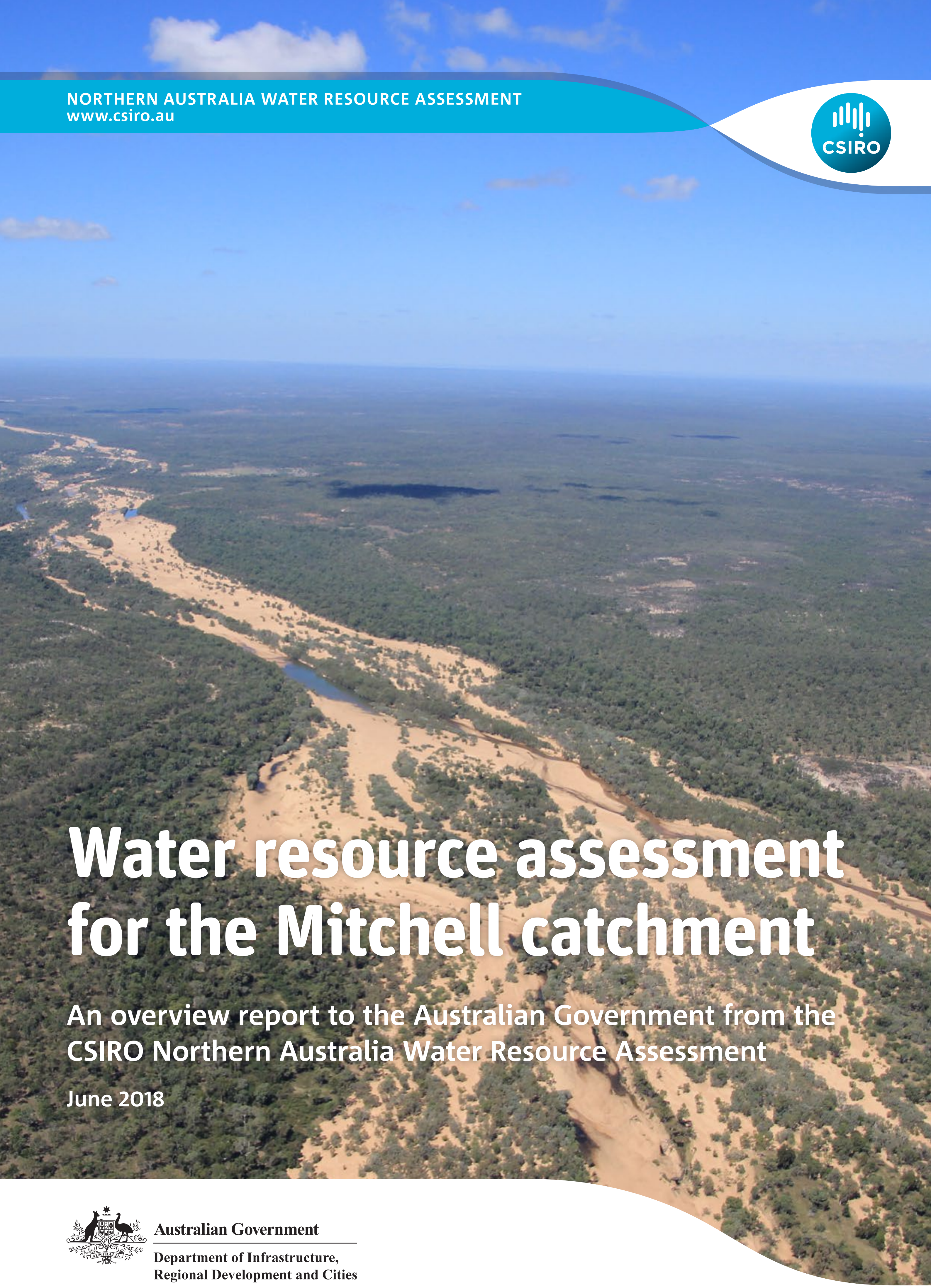

NORTHERN AUSTRALIA WATER RESOURCE ASSESSMENT
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Water resource assessment for the Mitchell catchment

An overview report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment

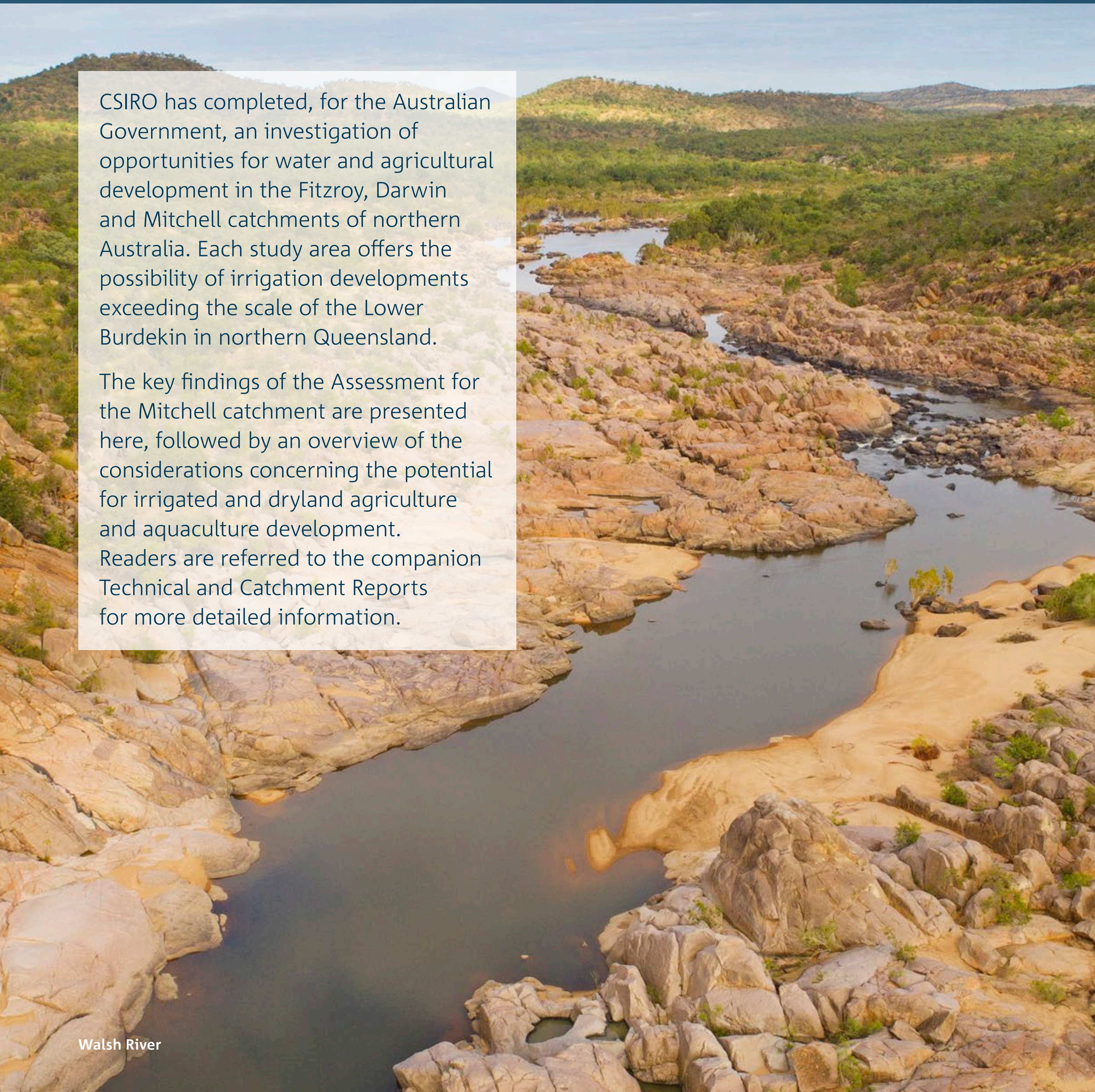
June 2018

Australian Government
Department of Infrastructure, Regional Development and Cities

The Northern Australia Water Resource Assessment

CSIRO has completed, for the Australian Government, an investigation of opportunities for water and agricultural development in the Fitzroy, Darwin and Mitchell catchments of northern Australia. Each study area offers the possibility of irrigation developments exceeding the scale of the Lower Burdekin in northern Queensland.

The key findings of the Assessment for the Mitchell catchment are presented here, followed by an overview of the considerations concerning the potential for irrigated and dryland agriculture and aquaculture development. Readers are referred to the companion Technical and Catchment Reports for more detailed information.



