and proposals to avoid, mitigate or offset those impacts. A less intensive impact assessment report (IAR) process can be used if the Coordinator-General is satisfied the environmental effects of the project do not require assessment via the full EIS process. An IAR may be used for well-defined, low–medium risk projects where the likely impacts are highly predictable and the proponent has well-defined proposals to avoid, minimise, mitigate and offset those impacts through accepted best practice in that industry. The IAR has no formal terms of reference and is focused on the key locations that may be subject to adverse impacts if projects are not well-managed[21].

Environmental Protection and Biodiversity Conservation Act 1999 and strategic assessment

Biodiversity considerations related to agricultural and water development in regions are managed through both the Commonwealth's *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Queensland Government's *Nature Conservation Act 1992*[22]. The EPBC Act is the Commonwealth Government's central piece of environmental legislation[23]. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places. These are defined in the Act as matters of national environmental significance (MNES). Of relevance to northern and central Queensland, these include world heritage properties, national heritage places, wetlands of international importance, nationally threatened species and ecological communities, migratory species, the Great Barrier Reef Marine Park, and water resources related to coal seam gas development and coal mining. The Act balances protecting environmental and cultural values with society's economic and social needs by creating a legal framework for decision making based on the guiding principles of ecologically sustainable development. Specifically, it aims to:

- protect the environment, especially MNES
- conserve Australia's biodiversity
- provide a streamlined environmental assessment and approvals process for MNES
- protect world and national heritage
- promote ecologically sustainable development.

If water developers conclude they might have a significant impact on MNES, they must apply for approval to proceed under the Act. This approval process is in addition to state or local government approvals that might be required. When a proponent wants an action assessed for environmental impacts under the Act, they must refer the project to the Australian Department of Agriculture, Water and the Environment. This referral is then released to the public and to relevant state and Commonwealth ministers for comment on whether the project will have a significant MNES impact[24]. The minister (or delegate) then decides if the likely environmental impact of the project is such that it should be assessed under the Act. In addition to considering potential impacts on MNES, the minister also decides the social and economic impact of the project[25].

Several significant policy tensions underpinned the need for a recent audit[26] and review[27] (the independent Samuel review, by Professor Graeme Samuel) of the Act. There have been unambiguous concerns that the Act is not effective in protecting MNES. There has also been concern in the development industry and among landholders about the complexity and delay in Act processes[28]. Traditional Owners have long been concerned the Act does not effectively frame the opportunities for development projects in ways that protect Indigenous cultural interests. Both Traditional Owners and the agricultural community consider that project assessment processes do not support positive partnerships and negotiation between proponents and landholders with relevant rights and interests[29].

In seeking to ensure proposed reforms can address these tensions and facilitate sustainable water development, Dale et al. outline the preconditions for successful implementation of the Samuel review recommendations[30]. They suggest that, while the architecture proposed by the review is sound, the strongest risk will be implementation failure. They warn it will not be adequate to simply adjust the Act's policy settings and outcome standards at the national scale without dedicating reform efforts and focus to improving the governance of decision making at national, state, regional, local and project scales, and integrating efforts, knowledge, data and reporting across those scales.

The process outlined by the Samuel review suggests Australia could end up with conceptually sound national outcome standards. Nonetheless, in the absence of strong, durable and collaborative implementation efforts in the next five years to ensure good governance, decision-making and delivery at all scales (particularly regionally and locally), Dale et al. predict environmental, biodiversity and cultural heritage outcomes will continue to decline, economic development will continue to stagnate in Australia's regions, and Indigenous people will remain marginalised in the development decision-making process[31].

Dale et al. suggest that process standards sitting above national outcome standards for implementing the Act could

set shared expectations between the Commonwealth, states and territories, local government, industry and the community about appropriate approaches to planning and decision making at various scales[32]. Consistent with the panel's view about the need for stronger regional and local approaches to water development planning, better process standards would reduce the risk of cumulative impacts arising from many poorly integrated water developments. Establishing strong and adaptively monitored and managed process standards would be key to avoiding and managing the risk of Act delivery failure.

Integrated regional planning, for example, would represent the primary scale for integrating social, economic and environmental landscape interests. Without these three agendas being combined, environmental outcomes will be marginalised, water development investors will face uncertainty, and the economic and social benefit of emerging ecosystem service markets will not be realised. Dale et al. suggest the achievement of national process standards at this scale would need to demonstrate:

- a stable governance arrangement is in place for partnership-based approaches between Commonwealth, state and territory, and local governments
- similarly stable frameworks exist for collaborating with the region's key industry sectors, the social and environmental community and Traditional Owners
- strong collaborative research and data-oriented partnerships exist with key knowledge-based institutions (e.g. National Environmental Science Program (NESP) Hubs, universities, cooperative research centres (CRCs), research and development corporations (RDCs), CSIRO, Geoscience Australia, the Australian Bureau of Agricultural and Resource Economics and Sciences etc.)
- a cohesive vision and delivery system has been explored and established to progress economic, environmental and social opportunities and trade-offs
- cohesive regional land use and infrastructure plans are established
- a regional interpretation of the Act's national outcome standards is developed and regional efforts are aligned to achieve these targets
- clear regional monitoring approaches exist through some form of state of the region reporting and an integrated approach to identifying and aligning research and development efforts
- a clear strategy for empowering the planning capacities of councils exists within the region, encompassing key industry sectors, natural resource and environment management groups, and Traditional Owner-based land and sea institutions.

At a finer scale of decision making, development area or development precinct planning would also be increasingly needed to focus on sending the right market signals to private capital for development (e.g. via an SDA). Development precinct planning in the right places and scales would send the strongest possible messages and incentives for private sector development investment but would equally provide for a more intense focus on understanding, avoiding, mitigating and offsetting biodiversity impacts[33].

State-wide policies, regional plans, planning schemes and development approval

Under the *Planning Act 2016 (Qld)*, Queensland's State Planning Policy (SPP) provides a consolidated and comprehensive view of the state's interests in land use, planning and development. It sets out matters that must be addressed in local government planning schemes and regional plans. Agriculture is identified as a state interest under the economic growth theme of the SPP. Planning protects the resources on which agriculture depends and supports the long-term viability and growth of the agriculture sector. This includes promoting and optimising agricultural development and increasing production in key areas. A detailed, non-statutory guideline has been developed to help local governments integrate the state's interest for agriculture into planning schemes[34]. It should be noted that good quality agricultural land (GQAL) elements in the SPP are based on technical material established in the late 1980s to early 1990s. An updated review of the policy on protection of actual GQAL and promotion of rural and agricultural land uses could be appropriate if greater use of this provision would benefit water development[35].

The Queensland Government is developing a suite of new-generation regional plans that could be revamped to better support new approaches to water development planning[36]. Regional plans identify and interpret the state's interests in land use planning and development, as identified in the SPP, for particular regions. There may be future opportunities for agriculture developments to be identified through regional plans based on local government areas (i.e. not catchments). Regional plans define regional outcomes and identify regional policies to achieve these outcomes. They guide land use planning and development decisions in a region and are prepared in collaboration with the wider community, local government and key industry groups. Under Queensland's planning legislation, the SPP and regional plans perform complementary roles, with regional plans providing the basis for prioritising, qualifying or resolving the state's interests in a particular region, as necessary[37].

Local government planning for water development

Local governments are often champions of water and agricultural development in their regions[38]. They apply a range of strategies to advance this, including articulating intent in corporate or community plans and/or economic development strategies, or by recognising and incentivising agricultural development in planning schemes (including identifying and protecting GQAL). An exceptional example of how local government can effectively lead this type of approach exists with the proactive role Flinders Shire Council has played in securing a coordinated project approach under the *State Development and Public Works Organisation Act 1971* and developing the Fifteen Mile agricultural development precinct by providing available land and water resources[39]. Rural and remote councils rarely have the resources needed to progress strong investment framing for agriculture through their available planning instruments. In the local planning scheme context, Priority Agricultural Development Areas can be recognised by local governments, rather than being identified or prioritised by Commonwealth or state interests. As such, where the concept has been used by local governments, they reflect the very localised views of agricultural development across 77 local governments in Queensland. GQALs, however, are identified via the SPP, and are then identified and protected through regional plans and local planning schemes. Notably, the regulation of GQALs is not necessarily a signal for strategic prioritisation of agricultural development effort[40].

Sunwater's water blueprint processes

Sunwater is northern and central Queensland's largest water service provider. The Sunwater Regional Blueprint is a strategy to increase the availability of water in water supply schemes it operates in several catchments (e.g. the Barron, the Burdekin and the Mary). These regionally engaged and prioritised processes examine opportunities for new water projects to generate economic prosperity and address future customer needs, as well as adapt to the impacts of climate change[41]. These processes inform the organisation's strategic and operational priorities. State government commitment to stronger regional water assessment also flags an increasing interest in more collaborative approaches to regional water planning.

Preconditions for success in regional water development planning

Dale and Marshall propose eight processes that, in one form or another, prioritise Commonwealth, state and local government efforts for water and agricultural development planning in northern and central Queensland[42]. The overall system is characterised by many fragmented efforts with limited resources. Without refinement, this system will struggle to facilitate the transformative, high quality investment in water development through northern and central Queensland envisaged by the panel. Key features of the system include:

- limited coordinated effort between Commonwealth, state and local governments
- strong but under-utilised knowledge sets to enable multi-criteria-based Queensland Government decision making
- several statutory development prioritisation mechanisms that spatially identify water-based agricultural opportunities but do little to facilitate the coordinated infrastructure and investment required
- few frameworks for driving or mobilising cross-government cooperation and private sector involvement
- lack of an overall integrative mechanism for prioritising, sequencing and aligning combined work efforts.

Without a more purposeful approach, it is unlikely the intended benefits of the panel's Regional Water Grid and Making Water Work scenarios could be achieved. This would require system adjustments to enable key preconditions for success, including:

- establishing clear boundaries for more effective regional and localised approaches to water development planning
- fostering effective partnership-based approaches in long-term and adaptive water development planning
- engaging and empowering Commonwealth, state and local governments, industry, Traditional Owners, communities and researchers in long-term planning
- strongly focusing on setting clear water development objectives, including security, affordability, availability, efficiency and effectiveness
- establishing robust frameworks for identifying, scoping, comparatively evaluating, prioritising and sequencing physical and social water development opportunities
- integrating water development with wider regional land use and infrastructure planning efforts, particularly energy, transport and communications
- ensuring the capacity for these processes to be adaptive over time, particularly in the light of emerging climate change data
- designing capacity to influence the processes of project sequencing and negotiating Commonwealth, state and private sector investment
- having foundations for monitoring and periodically evaluating long-term success against plan objectives
- having a lead agency or institution with clear and relatively independent accountability for this work.

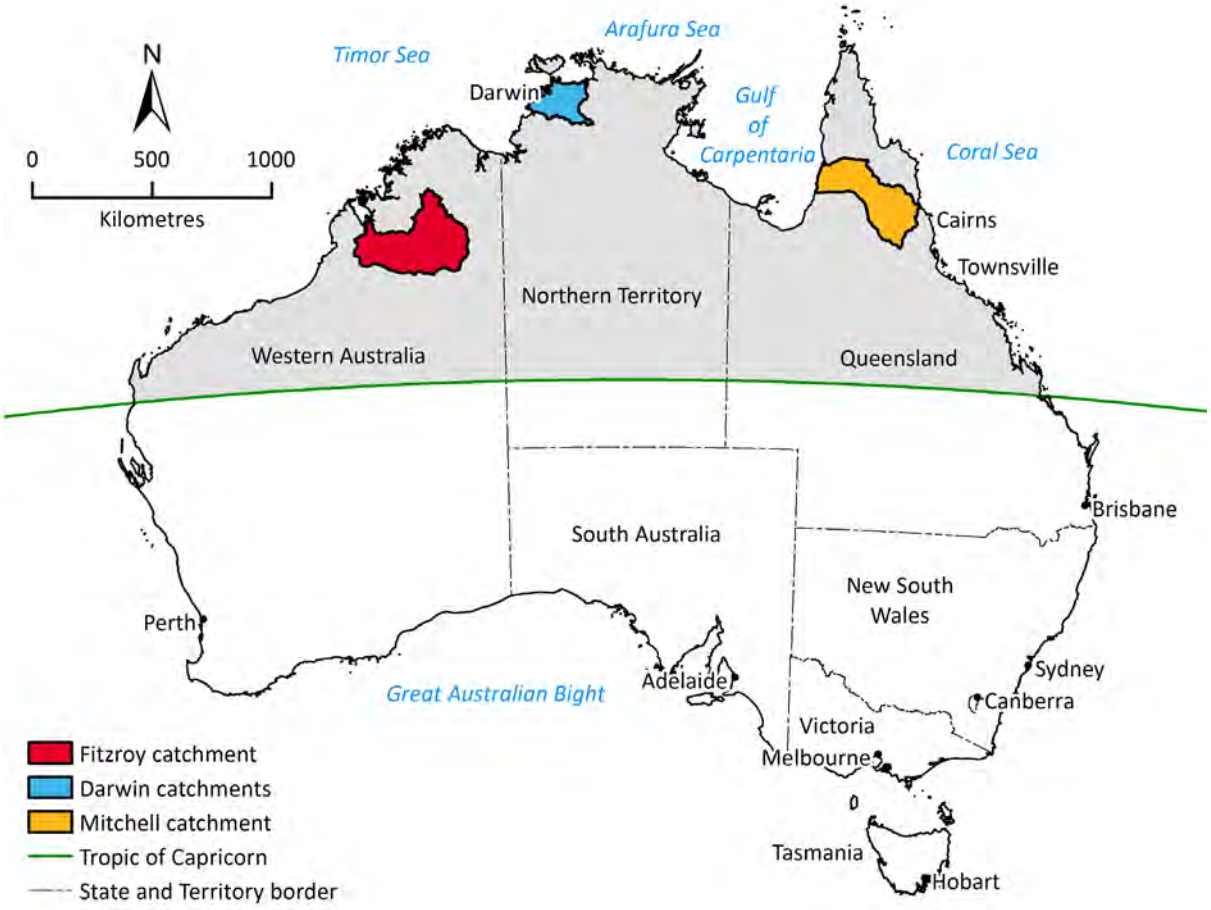


Figure A6-6: The NAWRA study boundaries.

Good practice in water development planning and project assessment

The following section covers known good practice approaches in the context of more integrated approaches to water development planning envisaged by the panel, and as a basis for implementing the panel's preferred place-based water development scenarios.

Regional water assessment

Queensland's water planning process is primarily focused on determining the allocation of water to environmental and consumptive purposes. These plans can help inform regional assessment of water for development purposes, but they are not water development plans. Much of northern Australia's land and water resources have not been mapped in sufficient detail to provide reliable resource allocation, mitigate investment or environmental risks or build policy settings that can support decisions.

One of the most notable activities in regional water assessment underpinning development in northern Queensland has been the Commonwealth-funded and CSIRO-based regional assessment models. These include the Flinders and Gilbert Agricultural Resources Assessment and the Northern Australian Water Resource Assessment (NAWRA) in Figure A6-6. These studies have investigated the potential of northern Australia's water resources to support regional development. They have worked with northern jurisdictions, research partners and communities to assess water resources for three priority regions in northern Australia for the Australian Government. This work has focused on the Fitzroy catchment in Western Australia, Darwin's catchments (Finniss, Adelaide, Mary and Wildman) in the Northern Territory, and the Flinders, Gilbert and Mitchell catchments in Queensland.

Regional water issues: a Pioneer case study

The Pioneer (and Eton) water supply schemes support a substantial portion of Queensland's sugarcane production but have seen production fall in recent years. Despite relatively dry years, just 28 per cent of irrigation water allocations were used in 2018, and use fell to 21 per cent of allocation in 2019.

More effective water resource management at the appropriate scale would have substantial regional economic benefits. Growers would be more productive, profitable and resilient to fluctuations in weather patterns and seasonal conditions. A stronger and more consistent supply base would enhance mill viability. The economy-wide effects in regional communities that flow from a more vibrant agricultural sector would be significant.

There are several issues in the Pioneer and Eton schemes that require strategic attention and there are potential opportunities to expand incomes and production.

The most commonly cited impediments to regional prosperity and growth are water and electricity prices. These account for between three and four per cent respectively of the average cash outlays for cane farms across the region. For those farms using irrigation water, the cash outlay is much higher (six per cent and seven per cent respectively):

- electricity costs, rising by more than nine per cent per annum, have doubled since 2007-08, contributing 80–90 per cent of the total increase in water charges in the area. Similar increases in electricity prices have occurred at the farm level[43]
- Sunwater's Bulk Water Prices have doubled since 2003–04, increasing at a compound rate of 4.5 per cent per annum.

The majority (60 per cent) of on-farm irrigation systems in these areas are high pressure with high pumping costs. The combined effect of declining cane production and increasing electricity costs has created a margin squeeze, inhibiting capital investment on more efficient but more expensive systems.

The determination of the cost of water and electricity are subject to complex governance arrangements, regulatory frameworks and decision-making processes that involve national agreements, multiple levels of government and a range of agencies.

There are many issues related to access to water and its use and the cost of that water and electricity. Access issues relate primarily to water allocations, water markets, regulatory arrangements and the availability of infrastructure services. Electricity issues include tariff structures and the adoption of relevant technology to improve efficiency.

For example, at a farm level:

- most growers are on entitlements of 2–3 megalitres per hectare. The requirement to meet crop water demand is in the region of five megalitres per hectare, on average
- capital outlays to install efficient low-pressured overhead irrigation systems is in the order of $3,000–$5,000 per hectare. Current water and electricity prices and low water use means on-farm investment does not pay
- with such low levels of water use, the fixed component of water prices makes the effective unit price (fixed plus variable) of water expensive, and many irrigators are seeking to surrender their entitlements. Water allocations are often used to meet crop demand only on the most productive blocks.
- relying on fixed charges for its survival, Pioneer Valley Water is not able to accept applications to surrender water entitlements and rights of access. To do so under current pricing rules would increase the fixed costs of remaining entitlement holders, risking triggering more surrenders, accelerating a downward spiral and the collapse of the scheme's economic viability.

A holistic area-wide approach would be required to review irrigation schemes such as the Pioneer, and implement recommendations to improve productivity and profitability and enhance environmental outcomes by improving water quality. Water and electricity pricing issues can be expected to dominate. The review would need to identify and seek to resolve issues arising in these areas.

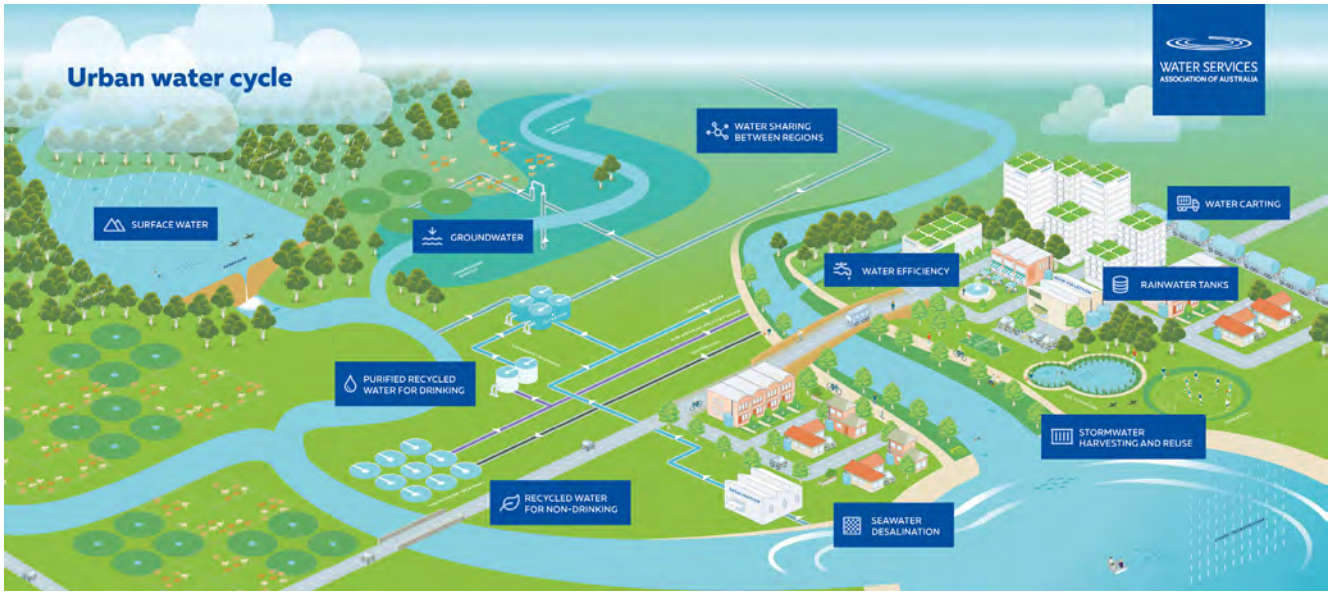


Figure A6-7: A conceptual design of more integrated water development planning[44].

These projects aimed to identify the potential to increase water-related development opportunities in northern Australia. They evaluated soil resources, water resources, and water capture and storage options, and identified and tested the commercial viability of irrigated agriculture opportunities. The work also evaluated potential environmental, social and economic impacts, and risks of water resource and irrigation development. All this work is part of CSIRO's delivery of the Australian Government's White Paper on Developing Northern Australia, which identifies the development of northern Australia's water resources as a key initiative.

