Agricultural resource assessment for the Flinders catchment

An overview report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy

December 2013
CSIRO has completed, for the Australian Government, an investigation of opportunities for water and agricultural development in the Flinders and Gilbert catchments of north Queensland. Each catchment offers the possibility of irrigation developments approaching (in Flinders) or exceeding (in Gilbert) the scale of the current Ord River Irrigation Area.

Here we present the key findings of the Assessment for the Flinders catchment, followed by an overview of the considerations concerning the potential for irrigated and dryland agricultural development. Readers are referred to the full reports for more detailed information.

**KEY FINDINGS**

- Despite their close proximity, the Flinders and Gilbert catchments differ significantly in their physical characteristics and, as a consequence, the extent to and methods by which agricultural development might occur.
- In the Flinders catchment, farm dams could support 10,000 to 20,000 ha of irrigation in 70 to 80% of years; irrigation may not be possible in very dry years. The precise area under irrigation will, in any year, vary depending on factors such as irrigation efficiency, water availability, crop choice and risk appetite.
- In the Gilbert catchment, large instream dams could support 20,000 to 30,000 ha of irrigation in 85% of years. Again, the precise area under irrigation will, in any year, vary depending on factors such as irrigation efficiency, water availability, crop choice and risk appetite.
- Instream dams enable more reliable irrigated production than farm dams, because they can more easily carry water from one year to the next.
- Significant water use would, in the downstream environment, amplify the environmental and social challenges associated with dry years and would have impacts on commercial and recreational fishing catches that have not been quantified in this study.

CITATION


Cover image: The township of Richmond in the Flinders catchment, North Queensland.
Key findings for the Flinders catchment

North Queensland’s Flinders catchment, comprising an area of approximately 109,000 km², drains into the southern Gulf of Carpentaria. Its population of approximately 6000 people is engaged mainly in pastoralism, but tourism, mining and commercial fishing make important contributions to the economy. Dryland and irrigated cropping currently occupy less than 0.02% of the landscape.

This overview report on the Flinders catchment seeks to:
- identify and evaluate water capture and storage options
- identify and test the commercial viability of irrigated agricultural opportunities
- assess potential environmental, social and economic impacts and risks.

The Assessment acknowledges that locals have insights, skills and aspirations to contribute to development plans for the benefit of their region, community and environment. Scientific knowledge of the type produced by this Assessment should complement rather than compete with local knowledge.

Water capture and storage options

Offstream storages such as farm dams provide the most promising method for supporting large-scale irrigation development in the Flinders catchment. Combined offstream storage is capable of delivering to crops approximately 175 gigalitres (GL) of irrigation water in 70 to 80% of years. This is approximately half of the full storage potential (350 GL) of offstream storages.

The six most promising instream dams in the Flinders catchment are collectively capable of delivering approximately 80 GL to crops, at a cost of >$6000/ML of water supplied at the dam wall, in 85% of years. Offstream storages in the Flinders catchment are likely to be approximately ten times more cost effective than instream storages.

There is more soil suited to irrigation in the Flinders catchment than there is water to irrigate it. If offstream storages were developed to their full (350 GL storage) potential, it would be possible to irrigate approximately 0.2% of the catchment’s irrigable soils.

Agricultural opportunities

Based on the identified water storage and the large areas of potentially irrigable agricultural soils (more than 8 million ha, 2 million of which are most promising), there is the potential for an irrigation development totalling 10,000 to 20,000 ha, supporting year-round mixed irrigated and dryland cropping.

Environmental impacts and risks

Irrigated agricultural development has a wide range of potential benefits and risks.

Offstream storage of 350 GL would, in the downstream environment, amplify the environmental and other challenges associated with dry years. Critical environmental processes (such as wetland inundation) would not be greatly affected by water extraction in ‘average’ or wet years, largely because water storage of 350 GL would intercept a mean 14% and a median 28% of flow to the Gulf of Carpentaria. Impacts of reduced river discharges to the Gulf on commercial and recreational fishing catches are possible but have not been quantified in this study. Large-scale change of land and water use is likely to require a wide range of regulatory, social and cultural responses, including consideration of native title implications.

Under the development scenarios examined, the high capital costs of instream and on-farm dams and water delivery infrastructure precludes reliable economic returns on combined investment in water assets and irrigated farming. Where third-party investment in water storage and delivery was examined, whether on-farm or instream, it was found that commercial returns on irrigated agriculture are possible when crops approach their full yield potential – a condition that becomes more probable with experience.
Overview of the Flinders catchment

A highly variable climate

Northern Australian graziers are already adept at managing seasonal variability and risk.

This report recognises the skills of pastoralists in managing seasonal risk, and seeks to provide them and others with the information required to assess a set of risk parameters that is relatively new to the Flinders catchment – those associated with large-scale water storage and crop production.