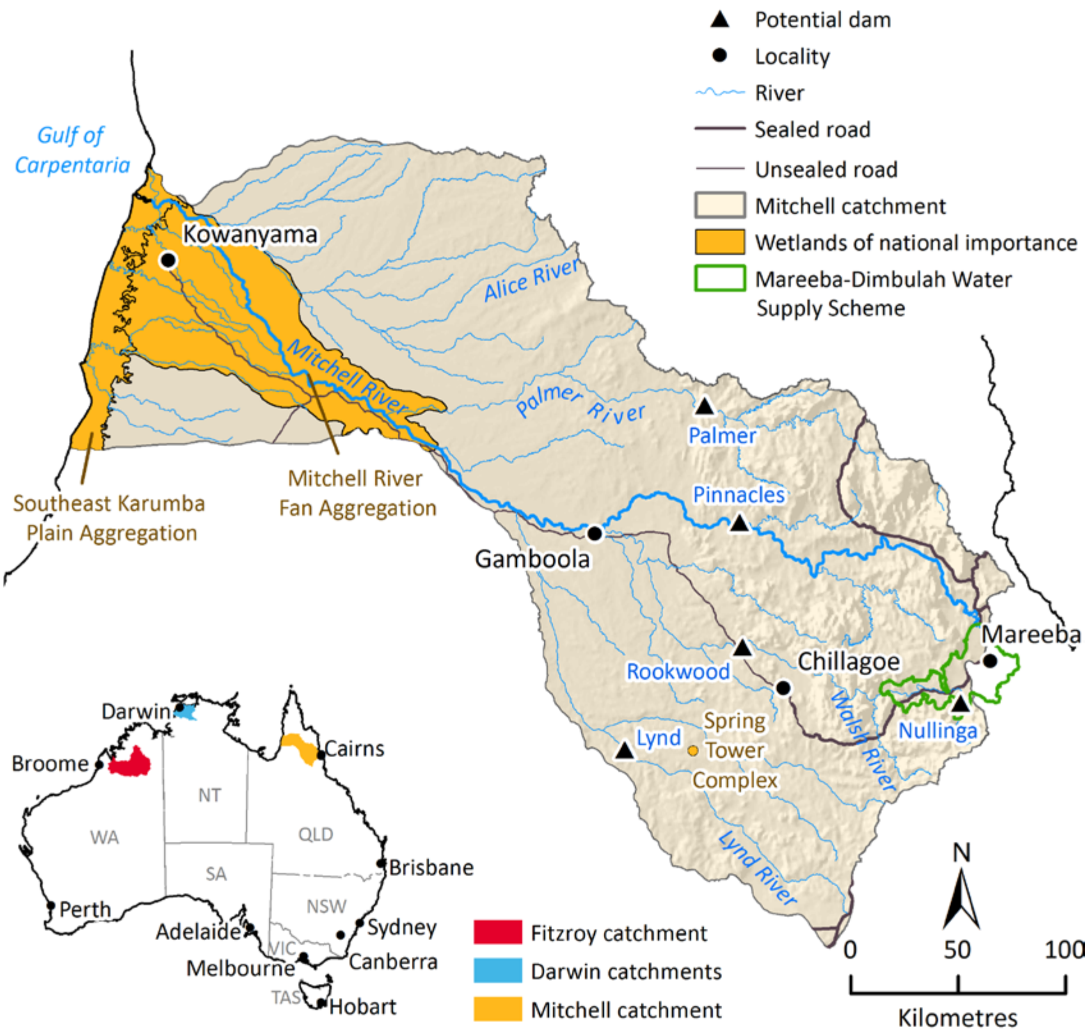
Walsh River

CITATION

CSIRO (2018) Water resource assessment for the Mitchell catchment. An overview report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments. CSIRO, Australia.

This is an overview of the following report: Petheram C, Watson I, Bruce C, Chilcott C (eds) (2018) Water resource assessment for the Mitchell catchment. A report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments. CSIRO, Australia.

- The three study areas support diverse land uses and contain largely free-flowing rivers that currently sustain areas of high biodiversity, cultural and aquatic ecological value, and support valuable industries.
- The Assessment identified that:
  – The Fitzroy, Darwin and Mitchell catchments differ significantly in their physical and social characteristics and, as a consequence, the extent to and methods by which agricultural development might occur.
  – In the Fitzroy catchment, water harvesting (water pumped into ringtanks) could potentially support 160,000 ha growing one dry-season crop a year in 85% of years. Independent of surface water, groundwater could potentially support up to 30,000 ha of hay production in all years.
  – In the Darwin catchments, a combination of major dams, farm-scale offstream storage and groundwater could potentially support up to 90,000 ha of dry-season horticulture and mango trees.
  – In the Mitchell catchment, large instream dams could potentially support 140,000 ha of year-round irrigation. Alternatively, water harvesting could potentially enable up to 200,000 ha, growing one dry-season crop per year.
- If irrigated opportunities were pursued to their fullest extent they would only occupy about 3% of the Assessment area. Impacts on ecological function are not confined to the direct development footprint and would warrant attention, especially immediately downstream of development and in drier years.
- Understanding how diverse stakeholder, investor and developer perspectives interact will be crucial in building and maintaining ongoing social licence to operate for future water and agricultural development.



The Mitchell catchment

Key findings for the Mitchell catchment


Soil sampling using a hydraluic corer near the Walsh River in the upper catchment

The Mitchell catchment is approximately 72,000 km² and flows into the Gulf of Carpentaria. It includes part of the Mareeba–Dimbulah Water Supply Scheme (MDWSS) and supports a population of approximately 6000 people. There are no major urban centres. Pastoralism comprises over 95% of the catchment land use. The second largest land use, conservation reserves, covers about 3% of the catchment.

Indigenous people have continuously occupied and managed the Mitchell catchment for tens of thousands of years and retain significant and growing rights and interests in land and water resources, including crucial roles in water and development planning and as co-investors in future development.

Agriculture and aquaculture opportunities

The Mitchell catchment has up to 3 million ha of potentially irrigable agricultural soils. Of this land area, 2.5 million ha are suitable for dry-season spray irrigation of cereals, cotton and soybean. The area suitable for furrow irrigation of the same crops is 1.3 million ha. There are 2.5 million ha and 1.3 million ha suitable for irrigation of sugarcane by spray and furrow irrigation, respectively. Just over 3 million ha are suitable for Rhodes grass with spray irrigation and 600,000 ha suitable for wet-season forage sorghum with spray irrigation. About 235,000 ha are suitable for aquaculture, such as prawns and barramundi grown in lined ponds. For all of these uses the land is considered moderately suitable with considerable limitations and would require careful soil management.

The total amount of beef produced each year by existing cattle breeding enterprises could be increased by using irrigated forages to overcome some of the productivity constraints inherent with reliance on native pastures. Access to standing green forage or high-quality hay could increase weight gain in young cattle and enable early weaning of calves which, in turn, increases subsequent calving percentage by reducing nutritional pressure on lactating cows.

Significant new instream storages are possible. The four most cost-effective major instream dams in the Mitchell catchment are capable of delivering approximately 2800 GL in 85% of years, which is sufficient water to irrigate 140,000 ha of sugarcane. This could generate an annual gross value of production of approximately $720 million, and the region would benefit from $1.5 billion of economic activity reoccurring annually and the generation of about 7250 jobs.

Of the 2800 GL, 65% could be delivered by two potential dams, the Pinnacles dam site on the Mitchell River (2316-GL capacity) and Rookwood dam site on the Walsh River (1288-GL storage). These would yield 1248 GL and 575 GL, respectively, to agriculture in 85% of years.

Offstream water harvesting could extract 2000 GL annually, with 85% reliability, which would be sufficient to irrigate 200,000 ha of cotton. Groundwater opportunities in the catchment are relatively small and localised, with the Bulimba aquifer offering up to a total of 5 GL/year with well-placed bores.

Impacts and risks

Whether based on groundwater or offstream storage, irrigated agricultural development has a wide range of potential benefits and risks that differentially intersect diverse stakeholder views on ecology, economy and culture. The detailed reports upon which this summary is based provide information that can be used to quantify the trade-offs required for agreed development plans.

Instream storages, such as the potential Pinnacles and Rookwood dams, require trade-offs that occur over both time and space. The upfront cost of the potential Pinnacles dam is estimated at $755 million and would generate an income stream that may contribute to the cost of construction. The dam would have a major impact on habitat immediately below the dam, and would potentially have an ongoing moderate impact downstream by affecting the perennial flow of the Mitchell River. Pumping water into offstream storages (water harvesting) was predicted to have a minor impact to the flow habitat of freshwater aquatic, riparian and marine ecosystems. Offstream water storages usually have lower impacts than major instream dams, partly because water extraction occurs during floods and is restricted in low-flow periods. Streams, wetlands and riparian areas remain of critical importance to Indigenous people. They have cultural significance and provide nutritional food.