Queensland is increasingly seeing the need for engaged regional water assessment. The Queensland Government is investing $9 million in regional water assessments in three areas across the state: the Tablelands, Burnett and Southern Downs regions. The Regional Water Assessment Program is a roadmap for economic growth in these significant food bowls. Building on previous water supply investigations, the program will create a comprehensive view of local water needs and identify gaps to be filled. Once complete, the assessments will set out how existing infrastructure, new infrastructure and non-infrastructure solutions can be used to maximise water supply and drive economic growth[45].

Regional water assessment can deal with a range of issues concerning effective water development and use. These approaches are critical to solve the complex water development and water use and efficiency issues experienced in northern and central Queensland's water basins. By example, the boxed story on page 230 outlines the complexity of some of those issues in the Pioneer catchment that may benefit from a regional water assessment approach.

Integrated whole-of-catchment design

Increasingly, as drivers towards a zero-net emission economy emerge, there are significant new concepts for the co-design of fully integrated whole-of-catchment approaches to water development (e.g. see Figure A6-7).

Good-practice examples of this include the Making Water Work initiative emerging from the Communities in Transition processes trialled in the Cook Shire and the Charters Towers Regional Council and Rockhampton Regional Council areas. A renewed NWI will recognise integrated water cycle management as an objective, but there are significant challenges in practically implementing this in Queensland. Moving to an integrated water management approach is

complex and may require substantial investment in planning and workforce capability over several years. It will require a significant review of the whole water business to identify opportunities and roadblocks to integrate currently-disconnected water management frameworks. This work is necessary to determine a realistic, efficient, fit-for-purpose and place-based policy position and process.

Integrated and place-based options assessment

Consistent with the panel's views on the Regional Water Grid and Making Water Work scenarios, the wider range of water development investment options (such as those outlined above) must be fully identified and rigorously evaluated against agreed criteria. Examples of these types of approaches include:

- *Cairns Integrated Water Security Strategy*
- Rockhampton's Regional Infrastructure Planning approach
- the CSIRO methods report for bulk water supply prioritisation
- Sunwater's *Regional Water Blueprint* in the Mary catchment.

Institutionalising project development within a regional context

While the panel did not undertake sufficient research to be definitive about the most appropriate institutional model to deliver more integrated regional water development planning, it suggests that no one existing institution in Queensland has the flexibility and capacity needed to deliver all the above preconditions for success. This means an appropriate institutional model would need to be designed to deliver on these challenges. The panel suggests that key features embedded in the Tasmanian Irrigation model below could offer strong pointers. The model eventually developed could be combined across central and northern Queensland or could have a more regionalised footprint (e.g. based around far northern, northern and central Queensland). The Commonwealth is currently exploring how the NQWIA could be refined, and how the new NWGA relates. This means there is a significant and necessary opportunity for the Commonwealth and the state to work together on the most appropriate mechanisms for cross-jurisdictional and cross-Ministerial cooperation, and on more collaborative approaches to the essential regional water development planning agenda in northern and central Queensland.

The Tasmanian Irrigation Model for regional water development

In partnership with the Commonwealth, the Tasmanian Government has established a refreshed policy and delivery approach for strategic water development for agriculture. Within the context of well-planned and allocated water resources (e.g. like those in place within water plans under the Queensland *Water Act 2000*), Tasmanian Irrigation is focused on the prioritisation of a clear project and works development program and an open and risk-focused approach to project development in partnership across Commonwealth, state, community and industry players. In recent years, three jointly funded tranches of investment have been progressively rolled out to progress investment plans. More than $160 million has been invested by state and Commonwealth governments and participating farmers in five (Tranche 2) irrigation schemes, creating 28,000 megalitres of new water entitlements in the Southern Highlands, Swan, Duck, Scottsdale and North Esk districts. Additional irrigation headlines Tasmania's future infrastructure priorities within the Pipeline to Prosperity (Tranche 3) Irrigation Program recently submitted to IA[46].

Tasmania Irrigation's Pipeline to Prosperity program includes another 10 potential development schemes state-wide, with a capital cost of up to $496 million. Its geographic scope and water availability is dwarfed by opportunities that could be explored in central and northern Queensland.

By observing successes occurring in other jurisdictions and in Queensland at various times, a fit-for-purpose institution and delivery mechanism should have the power to pull together integrated water and energy development options, and project feasibility and approval responsibilities across three levels of government. These approaches would need to be highly integrated with related decisions on energy, transport, telecommunications, agricultural research and development, and education and training. It matters less where such an institution is located within government, than it being established to meet well-designed governance and performance criteria. The institution would need to be influential in ensuring sound regulatory decisions were co-ordinated across all sectors, including on water and electricity pricing. It would also need to establish effective liaison with Commonwealth agencies responsible for Commonwealth funding and regulatory decisions.

The important story behind this Tasmanian Irrigation case study is the increased productivity and growth within the agricultural sector arising from the approach taken[47]. There has been a particularly good outcome in respect to the dairy industry, which has grown to nearly 11 per cent of the nation's overall dairy production. The introduction of irrigation has resolved a productivity constraint in the dairy production cycle, reduced the difficulties associated with keeping productivity even, and delivered nearly 97 per cent water security. Through discussions with stakeholders involved in the management of this system, Dale and Marshall identified key institutional design features that have contributed to success[48]:

- Tasmanian Irrigation, as a planning and proponent body, is relatively independent from governments. Tasmanian Irrigation takes a strong, systematic and risk-based leadership approach focused on cost-efficiency and trust-building with the irrigation sector. It is skills-based, with clear risk analysis, commercial and irrigation capability. The strategic purpose of the organisation is to progress irrigation development in a clear social licence that ensures wide public support.
- While independent from governments (but embedded within the state), the model means Tasmanian Irrigation's leadership has appropriate open-door access to both Commonwealth and state ministers, as well as a focus on building cooperative and coordinated relationships with relevant state and Commonwealth agencies. The resulting prioritisation and development sequencing process and strong, risk-based business case building and development approvals approach have enabled the negotiation of a progressive and stable series of bilateral investment tranches.
- A shared focus on managing all potential risks facing new schemes openly and ensuring the schemes are economically viable has been important. Additionally, the business models developed for projects that have been based on a multiple benefit approach (value stacking), including water development scheme uses such as recreation, sediment management, flood mitigation, environmental improvement and employment/social benefit, are all considered and integrated.
- Strong and early water demand assessment processes that have identified irrigators able to invest capital early in the design process establish the foundation for irrigator commitment/collaboration from the outset.
- The emphasis has been on working within statutory processes for water allocation and development planning, assessment and approval in Tasmania, the scoping of clearly available water development opportunities within those allocations, and the exploration of all potential options for developing that water.

Experiences from this model strike a cautionary note on the likelihood that the *Environment Protection and Biodiversity Conservation Act 1999* may place increasing constraints on irrigation opportunities in northern and central Queensland and underscore the importance of both a credible regional planning approach and a credible proponent or development lead organisation. The model illustrates a think-act-do-review approach to each water development within a basin context, with each project success building on previous ones.

Developing adaptive pathways for water development

Establishing adaptive pathways for water development provides an analytical approach to enable a catchment system to cope with different futures and uncertain conditions. Such pathways provide a process for deciding when and under which conditions acceptable actions need to be implemented to cope with multiple plausible futures or scenarios. Adaptive pathways consist of the development of sequences of options that can be taken and the circumstances in which alternative sequences might be selected. Planning adaptive pathways contributes to enabling investment in an initial management option, knowing changes can be made during plan implementation[49].

Enhancing environmental, social and governance frameworks for water infrastructure

Meaningful action on environmental, social and governance issues is now a baseline expectation as water infrastructure has a critical impact on economic outcomes and regional development pathways. As institutional investors gain exposure to infrastructure through portfolio investments, there is increasing recognition that environmental, social and governance factors are relevant for their investments[50].

According to the Infrastructure Sustainability Council of Australia (ISCA)[51], infrastructure is currently enabling about 70 per cent of Australia's emissions. As a result, consideration must be given to how existing and new water infrastructure and the businesses they serve adapt to zero emissions by 2050 or become stranded.

The ISCA has developed a strong sustainability certification for infrastructure, citing that for every $1 of investment in a project undertaking a sustainability rating, up to $2.40 is returned. This does not include the benefits that cannot be monetised, such as cultural and social outcomes, environmental influences, health impacts, risk management or human capital development. The most significant emission reductions that can be achieved, for example, are through the planning and decision-making stage, deciding what, where, why and if water infrastructure should be built. Similarly, the principles around resource efficiency, lifecycle assessment and the circular economy inform infrastructure design and technology selection.

IA has developed an assessment framework that provides a national standard for best-practice infrastructure development, which has embedded sustainability and resilience throughout. IA considers infrastructure sustainable when it is planned and designed to optimise social, economic, environmental and governance outcomes. Resilient infrastructure enables communities to anticipate, resist, absorb, recover, transform and thrive in response to shocks and stresses.

The panel acknowledges the growing number of global aspirations and commitments pertaining to integrating environmental, social and governance considerations into infrastructure development and construction, including:

- the UN Sustainable Development Goal 9 to build resilient infrastructure, promote sustainable industries and foster innovation[52]
- G20 Principles for Quality Infrastructure Investment, noting the importance of integrating both environmental and social considerations into infrastructure investments and strengthening infrastructure governance[53]
- COP26 priorities, including protecting communities and natural habitats, and restoring ecosystems through building defences and resilient infrastructure to avoid the loss of homes and livelihoods
- The Ellen MacArthur Foundation's universal circular economy policy goals, including investing in innovation, infrastructure and skills while stimulating design for the circular economy, managing resources to preserve value, collaborating for system change and making the economic development system work[54].

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3 Arup, 2016
4 National Indigenous Australians Agency, 2020
5 Department of Industry, Science, Energy and Resources, 2020
6 Department of Regional Development, Manufacturing and Water, 2021
7 Department of State Development, Infrastructure, Local Government and Planning, 2021
8 Engineers Australia, 2021
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19 Shepherd, 2021
20 Department of Industry, Science, Energy and Resources, 2020
21 Department of State Development, Tourism and Innovation, 2020
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27 Samuel, 2020
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32 Dale et al., 2020
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37 Department of Agriculture and Fisheries, 2020
38 Department of Industry, Science, Energy and Resources, 2020
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43 Davis, n.d.
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46 Barnett, 2018
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48 Department of Industry, Science, Energy and Resources, 2020
49 Bloeman et al., 2018
50 Organisation for Economic Cooperation and Development, 2020
51 Infrastructure Sustainability Council of Australia et al., 2020
52 United Nations, 2021
53 Nasu, 2021
54 Ellen MacArthur Foundation, 2021



01

Attachment 1

Computable general equilibrium modelling of potential water supply projects in regional Queensland

Computable general equilibrium modelling of potential water supply projects in regional Queensland

Author: Glyn Wittwer, Centre of Policy Studies, September 2021

Executive summary

This study examines the economic impacts of water infrastructure projects in four regions: Atherton Tablelands, Burdekin–Bowen Basin, Burnett, and Dawson–Darling Downs. The analysis is conducted using dynamic VU-TERM, a computable general model that represents Australian regions at the Statistical Areas Level 3 (SA3 level).

The study relies on estimates of the costs and timing of water infrastructure projects, plus estimated prospective costs and output of increased production of existing crops resulting from increased irrigation water availability. Data was not available to assess the new crop types, the value of which rises with the increasing value of carbon and of zero-emissions biomass substitutes for oil, gas and coal in industrial processes and energy.

A critical concern is the capital cost of each additional unit of water in each region. Based on the assumption that water utilisation rates will continue in line with historical data, capital costs per megalitre of additional water in net present terms are more than $11,500 in Atherton Tablelands, about $10,600 in Burdekin–Bowen Basin and about $9000 in Burnett. In each of these regions, additional earnings from expansion of production from crops may be sufficient to justify the projects. The modelled outcome differs in the project modelled for the Dawson–Darling Downs (Nathan Dam), mainly because the capital cost per megalitre of additional water is excessive, at around $43,600.

Construction costs for any water infrastructure works will change as engineering surveys provide more detail on required works. Moreover, the above cost estimates may not in all cases include the enhancements required to distribution networks. These may be necessary to ensure water is delivered in a timely manner to irrigators. Without distribution enhancements, irrigators may not be able to expand to the extent modelled in this study.

An important finding of the modelling is that terms of trade impacts differ at the regional, state and national levels. That is, additional farm output in each region may have a positive impact on national terms of trade but a negative impact on local and regional terms of trade. Additional fruit output in Atherton Tablelands lowers prices received by local producers, but benefits consumers. This justifies part-funding of economically defensible water infrastructure projects by the Commonwealth, alongside part-funding by the Queensland government.

Table At1-ES1: Welfare impacts of each scheme (NPV $m) relative to business-as-usual baseline.

	Local	State	National
Atherton Tablelands	287	20	208
Burdekin–Bowen Basin	-410	-558	-55
Burnett	-51	89	79
Dawson–Darling Downs	-70	-251	-994

When the scenarios are run relative to a baseline that includes a stylised climate change component, the welfare outcomes for each scenario improve to some extent. This is because additional water used for irrigation is more valuable.

In an alternative set of scenarios, irrigators increase water utilisation above historical levels. This requires additional on-farm investment as the number of hectares of irrigated land increases relative to the first set of scenarios. Additional output lowers local terms of trade but may improve state and national terms of trade relative to the first set of scenarios. The main beneficiaries of additional farm output are consumers outside the region, although it is sufficient from the local perspective to outweigh downward pressure on the terms of trade. National welfare outcomes improve relative to the first set of scenarios (Table At1-ES2).

Table At1-ES2: Welfare impacts of each scheme (NPV $m), higher utilisation relative to business-as-usual baseline.

	Local	State	National
Atherton Tablelands	360	69	357
Burdekin–Bowen Basin	-803	-808	1,463
Burnett	668	2,056	2,005
Dawson–Darling Downs	56	-114	-685

1. Introduction

The first set of model runs

This study examines the cost and benefits of various water supply projects using a dynamic computable general equilibrium (CGE) model, VU-TERM. The study is preliminary in nature. The net benefits hinge on cost estimates gleaned from available information that is potentially incomplete. The benefits are based on modelled returns to additional irrigation in each region. The choice of crops reflects, in part, existing crops in each region and is also based on judgements about the possible introduction of crops best suited to a particular region. Improved information has the potential to alter both costs and benefits.

Table At1-1.1: Project costs.

	Atherton Tablelands	Burdekin–Bowen	Burnett	Dawson River
Cost NPV $m	333	1,854	271	1,234
Water for irrigation GL	28.5	175	30.3	28.3
Capital cost, $ per ML	11,684	10,594	8,949	43,604

Table At1-1.1 shows the cost estimates for water infrastructure development used as inputs to the modelling. The costs are in net present value (NPV) terms. The table does not include on-farm investments required to increase the area of irrigation in each region. From the outset, judgements can be made from this table on whether a particular project justifies the public expenditure. Possible projects in Atherton Tablelands, Burdekin–Bowen and Burnett have capital costs that may lead to sufficient economic returns to justify them. Whether a given project is justifiable depends on the yields and prices of additional crops being high enough to cover public and on-farm investments. The mix of crops will vary between regions, and the output per unit of water will vary. Sections 2 to 5 detail modelled outcomes from runs based on additional water use.

Table At1-1.2 summarises the individual projects in each region depicted in this study. The additional gigalitres (GL) per annum yields shown in the table are not equivalent to expected additional water availability. Each of the projects concerning irrigation is designated as medium priority, implying announced allocations on average will be less than 100 per cent of additional capacities shown.

There may be additional costs, not modelled in any of the scenarios, to enable distribution networks to deliver water to expanded holdings. Issues arise on constraints in water volumes and timing of delivery. Gaps may remain between theoretical capacity, based on additional water catchment volumes, and delivery to irrigated holdings.

The second set of model runs

Notwithstanding potential delivery network shortcomings, a second set of runs was undertaken in which an additional impact was modelled. The assumed rate of water utilisation by irrigators rises from the first year of simulations.

There are several reasons irrigators historically have used less than available announced allocations. The first is risk-aversion. Investing in on-farm irrigation infrastructure to match potential allocations is costly. Unless irrigators are confident of obtaining close to a full allocation in a given year, they may judge that additional costs will not be exceeded by additional income.

Irrigators may not be able to take advantage of allocations announced late in the operating year as they may already have made cropping decisions. However, in some areas, some unused water from the previous year can be carried over to the next operating year.

In the southern Murray–Darling Basin, water trading is relatively mature. In part, water trading was borne out of necessity in the wake of the millennium drought. Rice growers in drought, for example, earn more from trading their diminished water allocations than from rice production. A trading pattern that has emerged in the southern basin is that perennial irrigators buy water from annual irrigators when water is scarce.

A maturing of water trading may enable irrigators to move closer to using all the water available in announced allocations. However, water trading requires the infrastructure to ensure water is delivered to potential buyers. There may be physical constraints that apply less in the southern Murray–Darling Basin. This study does not include estimates of costings that may be necessary to upgrade distribution networks.

Given ongoing concerns about risk aversion and physical constraints on water trading, this alternative scenario assumes irrigation decisions are made based on the following water use expressed as a percentage of water allocations:[1]

- Atherton Tablelands 90 per cent
- Burdekin–Bowen 90 per cent
- Burnett 90 per cent
- Dawson–Darling Downs 65 per cent.

The assumed water use for the Dawson–Darling Downs area is lower than in the other areas due to historically lower water availability. In some years, water is simply not available for authorities to supply users with the full amount of their allocations.

Table At1-1.2: Projects in each region.

Planning starts	Construction starts	Operations start	Capacity GL	Priority
Atherton Tablelands				
2023	2025	2029	25	Medium
2023	2026	2029	18	Medium
Burdekin–Bowen Basin				
2023	2025	2029	130	Medium
2023	2026	2029	20	Industrial use only
2024	2026	2028	100	Medium
2021	2023	2025	8.2	Medium + 1.8GL urban/industrial
Burnett				
2024	2026	2028	45	Medium
2023	2025	2028	24	Medium
2025	2026	2027	2.6	Medium
Dawson–Darling Downs East				
2024	2026	2031	66	Medium

There are additional costs with higher assumed water utilisation rates in each scenario. If more irrigation water is available each year, a higher level of on-farm investment is required to convert additional hectares of dry land to irrigable land.

Attachment 1 details the water infrastructure costs and implied costs per unit of additional water for both sets of model runs. The appendix also contains details on assumed yields and output prices used to calibrate model shocks.

The Central Queensland project

The Central Queensland inputs provided for this study included future expenditure on pipeline construction and water infrastructure with an NPV of $620 million. Many of the benefits from the proposed scheme concern increased water security for non-agricultural users. Any assessment of the project should include estimates of the risk benefits arising from improved water security. These were not available for this study. During the drought of 2017–19, many communities in northern New South Wales and southern Queensland resorted to water carting as mains supplies failed. The appropriate framework for assessing the scheme is cost-benefit analysis. Benefits will be greater than the water carting expenditures that arise as mains supplies fail. They could include reduced stress and time costs of managing without an assured water supply in households, businesses and industry. The potential non-agricultural beneficiaries from enhanced water security are greater in number than potential agricultural beneficiaries. Therefore, to include the costs of the scheme but only the agricultural benefits in modelling would provide misleadingly negative results. Data was not available to include these sources of value in the analysis. Ideally, cost-benefit analysis would provide inputs to CGE analysis as the two approaches are complementary.

1.1 The model

VU-TERM is a dynamic CGE model of the regions of Australia. It depicts combinations of SA3 regions. These do not align perfectly with the regions of the potential irrigation schemes under analysis.

Dynamic linkages

Dynamic models trace the effects of ascribed direct impacts across time periods. The theoretical basis of dynamics is in links between investment and capital across time, and the balance of trade and net foreign liabilities. Investment and balance of trade outcomes are flows that a comparative static model can include. Capital and net foreign liabilities are stocks that require a dynamic model.

Each of these links is important in the present project. Funding by the Queensland Government and the Commonwealth is ascribed to the model as investment shocks to a utilities sector. Investments in relevant agricultural sectors proceed once the water infrastructure is in place.

The multi-regional dimension

Dynamic VU-TERM combines much of the theory of dynamic national models[2] with bottom-up, regional representation. That is, each region in VU-TERM has its own production function, household demands, input-output database and inter-regional trade matrices. This enables the capacity to model relatively local issues. Dynamic VU-TERM uses an underlying forecast. This may be based on the macro forecasts of other agencies. The underlying forecast or baseline gives a year-by-year business-as-usual case. GEMPACK software is used to run the model.[3]

In the modelling of this study, the project is evaluated relative to two baselines. The first is a business-as-usual baseline. The second includes an assumption of climate change. Based on a survey of global modelling impacts of climate change, crop prices are projected to rise with global warming. Climate change will mean rising temperatures, so the model also assumes water requirements per hectare will rise. This is depicted by reduction in agricultural land over time, reaching five per cent below business-as-usual levels by 2049–50. In summary, climate change will raise the scarcity of farm outputs. Individual regions within Australia may lose in terms of output but gain from upward global price movements.