Climate is a key driver of processes that affect agricultural and pastoral production and risk.

The tropical climate of the north, characterised by alternating periods of extreme wet and dry, also has implications for the location, scale, function and risk associated with industrial and domestic infrastructure.

The climate of the Flinders catchment is hot and semi-arid. It is a generally 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 Flinders catchment – are 492 mm and 454 mm, respectively.
- 12% of the average annual rainfall occurs the dry season, (May to October). The length and intensity of the dry season limits the choice of crops that can be grown under dryland agriculture and increases the water requirements of irrigated agriculture.
- 88% of the average annual rainfall occurs in the wet season (November to April), during this time rainfall can be very intense, increasing the risks of flooding, erosion and soil structural decline.

Rainfall is difficult to capture.

- 90% of rainfall is lost as evaporation; only 8% enters streamflow.
- There is a strong rainfall gradient that runs from the coast (800 mm annual mean) to the south of the catchment (350 mm annual mean).

Rainfall is difficult to store.

- The predominantly very flat landscape of the Flinders catchment makes possible only shallow dams that are susceptible to high evaporative loss.
- Evaporation is high (1860 mm annual mean), and exceeds rainfall by a factor of 3.8 to 1.
- For the 15 potential large instream storages (dams) examined in the Flinders catchment, water yields at 85% reliability averaged only 10% of their total storage capacity. Dams are capable of delivering to farms an average of only 5 to 7% of their total storage capacity.

Rainfall is unreliable, which increases production risks for dryland and irrigated agriculture.

- Annual rainfall totals in the Flinders 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.
- While rainfall is highly unreliable, 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. Farmers and water managers can manage risk by using seasonal rainfall outlooks.
Droughts are much more intense in the Flinders catchment than in other agricultural areas of Australia.

- The frequency and duration of droughts in the Flinders catchment is comparable with other agricultural areas of Australia, such as the Murray–Darling Basin. When drought occurs, however, it is more intense because of high rates of evaporation and strongly seasonal rainfall.

- To consistently supply water during intense dry periods, dams need to be large enough to contain multiple years of potential water use, while crop areas need to be reduced. Water captured in shallow, offstream storages needs to be used as soon as possible.

- The timing of drought in the Flinders catchment broadly correlates with drought in most of eastern and northern Australia.

Tropical cyclones bring rainfall but their winds do not tend to have destructive impacts in the Flinders catchment.

- Tropical cyclones are rare in El Nino years. During La Nina periods they may occur one to two years in ten in the northern- and eastern- most reaches of the Flinders catchment.

The historical (1890 to 2011) climate record provides the best available information to support short- to medium-term planning.

- Half of the climate models used in the Assessment indicated an increase in mean annual rainfall of up to 17% and half indicated a decrease in mean annual rainfall of 33%, relative to the historical climate. Importantly, approximately 60% of the models differed by less than ±10% from the historical rainfall. Significant changes in the amount and distribution of rainfall over the next 40 years appear unlikely.

Water resources

Groundwater resources in the Flinders catchment are not well understood, and detailed investigations were beyond the scope of the Assessment. Previous multi-catchment-scale analyses suggest moderate groundwater prospectivity.

Groundwater is unlikely to support substantial irrigation development, but where favourable conditions exist, local-scale systems may be able to support small-scale (approximately 200 ha) mosaic irrigation.

- Water quality in alluvial aquifers is highly variable. Many bores in the central catchment have low to moderate salinity (<0.75 dS/m).
Recharge rates are likely to be very low (<5 mm/year) in most of the catchment, though areas of much higher recharge (<50 mm/year) occur in the catchment’s basalt uplands and in the lower reaches of the Flinders River. Recharge rates to the Flinders River alluvium are low, which reduces the likelihood of groundwater development adjacent to the rivers.

Baseflow index data (generally <0.1) and chemical analyses indicate that groundwater discharge constitutes a negligible proportion of the overall streamflow in most of the rivers.

Reliable estimates of potential groundwater yield would require further study.

In the likely absence of substantial groundwater resources, water-based developments will depend on streamflow for access to water, with storage either instream (e.g. dams) or offstream (e.g. ring tanks).

The majority of streamflow within the Flinders catchment cannot be readily captured or stored instream.

The total amount of controlled water releases possible from the six most promising instream dams in the Flinders catchment is approximately 140 GL in 85% of years. This is approximately 6% and 11% of the mean and median annual streamflow near the mouth of the Flinders River, respectively.

The majority of streamflow within the Flinders catchment cannot be readily captured or stored offstream.