Overview of the Mitchell catchment

A highly variable climate

Tropical storm clouds

The world's tropics are united by their geography but divided by their climates. Northern Australia's tropical climate is unique for the extremely high variability of rainfall between seasons and especially between years. This has major implications for the assessment and management of risks to development, infrastructure and industry.

The climate of the Mitchell catchment is hot and semi-arid to dry subhumid. Generally, it is a water-limited environment and, as such, efficient and effective methods for capturing, storing and using water are at a premium.

- The mean and median annual rainfall – averaged across the Mitchell catchment – are 996 mm and 1002 mm, respectively. There is a strong rainfall gradient that runs from the flat north-west coastal corner (1300 mm annual mean) to the hilly south-east corner of the catchment (700 mm annual mean).
- Averaged across the catchment, 4% of rainfall occurs in the dry season (May to October). However, along the easternmost margins of the catchment, including in the MDWSS, low monthly rainfall totals (20 to 50 mm per month) occur throughout the dry season.
- Annual rainfall totals in the Mitchell catchment are unreliable against both national and global benchmarks; these totals are approximately 1.3 times more variable year on year than in comparable parts of the world.

The seasonality of rainfall presents challenges for both wet- and dry-season cropping.

- While annual rainfall is not always reliable, farmers and water managers can manage risk by using seasonal rainfall outlooks. Seasonal rainfall outlooks in January can be made with 65% skill.
- Important information about water availability (i.e. soil water and water in dams) is available when it is most important agriculturally – before planting time for most crops. By this means farmers can manage risk by choosing crops that optimise use of the available water, or by deciding to forfeit cropping.

Rainfall is difficult to store.

- Potential evaporation is higher than rainfall and exceeds 1500 mm over most of the catchment.
- Large farm-scale ringtanks lose about half their capacity to evaporation and seepage between April and December. Deeper farm-scale gully dams lose about 20% of their capacity over the same period. Using stored water early in the season is the most effective way to reduce losses.

No trend in annual rainfall is evident over the Mitchell catchment.

- Paleo-climate records indicate past climates have been both wetter and drier.
- Climate and hydrology data that support short- to medium-term water resource planning should encapsulate the full range of likely/plausible conditions and variability at different time scales, and particularly for periods when water is scarce. These are the periods that most affect businesses and the environment.
- Detailed scenario modelling and planning should be broader than just comparing a single climate scenario to an alternative future.

The Mitchell catchment has large areas of agriculturally suitable land protected from the most destructive cyclonic winds by their distance inland.

- Tropical cyclone season in the Mitchell catchment is between November and April and, while the storms bring rainfall, the winds that harm perennial tree crops are generally limited to the coastal regions.
- On average, the Mitchell catchment receives at least one cyclone in 75% of years. Between 1970 and 2016, a single cyclone occurred in 49% of years and two or more in 25% of years.

Climate change is unlikely to pose significant limitations to irrigated agriculture in the Mitchell catchment.

- For the Mitchell catchment, 24% of climate models project a drier future for the Mitchell catchment, 33% project a wetter future and 43% are within ±5% of the historical mean, indicating 'little change'. Recent research indicates tropical cyclones will be fewer but more intense in the future, though uncertainties remain.
- Annual variability, particularly in rainfall, is likely to pose the greatest climate challenge for irrigated agriculture.
- Future changes in temperature, vapour pressure deficit, solar radiation, wind and carbon dioxide will result in positive and negative changes to crop applied irrigation water and yield under irrigation in northern Australia. However, changes to irrigated crop applied irrigation water and yield under future climates are likely to be modest compared to improvements arising from new crop varieties over the next 40 years. These changes will be large and are unpredictable.

Burke Developmental Road crossing the Walsh River near Gamboola during the late dry season

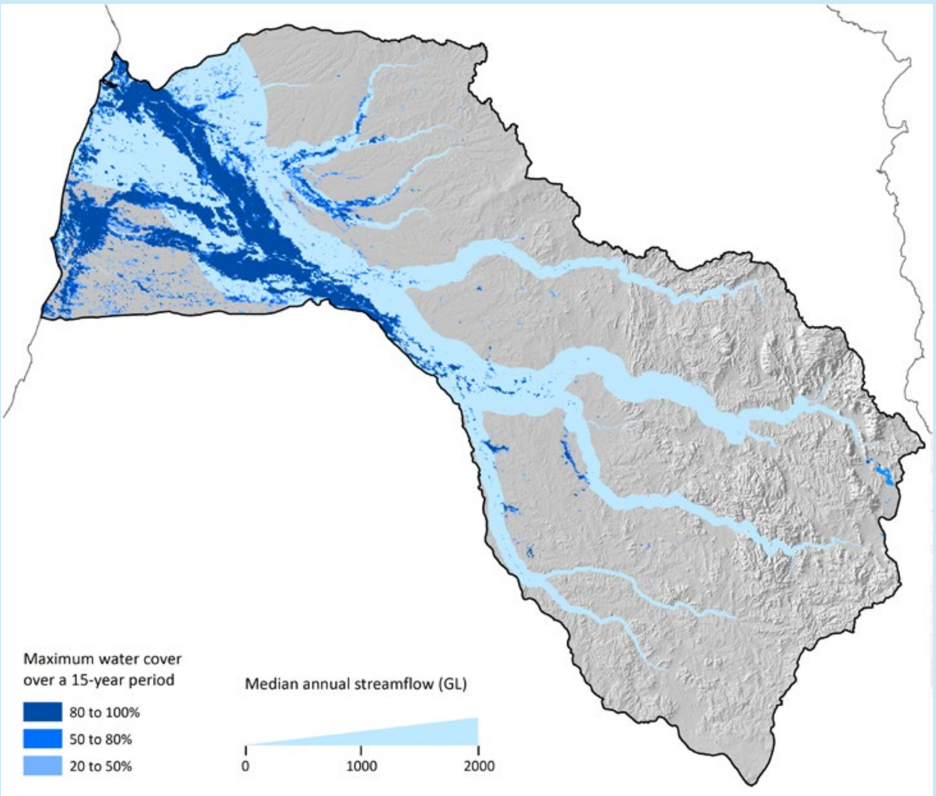
The Mitchell River

The Mitchell River has the largest median annual streamflow of any river in northern Australia. It flows into the Gulf of Carpentaria, an important part of northern Australia's marine environment with high ecological and economic values.

- The mean annual streamflow from the Mitchell catchment into the Gulf of Carpentaria is 15,570 GL. A small proportion of very wet years bias the mean, such that it is 20% higher than the median annual streamflow.
- Annual variability in streamflow is comparable with other rivers in Australia that have similar mean annual runoff, but two to three times greater than rivers from the rest of the world in similar climates.
- Approximately 95% of the runoff in the Mitchell catchment occurs during the wet season. This means that in the absence of suitable groundwater, irrigation during the dry season will require surface water storage.

Broadscale flooding is common below the confluence of the Palmer and Mitchell rivers.

- The current apex of the Mitchell River Fan Aggregation, a series of alluvial plains of varying geological ages, is located near the confluence of the Palmer and Mitchell rivers. Below the apex flood flows spread extensively across a large number of distributary channels.
- Although large areas of potential agricultural soil below the apex are prone to broadscale flooding and access limitations, there are large areas of land above the confluence of the Palmer and Mitchell rivers that do not regularly flood.
- Of the ten largest flood events over the last 35 years at Gamboola, a gauging station about halfway down the catchment, one event occurred during January, six in February and three in March. Even with flood protection, sowing on the flood-prone areas of the Mitchell Fan Aggregation before April is challenging due to access limitations.
- Flooding is ecologically critical because it connects offstream wetlands to the main river channel, allowing the exchange of fauna, flora and nutrients required for wetland survival.
- Floods are economically critical because they underpin the health of the recreational and commercial fisheries in the Gulf of Carpentaria, including a barramundi fishery and the Northern Prawn Fishery, whose catch of prawns was worth $107 million in 2015.



Historical (1890 to 2015) median annual streamflow and flood inundation (between 2000 and 2015) based on Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data in the Mitchell catchment

Indigenous values, rights and development goals

Indigenous people are a significant and growing population of the Mitchell catchment.