Labour market—forecast versus policy scenario

In the theory of regional labour market adjustment, if regional labour market conditions improve or deteriorate relative to forecast, adjustment occurs in the short term mainly via changes in employment. Regional wages adjust sluggishly, with gradual adjustment in regional labour market supply (i.e., through migration between regions). Real wages will fall or rise to close the gap between employment and slowly adjusting labour supply. Once the deviation in employment is equal to the deviation in labour supply, real wages reach a turning point. They bottom out in the case of a weakening labour market, or they peak in the case of strengthened labour market conditions. Within this theory, adjustment in the longer term occurs via a combination of altered regional labour supply and real wages that deviate relative to those in other regions. Figure At1-1.1 shows an example, in which weakened labour market conditions in a region lead to unemployment in the short run and a lower real wage in the region in the long run.

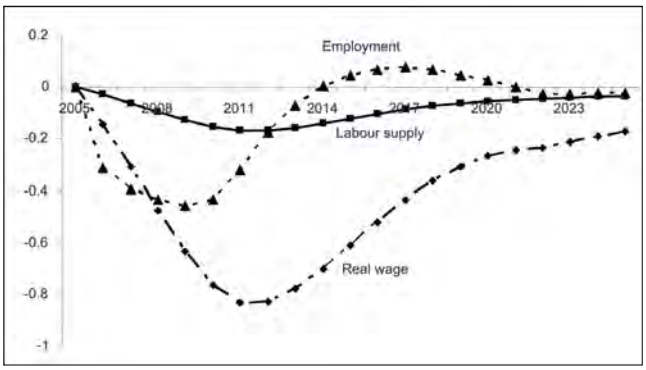


Figure At1-1.1: An example of a weakened regional labour market with eventual recovery (% change from forecast).

Discount rate

Given low global interest rates of the past few years and a medium-term expectation that real interest rates will remain at low levels, a discount rate of 2.5 per cent has been used to estimate the NPV of project impacts. This implies that, although assuming, for example, a longer maturation period for perennial crops would lower the NPV of the project, the sensitivity to maturation period is less than if a higher discount rate were applied.

Although investment phases typically stimulate local, state and national economies, over time they need to earn a return to be justifiable. The assumption within VU-TERM is that investment is paid for by borrowing from foreign entities.

2. Summary of Atherton Tablelands scenario

The Atherton Tablelands irrigation scheme (using the Tablelands East–Kuranda SA3 region within VU-TERM) consists of two components in this study: Quaid's Dam and North Johnstone diversion. These works occur between 2022–23 and 2026–27, costing $370 million in 2021 dollars or $334 million in NPV terms.

Under this scenario, investments in new plantations start in 2027–28. In the case of bananas and sugar cane, new crops reach full yields in 2029–30. Citrus and orchard fruit (mangoes, avocadoes and other fruit) require several years to reach full yields. They eventually do so by 2035–36. The volume of water used in irrigation activities in the Atherton Tablelands increases from the present 100 gigalitres to 128 gigalitres. The capital cost of additional water is $11,684 per megalitre.

The NPV of additional water infrastructure costs is $334 million (i.e., discounting the $370 million back to the present). This is a capital cost of around $11,700 NPV per megalitre for the additional volume.

Table At1-2.1 shows additional crops that will come into production under the project. The capital costs per hectare refer to on-farm investments required to make additional land irrigable and to establish irrigated crops.

Table At1-2.1: Additional water use and hectares.

	GL	Hectares	Yield t/ha	Capital cost $/ha
Citrus	3.1	388	28.0	41,500
Bananas	5.6	471	35.0	20,000
Orchard fruit	14.6	1,953	*	34,000
Sugarcane	5.2	1,299	1.0	3,750

* Mango 7.0 t/ha, Avocado 11.0 t/ha, Other 37.5 t/ha: the capital cost is the weighted average of the three.

Queensland Government department information provided the basis for estimated additional yields and returns for all but sugarcane. The latter relied on information from the Australian Sugar Milling Council.[4]

The scenario assumes construction costs for water infrastructure are paid for half by the Queensland Government and half by the Commonwealth.

In the case of the Atherton Tablelands irrigation region, the Tablelands (East)–Kuranda SA3 covers most but not all the region (Figure At1-2.1). The modelling in this study treats the proposed scheme as though it is located entirely within the Tablelands (East)–Kuranda statistical region.

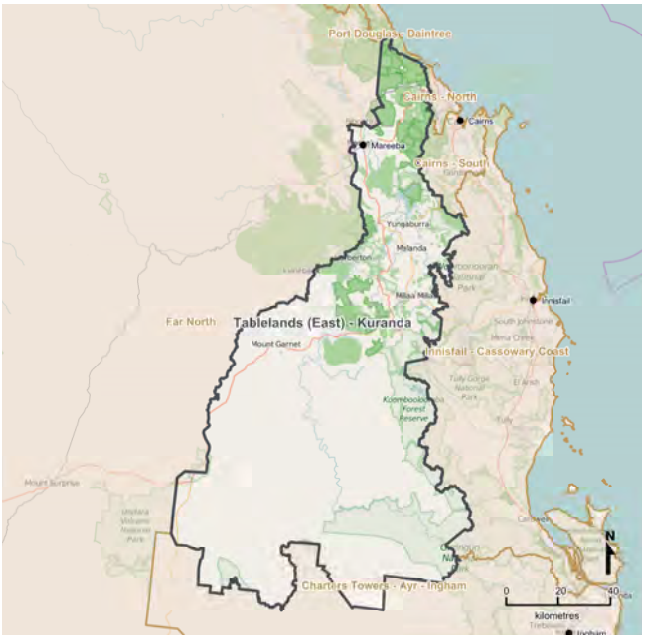


Figure At1-2.1: Tablelands (East)–Kuranda SA3 region.

2.1 Atherton Tablelands development relative to business-as-usual base

Figure At1-2.2 shows the aggregate real investment in Tablelands (East)–Kuranda rises above base in 2022–23 before peaking in 2025–26. The final year of water infrastructure investment is 2026–27, which is also the first of three on-farm investment years. The investment phase increases demand in the region and in Queensland for goods and services. This implies both aggregate consumption (figures At1-2.2 and At1-2.3) and employment (figures At1-2.4 and At1-2.5) rise above base at regional and statewide levels.

The theory of VU-TERM assumes real wages adjust sluggishly. This implies that, as the labour market strengthens due to additional investment demands, the labour market response at the regional and state levels is initially an increase in employment. Jobs peak in Tablelands (East)–Kuranda at 2.4 per cent or 360 full-time equivalent (FTE) jobs above base in 2025–26 (Figure At1-2.4). At the state level, jobs peak at 0.018 per cent or 420 FTE jobs in the same year (Figure At1-2.5).

In succeeding years, real wages adjust upwards, choking off additional jobs to some extent (see section 1.1). By 2027–28, when water infrastructure investments have ceased, regional employment falls below base due to real wages persisting almost 1.5 per cent above forecast even as investment moves down towards base (Figure At1-2.4). When labour supply exceeds demand (employment), there is upward pressure on real wages. In the later years, when the additional irrigation

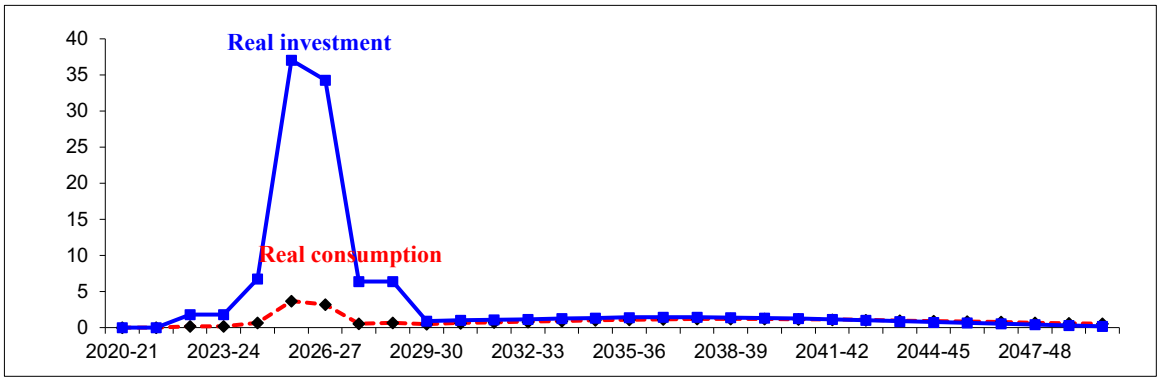


Figure At1-2.2: Tablelands (East)–Kuranda aggregate consumption and investment (% deviation from base).

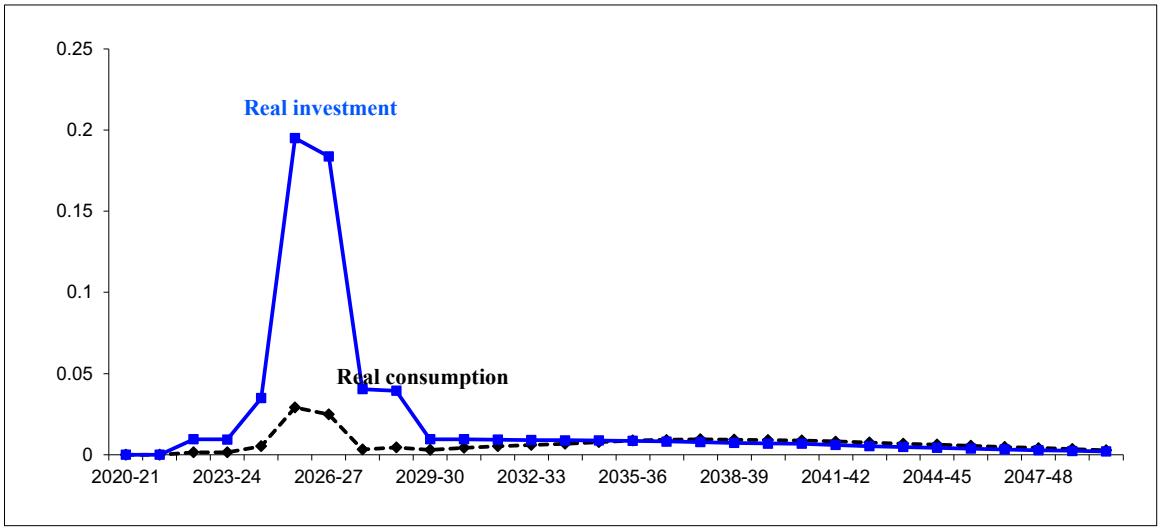


Figure At1-2.3: Queensland aggregate consumption and investment (% deviation from base).

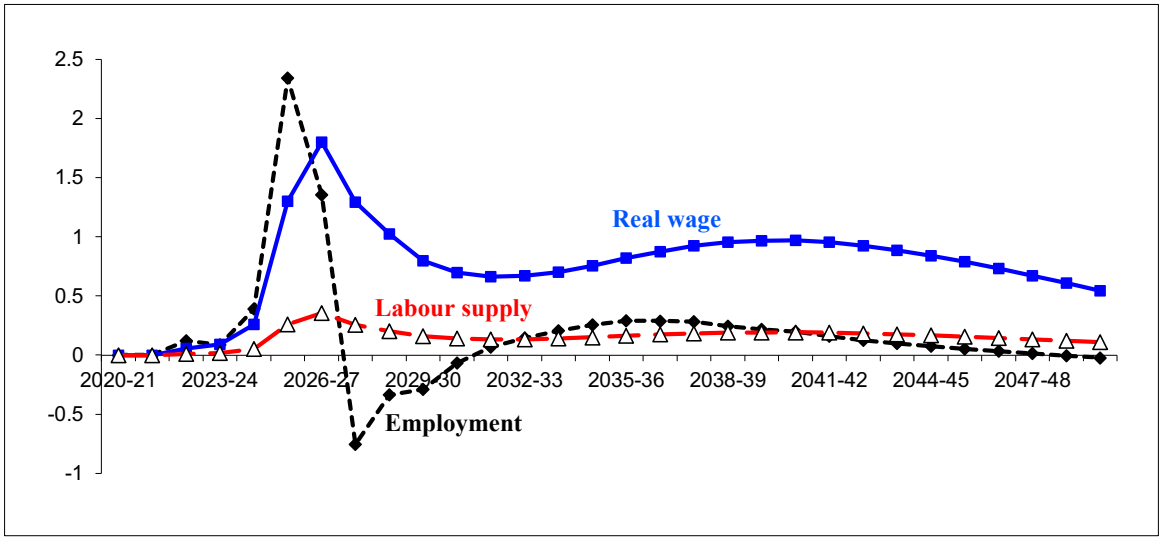


Figure At1-2.4: Tablelands (East)–Kuranda labour market (% deviation from base).

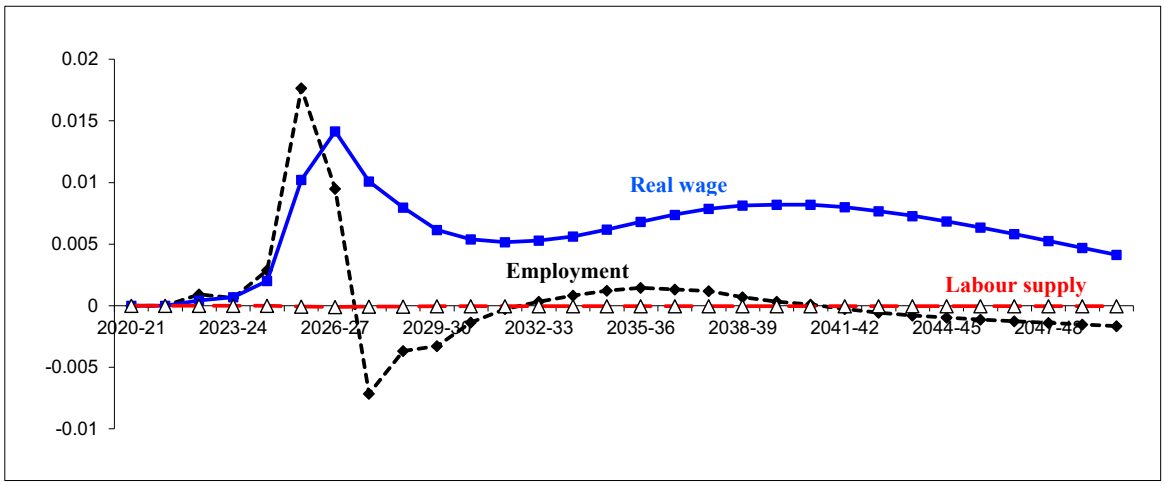


Figure At1-2.5: Queensland labour market (% deviation from base).

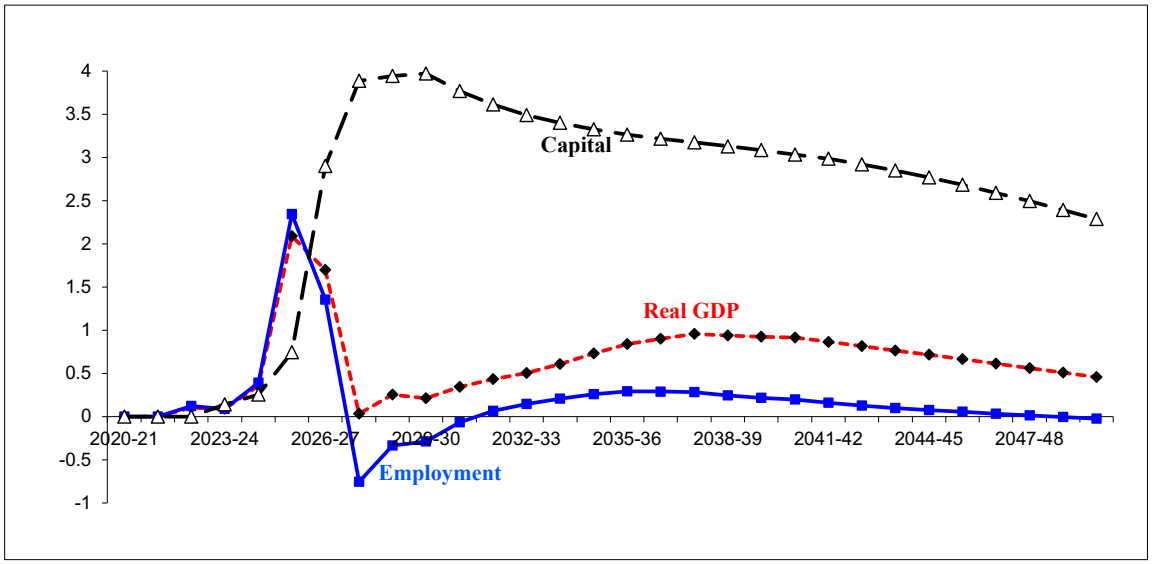


Figure At1-2.6: Tablelands (East)–Kuranda real GDP, income side (% deviation from base).

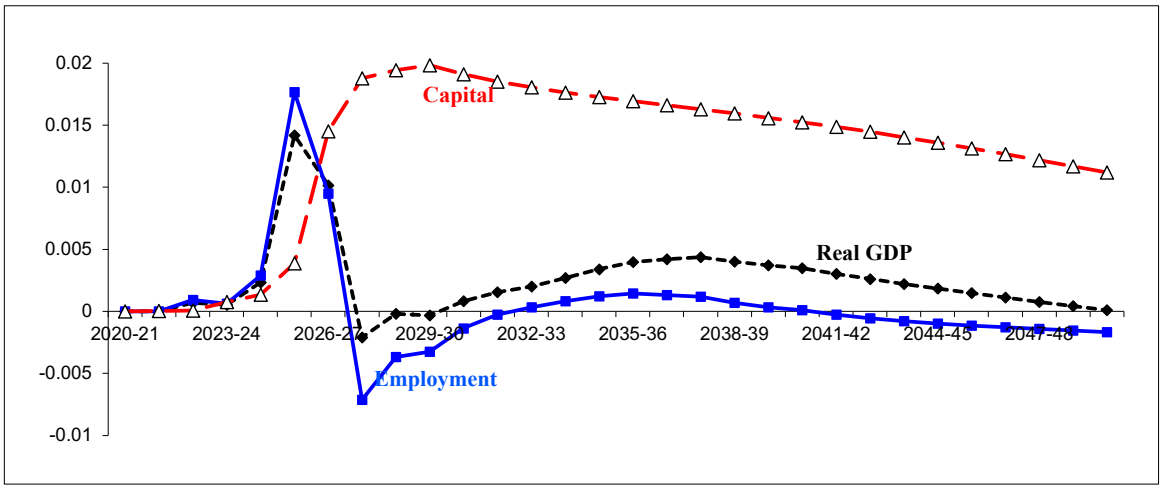


Figure At1-2.7: Queensland real GDP, income side (% deviation from base).

agriculture is fully operational, employment falls to and slightly below base due to real wages moving only slowly downwards.

Real GDP remains above base in Tablelands (East)–Kuranda for all but one year of the scenario. The peak occurs in 2025–26 at two per cent or $50 million (2021 dollars) above base (Figure At1-2.6). At the statewide level, real GDP peaks at 0.015 per cent or around $60 million (2021 dollars) above base (Figure At1-2.7).

Table At1-2.2 shows sectoral value-added output from 2029–30 on, using base level prices. The modelled prices for the four sectors—citrus fruit, bananas, orchard fruit and sugarcane—decline relative to base as output increases. The table does not include the modelled fall in prices. In reality, a combination of marketing efforts both in Australia and overseas, combined with the impact of climate change on commodity prices, may enable an increase in production without a decline in prices relative to base. Such efforts would raise the terms of trade and welfare impacts of the project.

What is typical of CGE-modelled outcomes is a decline in output for sectors in the region that are not direct beneficiaries of the irrigation expansion. Other services decline in output due to a cost squeeze arising from above-base real wages (Figure At1-2.5). Primary industry sectors other than the four expanding irrigation sectors also suffer slightly from cost squeezes.

Table At1-2.2: Sectoral output in Tablelands (East)–Kuranda from 2029–30 to 2049–50 ($m value-added, 2021 prices).

	2029–30	2030–31	2031–32	2032–33	2033–34	2034–35	2035–36	2036–37	2037–38	2038–39	2039–40	2040–41	2041–42	2042–43	2043–44	2044–45	2045–46	2046–47	2047–48	2048–49	2049–50
Other agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vegetables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Citrus fruit	1	1	2	2	3	4	6	7	8	8	8	8	8	8	8	8	8	8	8	8	8
Bananas	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orchard fruit	2	4	6	8	12	18	23	27	31	31	32	32	32	32	32	32	32	31	31	31	31
Livestock	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-3	-3	-3	-3
Sugarcane	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Coal—black	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-2	-3	-3	-3
Other mining	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Metal ores	-2	-2	-2	-2	-2	-2	-2	-3	-3	-3	-3	-4	-4	-4	-4	-4	-4	-5	-5	-5	-5
Meat production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1
Other food	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Other manufacturing	-1	-1	-1	-1	-1	-1	-2	-2	-2	-2	-2	-2	-3	-3	-3	-3	-3	-3	-3	-3	-3
Construction	4	3	2	2	2	1	1	2	2	1	1	1	1	1	1	1	0	0	0	0	0
Trade	0	1	2	2	4	5	7	8	9	9	9	10	9	9	9	9	9	9	9	9	9
Transport	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0
Other services	-3	-2	-2	-2	-2	-3	-3	-3	-4	-4	-4	-4	-4	-4	-4	-5	-5	-5	-5	-5	-6
Health and education	-1	-1	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-3	-3	-3	-3	-3	-3	-3	-3	-3
CommunCre	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owner dwelling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2.1 State, local and national welfare impacts of the Atherton Tablelands project

Figure At1-2.3 shows a small increase in real household consumption relative to base in Queensland. The deviation in welfare (dWELF) at the state level is computed as:

$$dWELF = \sum_d \sum_t \frac{dCON(d,t)+dGOV(d,t)}{(1+r)^t} - \frac{dNFL(z)}{(1+r)^z} + \frac{dKstock(z)}{(1+r)^z} \quad (1)$$

- dCON and dGOV are the deviations in real household consumption and government spending in region d and year t
- dNFL is the deviation in real net foreign liabilities in the final year (z) of the simulation
- dKstock is the deviation in value of capital stock in the final year (z) of the simulation
- r is the discount rate.

The latter is set at 2.5 per cent. The welfare calculation accounts for both legacy capital stock and legacy debt.

The current consumption ($m) and capital stock contributions ($m) are positive. However, the project is funded through foreign borrowing. If the Commonwealth pays for half of the water infrastructure, a contribution with an NPV of $167 million, the change in welfare from the state's perspective is $20 million (Table At1-3). The overall cost of the water infrastructure investment is critical in determining if the state wins or loses from the project.

At the local level, that is, in the Tablelands (East)–Kuranda SA3 region that best matches the project, the welfare gain is $287 million, slightly smaller than the transfer ($333 million) from the Commonwealth and Queensland governments.

Table At1-2.3: Components of welfare impact of Atherton Tablelands project ($m).

	Local	State	National
Transfer	333	167	0
Consumption	400	615	1,222
– Legacy debt	-574	-873	-1,129
Legacy capital	128	112	114
Total	287	20	208

To explain why the national welfare gain is larger than the state gain, the scenario examines the terms of trade. At national level, the terms of trade is the price of international exports divided by the price of international imports. From Queensland's perspective, the terms of trade is the price of interstate plus international exports divided by the price of interstate plus international imports.

An improvement in the terms of trade relative to base increases spending power for a given level of real income. This means if the terms of trade improve, aggregate consumption (a component in the welfare calculation) will increase. At present, international exports amount to about $500 billion in Australia. This implies each 0.001 per cent improvement in the national terms of trade is equivalent to $5 million per annum of increasing spending power for a given level of real income. In Queensland, with base exports of about $100 billion, each 0.001 per cent decrease is equivalent to a loss of $1 million per annum in the state's spending power (Figure At1-2.8). The NPV of the national terms of trade gain in this scenario is $294 million.

Australia's terms of trade increase because the increase in the supply of farm output from the Atherton Tablelands lowers prices paid by Australian consumers, due to downward-sloping demand curves. From Queensland's perspective, the negative impact of lower farm output prices outweighs the positive impact on Queensland's consumers. However, with a transfer from the Commonwealth, a statewide gain is the result.

Based on the costs and returns modelled, this project is potentially good for the local, state and national regions. This is not always the case. To arrive at this outcome, returns from the national perspective must outweigh costs. From the local and state perspectives, in which the terms of trade are negative, transfers are necessary for a positive welfare outcome to result.

2.2 Atherton Tablelands development relative to climate change baseline

The welfare outcome of the project is likely to differ against a background of climate change. On the demand side in a stylised baseline, climate change will raise agricultural and food prices relative to business-as-usual. This is modelled in an alternative baseline as a modest increase in export prices, reaching 10 per cent above business-as-usual levels by 2049–50. On the supply side, climate change is depicted as a gradual decline in the land endowment of each agricultural sector in each region, falling to five per cent below business-as-usual levels by 2049–50. The second element—a decline in agricultural productivity, captured here as a decline in land endowment—is likely to be large in regions where climate change is associated with reductions in rainfall. It may not be negative in regions where rainfall increases with climate change. This scenario has applied a stylised reality in modelling for the four Regional Water Grids regions, knowing the reality varies from region to region. The effects of climate change on rainfall and water availability across the four grid catchments are discussed in Appendix At1-3.

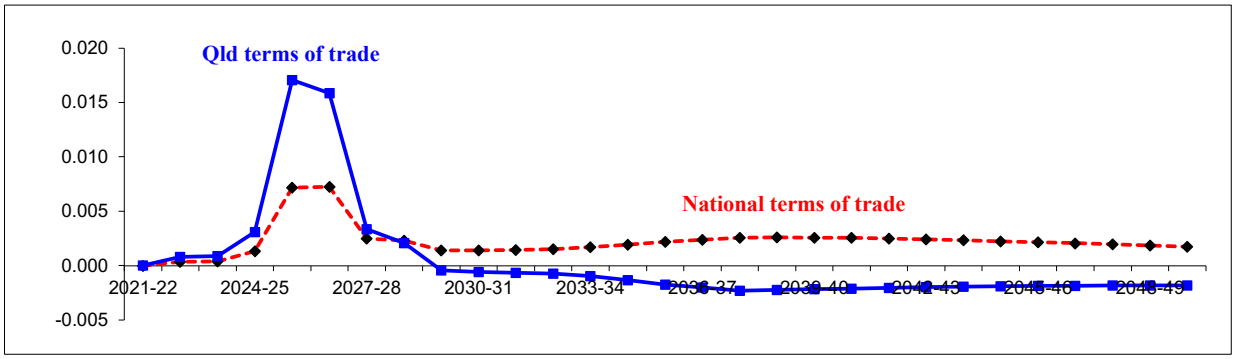


Figure At1-2.8: Terms of trade, national and Queensland (% deviation from base).

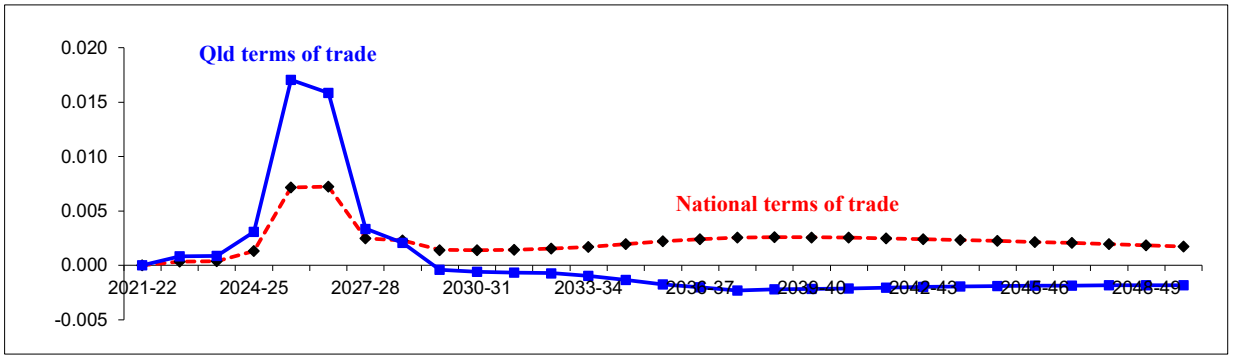


Figure At1-2.9: Terms of trade, national and Queensland (% deviation from stylised climate change base).

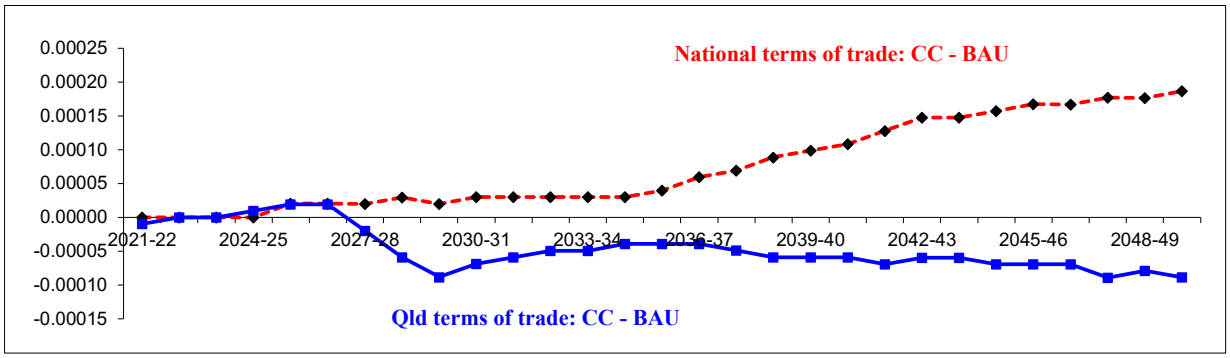


Figure At1-2.10: Differences in terms of trade deviations, national and Queensland (climate change (CC) deviation minus business-as-usual (BAU) deviation).

Figure At1-2.9, showing the deviation in the terms of trade relative to a climate change baseline, differs little from Figure At1-2.8. The NPV of Queensland's welfare outcome falls slightly to $14 million with this stylised depiction of climate change. National welfare increases slightly to $224 million (Table At1-2.4). The terms of trade differences (scenario deviation from climate change base minus the deviation from a business-as-usual base) are observable only at the fourth decimal place (Figure At1-2.10).

Table At1-2.4: Components of welfare impact of Atherton Tablelands project, relative to stylised climate change baseline ($m).

	Local	State	National
Transfer	333	167	0
Consumption	408	631	1,288
– Legacy debt	-574	-893	-1,176
Legacy capital	128	109	113
Total	295	14	224

3. Burdekin Falls–Bowen Basin scenario

This scenario includes raising the Burdekin Falls Dam and constructing the Big Rocks weir and pipeline (from Burdekin Falls to the Bowen Basin region, and duplicating the Burdekin to Moranbah pipeline) as part of the water infrastructure development. The real cost of infrastructure development is $2,071 million or $1,854 million in NPV terms.

Additional water will include 175 gigalitres for irrigation purposes and 22 gigalitres for non-farm uses. Note that the region has substantial black coal activity. A contentious part of ascribing a benefit to additional water concerns its use in expanding coal production. A productivity gain equivalent to $15 million per annum was ascribed to coal production to depict the impact of increased water availability. Another potential omission is any consideration of sugarcane as an input into future industrial uses beyond current uses.

The NPV of water infrastructure development is about $9,400 per megalitre.

Table At1-3.1: Additional water use and hectares.

	GL	Hectares	Yield t/ha	Capital cost $/ha
Other fruit and vegetables*	2.1	396	40.0	20,000
Potatoes	0.7	132	5.0	20,000
Wheat	0.4	264	6.5	3,750
Other grains and legumes	0.4	264	2.0	3,750
Sugarcane	172	12,265	116.5	3,750

* Melons and pumpkins

In this scenario, water infrastructure development proceeds from 2021–22 to 2026–27. Some on-farm investments start in 2023–24, with accelerated investment in 2026–27. The last year of the on-farm investment phase is 2032–33. Table At1-3.1 shows the area of farm investment by crop type and eventual annual water requirements arising from this.

Figure At1-3.1 shows the continuous Burdekin (Charters Towers–Ayr–Ingham) and Bowen Basin–North regions in which the project occurs. These two SA3 regions are modelled as a composite region in this study.

The water infrastructure investment phase raises the Burdekin–Bowen investment to about 40 per cent above base levels, with increased regional real consumption peaking at almost three per cent above base in 2026–27 (Figure At1-3.2).

As the labour market strengthens due to additional investment demands, there is an increase in employment relative to base. Jobs peak in Burdekin–Bowen at 1.5 per cent or 440 FTE jobs above base in 2025–26 (Figure At1-3.4). At the state level, jobs peak at 0.1 per cent or 1,980 FTE jobs in the same year (Figure At1-3.5).

In succeeding years, real wages adjust upwards, choking off additional jobs to some extent. By 2027–28, when water infrastructure investments have ceased, regional employment falls below base due to real wages persisting around one per cent above forecast, even as investment moves down towards base.

Real GDP remains above base in Burdekin–Bowen for all but one year of the scenario. There is a plateau from 2030–31 onwards, with real GDP persisting at about 0.7 per cent or $70 million (2021 dollars) above base (Figure At1-3.6). Figures At1-3.3, At1-3.5 and At1-3.7 show the corresponding state level deviations.

Table At1-3.2 shows the deviations in real output from base in the years when the upgraded scheme has finished and industries have responded. One assumption in modelling is

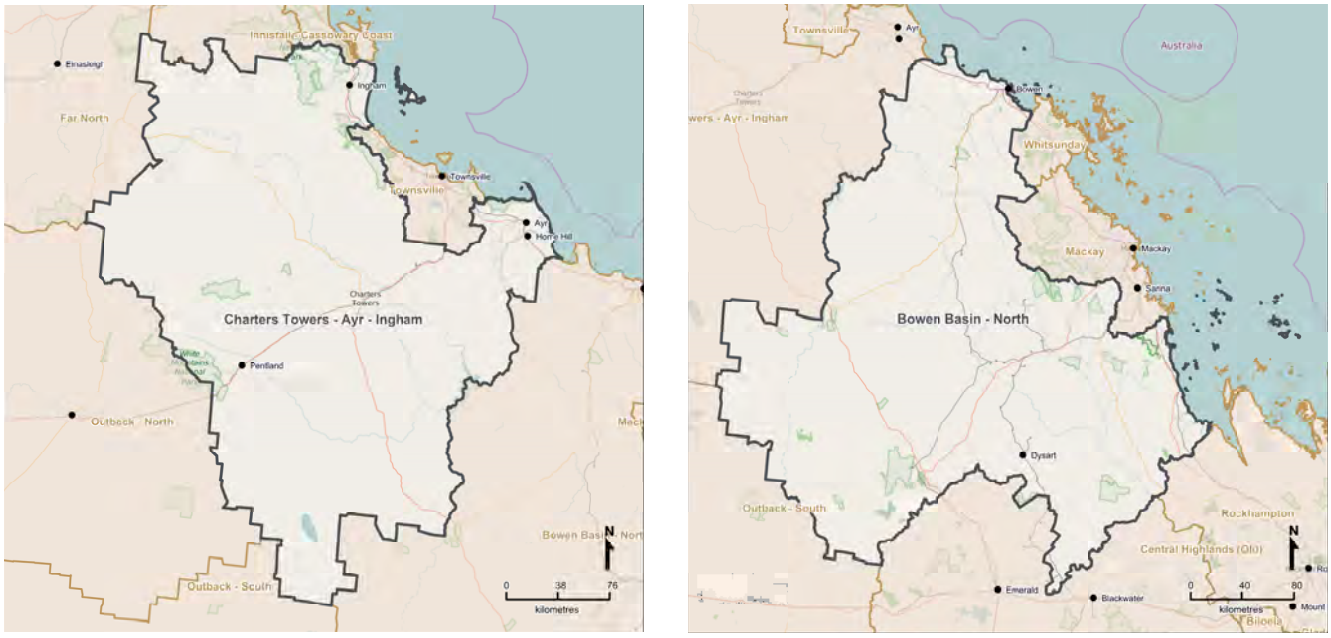


Figure At1-3.1: Maps of contiguous Burdekin and Bowen Basin regions.

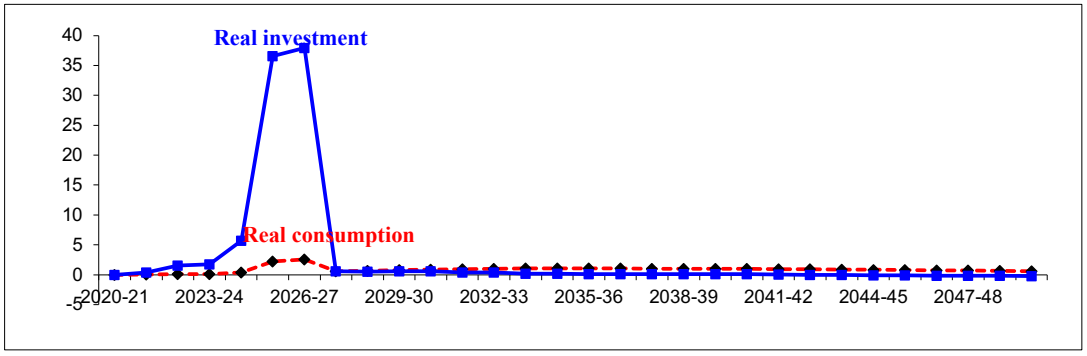


Figure At1-3.2: Burdekin–Bowen aggregate consumption and investment (% deviation from base).

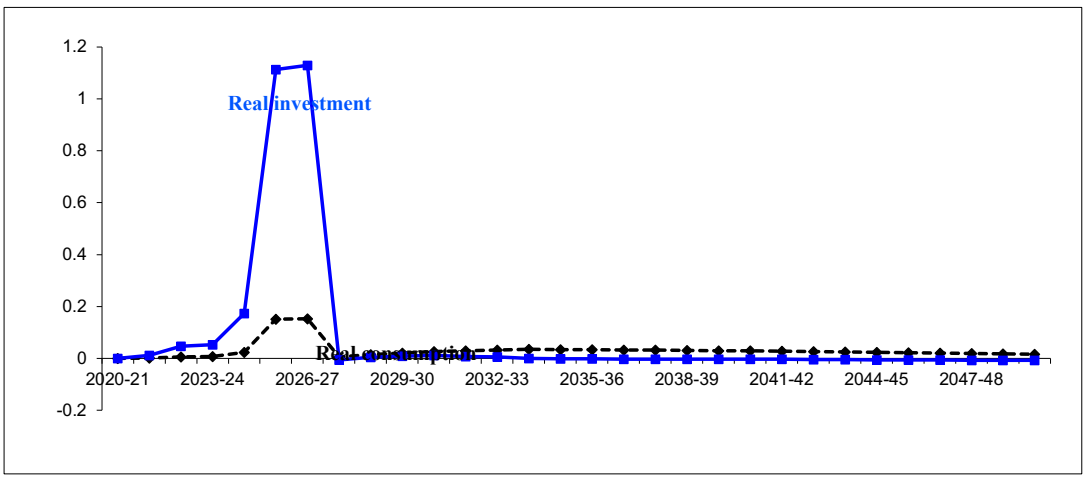


Figure At1-3.3: Queensland aggregate consumption and investment (% deviation from base).

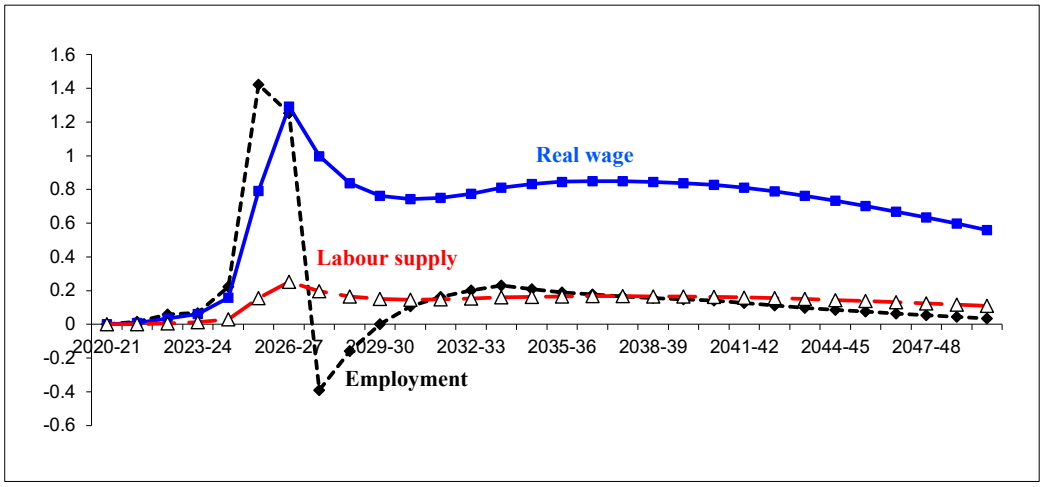


Figure At1-3.4: Burdekin–Bowen labour market (% deviation from base).

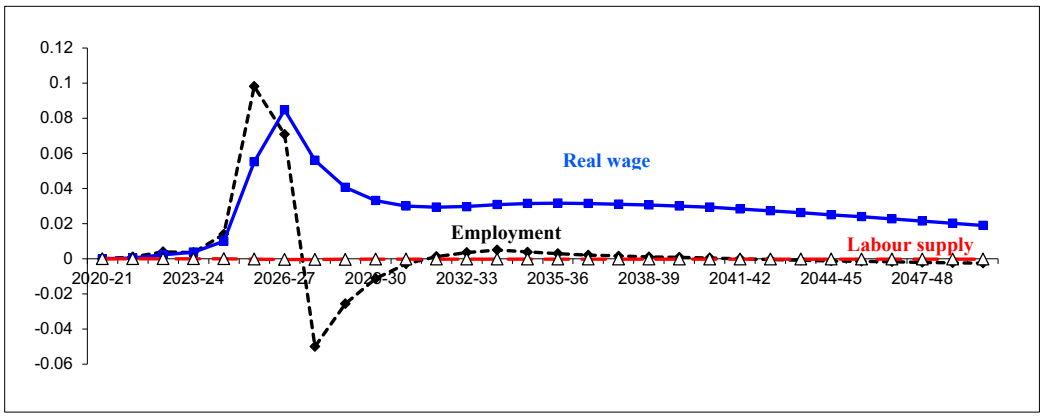


Figure At1-3.5: Queensland labour market (% deviation from base).