- Traditional Owners have recognised native title and cultural heritage rights, and control significant natural and cultural resources, including land, water and coastline.
- Water-dependent fishing and hunting play a key health and economic role for Indigenous people in the Mitchell catchment. The river supports food security and good nutrition, particularly at Kowanyama where incomes are low and food costs are high.
- The history of pre-colonial and colonial patterns of land and natural resource use in the Mitchell catchment is important to understanding present circumstances. This history also informs responses by the Indigenous people to future development possibilities.

From an Indigenous perspective, ancestral powers are still present in the landscape and intimately connect people, country and culture.

- Those powers must be considered in any action that takes place on country.
- Riverine and aquatic areas are known to be strongly correlated with cultural heritage sites.
- There are current cultural heritage considerations that restrict Indigenous capacity to respond to development proposals.

Native title and Indigenous land use agreements are important ways in which Indigenous interests in country are recognised and managed. Securing native title remains an important development goal for Indigenous people in the Mitchell catchment.

- Indigenous people established the first catchment management group in the Mitchell catchment and have strong expectations for ongoing involvement in water, catchment and development planning.
- Should development of water resources occur, participants in this study area generally preferred flood harvesting, which would fill offstream storages. Large instream dams in major rivers were consistently among the least preferred options.
- Indigenous people have business development objectives designed to create opportunities for existing residential populations and to aid the resettlement and return of people currently living elsewhere.
- Indigenous people want to be owners, partners, investors and stakeholders in any future development. This reflects their status as the longest term residents with deep inter-generational ties to the catchment for the foreseeable future.

Our wetlands provides bush tucker for future generations, when we die we want our kids living like that. Not living off whiteman's tucker, (but) free tucker. Got to have water or this country would be dead.

Mitchell catchment Traditional Owner

We need state, federal and local governments to take us seriously to develop Traditional Owner economic opportunities. We need investment in our region that includes Traditional Owners.

Mitchell catchment Traditional Owner

The Mitchell catchment supports high-value conservation, recreational and commercial uses

The Mitchell catchment is largely intact, though it is not pristine.

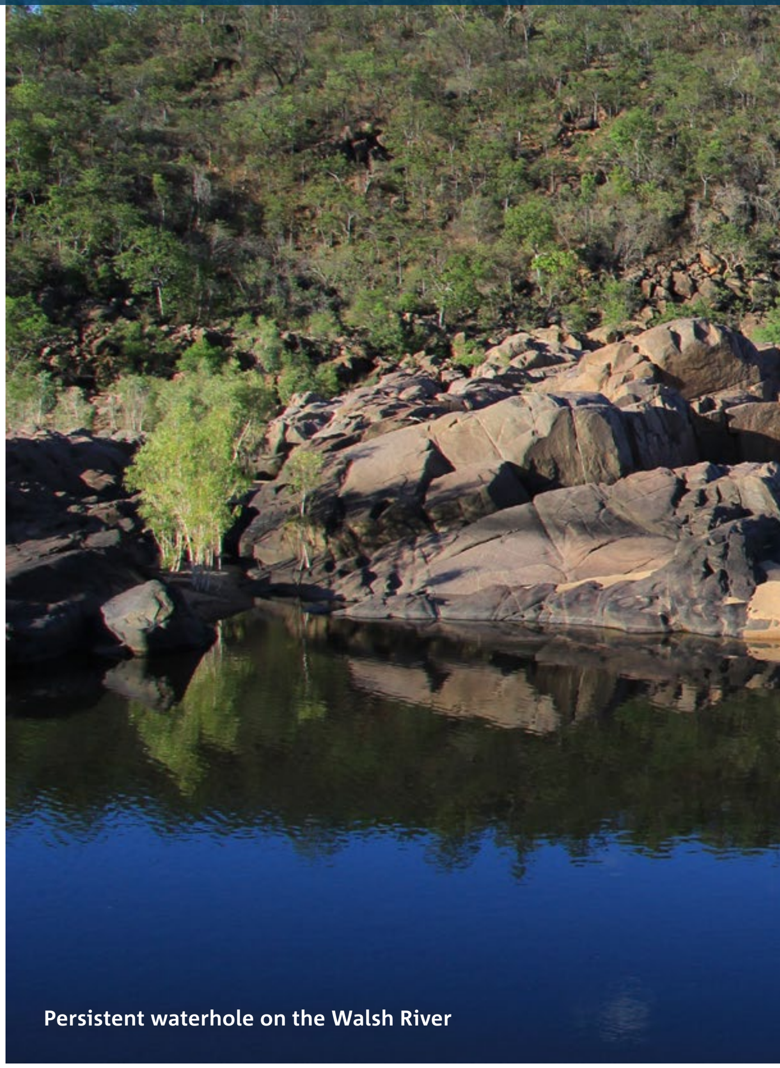
- The rivers of the Mitchell catchment mainly flow freely. Interruptions to flow have been restricted to the creation of Lake Mitchell in the upper reaches of the Mitchell River and riparian pumping and releases into the upper Walsh River from the Barron River system.
- There has been relatively little clearing, except in the MDWSS, and little agricultural development other than pastoralism.
- Livestock grazing has reduced ground cover vegetation, and increased soil erosion, especially along some of the more highly productive river country. There have been deliberate and accidental plant and animal introductions, including the release of exotic fish such as the spotted tilapia.

The Mitchell catchment supports wetlands of national importance.

- The Mitchell catchment has three wetlands of national importance: the Mitchell River Fan Aggregation (Mitchell River delta), the Spring Tower Complex, and the Southeast Karumba Plain Aggregation.
- Being perennial, the Mitchell River differs from its four major tributaries: the Alice, Palmer, Walsh and Lynd rivers and the many minor tributaries, which only flow for part of the year.
- The Southeast Karumba Plain Aggregation is one of four important bird habitats in the catchment. It supports the second largest summer population of wader birds in Australia.

The Mitchell catchment supports several important habitats, including riparian vegetation, permanent waterholes, mangroves and salt flats.

- Riparian vegetation lines many of the larger watercourses and are generally more fertile and productive than surrounding terrestrial vegetation.
- Persistent waterholes are key aquatic ‘refugia’, important for sustaining ecosystems in the Mitchell catchment. Some persistent waterholes have cultural significance.



Persistent waterhole on the Walsh River

The Mitchell River supports a high species richness of freshwater fishes, with 57 species recorded, as well as high endemism for fish.

- Several fish in the Mitchell catchment are migratory, undertaking large-scale movement through streams and across the floodplain during their life cycle, including the freshwater sawfish, black catfish, spangled perch and barramundi (a species of commercial and recreational significance).
- The freshwater sawfish, which is listed as vulnerable in the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) is found in the Mitchell catchment. This fish is now rarely detected on the east coast of Queensland.
- The catchment is also home to the little-known freshwater whipray; although, due to their rarity, there are few recorded observations in the Mitchell catchment.

Opportunities for agriculture and aquaculture

- About two-thirds (16,000 ha) of the MDWSS is in the upper Walsh River part of the Mitchell catchment. Production is dominated by mangoes, bananas, avocados, sugarcane and a range of other tree, field and horticultural crops.
- Compared to the rest of the catchment, this irrigation area, about 0.2% of the catchment, experiences a more forgiving, temperate climate for cropping, including receiving more dry-season rainfall.
- There is very little broadacre cropping in the Mitchell catchment below the MDWSS, although trials in the early 1950s grew sorghum, cowpea, lucerne, Rhodes grass and other crops further downstream.

There is much more soil suited for irrigated agriculture in the Mitchell catchment than there is water to irrigate it.

Up to 3 million ha of the Mitchell catchment are classified as moderately suitable with considerable limitations (Class 3) for irrigated agriculture, depending on the crop and irrigation method chosen.

- These Class 3 soils have considerable limitations that lower production potential or require more careful management than more suitable soils (i.e. Class 1 or Class 2). In this respect, they do not differ from many of Australia's agricultural soils.

Descriptions of each Class (1 to 5) are found in the map legend. The classes were derived from a set of attributes such as erodibility, slope, soil depth, permeability, rockiness and others.

The area estimates given here are derived from assessing soil, landscape and climate factors within the whole catchment, as an upper starting point. The area actually available for irrigation will be less – once considerations relating to land tenure, land use, flooding risk, availability of water for irrigation and other factors are taken into account.

- About 2.5 million ha of the Mitchell catchment are Class 3 for irrigated cereals, cotton and soybeans using spray irrigation, but only about 1.3 million ha are suitable using furrow irrigation for the same crops.
- About 2.5 million ha of the Mitchell catchment are Class 3 for irrigated sugarcane using spray irrigation, but only about 1.3 million ha are suitable using furrow irrigation.
- Just over 3 million ha of the Mitchell catchment are Class 3 for Rhodes grass using spray irrigation. About 600,000 ha are classified similarly for wet-season forage sorghum using spray irrigation.