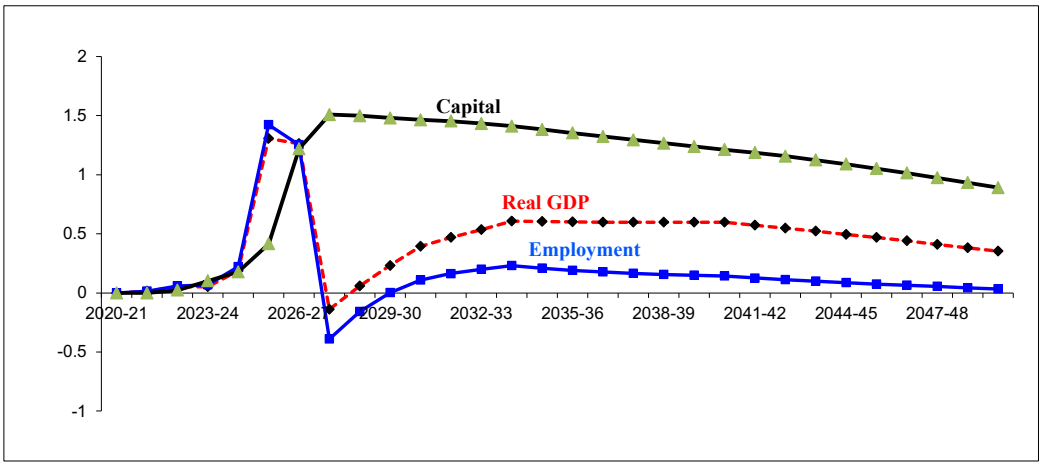


Figure At1-3.6: Burdekin–Bowen real GDP, income side (% deviation from base).

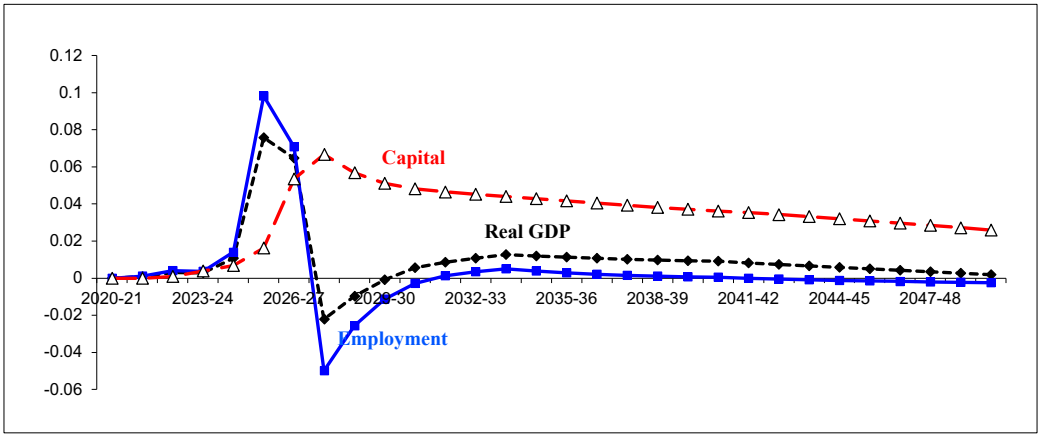


Figure At1-3.7: Queensland real GDP, income side (% deviation from base).

the coal sector is a beneficiary of additional water. Given the global outlook for coal has deteriorated over the past year or two, this assumption may not hold over time. Sugarcane accounts for most additional agricultural water use. Different assumptions concerning long-term outlooks for different products will alter the imposed crop mix in the scenario.

It is possible that, with changing technologies, sugarcane will become an input into industrial processes that add to its value. This scenario does not attempt to impose additional value on sugarcane, confining its uses to current processing technologies.

Table At1-3.2: Sectoral output in Burdekin–Bowen from 2029–30 to 2049–50 ($m value-added, 2021 prices).

	2029–30	2030–31	2031–32	2032–33	2033–34	2034–35	2035–36	2036–37	2037–38	2038–39	2039–40	2040–41	2041–42	2042–43	2043–44	2044–45	2045–46	2046–47	2047–48	2048–49	2049–50
Other agriculture	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Other vegetables	5	8	11	15	19	19	19	19	19	18	18	18	18	17	17	17	16	16	16	15	15
Potatoes	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Livestock	-3	-3	-3	-4	-4	-4	-4	-4	-5	-5	-5	-5	-5	-6	-6	-6	-7	-7	-8	-9	-9
Wheat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other grains and legumes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sugarcane	21	29	36	42	49	51	53	54	56	57	59	60	61	62	63	64	65	66	66	67	67
Coal—black	-11	-2	0	1	2	2	2	2	2	2	2	2	2	2	1	1	1	0	0	-1	-1
Other mining	-1	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-3	-3	-3
Metal ores	-3	-3	-3	-4	-4	-4	-4	-5	-5	-5	-5	-5	-5	-6	-6	-6	-6	-6	-7	-7	-7
Meat production	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other food	2	3	5	6	7	8	8	8	9	9	9	9	9	9	9	8	8	8	7	7	7
Other manufacturing	-2	-2	-3	-3	-3	-3	-3	-4	-4	-4	-4	-4	-4	-4	-4	-5	-5	-5	-5	-6	-6
Trade	2	4	5	6	8	8	8	8	8	8	8	8	8	8	8	7	7	7	6	6	6
Transport	-1	-1	-1	-1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Other services	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-4	-4	-4	-5	-5	-6	-6	-6	-7
Owner dwelling	5	6	6	7	7	8	8	9	9	10	10	10	10	11	11	11	11	11	11	11	11
Education	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Health	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-2
Other agriculture	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

As shown in Figure At1-3.3, Queensland's aggregate consumption rises above base only during the investment phase. The positive current consumption and capital stock contributions are more than offset by the increase in net foreign liabilities. Assuming the Commonwealth pays for half the water infrastructure—a contribution with an NPV of $927 million—the change in welfare from the state's perspective is minus $558 million. At the local level, the welfare impact is minus $410 million. The national welfare outcome is smaller at minus $55 million.

Table At1-3.3: Components of welfare impact of Burdekin–Bowen Basin project.

	Local	State	National
Transfer	1,853	927	0
Consumption	361	2,309	4,534
– Legacy debt	-2,867	-4,084	-4,842
Legacy capital	244	290	253
Total	-410	-558	-55

Once the additional irrigation activity is fully operational, the national terms of trade persist at 0.008 per cent above base (Figure At1-3.8). This is equivalent to an annual increase in national spending power of $40 million. The impact of additional production in Queensland on the terms of trade more than offsets the lower price to Queensland users, so the statewide terms of trade decline.

More information on future project costings and a more detailed evaluation of benefits, particularly potential new uses for sugarcane, may alter the scenario outcome. For example, if new industries in Queensland rely on sugarcane inputs, the statewide terms of trade may become more favourable, in turn improving the statewide welfare outcome. If additional water provides no marginal regional benefit through its impact on the coal sector, it will slightly worsen local, state and national welfare outcomes.

3.1 Burdekin Falls development relative to climate change baseline

As in all climate change baselines depicted in this study, there is an ongoing small increase in agricultural and food export prices and an ongoing small decrease in agricultural land availability within Australia.

Relative to this baseline, the NPV of Queensland's welfare outcome is minus $565 million with this stylised depiction of climate change. The local welfare loss is $452 million. Yet, at the national level, there is now a welfare gain of $308 million. To explain this, comparison of the deviations in terms of trade for the first baseline (Figure At1-3.8) with those for the climate change baseline (Figure At1-3.9) was needed. The differences are observable at the third decimal place (Figure At1-3.10). This raises the national terms of trade sufficiently that the national welfare outcome changes. The difference reaches 0.002 per cent in later years, or well over $10 million per annum in terms of increased spending power.

Table At1-3.4: Components of welfare impact of Burdekin–Bowen Basin project relative to stylised climate change scenario.

	Local	State	National
Transfer NPV	1,853	927	0
Consumption NPV	378	2,521	5,187
– Legacy debt NPV	-2,919	-4,288	-5,135
Legacy capital NPV	236	276	256
Total NPV	-452	-565	30

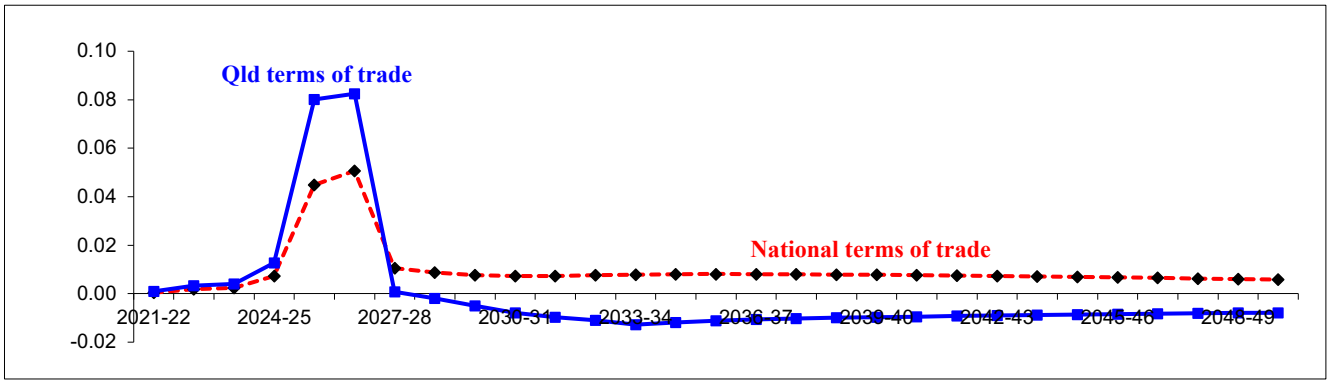


Figure At1-3.8: Terms of trade, national and Queensland, Burdekin–Bowen scenario (% deviation from business-as-usual base).

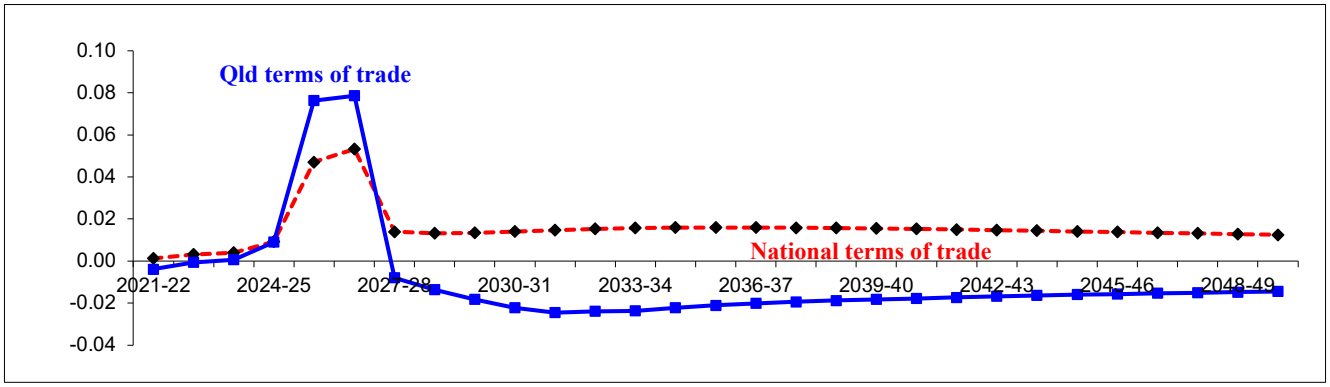


Figure At1-3.9: Terms of trade, national and Queensland, Burdekin–Bowen scenario (% deviation from stylised climate change base).

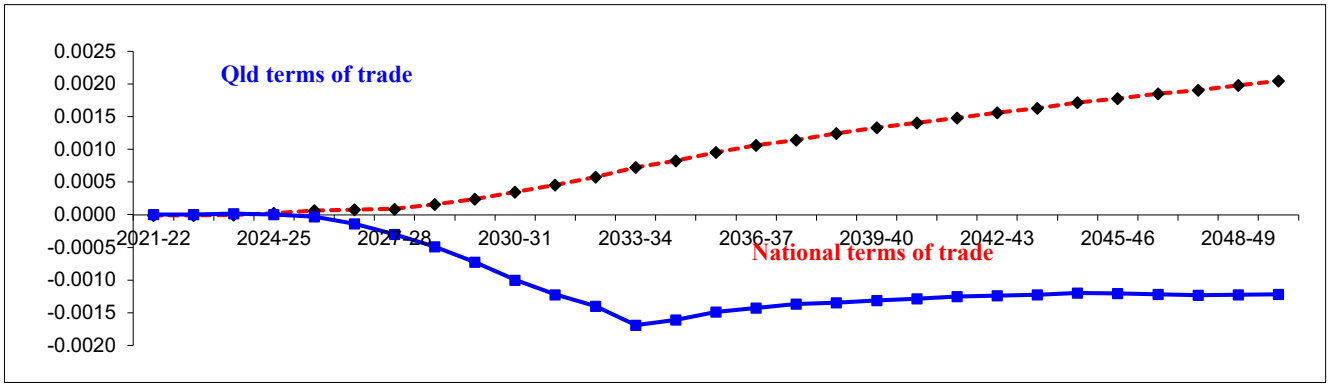


Figure At1-3.10: Differences in terms of trade deviations, Burdekin–Bowen scenario (climate change (CC) deviation minus business-as-usual (BAU) deviation).

4. Burnett scenario

In this scenario, water infrastructure works include expanding Paradise Dam and constructing the Coalstoun Lakes pipeline and Glendorf offstream storage. Development proceeds from 2021–22 to 2026–27. The capital cost per megalitre is $8,949. Some on-farm investments start in 2023–24, with accelerated investment in 2026–27. The last year of the on-farm investment phase is 2032–33. On-farm investments total $113 million. New wheat, barley and sugarcane plantings reach full yields by 2031–32. Citrus, macadamia (i.e., almond and macadamia, as prepared from available ABS data) and avocado plantations do not reach full yields until 2037–38. Table At1-4.1 summarises crop development and water use.

Table At1-4.1: Additional water use and hectares, Burnett scenario.

	GL	Hectares	Yield t/ha	Capital cost $/ha
Sugarcane	17.9	4,769	96.5	3,750
Citrus	5.3	701	28	41,500
Wheat	1.2	491	6	3,750
Barley	2.5	491	6.5	3,750
Almond macadamia	1.4	351	1	45,000
Avocadoes	2.1	210	11	41,000

Figure At1-4.1 shows the modelled region. The mapped region for the possible irrigation development also includes some parts of the Bundaberg and Maryborough SA3 regions. The justification for excluding these two parts of the regions from the project region is that those two regions are relatively less intensive in agriculture in their economic base. Burnett's agricultural value-added output as a share of total region income is around 15.8 per cent, while Bundaberg's is 8.6 per cent and Maryborough's is 2.7 per cent. If the model included a composite of the three SA3 regions, reported dollar outcomes may differ to some extent for the local welfare impact due to the local terms of trade effect being more favourable. This is discussed below.

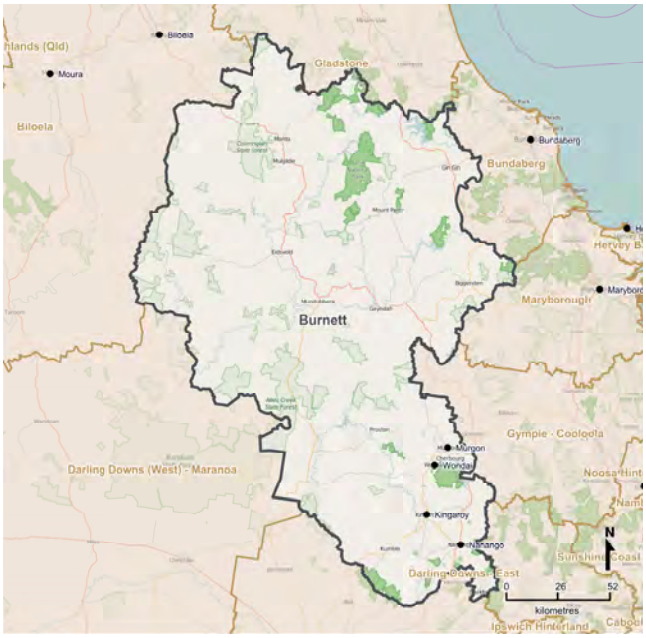


Figure At1-4.1: Burnett SA3 region.

During the water infrastructure investment phase, investment in the Burnett region rises to a peak of 17 per cent above base (Figure At1-4.2). In Burnett, jobs peak in 2026–27 at 135 FTE above base (Figure At1-4.4). At the state level, in the same year, jobs peaks at 310 FTE above base (Figure At1-4.5). Although real wage increases choke off additional jobs in later years, through a combination of on-farm investment and realised farm output increases, employment remains above base in Burnett for the duration of the simulation period (Figure At1-4.4).

Earlier, in the investment phase, Burnett's real GDP peaked at $20 million above base, with a corresponding statewide $50 million deviation. The eventual realisation of full yields on tree crops in 2036–37 results in a small jump in real GDP in Burnett relative to base (Figure At1-4.6). This jump is equivalent to around $4 million.

The slightly negative welfare outcome for Burnett (Table At1-4.3) is in part an artifact of the regional aggregation. The local sugar mills are concentrated in the adjacent Bundaberg region. In the later years of the scenario, Burnett's terms of trade fall 0.12 per cent relative to base. With increased sugarcane production in the local region, this terms of trade effect would diminish and potentially turn the local welfare impact positive.

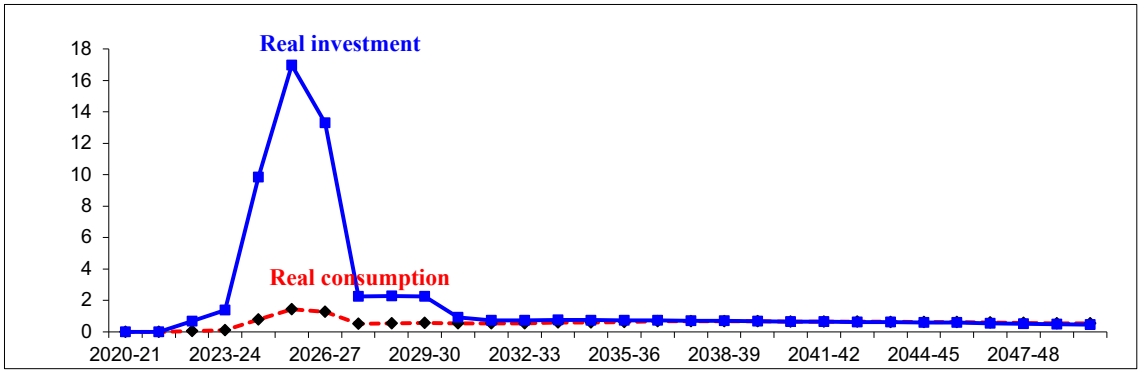


Figure At1-4.2: Burnett aggregate consumption and investment (% deviation from base).

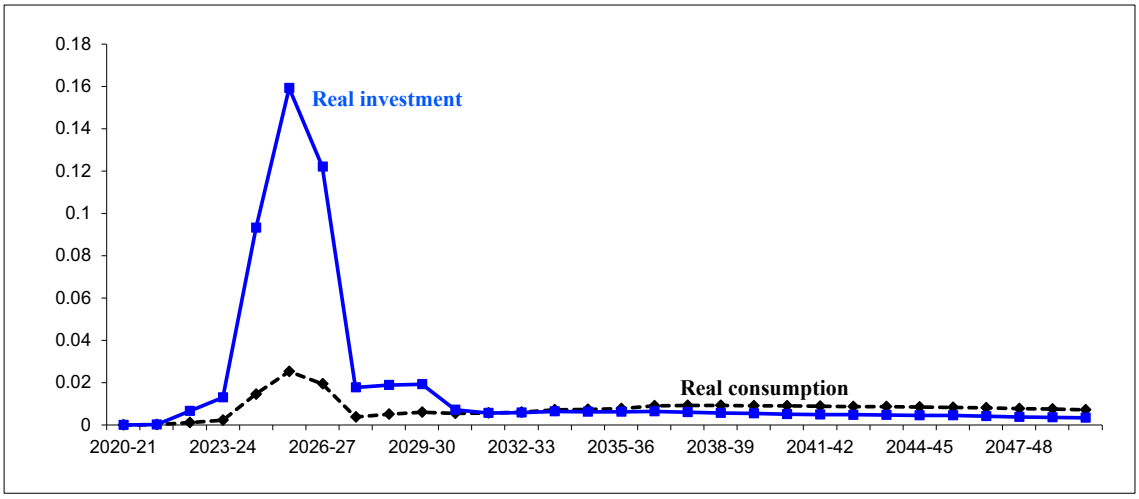


Figure At1-4.3: Queensland aggregate consumption and investment, Burnett scenario (% deviation from base).

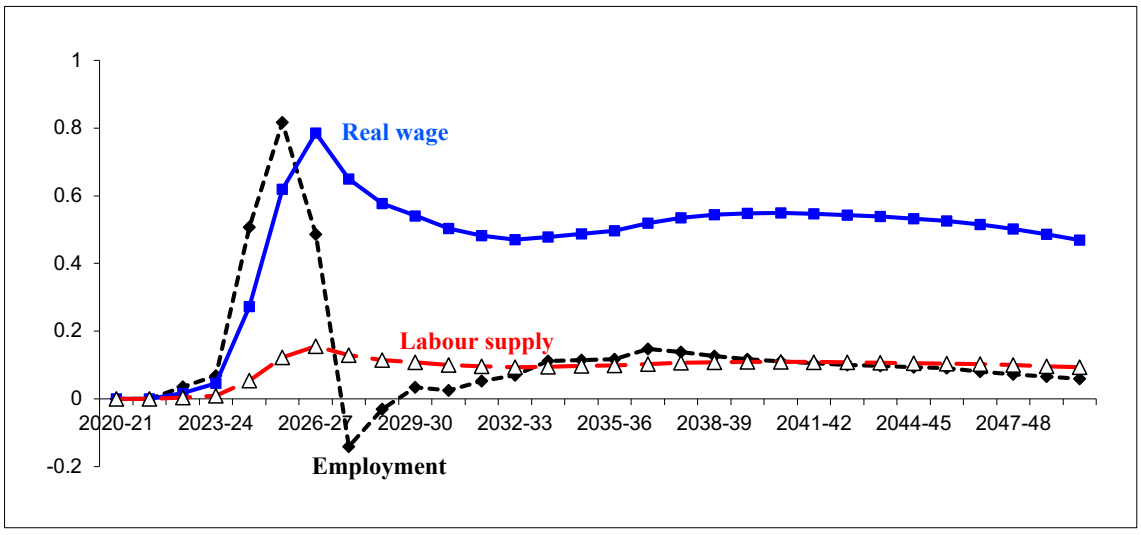


Figure At1-4.4: Burnett labour market (% deviation from base).

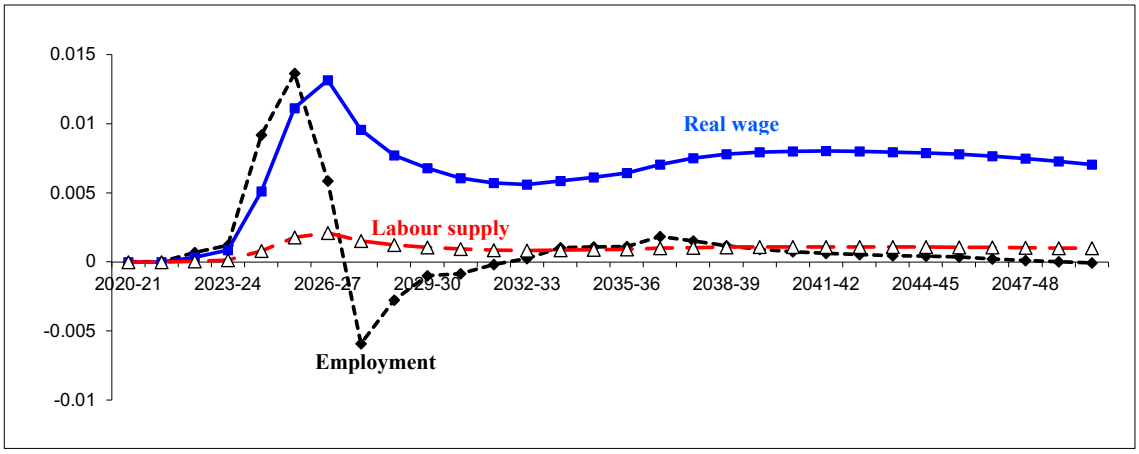


Figure At1-4.5: Queensland labour market, Burnett scenario (% deviation from base).

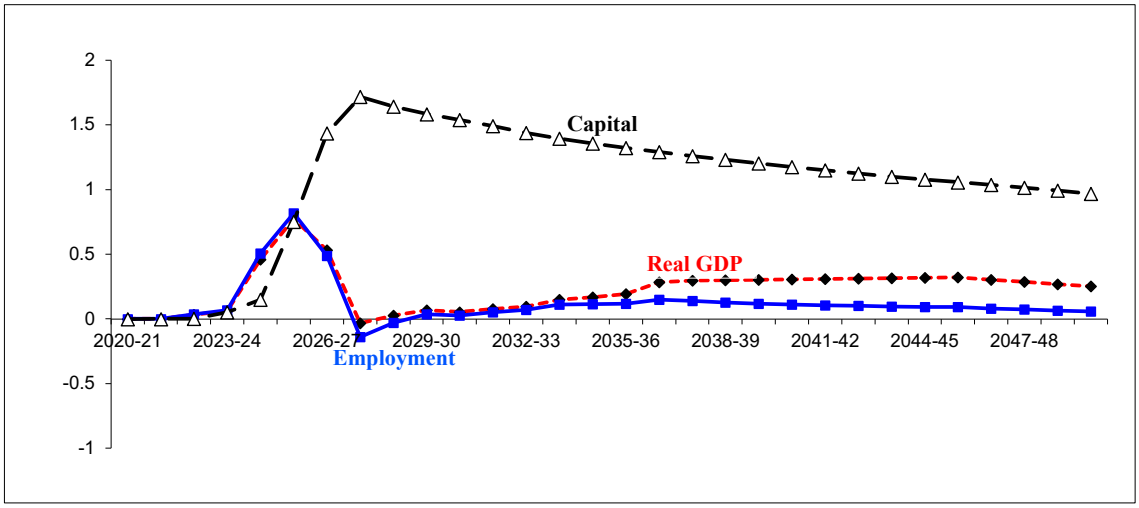


Figure At1-4.6: Burnett real GDP, income side (% deviation from base).

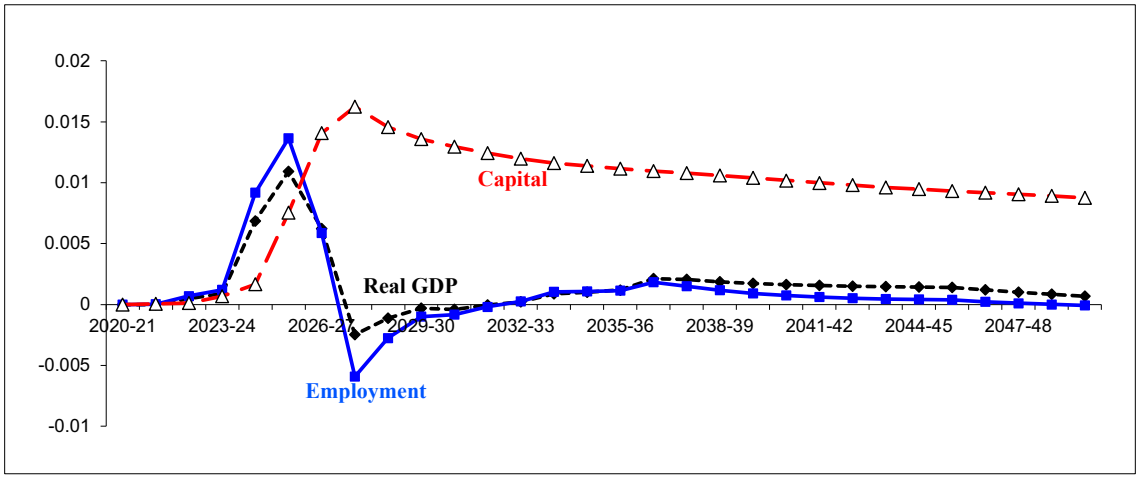


Figure At1-4.7: Queensland real GDP, income side, Burnett scenario (% deviation from base).

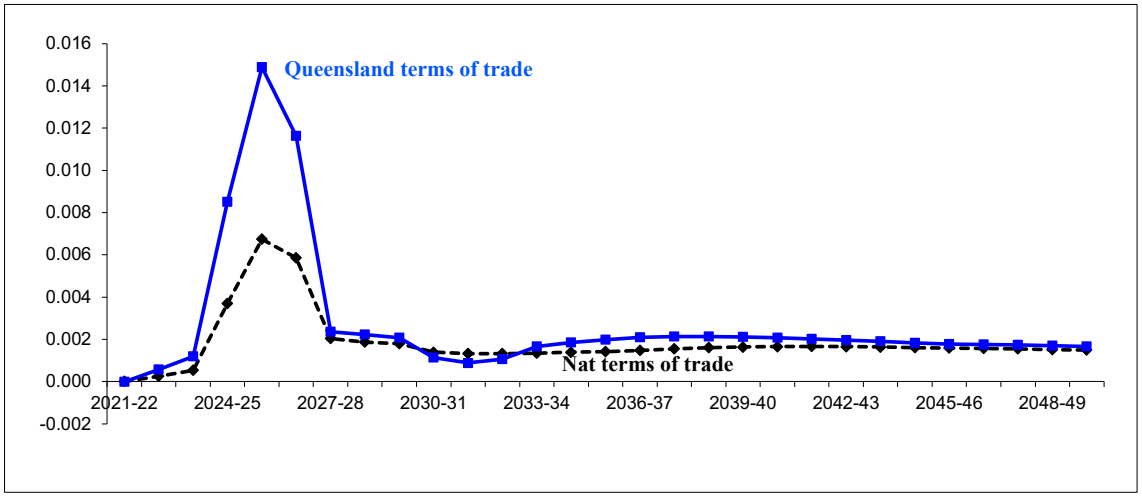


Figure At1-4.8: Queensland and national terms of trade (% deviation from base).

Table At1-4.3: Components of welfare impact of Burnett project.

	Local	State	National
Transfer NPV	271	136	0
Consumption NPV	247	700	1,011
– Legacy debt NPV	-613	-844	-1,045
Legacy capital NPV	43	98	113
Total NPV	-51	89	79

Figure At1-4.8 shows this scenario slightly favours Queensland's terms of trade, as the price-reducing effect of increased output is more than offset by cheaper inputs to Queensland food processors. This contributes to Queensland's welfare impact being slightly larger than the national impact after accounting for half-payment of water infrastructure works by the Commonwealth.

Table At1-4.4: Components of welfare impact of Burnett project, climate change baseline.

	Local	State	National
Transfer NPV	271	136	0
Consumption NPV	251	715	1,044
– Legacy debt NPV	-614	-854	-1,065
Legacy capital NPV	43	97	107
Total NPV	-49	93	86

In the Burnett scenario relative to a stylised climate change baseline, the differences in welfare at the local, national and state levels are minor. This reflects minor movements in the terms of trade deviation from switching to a climate change baseline.

5. Dawson River–Darling Downs scenario

In this scenario, water infrastructure development (Nathan Dam) proceeds from 2021–22 to 2026–27. The cost in real terms is $1,412 million or a NPV of $1,234 million. On-farm investments occur from 2029–30 to 2032–33, totalling $113 million. The new crops chosen are all annuals: cotton, wheat, maize and chickpeas. The other grains and legumes sector depicts the latter two crops in VU-TERM.

Table At1-5.1: Additional water use and hectares, Dawson–Darling Downs scenario.

	GL	Hectares	Yield t/ha	Capital cost $/ha
Cotton	23.4	4,254	14.1	7,500
Wheat	1.6	637	6.0	3,750
Other grains and legumes	3.3	898	7	7,500

Table At1-5.1 shows the capital cost per megalitre (exceeding $40,000) is much higher than for water infrastructure works in other regions. This makes it unlikely the project is economically viable. Figure At1-5.1 shows the Darling Downs–East region, which is to have water piped from the Dawson River in the north.

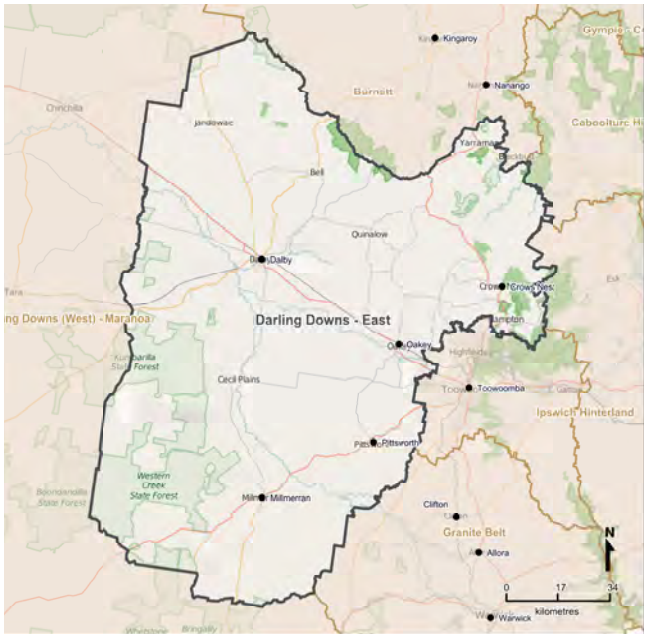


Figure At1-5.1: Darling Downs–East SA3 region.

Figures At1-5.2, At1-5.4 and At1-5.6 show the Darling Downs–East macro impacts. Jobs in the first water infrastructure investment year 2025–26 within Darling Downs–East peak at 750 FTE above base (Figure At1-5.4). Queensland jobs peak 1,270 FTE above base in the same year (Figure At1-5.5).

Table At1-5.3 shows the modelled welfare impacts of the Dawson–Darling Downs project at the local, state and national levels. The investments required in the project do not earn a sufficient return for there to be welfare gains. If anything, the welfare figures shown in the table underestimate the welfare loss. This is because one component concerning water infrastructure—legacy capital—earns a low return as it is calculated based on cost rather than returns.

Table At1-5.3: Components of welfare impact of Dawson–Darling Downs project.

	Local	State	National
Transfer NPV	1,234	617	0
Consumption NPV	450	1,138	1,235
– Legacy debt NPV	-1,898	-2,310	-2,515
Legacy capital NPV	144	304	286
Total NPV	-70	-251	-994

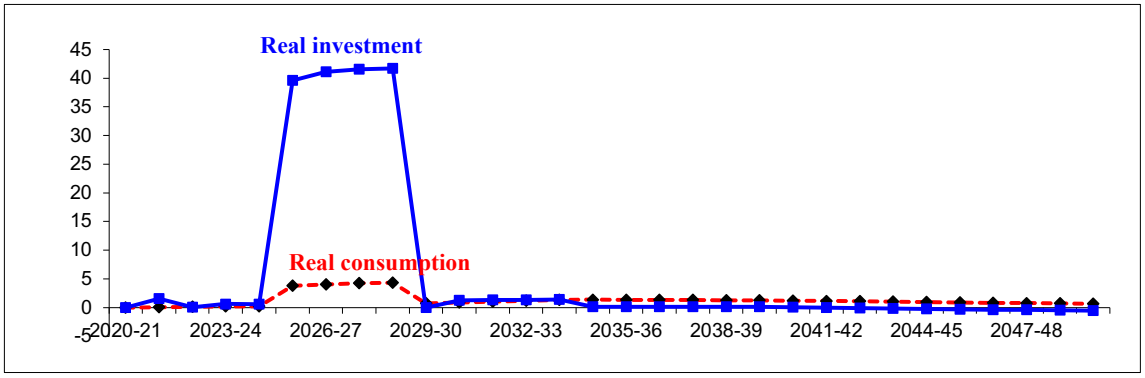


Figure At1-5.2: Darling Downs–East aggregate consumption and investment (% deviation from base).

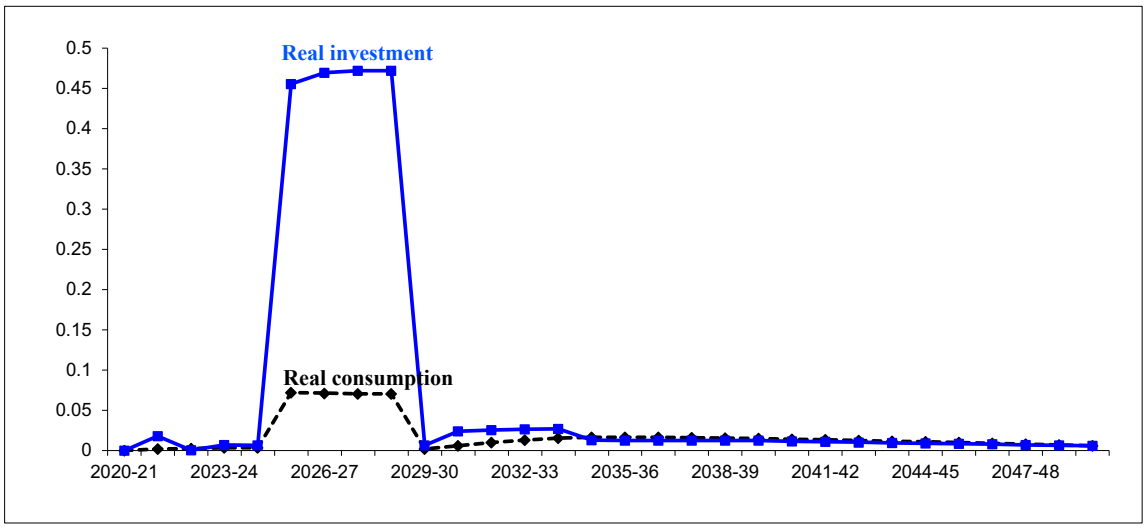


Figure At1-5.3: Queensland aggregate consumption and investment, Darling Downs–East scenario (% deviation from base).

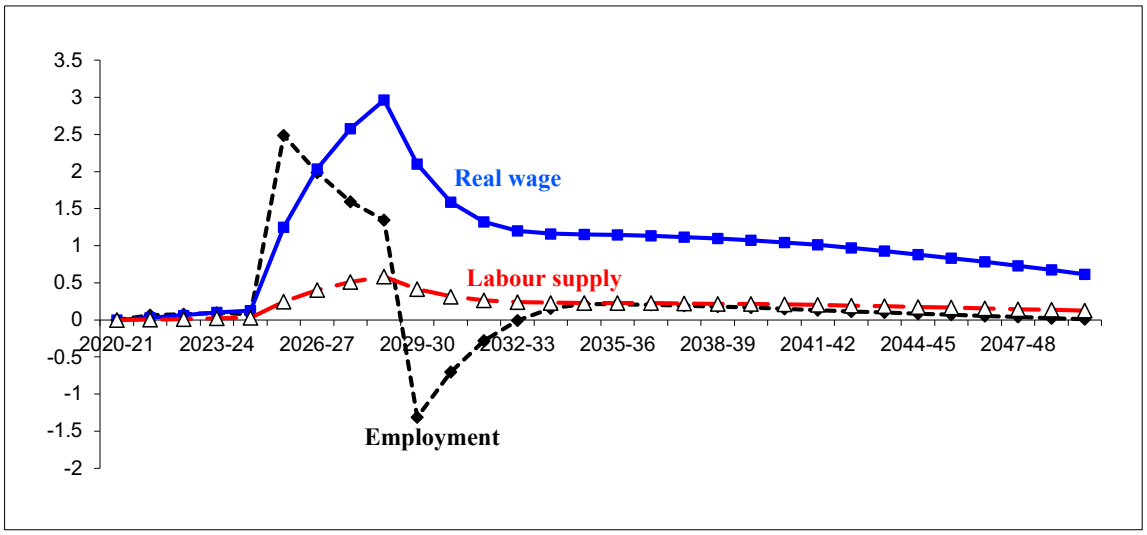


Figure At1-5.4: Darling Downs–East labour market (% deviation from base).

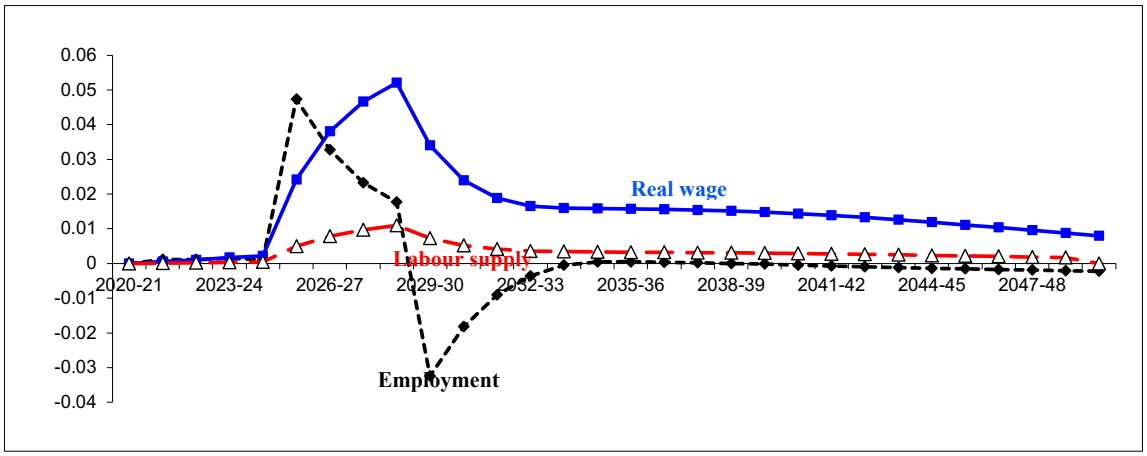


Figure At1-5.5: Queensland labour market, Darling Downs–East scenario (% deviation from base).