Opportunistic dryland cropping is possible, but it carries considerable risk.

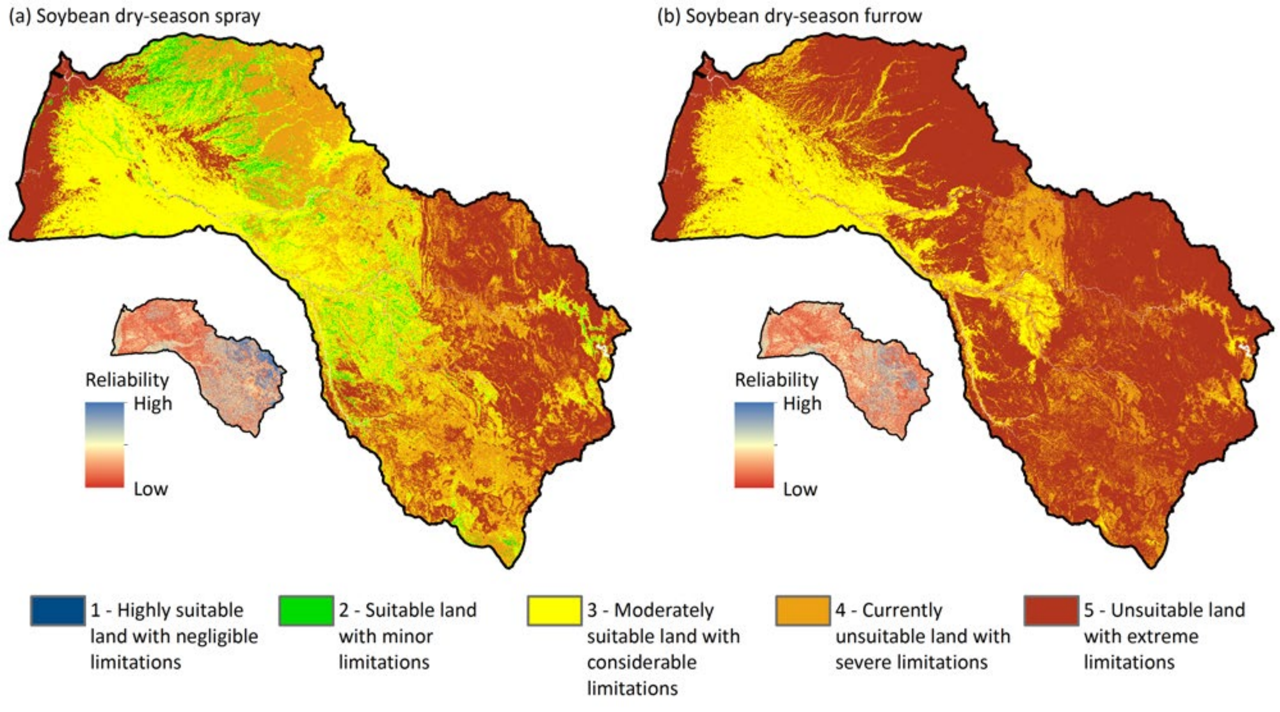
- For many dryland crops January is the sowing window for maximum yield. When trafficability allows for sowing in this period, yields that achieve break-even gross margins can be obtained with most crops in 80% of years. However in practice, break-even yields are unlikely to be achieved in 80% of years because trafficability will be limited at optimum sowing time.
- Dryland cropping has potential on the heavier-textured (clay) soils of the Mitchell catchment as a consequence of their higher soil water storage capacity. These soils are mainly found on the Mitchell River delta and in the mid-catchment.
- The better clay soils are, however, often not trafficable during the wet season. This provides significant operational challenges for dryland cropping, and potential yields may not be realised in many years.

Irrigation provides not only for higher yields, but also more reliable production compared with dryland crops.

- Irrigation can increase yield by up to about 50% compared with dryland crops, and can increase the likelihood of achieving break-even gross margins by about 25%.
- A wide range of crops is potentially suited to irrigated production in the Mitchell catchment. These include cereals, pulses, forages, vegetables and perennial fruit tree crops, as well as industrial crops such as sugarcane and cotton.
- Broadacre crop yields under irrigation compare favourably with crop yields for other irrigated areas of north Queensland (e.g. the Burdekin).
- Seasonal applied irrigation water by crops can vary enormously with crop type (i.e. its duration of growth), season of growth and, to a lesser extent, soil type. For example, sorghum planted during the wet season will usually require 2 ML/ha of supplementary irrigation only in the final stages of growth, while a high-yielding perennial forage such as Rhodes grass requires up to 15 ML/ha during the production cycle.

An excess of water also carries risks.

- High rainfall and possible flooding mean that wet-season cropping carries considerable risk due to potential difficulties with access to paddocks, trafficability and waterlogging of immature crops.
- The alluvial lowlands in the western part of the catchment and the clay soils in the mid-catchment are most suitable for furrow irrigation, although there are risks due to flooding and secondary salinisation.
- While dryland cropping is unlikely to be viable on its own, particularly due to poor trafficability at sowing time, it is likely to be a component of irrigated farming systems, expanding or contracting based on the amount of land that can be irrigated each year and on the spare capacity of time, labour and machinery.



Modelled land suitability class for dry-season soybean using (a) spray irrigation and (b) furrow irrigation in the Mitchell catchment

The inset for each map shows the reliability of this classification.
This map does not consider risk of flooding, secondary salinisation or water availability.

Establishing irrigated cropping is challenging, with high input costs and high capital requirements for greenfield development.

- Gross margins are highly variable between crops, with the industrial crops (sugarcane and cotton) and peanuts returning the highest gross margins. For sugarcane and cotton, positive gross margins are only achieved if processing facilities (sugar mill, cotton gin) are available locally to reduce cartage costs.
- The gross margins for sugarcane and cotton are consistent with other regions in Queensland.
- Compared with broadacre crops, gross margins of horticultural crops are considerably higher for avocados, bananas, melons and mangoes. Horticultural returns are highly sensitive to prices received, so the locational advantage of supplying markets earlier than other regions is critical to viability.

More than one crop per year may be required to sustain greenfield irrigation development.

- The cash generated from a single crop each year is unlikely to enable the capital costs of development to be met.
- Outside of the MDWSS there is relatively little experience in implementing rotational two-crops-peryear farming systems.
- In addition to the potential for higher gross margins, rotations can be designed to help manage disease, pests and weeds; minimise soil and nutrient losses; and reduce the need for inorganic nitrogen.
- A rotation system of cotton and mungbean grown within a year is capable of producing yields similar to the sum of the individually grown crops, and could be sufficient to meet capital costs of development in the order of $25,000/ha.
- The development of a range of alternatives for rotational two-crops-per-year farming systems, and the management packages and skills to support them, is a likely pre-requisite for economically sustainable irrigated broadacre cropping. The challenges in developing these should not be under-estimated.

Hay production in the Mareeba-Dimbulah Water Supply Scheme

Irrigated cropping has the potential to produce off-site environmental impacts, although these can be mitigated by good management and new technology.

- The pesticide and fertiliser application rates required to sustain crop growth vary widely among crop types. Selecting crops and production systems that minimise the requirement for pesticides and fertilisers can simultaneously reduce costs and negative environmental impacts.
- Poorly managed irrigated agriculture can result in the addition of nutrients to waterways and a rise in groundwater levels. This has the potential to boost production of algae, which can result in ecological changes.
- Refining application rates of fertiliser to better match crop requirements, using controlled-release fertilisers, and improving irrigation management are effective ways to minimise nutrient additions to waterways and, hence, the risk of harmful microalgae blooms.
- The use of 'best management practices', including controlled traffic and banded application of herbicides, can substantially reduce their efflux into waterways.
- Adherence to well-established 'best management practices' can significantly reduce erosion where intense rainfall and slope would otherwise promote risk.

- Genetically modified (GM) crops allow industry to substantially reduce insecticide and herbicide application. In recent years GM cotton has enabled Australian cotton farmers to use 85% less insecticide, 62% less residual-grass herbicide and 33% less residual-broadleaf weed herbicide. In addition to reducing the likelihood and severity of off-site impacts, GM crops offer health benefits to farmer workers through handling fewer chemicals. This technology has considerable relevance to northern Australia.

Irrigated forages can improve beef turnoff and profitability of cattle enterprises.