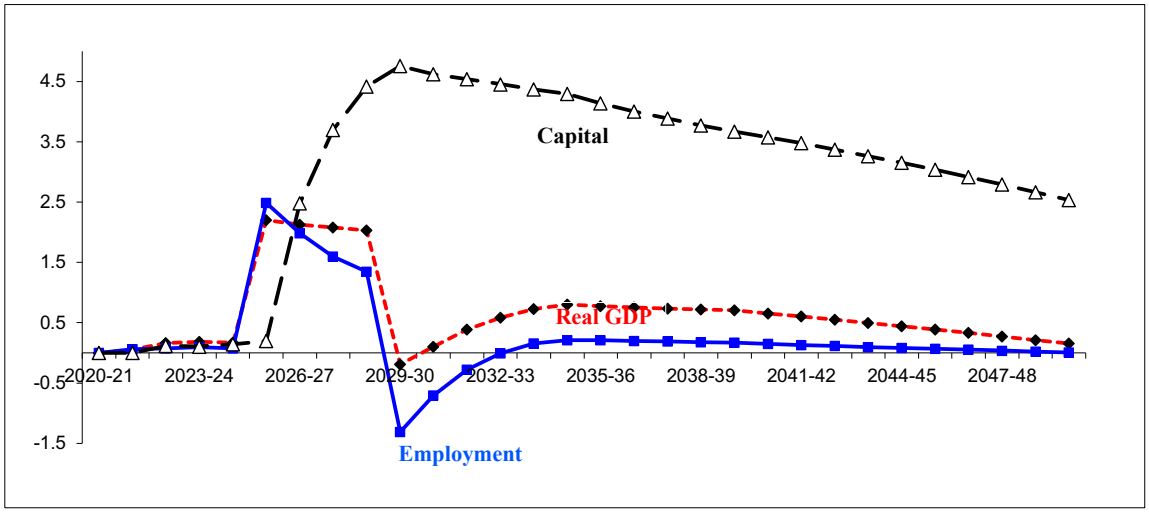


Figure At1-5.6: Darling Downs–East real GDP, income side (% deviation from base).

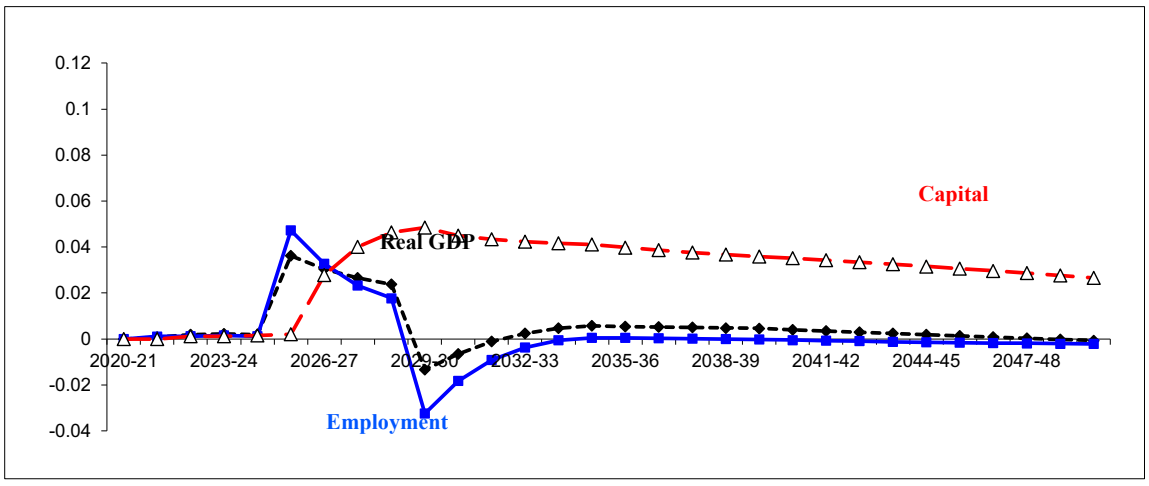


Figure At1-5.7: Queensland GDP income side, Darling Downs-East scenario (% deviation from base).

6. Assuming a high level of water utilisation by irrigators

Burdekin–Bowen Basin, first set

The first set of scenarios detailed in sections 2 to 5 assumes water utilisation by irrigators as a share of allocations follows the 12-year average historical pattern. Queensland irrigation farmers typically use relatively small proportions of the water to which they have legal rights.

Leaving aside water distribution constraints, it is possible additional water infrastructure would enhance water supply certainty, so farmers would use a higher proportion of available water than in the past. Irrigators may have been risk-averse in the past, undertaking on-farm investment at a lower level than reflected by their water allocations. Such risk-aversion may reflect in part the possibility of years in which available water is far below usual due to catchment drought. Other reasons for under-utilisation may include weaknesses in institutions for trading rights of access to water, distortions in water pricing and poor knowledge of opportunities for profitable water use that may be corrected over time.

The modelling reported in this section reports the marginal impacts of water infrastructure investment and additional on-farm investments. Higher on-farm investments and plantings reflect the response of farmers to both increased water availability and a shift in risk perception associated with increased availability.

One assumption underpinning higher water utilisation is that, for annual crops in Atherton Tablelands and Burdekin–Bowen Basin, there is no additional on-farm investment. Higher rates of utilisation start in 2022 and there are two ways this may occur. First, more water may be applied per hectare on sugarcane fields, resulting in higher yields. Second, the modelling assumes farmers use a higher proportion of their irrigable land (i.e. the land on which the on-farm irrigation infrastructure exists) for cropping each year. In general terms, neither of these assumptions requires additional on-farm investment beyond the costs of planting an annual crop. The increased irrigation areas in Burnett and Dawson–Darling Downs are proportionally much larger, so it is more defensible to assume that additional on-farm investment is necessary. That is, on-farm irrigation infrastructure investment is necessary to convert former dry-land holdings to irrigable land.

Perennials are a different matter. Even if the model assumes additional plantings in response to lower risk aversion in the early years of the scenario, these require additional on-farm investment in all regions, and there is a lag in output increases until plantings reach maturity.

Atherton Tablelands, second set

Table At1-6.1 shows that additional water use, inclusive of higher utilisation, rises from 28.5 gigalitres in the first set of scenarios to 76.6 gigalitres in the second set. Additional irrigated hectares rise from 4,111 to 11,242.

Table At1-6.1: Additional water use and hectares, Atherton Tablelands (2).

	GL (1)	Hectares (1)	GL (2)	Hectares (2)
Citrus	3.1	388	8.3	1,042
Bananas	5.6	471	15.2	1,265
Orchard fruit	14.6	1,953	39.1	5,445
Sugarcane	5.2	1,299	14.0	3,490
Total	28.5	4,111	76.6	11,242

Farm output increases in this scenario relative to the first Atherton Tablelands scenario, detailed in section 2. However, farm costs also rise as the number of hectares of perennials increases in this scenario. The welfare gains shown in Table At1-6.2 are slightly larger than those shown in Table At1-2.3. The NPV of the national terms of trade gain is $329 million.

Table At1-6.2: Components of welfare impact of Atherton Tablelands project ($m) (2).

	Local	State	National
Transfer	333	167	0
Consumption	453	708	1,494
– Legacy debt	-533	-894	-1,224
Legacy capital	106	89	88
Total	360	69	357
First scenario	287	20	205

Burdekin–Bowen Basin, second set

Greater utilisation of existing and new water resources in Burdekin–Bowen Basin mainly affects sugarcane production, with a further 10,000 hectares being planted (Table At1-6.3).

Table At1-6.3: Additional water use and hectares, Burdekin–Bowen Basin (2).

	GL (1)	Hectares (1)	GL (2)	Hectares (2)
Other fruit and vegetables*	2.1	396	3.8	720
Potatoes	0.7	132	1.2	240
Wheat	0.4	132	0.7	240
Other grains and legumes	0.4	264	0.7	480
Sugarcane	172	12,265	321	22,317

*Melons and pumpkins

There is a marked improvement in national welfare relative to the first scenario. This is driven partly by increased output and partly by the national terms of trade contribution, which had an NPV of $1,293 million in the first scenario. In this scenario, the contribution rises to $2,048 million.

Table At1-6.4: Components of welfare impact of Burdekin–Bowen Basin project ($m) (2).

	Local	State	National
Transfer	1,853	927	0
Consumption	569	3,599	8,330
– Legacy debt	-3,354	-5,447	-6,906
Legacy capital	129	113	38
Total	-803	-808	1,463
First scenario	-410	-558	-55

Given that sugarcane accounts for most of the additional output, future developments in sugarcane use may drive positive results at the local and state levels, instead of the local and state welfare losses as shown in Table At1-6.4. New industrial uses for sugarcane may enhance local manufacturing capacity, bringing more economic activity to the region. Such potential uses may raise the economic value of sugarcane[5].

Burnett, second set

Greater utilisation of available water in the Burnett region implies a much greater number of hectares of irrigated land (more than double) than the business-as-usual baseline. For this reason, on-farm investments proceed in 2022 for all irrigated crops to reflect higher utilisation, as existing dry land is converted to irrigable land to use additional water. Costs per hectare for this conversion vary according to crop type.

Table At1-6.5: Additional water use and hectares, Burnett (2).

	GL (1)	Hectares (1)	GL (2)	Hectares (2)
Sugarcane	17.9	4,769	112.9	30,100
Citrus	5.3	701	33.2	4,427
Wheat	1.2	491	7.7	3,099
Barley	2.5	491	15.5	3,099
Almond macadamia	1.4	351	8.9	2,213
Avocadoes	2.1	210	13.3	1,328

Table At1- 6.5 shows the irrigated hectares and water used for the first and second set of scenarios. Of the additional 44,265 hectares of irrigated land, 29,365 hectares are added through higher water utilisation. The remainder come into production after the water infrastructure development. Similarly, of the additional 191 gigalitres of irrigated water used, 127 gigalitres are a consequence of higher utilisation before the infrastructure is completed. The additional hectares and water used require substantial on-farm investment prior to completion of water infrastructure works.

Table At1-6.6: Components of welfare impact of Burnett project ($m) (2).

	Local	State	National
Transfer	271	136	0
Consumption	1361	4138	5515
– Legacy debt	-1101	-2456	-3658
Legacy capital	137	239	147
Total	668	2056	2005
First scenario	-51	89	79

Given the relatively modest NPV of infrastructure works ($271 million) and leaving aside concerns about the local water distribution network, higher utilisation results in substantial welfare gains in this scenario, relative to the business-as-usual baseline and also relative to a scenario with a lower level of utilisation. The latter is shown in the bottom row of Table At1-6.6. The fact that the welfare impact is positive at the state and national levels reflects positive terms of trade impacts at both levels.

Dawson River–Darling Downs, second set

In this scenario, the additional water for irrigation eventually increases by 54 gigalitres per annum, spread over more than 11,000 additional hectares (Table At1-6.7). There is an increase initially of 11 gigalitres per annum from increased utilisation of existing water resources.

Table At1-6.7: Additional water use and hectares, Dawson–Darling Downs (2).

	GL (1)	Hectares (1)	GL (2)	Hectares (2)
Cotton	23.4	4,254	44.7	8,131
Wheat	1.6	637	3.0	1,218
Other grains and legumes	3.3	898	6.3	1,715

Even with a higher degree of utilisation, the cost of water infrastructure works remains excessive relative to the benefit of additional water. Consequently, there is only a moderate decrease in the welfare loss relative to that of the same project in the first set of scenarios (Table At1-6.8).

Table At1-6.8: Components of welfare impact of Dawson–Darling Downs project (2).

	Local	State	National
Transfer NPV	1,234	617	0
Consumption NPV	562	1,434	1,907
– Legacy debt NPV	-1,876	-2,440	-2,841
Legacy capital NPV	136	275	249
Total	56	-114	-685
First scenario	-70	-251	-994

Appendix At1-A: Direct cost and returns used in modelled scenarios

Table At1-A.1: Cost recovery per ML of water: first set of model runs.

	Atherton Tablelands	Burdekin–Bowen	Burnett	Dawson River
(1) Cost NPV $m	333	1,854	271	1,234
(2) Water for irrigation GL	28.5	175	30.3	28.3
(3) Capital cost, $ per ML	11,684	10,594	8,949	43,604
(4) 50-year asset life: annual cost $m	6.66	37.08	5.42	24.68
(5) 2.5% annuity $m	8.33	46.35	6.78	30.85
(6) Required $/ML	526	477	403	1,962
(7) Annuity alone $/ML	292	265	224	1,090
Indirect national gains				
(8) National terms of trade NPV $m (BAU)	294	1,293	245	586
(9) National terms of trade NPV $m (CC)	303	1,407	249	597

Table At1-A.1 shows the annual water price per ML that will cover costs, calculated as an annuity of the NPV of costs plus an annual contribution to a 50-year asset lifetime. This is based on the first set of model runs in which the assumed additional water used by irrigators is lower than in the second set of runs. Rows (8) and (9) show the NPV of national terms of trade gains in the first set of runs relative to the business-as-usual (BAU) and climate change (CC) baselines. With higher assumed water utilisation levels, as in the second set of model runs (see Table At1-A.3), the implied water recovery charges shown in rows (6)

Table At1-A.2: Estimate costs and earning by crop and region.

	Irrigation water (ML per ha)	Crop yield (tonnes per ha)	Price (per tonne)	Variable cost (per ha)	Fixed cost (per ha)	Capital cost (per ha)	Annualised capital cost	Max water price
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Atherton Tablelands								
Sugarcane	4.00	1.0	$3,565	$1,410	$1,040	$3,750	$75	$260
Mango	7.00	15.0	$3,000	$34,400	$1,200	$45,000	$900	$2,125
Avocado	10.00	11.0	$4,500	$31,000	$1,200	$41,500	$830	$4,118
Banana	12.00	35.0	$1,525	$45,750	$1,200	$20,000	$400	$1,506
Citrus	8.00	28.0	$1,850	$33,970	$1,200	$41,500	$830	$3,950
Other	6.00	37.5	$660	$18,640	$1,200	$20,000	$400	$1,128
Burdekin–Bowen								
Sugarcane	14.00	116.5	$40	$1,970	$1,608	$3,750	$75	$252
Mung beans	1.50	2.0	$1,100	$660	$600	$3,750	$75	$216
Melon	5.00	50.0	$660	$25,125	$1,200	$20,000	$400	$1,569
Wheat	3.00	6.5	$320	$487	$600	$3,750	$75	$230
Pumpkins	6.00	30.0	$600	$11,400	$1,200	$20,000	$400	$1,250
Potatoes	5.00	47.5	$535	$17,565	$1,200	$20,000	$400	$1,562
Burnett								
Sugarcane	3.75	96.5	$37	$1,525	$1,040	$3,750	$75	$233
Citrus (mandarins)	7.50	28.0	$1,850	$33,970	$1,200	$41,500	$830	$3,950
Wheat	2.50	6.0	$320	$755	$600	$3,750	$75	$123
Barley	5.00	6.5	$300	$840	$600	$3,750	$75	$109
Macadamia	4.00	1.0	$4,407	$2,000	$1,200	$45,000	$900	$77
Avocadoes	10.00	11.0	$4,500	$31,000	$1,200	$41,500	$830	$4,118
Dawson–Darling								
Cotton	5.50	14.1	$421	$2,701	$600	$7,500	$150	$621
Wheat	2.50	6.0	$320	$487	$600	$3,750	$75	$190
Maize	4.30	10.0	$300	$1,235	$600	$7,500	$150	$254
Chickpea	2.50	3.0	$700	$534	$600	$7,500	$150	$204

and (7) will be lower. What is missing from Table At1-A.1 is any costing of capital works to enhance distribution networks. Any expansion of water catchment volumes is likely to exacerbate constraints on existing distribution networks.

Table At1-A.2 shows the assumed costs and earnings for each crop. The purpose of the table is to show the willingness to pay for water could be calculated, given a set of assumptions concerning capital costs, annual costs, yields, water requirements and output prices. Column (7) of the table calculates the capital cost as column (6) divided by 50. The longevity of crop-specific capital will vary from crop to crop.

Earnings per hectare = columns (2) x (3)

Costs per hectare = columns (4) + (5) + (7)

Earnings minus costs divided by the water requirement per hectare (1) provides a 'maximum' water price shown in column (8). There are several caveats concerning the table, including whether the full costs of water delivery are included in the calculations.

Nevertheless, Table At1-A.2 provides some guidance as to whether the costs of additional water per ML made available by each scheme are less than the 'maximum' water price. In Atherton Tablelands, this appears to be so except for sugarcane. However, the amount of water required by sugarcane is not fixed: In times of relative water scarcity, growers could apply less water.

Both Burdekin–Bowen and Burnett contain a mix of crops in which the indicative price shown in (8) is either side of the water cost shown in row (6) of Table At1-A.1. Terms of trade impacts may determine whether these projects are worthwhile.

In the case of Dawson–Darling Downs, the indicative water price calculated in Table At1-A.2 is far below water costs shown in Table At1-A.1.

Table At1-A.3: Cost recovery per ML of water: second set of model runs.

	Atherton Tablelands	Burdekin–Bowen	Burnett	Dawson River
(1) Cost NPV $m	333	1,854	271	1,234
(2) Water for irrigation GL	41	214	64	53
(3) Capital cost, $ per ML	8,122	8,664	4,237	23,283
(4) 50-year asset life: annual cost $m	6.66	37.08	5.42	24.68
(5) 2.5% annuity $m	8.33	46.35	6.78	30.85
(6) Required $/ML	366	390	191	1,048
(7) Annuity alone $/ML	203	217	106	582
(8) Initial higher utilisation	36	104	127	11
Indirect national gains				
(9) National terms of trade NPV $m (CC)	329	2,048	769	647

Appendix At1-B: Sources of estimated costs and earning by crop and region

(Provided by Sandro Marin, Indec)[6]

The information in the table above was sourced from various reports prepared for the Department of Regional Development, Manufacturing and Water relating to the Queensland Bulk Water Opportunities analysis in January 2020.

The basis of the approach applied by the Queensland Bulk Water Opportunities analysis in developing the required metrics was as follows:

- an assessment of documentation containing estimates of the above for each crop type across the respective regions, including previously completed studies by consultants
- AgMargins gross margin budgets
- the Queensland AgTrends 2018-19 Report
- the Australian Bureau of Statistics (ABS) Agricultural Commodities, Australia (publication 7121.0)
- publicly available reports including:
  - www.statedevelopment.qld.gov.au/coordinator-general/assessments-and-approvals/coordinated-projects/completed-projects/emu-swamp-dam-project
  - www.statedevelopment.qld.gov.au/__data/assets/pdf_file/0017/54521/Lower-Fitzroy-River-Infrastructure-Project-CBA-summary.pdf
  - www.synergies.com.au/case-studies/assessing-the-economic-value-of-bulk-water-infrastructure-in-regional-queensland/
- the economic report for the (former) Department of Natural Resources and Mines on the Lower Burdekin
- other publicly available data and information, such as regional mapping sourced from Queensland Globe/DNRME (topographical, geological, soils, crop suitability etc)
- consultation with key stakeholders during the Queensland Bulk Water Opportunities analysis, including relevant personnel from the Department of Agriculture and Fisheries, to understand how key crop parameters (i.e., irrigation application rate, crop yield) vary across regions.

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1 Under the *Water Act 2000 (Qld)*, the permanent right to water is the 'allocation' and the water available for use at a given time is the 'water access entitlement'. www.legislation.qld.gov.au/view/pdf/inforce/current/act-2000-034 and www.business.qld.gov.au/industries/mining-energy-water/water/water-markets.

2 Dixon and Rimmer, 2002

3 Horridge et al., 2018

4 era.daf.qld.gov.au/id/eprint/1649/2/1befocit.pdf,era.daf.qld.gov.au/id/eprint/1656/2/1beftrba.pdf, era.daf.qld.gov.au/id/eprint/1647/2/1bef-mango.pdf, era.daf.qld.gov.au/id/eprint/1642/13/01-bef-avo.pdf, and asmc.com.au/concerning-sugarcane-production-trends-revealed/

5 packagingeurope.com/a-sweet-alternative-plastic-mailing-bags-made-from-sugarcane/

6 Consultancy firm Indec compiled direct water infrastructure and on-farm costs used in this study together with estimates of expanded irrigated hectares and output.