- The dominant beef production system in the Mitchell catchment is cow–calf breeding, with several variations in the post-weaning management and marketing of male animals produced by the breeding herds.
- While native pastures are generally well adapted to harsh environments, they impose constraints on beef production through their low productivity and digestibility. An opportunity exists to complement native pastures with improved forage species, such as Rhodes grass, forage sorghum and lablab, which are suited to the Mitchell catchment.
- Dryland forage sorghum, sown halfway through the wet season when soil profiles are full of water, can produce up to about 10 t/ha of forage, especially on a clay soil that can store soil water well into the dry season.

Furrow irrigation in the Mareeba-Dimbulah Water Supply Scheme

- Irrigated forage sorghum can produce yields of around 20 t dry matter/ha, while Rhodes grass can produce forage yields in excess of 30 t dry matter/ha, especially when it is fertilised with large amounts of nitrogen and other major nutrients.
- Until now, irrigated forages in tropical Australia have mostly been used for small-scale hay production rather than direct grazing. There is an opportunity for irrigated forages, grown at the hundreds of ha scale, to fundamentally alter production of particular animal cohorts and so transform management of large pastoral enterprises. The potential options to do this are numerous:
  - grazing of forages by young cattle to increase their weight at sale from approximately 300 to 450 kg so that sale options and returns are increased;
  - producing high-quality hay to enable early weaning of calves, thereby reducing lactation pressures on cows and increasing their body condition to improve subsequent calving percentages.
- Analysis shows that both of these options markedly increase the total amount of beef produced per year. Furthermore, both options yield positive net profits. However, when the on-farm capital costs of development are considered in a Net Present Value (NPV) analysis, very few options can achieve a positive NPV. The forage options that can produce a positive NPV assume moderate capital costs of around $12,000 per ha and beef prices of at least $3.00/kg.

Pond-based black tiger prawns or barramundi in saltwater or red claw crayfish in freshwater ponds offer potentially high returns.

- For marine species, there are approximately 235,000 ha of coastal land suitable for lined aquaculture ponds.
- Prawns and barramundi have proven land-based culture practices and well-established markets for harvested products. These are not fully established for other aquaculture species being trialled in northern Australia.
- Prawns could potentially be cultured in either extensive (low density, low input) or intensive (higher density, higher input) pond-based systems. Land-based culture of barramundi would likely be intensive.
- Long transport distances for specially formulated feed and finished products contribute to high costs of aquaculture production, and year–round road access to coastal areas is not currently possible. Overcoming these challenges, skilfully managed prawn and barramundi pond-based aquaculture enterprises can be profitable in the Mitchell catchment.
- The remote location of the Mitchell catchment confers some biosecurity advantages to aquaculture production.
- Aquaculture enterprise development in the Mitchell catchment will face fewer regulatory constraints than those in catchments that drain into the Great Barrier Reef. For example, while Australian prawn farms have been found to be some of the most environmentally sustainable in the world, approval processes and strict regulations constrain development along the east coast of Australia.


Prawn trawlers in the Gulf of Carpentaria

Groundwater resources in the Mitchell catchment are localised

- The Bulimba Formation aquifer, within the Karumba Basin and overlapping the lower half of the Mitchell catchment, offers the greatest opportunity for groundwater resource development in the Mitchell catchment.
  - This aquifer is artesian and located approximately 50 km west of where the rocks of the Bulimba Formation aquifer outcrop the aquifer. This means that water is currently under pressure, sufficient to make bores flow without the cost of pumping. If sufficiently large quantities of groundwater were extracted from this aquifer, then it may cease being artesian.
  - Recharge to the Bulimba Formation aquifer occurs as infiltration, in the vicinity of where the aquifer outcrops at the ground surface, following intense wet-season rainfall events and from streamflow where rivers traverse the outcropping rock. It is estimated to be 10 GL/year.
  - Groundwater is fresh, with low salinity (<1000 µS/cm) and low ionic composition making the water suitable for a variety of uses. However, low pH groundwater can be corrosive to bore infrastructure.
  - The aquifer is located at potentially economic depths at most locations, with the depth below land surface ranging from approximately 20 m in the outcrop and subcrop area to 150 m towards the coast.
  - With appropriately sited groundwater bores, up to 5 GL of water could be extracted from the Bulimba Formation aquifer. Site-specific extraction volumes will vary for each location depending on vicinity to and impact on existing users or environmental assets.

Groundwater bore in the Bulimba Formation under artesian conditions

- The Gilbert River Formation may offer up to 5 GL of water for extraction in and near (within 50 km) of the aquifer outcrop. However, this formation is deeper than the Bulimba Formation and, beyond 50 km of the outcrop, drilling costs will be prohibitively expensive.
- Elsewhere in the Mitchell catchment, groundwater use is largely limited to stock and domestic use (<0.5 GL/year). There may be some localised opportunities for small-scale irrigation from alluvial aquifers.

Groundwater discharge supports a diverse range of ecosystems.

- Natural discharge to the land surface supports a range of groundwater-dependent ecosystems such as dry-season streamflows, persistence of instream waterholes and groundwater-fed vegetation. 'Submarine' discharge to the ocean sustains unique marine ecosystems.
- Extraction of groundwater for consumptive purposes will result in a corresponding reduction in 'natural' discharge to water bodies and vegetation. These changes will be location dependent and will need to be considered on a case-by-case basis if in the vicinity of new groundwater developments.

Groundwater, which is more economically attractive than managed aquifer recharge (MAR), will always be developed first. However, MAR can enhance the quantity of water available for extraction and help mitigate impacts to the environment.

- An advantage of MAR over surface water storage options is that evaporative losses can be avoided.
- In some ephemeral river reaches streambed recharge weirs, up to 3 m in height, have potential to augment groundwater recharge in areas of groundwater extraction. The potential for siltation to reduce their effectiveness over time would need to be investigated.
- The cost-effectiveness of these structures is similar to large farm-scale ringtanks and lower than large farm-scale gully dams, measured as combined capital and operational costs per ML water supplied.
- A likely impediment to the uptake of MAR in northern Australia is that current site-specific investigative costs are higher and more risky than those for farm-scale ringtanks and gully dams of equivalent yield.

Surface water storage potential

Large water resource developments in the Mitchell will require surface water capture and storage.

- Less than 33% of the catchment's water presents itself for storage in major dams. Approximately 67% of runoff from the Mitchell catchment is generated below the confluence of the Mitchell and Lynd rivers, where the topography and geology are unsuitable for major dams.
- The total amount of controlled water releases possible from four of the more commercially favourable major instream dams in the Mitchell catchment (Palmer, Pinnacles, Rookwood and Lynd) is approximately 2800 GL in 85% of years. This is sufficient water to irrigate 140,000 ha of sugarcane (2% of the catchment) after accounting for conveyance and field application losses. Collectively, the four dams would cost about $2.75 billion, or $980/ML released at the dam wall.
- This could generate an annual gross value of production of approximately $720 million, and the region would benefit from $1.5 billion of economic activity reoccurring annually and the generation of about 7250 jobs.
- If used to their full amount, the four potential dams would reduce mean and median annual discharge from the Mitchell River by about 22% and 24%, respectively.
- Suitably sited large farm-scale gully dams are a relatively cost-effective method of supplying water. Favourable sites in the Mitchell catchment are mainly limited to the Alice River system, where there is a coincidence of suitable topography and soil for embankments close to soils suitable for irrigated agriculture.
- Indigenous customary residential and economic sites were usually concentrated along major watercourses and drainage lines. Consequently, potential instream dams are more likely to impact on areas of high cultural significance than most other infrastructure developments of comparable size.
- Most potential dam sites in the Mitchell catchment would inundate some regional ecosystems considered to be 'of concern'. Complex changes in habitat resulting from inundation could create new habitat to benefit some of these species, while other species would be negatively impacted by loss of habitat.

Most streamflow within the Mitchell catchment cannot be readily captured or stored offstream. Approximately 80% of total streamflow is discharged in the highest 10% of days, of which only a small proportion could be pumped.

- Water released from ringtanks for irrigation (after evaporative and seepage losses) would cost about $780/ML. This estimate does not including pumping costs, and assumes irrigation of short (2 to 3 months) or medium (4 to 6 months) duration crops. The cost of ringtanks would be about twice that of the more cost-effective major dams, including the operating costs.
- It is physically possible to pump 2000 GL of water in 85% of years from the Mitchell catchment into ringtanks adjacent to soils suitable for irrigated agriculture. This would reduce the mean and median streamflow by approximately 15% and 28% respectively, near the mouth of the Mitchell River.
- This volume of water could potentially be stored in 500 ringtanks (each of 4-GL capacity). Assuming unconstrained development, this could irrigate up to 200,000 ha of cotton (2.7% of the catchment) after accounting for evaporative, conveyance and field application losses.
- This could potentially generate an annual gross value of production of approximately $1.2 billion, creating an additional $1.3 billion/year of regional economic benefits and generating about 11,800 full-time equivalent jobs.
- Pumping water into ringtanks will slightly reduce floodplain inundation during 'low flood' years (<1 in 2 annual exceedance probability) and have negligible effect on floodplain inundation during 'moderate' and 'large' flood events.
- The scale of irrigation that natural waterholes could support is typically small (e.g. 1 to 60 ha). However, where they coincide with land suitable for irrigation they may be cost-effective in staging a development, where lessons are learned and mistakes made on a small-scale area before large capital investment occurs.
- The main limitations to the use of wetlands and persistent waterholes for the consumptive use of water is that they have considerable ecological and, in some cases, cultural significance.

The potential Pinnacles dam site on the Mitchell River looking upstream

The two most cost-effective potential dam sites in the Mitchell catchment illustrate the opportunities to provide sufficient water to support an area of sugarcane the size of the lower Burdekin.

- The potential Pinnacles dam site on the Mitchell River, located approximately 80 km upstream of the confluence of the Mitchell and Walsh rivers where there is a large area (greater than 100,000 ha) of soils that are moderately suitable for irrigated agriculture.
- The optimum construction for the potential Pinnacles dam is a roller compacted concrete dam. At the nominated full supply level it would require a 1.85-km long earth-fill embankment saddle dam, both of which could be constructed for an estimated $755 million.
- The reservoir of the potential Pinnacles dam site could potentially store 2316 GL and would yield 1248 GL at the dam wall in 85% of years.
- Water from the potential Pinnacles dam is likely to cost approximately $605/ML when supplied at the dam wall in 85% of years; losses in conveying water down the river and along supply channels to the farm gate would significantly increase on-farm water costs.
- If used to its full extent, the potential Pinnacles dam would reduce mean and median annual discharge from the Mitchell catchment by about 8% and 10%, respectively.

The next most cost-effective potential major dams are on the Walsh and Palmer rivers; the former is closer to soils suitable for irrigated agriculture.

- The potential Rookwood dam on the Walsh River would be a roller compacted concrete dam located about 28 km north-west of Chillagoe, below which a large area of soils (greater than 100,000 ha) exists that are moderately suitable for irrigated agriculture.
- The reservoir impounded by the dam could potentially store 1288 GL at the nominated full supply level and yield 575 GL in 85% of years.
- Water from the potential Rookwood dam is likely to cost approximately $1140/ML when released at the dam wall in 85% of years; losses in conveying water down the river and along supply channels to the farm gate would significantly increase on-farm water costs.

A dam at the Nullinga site on the upper Walsh River could provide for an expansion of irrigated production in the MDWSS and with a delivery pipeline could irrigate areas currently supplied from Tinaroo Falls Dam.

- Although the Nullinga site has a high cost to yield ratio, its proximity to the existing MDWSS and its potential to ensure the long-term security of the Cairns water supply have led to interest in its possible development.

Changes in timing and volume of flow have ecological impacts

- While irrigated agriculture might, at its upper limit, occupy only 3% of the landscape, it can result in substantial changes to river flow volumes and patterns.

The impact of a major instream dam on aquatic, riparian and near-shore marine ecology is strongly related to its position in a catchment and the size of the reservoir relative to the volume of streamflow.

- The potential Pinnacles dam would have a major impact on freshwater sawfish immediately below the dam, but would have a minor impact on sawfish near the mouth of the Mitchell River.
- The potential Pinnacles dam would have a moderate impact on the flow habitat of 1 of 11 marine and estuarine species and habitats examined at the Mitchell River mouth and a minor impact on the other 10. By contrast, dams on the Palmer, Mitchell, Walsh or Lynd would have negligible impact on the flow habitat of species near the river mouth.
- A potential single dam on the Mitchell River would have a considerably larger impact on species and habitats at the river mouth and floodplain than single dams on the Walsh or Palmer rivers. This is partly due to the larger capacity of the potential Pinnacles dam. It also highlights the importance of the perennial flow regime of the Mitchell River above its confluence with the Walsh River relative to its ephemeral tributaries.
- The high position of the potential Nullinga dam site in the Walsh River catchment and the reservoir's relatively small capacity mean that its impact is highly localised. The impact of the potential Nullinga dam on species and key habitats at the mouth of the Mitchell River is negligible.

At equivalent storage capacities, pumping water into offstream storages (water harvesting) has less impact on freshwater aquatic, riparian and marine ecosystems than major instream dams.

- Water harvesting at high commence-to-pump thresholds of 2400 GL/year will have minor environmental impacts.
- There are several effective strategies for minimising the impacts of water extraction on species and habitat, such as increasing the water-level thresholds above which water can be pumped, or only permitting pumping to commence once a certain volume of water has flowed past the lowermost gauge. These strategies, however, all lower the reliability at which potential irrigators can extract their allocation of water.
- The species most heavily impacted by water harvesting are migratory fish, and the species least impacted are the stable-flow spawners, which are food for the larger predatory species.
- A reduction in annual streamflow of 20% from the Mitchell catchment was calculated to reduce the median annual prawn catch across the whole Northern Prawn Fishery by about 2.5%, though the median annual reduction in some regions could be as high as 11%.

Although intensive land management has the potential to improve some ecological outcomes, past experience suggests this is unlikely to occur; there are currently no incentives for irrigation developments to manage beyond their boundaries or for issues that do not impact their production.

- Direct impacts of irrigation on the terrestrial environment are typically small. However, indirect impacts, such as weeds, pests and landscape fragmentation, particularly to riparian zones, may be considerable.

Commercial viability and other considerations

There is potential for the economic value of irrigated agriculture in the Mitchell catchment to increase three to four times.

- The total gross value of agricultural production in 2015–16 was approximately $225 million. Of this, livestock commodities account for just over 50% of the total ($117 million) and cropping about 40% ($95 million).
- Agriculture provides about 32% of all jobs in the Mitchell catchment.

While the natural environment of northern Australia presents some challenges for agriculture, the most important factors determining the commercial viability of new developments are management, planning and finances.

- Large infrastructure developments are complex and costly. It would be prudent to ensure that sufficient funds remain after the construction phase to safeguard the operation of new enterprises in the likely occurrence of 'failed' years at the start of its operation.
- There is a strong incentive to start any new irrigation development with well-established and understood crops, farming systems and technologies as this will reduce the likelihood of initial setbacks and failures.
- There is a systematic tendency of proponents of large infrastructure projects to substantially under-estimate development costs and risks and/or over estimate benefits. This can be partly due to financial return imperatives driving an overly optimistic assessment of the time frame for positive returns; unanticipated difficulties, particularly where subsurface excavations are required; and the difficulty of accurately planning and budgeting over many years.

It is prudent to stage developments to limit negative economic impact and to allow small-scale testing on new farms.

- The initial challenge of establishing and adapting agriculture in a new location can be mitigated by learning from past experiences in northern Australia. However, despite these learnings, each new location and development will provide unique challenges.
- Staging and allowing sufficient learning time can limit losses where small-scale testing proves initial assumptions of costs and benefits to be overly optimistic or it reveals unanticipated challenges in adapting farming practices to local conditions.


Chillagoe is a major settlement in the Mitchell catchment

Synergies through vertical and horizontal integration present opportunities for commercial returns but increase risk.

- Aggregated farm revenue from broadacre agriculture is unlikely to cover the cost of infrastructure for an irrigation scheme under current farming systems. Value adding through processing will increase revenues and will greatly assist in improving the commercial viability of an irrigation scheme.
- Analysis of building a local sugar mill with electricity cogeneration resulted in a substantial increase in revenues, making an integrated sugar development viable and potentially attractive to an investor.
- Vertically integrated agricultural enterprises require a sufficient scale of development in order to be viable, with supply commitments of raw farm products to justify the investment in processing facilities.
- The more complex a scheme, and the more strongly interdependent its components are, the greater the risk that underperformance of one component could undermine the viability of the entire scheme.

Distance from the farm gate to agricultural processing plants places a significant cost burden on industry in the Mitchell catchment.