Abbreviations

Abbreviation	Explanation
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
AC	Companion of the Order of Australia
ADA	Aquaculture development area
AHD	Australian height datum
AO	Officer of the Order of Australia
ASR	Aquifer Storage and Recovery
AVL	Annual volumetric limit
BAU	Business as usual
BCDF	Business Case Development Framework
BMP	Best management practice
CCAM	Conformal Cubic Atmospheric Model
CEnv	Chartered Environmentalist
CGE Modelling	Computable general equilibrium modelling
COAG	Council of Australian Governments
COAGSOWG	Council of Australian Governments Senior Officers Working Group
CoPS	Centre of Policy Studies
COVID-19	Coronavirus Disease 2019
CRCNA	Cooperative Research Centre for Developing Northern Australia
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cth	Commonwealth
CYPHA	Cape York Peninsula Heritage Area
DBC	Detailed Business Case
DNRME	(former) Department of Natural Resources, Mines and Energy
Dr	Doctor
EBA	Enterprise bargaining agreement
EFO	Environmental flow objective
EGM96	Earth gravitational model 96
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999 (Cth)*
FSL	Fully supply level
FTE	Full-time equivalents
GAB	Great Artesian Basin
GABORA	Great Artesian Basin and other regional aquifers

Abbreviation	Explanation
GCM	Global circulation model
GDP	Gross domestic product
GL	Gigalitre/s
GL/a	Gigalitre/s per annum
GOCs	Government-owned corporations
GQAL	Good quality agricultural land
GST	Goods and services tax
GVP	Gross value of production
ha	Hectare
HGL	Hydraulic grade line
HP	High priority
IA	Infrastructure Australia
IGABDR	Improving Great Artesian Basin Drought Resilience Program
IGABIIP	Interim Great Artesian Basin Infrastructure Investment Program 2018–2020
ILSC	Indigenous Land and Sea Corporation
IPCC	Intergovernmental Panel on Climate Change
IQQM	Integrated Quantity and Quality Model
ISCA	Infrastructure Sustainability Council of Australia
LNG	Liquefied natural gas
MAD	Mean annual discharge
MAR	Managed aquifer recharge
MDIA	Mareeba–Dimbulah Irrigation Area
ML	Megalitre/s
mm/a	Millimetre/s per annum
mm/d	Millimetre/s per day
MNES	Matter/s of national environmental significance
MP	Medium priority
NAWRA	Northern Australia Water Resource Assessment
NESP	National Environmental Science Program
NIAA	National Indigenous Australians Agency
NPV	Net present value
NQWIA	North Queensland Water Infrastructure Authority
NRM region	Natural Resource Management region
NWGA	National Water Grid Authority
NWGF	National Water Grid Fund
NWI	National Water Initiative

Abbreviation	Explanation
OECD	Organisation for Economic Cooperation and Development
PAF	Project Assessment Framework
PET	Potential evapotranspiration
PHS	Pumped hydro-electric storage
Prof	Professor
QBWOS	*Queensland Bulk Water Opportunities Statement*
QFF	Queensland Farmers' Federation
Qld	Queensland
RAPAD	Remote Area Planning and Development
RCM	Regional climate model
RCP	Representative Concentration Pathway
RD&E	Research, development and extension
RDCs	Research and development corporations
REDOs	Regional economic development organisations
ROCs	Regional organisations of councils
RWG	Regional Water Grid
SA3	Statistical Area Level 3
SDA	State development area
SDGs	Sustainable Development Goals
SDPWO Act	*State Development and Public Works Organisation Act 1971 (Qld)*
SPP	State Planning Policy
SIS	State Infrastructure Strategy
t/ha	Tonne/s per hectare
TBMs	Tunnel boring machines
TEL	Townsville Enterprise Limited
The Grid	The National Water Grid
The panel	The Bradfield Regional Assessment and Development Panel
UAW	Unallocated water
UNFCCC	United Nations Framework Convention on Climate Change
W/m2	Watt per square metre
WASOs	Water allocation security objectives
WATER Development Zone	Water Agri-business Technology Energy Region (WATER) Development Zone
WP	Water plan
WSAA	Water Services Association of Australia
WSS	Water Supply Scheme

Glossary of terms

Term	Definition
Aquifer	A saturated underground geological formation or group of formations that can store water and yield it to a bore or spring. A saturated formation that will not bring water in usable quantities is not considered an aquifer.
Artesian water	Water that occurs naturally in, or is introduced artificially into, an aquifer, which if tapped by a bore, would flow naturally to the surface.
Available water	The amount or volume identified in a water plan area that is not already allocated for consumptive purposes or required to ensure a healthy environment. For example, a water plan may identify an available water volume as unallocated water.
Basin	The total area from which water drains to a river system, or a grouping of adjacent river systems. In geological terms, a basin is defined as either a broad tract of land in which the rock strata are tilted toward a common centre, or a large bowl-shaped depression in the surface of the land or ocean floor (such as the Great Artesian Basin).
Bore	A hole drilled to extract, recharge, monitor or investigate groundwater resources. In legislation such as the *Water Act 2000*, it is defined as a shaft, well, gallery, spear or excavation and any works constructed in connection with the shaft, well, gallery, spear or excavation, which taps the aquifer.
Bulk water storage	Infrastructure for storing large amounts of water e.g. a dam usually managed by a bulk water provider.
Business case	The Queensland Government's *Business Case Development Framework* provides evidence for investing in an infrastructure project. Business cases are comprised of three stages: 1. Strategic Assessment: identifies the service need and provides a long list of options that may be viable. 2. Options Analysis: narrows the list of options through robust analysis 3. Detailed Business Case: evaluates the viability of the highest ranked option or options to provide clear, comprehensive evidence for decision-makers.
Catchment	An area, bounded by natural topographic features such as hills or mountains, from which a drainage system derives its water.
Centre of Policy Studies (CoPS)	A think tank of academics and professionals who undertake research and analyse a range of policy challenges and issues. CoPS is associated with the Victoria University.
Climate change	The cumulative effect of many different components, including atmospheric concentrations of greenhouse gases and the amount of solar radiation the earth receives and retains. Factors influenced by climate include temperature rainfall, evaporation, sea levels, ocean acidity and environmental functions.
Computable general equilibrium (CGE) modelling	A class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors.
Consumptive use	The use of water for private benefit, consumptive purposes including economic, irrigation, industry, urban, and stock and domestic use (Australian Bureau of Statistics and National Water Initiative definition).

Term	Definition
CopperString	A proposed high-voltage overhead electricity transmission line that would connect the North West Minerals Provence and Mount Isa to the National Electricity Market grid south of Townsville. The transmission line would run from a new sub-station at Woodstock, south of Townsville, to the Chumvale sub-station, near Cloncurry. Subject to demand, the line may extend west to Mount Isa and south to existing and potential mining operations.
Crop Suitability Tool	An online tool from Queensland Government that shows the location and details for land that is suitable for growing different irrigated crop types.
CSIRO	The Commonwealth Scientific and Industrial Research Organisation is an Australian Government agency.
Dam	Works that include a barrier, whether permanent or temporary, that does (or could or would) impound, divert or control water; and the storage area created by the work.
Detailed Business Case	Refer to the definition of business case stages.
Distribution losses	Water that is lost when delivering water for water allocations in reticulated areas via constructed infrastructure through processes such as (but not limited to) evaporation, seepage, pipeline leakage, accidental loss through temporary pipe failure (breaks), loss through pressure relief systems and scouring.
Diversion	Diverting the course of water in a watercourse outside of its bed and banks.
Domestic consumption	The consumption of water for normal household purposes in domestic premises situated on the land.
Earth gravitational model 96 (EGM96)	Earth gravitation models are a series of geopotential models of the Earth, published by the United States of America's National Geospatial Intelligence Agency. EGM96 is a model that was developed in 1996 that contains surface gravity data from many different regions of the globe.
Entitlement	A right to take, use, extract or have water under a water licence or water allocation that may be limited by conditions. Different entitlements are necessary depending on where and how water is taken, and what it is then used for.
Environmental flow	Any river flow pattern provided with the intention of maintaining or improving river health.
Environmental flow objectives	A flow objective stated in a water plan to protect the share of water available to the environment.
Environmental flow requirements	Requirement to meet an environmental flow objective under a water plan.
Ephemeral stream	Watercourses that do not have surface water flow for the entire year. They are also called: seasonal streams, intermittent or fleeting streams, episodic streams or temporary streams.
Evapotranspiration	The term used to describe the part of the water cycle that removes liquid water from an area with vegetation and into the atmosphere by the processes of both transpiration and evaporation.
Extraction	The act of taking water from a stream or storage.

Term	Definition
Free, prior and informed consent (FPIC)	Australian law recognises that Aboriginal and Torres Strait Islander people have rights and interests in the land and sea under their traditional laws and customs—that they are Traditional Owners. Any engagement processes need to be based on the principles of free, prior and informed consent (FPIC) that recognise the critical decision making role of Traditional Owners. A central element of FPIC is genuine inclusion, disclosure and respect for Indigenous Peoples' decision-making processes. The three elements (free, prior and informed) qualify and set the conditions of consent as a decision-making process. In the native title context, consent refers to the decisions made by the Traditional Owners being reached through their customary decision-making processes. FPIC is not merely informing and getting consent, it is about effective and meaningful participation to ensure the best decision making for sustainable outcomes—especially where intergenerational decisions are involved.
Global circulation model (GCM)	Mathematical representations of the climate system run on powerful computers. Their fundamentals are based on the laws of physics, including conservation of mass, energy and momentum. GCMs are closely related to models used for daily weather prediction.
General reserve	General reserve water is a type of unallocated water reserved under a water planning instrument. Unallocated water can be made available for future use without compromising the security of existing users or the environmental values within a catchment. General reserve unallocated water can be made available for any purpose.
Greenhouse gas	Atmospheric gases are known as greenhouse gases, and include carbon dioxide, nitrous oxide, methane and ozone, among others. These gases form the Earth's atmosphere and regulate the amount of solar radiation land surfaces and oceans receive, helping to regulate the Earth's climate. Measuring greenhouse gas levels is an important starting point to model current and future climate. Human activities contribute to greenhouse gases in the atmosphere.
Groundwater	Water occurring naturally below ground level (whether stored in or flowing through aquifers or within low-permeability aquitards), or water occurring at a place below ground that has been pumped, diverted or released to that place for storage there. This does not include water held in underground tanks, pipes or other works.
High-priority users	Users of high-priority water. High-priority water allocations are the most reliable water allocation and are typically used for town water supply, industrial use, including mining and power generation, and for high-value cropping. High-priority water allocation holders can usually access water more frequently and with fewer restrictions than holders with medium-priority water. During extended dry periods, high-priority water allocations are the last group to be placed on restrictions. High-priority water allocation holders pay higher fees and charges than those with medium-priority water allocations so they can have more reliable access.
Hydraulic gradient	The slope of the water surface. The hydraulic gradient indicates which direction groundwater will flow, and how rapidly. Water always will flow from higher water surface elevations (or pressure) to lower water surface elevations (or pressure).
Hydrologic model	A hydrologic model is a simplification of a real-world system (e.g. surface water, soil water, wetland, groundwater, estuary) that aids in understanding, predicting and managing water resources. Both the flow and quality of water are commonly studied using hydrologic models.
Hydrology	Refers to the physical movement of a body of water either on the surface or underground and includes changes in water level and flow rates (including timing and duration, flow direction and other dynamic processes).

Term	Definition
Indigenous strategic reserve	A type of unallocated water reserved under a water planning instrument. Unallocated water can be made available for future use without compromising the security of existing users or the environmental values within a catchment. Indigenous reserve unallocated water can be made available for projects that advance the social and economic aspirations of Indigenous people.
Inflows	A volume of water flowing into a defined location from a defined source.
In-stream	In-stream use refers to taking place within a stream channel.
Integrated Quantity and Quality Model (IQQM)	A computer program, and associated statistical analysis and reporting programs, that simulate daily stream flows, flow management, storages, releases, in-stream infrastructure, water diversions, water demands and other hydrologic events in the plan area.
Isohyet	A term used to describe lines on a map or chart showing places of equal rainfall. Commonly used for weather maps.
Medium-priority users	These are water users that hold medium-priority water allocations. Medium-priority water allocations are a type of water allocation supplied by a water supply scheme operator. Medium-priority water allocations have lower reliability than high-priority water allocations and are mainly used for agriculture. This means that, during drier conditions and when storage levels are low, these water allocations are often the first to be restricted.
Model (hydrologic)	A computer program that simulates streamflows, water losses, storages, releases, in-stream infrastructure, water diversion and water management rules within a river system.
Modelling	Application of a mathematical process or simulation framework (such as a mathematical or econometric model) to describe various phenomena and analyse the effects of changes in some characteristics on others.
Murray–Darling Basin	The Murray–Darling is Australia's most significant river system. Its basin covers parts of Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory.
National Water Commission (NWC)	An independent statutory authority in Australia established by the *National Water Commission Act 2004* to implement the National Water Initiative and reform the broader national water agenda. The Commission reported to the Department of Sustainability, Environment, Water, Population and Communities portfolio, and provided independent, evidence-based advice to the Council of Australian Governments and the Australian Government on national water issues. The Commission was abolished by the *National Water Commission (Abolition) Act 2015* in October 2014. The key functions of the Commission were transferred to other existing Commonwealth agencies, such as the Productivity Commission and the Department of Environment.
National Water Initiative (NWI)	The National Water Initiative, agreed in 2004 by the Council of Australian Governments is the national blueprint for water reform. The NWI is a shared commitment by governments to increase the efficiency of Australia's water use, leading to greater certainty for investment and productivity, for rural and urban communities and for the environment. The NWI built upon the 1994 *COAG Water Reform Framework*. Under the NWI, governments commit to: • prepare comprehensive water plans • achieve sustainable water use in over-allocated or stressed water systems • introduce registers of water rights and standards for water accounting • expand trade in water rights • improve pricing for water storage and delivery • better manage urban water demands.

Term	Definition
National Water Reform Committee (NWRC)	An interjurisdictional committee that considers and progresses national water reforms of the NWI and other national agreements. The work of the NWRC promotes sustainable water use across Australia to enhance social, human health, economic and environmental outcomes for current and future generations, and support sustainable water management through interjurisdictional development, oversight, coordination and implementation of water reform policy.
Native title	The recognition in Australian law that some Indigenous people continue to hold rights to their land and waters, based on their traditional laws and customs. By legal definition, it means "the communal, group or individual rights and interest of Aboriginal peoples or Torres Strait Islanders in relation to land or waters".
Net zero emissions	An overall balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere.
Non-consumptive water requirements	Non-consumptive use is when there is no diversion from or diminishment of the resource, for example water used to generate hydro-electricity. Held and planned environmental water is a non-consumptive water use.
Offstream storage	Generally constructed from earth and rockfill outside the bed and banks of the water course and are utilised to store water by pumping from the adjacent water course during run off events.
Overland flow	Water, including floodwater, flowing over land, other than in a watercourse or lake, after having fallen as rain or after rising to the surface naturally from underground, or in any other way.
Pan evaporation	A measurement of evaporation that combines or integrates the effects of several climate elements: temperature, humidity, rain fall, drought dispersion, solar radiation and wind.
Paris goals	Relate to the *Paris Agreement*, a global agreement to limit global warming to well below two degrees Celsius (2°C) above pre-industrial times, and as close to 1.5°C as possible. Achieving the Paris objectives involves decarbonisation of the global economy by 2050.
Plan area	The whole of the area to be managed under a water plan.
Pre-development flow	Pre-development water flow represents the natural flows present in the river system or catchment area. The term pre-development is used in water planning and modelling of impacts to indicate what flows to the environment would be if there was no water resource development (such as dams and irrigation).
Preliminary business case	Refer to the definition of business case.
Queensland's Water Planning Framework	The water planning framework enables water in our rivers, lakes, springs and underground to be sustainably managed across Queensland. Water plans are developed in accordance with a broader legislative framework that assists Queensland to sustainably manage its water resources. The overarching legislative document is the *Water Act 2000*. There are several regulatory documents that provide for the sustainable allocation and management of water that forms Queensland's water planning framework. These documents include water management protocols, resource operations licences, water supply scheme operation manuals and water entitlement notices.
Queensland Bulk Water Opportunities Statement **(QBWOS)**	The QBWOS is the bulk water security strategy and direction statement for Queensland. It is one of five strategic infrastructure documents outlined in the *State Infrastructure Plan*.

Term	Definition
Ramsar Convention	The *Convention on Wetlands of International Importance* (known as the Ramsar Convention) was adopted in 1971 in the Iranian city of Ramsar. The convention aims to halt the worldwide loss of wetlands and to conserve remaining wetlands through wise use and careful management. The Ramsar Convention encourages the designation of sites containing representative, rare or unique wetlands, or wetlands that are important for conserving biological diversity. Australia was one of the first signatories.
Regional climate model (RCM)	Factors that shape a region's climate include temperature, rainfall, humidity, cloud-cover, wind and solar radiation, which in turn affect the amount of water available in that area's springs, rivers, lakes and open storages (such as dams). Before the impact of climate risks on water resources can be identified, regional climate modelling is needed to understand the likely changes to rainfall, temperature and evaporation. Regional models are calibrated using historical data inputs to successfully reproduce past weather events and climate condition. Once this is achieved, general circulation model outputs can be applied to simulate how those temperature, rainfall and evaporation changes would affect a region.
Representative Concentration Pathways (RCPs)	Describe different potential climates futures depending on future greenhouse gas levels. Four RCPs are used in Australian modelling to map climate trajectories and to produce a range of outcomes.
Riparian	The area adjacent to a watercourse e.g. the bank of a natural waterway.
Riverine	Refers to the physical environment and ecosystems connected to rivers and their flood plains.
Seasonal flows	The basis for allocations in unregulated systems. Once predetermined flow conditions are met, water may be taken. Extraction of water is limited by placing restrictions on maximum daily extraction, and the timing of extractions.
Strategic business case	Refer to the definition of business case.
Strategic reserve	A type of unallocated water reserved under a water planning instrument (also known as a state reserve). Strategic reserve water can be made available for projects that the state considers to be of regional significance for the plan area, or for coordinated projects under the *State Development and Public Works Organisation Act 1971*.
Stream morphology	Describes the shapes of stream channels and how they change in shape and direction over time due to sedimentation and erosion processes.
Streamflow	An amount of water passing a defined stream location over time.
Sub-artesian water	Water that occurs naturally in, or is introduced artificially into an aquifer, which, if tapped by a bore, would not flow naturally to the surface. A pump is needed to extract this water.
Sub-catchment area	Sub-catchments are separated by a raised ridge or natural boundary within a catchment. In general, surface water does not flow from one sub-catchment to another, however in relatively flat areas flood waters may cross a sub-catchment boundary. In some cases, groundwater may cross sub-catchment boundaries due to the underlying geology.
Supplemented water	Water that is supplied from water infrastructure as part of a water supply scheme.
Supplemented water allocation	The right to take water supplied from water infrastructure as part of a water supply scheme.
Surface water	Water that is on the earth's surface, such as in a watercourse, spring, lake or reservoir.
Sustainable management	Management that allows for the allocation and use of water for the physical, economic and social wellbeing of people within limits that can be sustained indefinitely while protecting the biological diversity and health of natural ecosystems.

Term	Definition
Take	The removal of water from, or the reduction in flow of water into, a water resource.
Traditional Owners	Australian law recognises that Aboriginal and Torres Strait Islander people have rights and interests in the land and sea under their traditional laws and customs: that they are Traditional Owners.
Transmission losses	Losses from surface water (other than into defined groundwater systems) as it flows from one location in a system to another. This can include evaporation, seepage, and uptake by plants and unauthorised usage.
Unallocated water or water reserve	The volume of water set aside under water planning instruments that can be made available for future use without compromising the security of existing users or the environmental values within a catchment.
Unsupplemented water	Refers to water in a watercourse that is not supplemented from water infrastructure as part of a water supply scheme.
Unsupplemented water allocation	The right to take water that is not supplied by water infrastructure as part of a water supply scheme.
Volumetric limit	For a water licence, this means the maximum volume of water, in megalitres, that may be taken under the licence during a water year.
Water Act 2000 (Qld)	A law made by the Queensland Parliamentary process.
Water allocation	An authority granted under the Water Act to take a volumetric share of a water resource.
Water allocation security objectives (WASOs)	Objectives that may be expressed as performance indicators and are stated in a water plan to ensure protection of a water entitlement to obtain water in accordance with a water allocation.
Water allocation	The specific volume of water allocated to water access entitlements in a given season, defined according to rules established in the relevant water plan.
Water authorisation	A water licence, water permit, interim water allocation, water allocation or other authority to take or interfere with water under the Water Act.
Water discharge	The rate at which a volume of water passes through a cross-section per unit of time; measured in cubic metres per second (m^3/s) or in megalitres per day (ML/d).
Water entitlement	A right to take water e.g. a water allocation, interim water allocation or water licence. On occasion, the panel uses the term to refer to tradeable water entitlements (i.e. water allocations).
Water infrastructure	A broad term for systems of water supply, treatment, storage, water resource management, flood prevention and hydropower.
Water licence	An authority to take or interfere with the flow of water.
Water plan	A plan that applies to a part of the state to advance the sustainable management of water in that area.
Water plan area	The area covered by a water plan.
Water resource plan	The panel has used this term and water plan interchangeably throughout the report. Refer to the definition of water plan above.
Water service provider (WSP)	A person or organisation registered under the *Water Supply (Safety and Reliability) Act 2008* as a service provider for a water service.

Term	Definition
Water-sharing arrangements	Describe the arrangements under which access to water in an area is managed.
Water supply scheme (WSS)	Combinations of dams, weirs, pipelines, channels and other storage or water delivery infrastructure, operated conjunctively to supply water to supplemented water allocations.
Water trading	The act of seasonally or permanently transferring water allocations.
Zero-carbon economy	In a zero-carbon economy, there is no production of carbon emissions from a product or service. Therefore, there is no need to capture or offset carbon pollution or emissions.

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