- The current road network is sparse and the major roads are often prone to flooding, restricting wet-season access. The main road to Kowanyama is typically closed between December and April, which presents challenges to costal aquaculture and large scale water harvesting.
- Most truck movements comprise cattle to southern feedlots, to Karumba Port for export or to export-certified abattoirs in north Queensland.
- There is currently no broadacre cropping in the catchment. The nearest cotton gin to the catchment is in Emerald, a road trip of 995 km. There is a sugar mill in Mareeba.
- Transport costs to major southern markets will add significant costs and make supplying low-value crops unviable when competing against southern production. Local processing will ensure better farm gate returns and potentially generate by-products such as the cogeneration of energy.
- There are established export supply chains for live cattle and wild harvested fisheries. Exports of locally processed beef and horticultural or broadacre crops out of local ports and airports are not yet at a sufficient scale to justify investment in export infrastructure. There are currently no refrigerated backloading opportunities in the Mitchell catchment, although any future development could use consolidation, packing and transport facilities at Mareeba or Cairns.

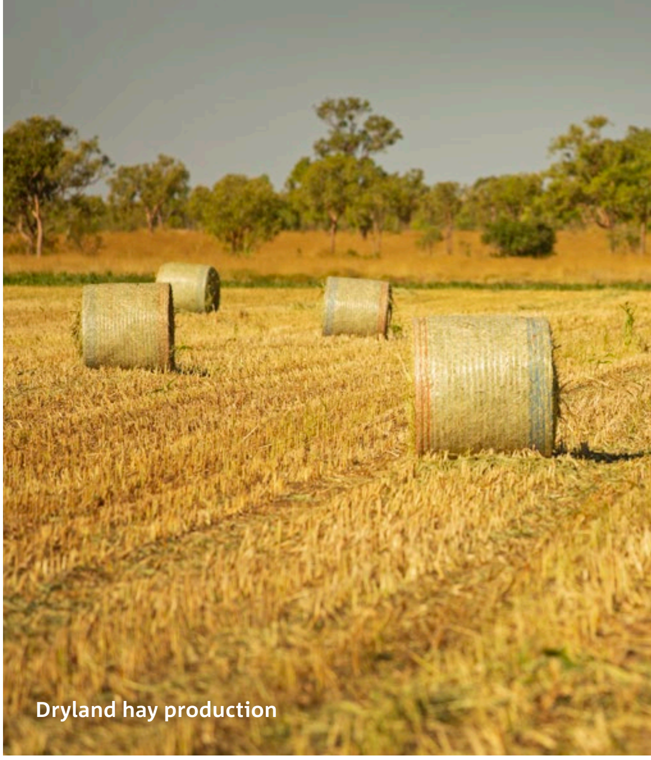

Loading cattle on to road trains

Irrigated agriculture has a greater potential to generate economic and community activity than dryland production.

- Studies in the southern Murray–Darling Basin have shown that irrigation generates a level of economic and community activity that is three to five times higher than would be generated by dryland production.
- In the Mitchell catchment, irrigation development could result in an additional $1.22 of indirect regional economic benefits for every $1.00 spent on construction during the construction phase. The regional economic impact of an annual increase in irrigated agricultural output of $100 million per year is estimated to be an additional $110 million of increased economic activity.
- During the construction phases, aquaculture development may result in a regional economic benefit similar to that of irrigated agriculture. Once the business has been established, the regional economic impact of aquaculture, for every $100 million per year output, is estimated to be an additional $96 million of increased economic activity.

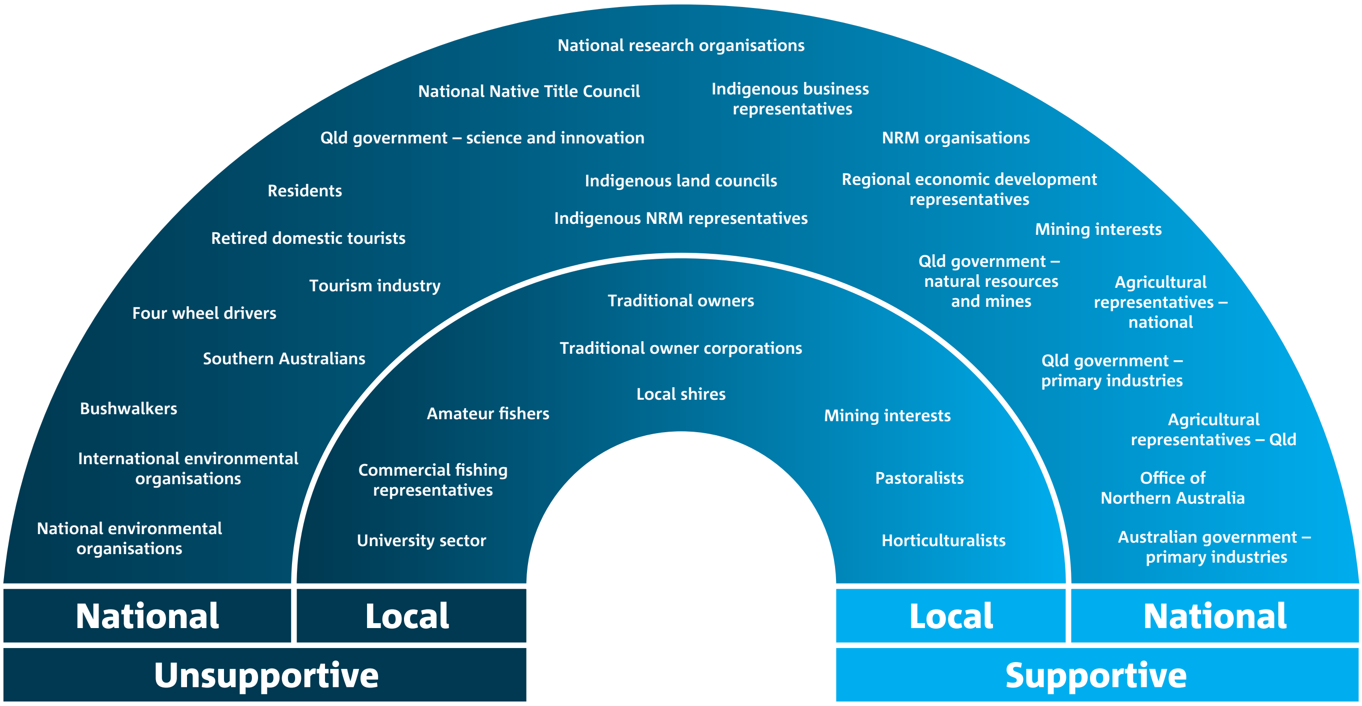
Community infrastructure in the Mitchell catchment requires investment in the event of a large-scale irrigation development.

- The population increase needed to sustain a substantial irrigation development would require significant investment in community infrastructure and services, such as schools, medical services and housing.
- Recent developments (such as the expansion of the Ord River Irrigation Area in WA) have shown that significant investment in community infrastructure is required to support new irrigation schemes.



Sustainable irrigated development requires resolution of diverse stakeholder values and interests.

- Establishing and maintaining a social licence to operate is a precondition for substantial irrigation development.
- The geographic, institutional, social, and economic diversity of stakeholders increases the resources required to develop a social licence and reduces the size of the 'sweet spot' in which a social licence can be established.
- Key interests and values that stakeholders seek to address include the purpose and beneficiaries of development, the environmental conditions and environmental services that development may alter and the degree to which stakeholders are engaged.
- Potential agricultural investors identified institutional certainty, simplicity and bureaucratic speed as key to enabling investment in irrigated agriculture.



Stakeholder classification according to their likely support for irrigated agriculture in a greenfield site in the Mitchell catchment Stakeholders to the right of the diagram are more likely to be supportive. Internal ring = local stakeholders, external ring = regional, national and international stakeholders.
NRM = natural resource management.

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The Northern Australia Water Resources Assessment (NAWRA) was conducted for the Commonwealth of Australia represented by the Department of Infrastructure, Regional Development and Cities. As part of our engagement in delivery of the Australian Government's White Paper on Developing Northern Australia and the Agricultural Competitiveness White Paper, CSIRO was commissioned to investigate the potential of northern Australia's water resources to support increased regional development in three priority regions in northern Australia: Fitzroy catchment, Western Australia; Darwin catchments (Finniss, Adelaide, Mary, Wildman), Northern Territory; and Mitchell catchment, Queensland. Parts of the Assessment were undertaken in conjunction with the Northern Territory Government, the Western Australian Government, and the Queensland Government. It builds on our previous success in delivering the Flinders and Gilbert Agricultural Resource Assessment, and a broader body of work contributing to the sustainable development of northern Australia. NAWRA was funded through the Australian Government's National Water Infrastructure Development Fund, an initiative of the Agricultural Competitiveness White Paper.

Cover: The Tate River during the dry season