Combined offstream storage is capable of impounding approximately 350 GL of water in 70 to 80% of years, comprising approximately 14% and 28% of the mean and median annual streamflow near the mouth of the Flinders River, respectively.

Streamflow in the Flinders catchment is highly variable, or ‘flashy’, with rapidly rising peaks and rapidly falling troughs of flow. In these conditions, efficient offstream capture of streamflow is likely to require pumps with a much greater work rate than usual in southern Australia.

Mean annual streamflow is approximately twice the median annual streamflow, which means that a small number of large flows skew the distribution of flows.

Mean annual runoff across the Flinders catchment is 37 mm, which is very low for northern Australia. The median annual runoff is 22 mm.

Approximately 95% of the runoff in the Flinders catchment occurs during the wet season.

Annual variability in runoff 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.
Water storage potential

The topography, geology, hydrology and climate of the Flinders catchment militate against large-scale or cost-effective instream dams. Two of the more prospective dam sites illustrate the challenges associated with instream water capture, storage and use in the Flinders catchment.

- Cave Hill is a potential dam site on the Cloncurry River, located approximately 20 km upstream of Cloncurry and upstream of a significant area (>70,000 ha) of soils that are moderately suitable for irrigation.
- The optimum construction for the potential Cave Hill dam is a zoned earth and rock fill embankment dam with an earth fill embankment saddle dam, both of which could be constructed for an estimated $250 million.

- Cave Hill dam could potentially store 248 GL but would yield 40 GL at the dam wall in 85% of years. This is because over half the reservoir would be less than 5 m deep and, as a consequence, evaporative losses would be large: i.e. 1.2 GL per GL of water available for distribution.
- Water from the Cave Hill dam is likely to cost approximately $6200/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.
- When in use, the dam would inundate parts of two pastoral properties and a large area of regional ecosystems with ‘of concern’ conservation status.
O’Connell Creek offstream storage provides the most promising option for supporting large-scale irrigation in the Flinders catchment.

Combined total offstream storage of the order of 350 GL, with an inter-annual reliability of 70 to 80%, appears to be physically feasible, with relatively minor impacts on existing entitlement holders. Extraction and storage of this volume of water could occur via a large number of offstream storages such as on-farm ring tanks, scattered throughout many parts of the catchment (e.g. 50 ring tanks of 7 GL each).

Efficiency of water use from offstream storages is of the order of 50%, meaning that a total of approximately 175 GL of water could, in the above scenario, be applied to crops with 70 to 80% reliability. This is significantly greater than the total divertible yield from potential instream dams within the Flinders catchment (140 GL at 85% reliability) which could contribute approximately 90 GL for application to crops.
Opportunities for agriculture

More than 8 million ha of the Flinders catchment is classified as moderately suitable (class 3) for a wide range of crops and irrigation methods. These soils have considerable limitations that lower production potential or require more careful management than more suitable (e.g. class 1 or 2) soils. In this respect, they do not differ from many of Australia’s agricultural soils.

- The area, location and properties of soil appropriate for agricultural production are critical to determining the types of crops and production methods possible and to setting and realising agricultural production potential.
- More than 8 million ha of soils are classified as moderately suitable for trickle irrigation of intensive horticultural crops (such as capsicum, cucurbits and sweet corn).
- More than 8 million ha of soil are classified as moderately suitable for production of spray-irrigated cotton or sugarcane; approximately 7.8 million hectares may be moderately suitable for furrow-irrigated sugarcane or cotton.
- Approximately 7.7 million ha of soil are classified as moderately suitable for flood-irrigated rice.
- More than 8 million ha of soil are classified as moderately suitable for production of furrow-irrigated horticultural or cereal crops such as sorghum.

Smaller – but still large – areas of the Flinders catchment (<300,000 ha) are classified as suitable (class 2) for production of mainly trickle-irrigated crops. These soils have minor limitations that affect production or require more careful management than class 1 soils to maintain economic production.

The combined risks of secondary salinity and flooding may reduce the area of soil that is suitable for dryland or irrigated cropping.

- If the area of soil under which there is a secondary salinity risk is combined with that for which flooding is also a risk, there remains a total of approximately 3.7 million ha that is at least moderately suited to agriculture.
- If the area under which there is a secondary salinity risk is combined with that for which flooding is also a risk, and cropping is restricted to within 5 km of a river (the most likely scenario for irrigation based on offstream storage) there remains 2 to 2.4 million ha of soil that is at least moderately suited to cropping.

Mungbeans – one of a wide range of crops suited to irrigated production in the Flinders catchment
Modelled land suitability, based on soil class, for Rhodes grass and sorghum (grain) in the Flinders catchment

Note: this map does not consider risk of flooding or water availability

### Extensive grazing of (mostly) native pasture comprises the vast majority of agriculture in the Flinders catchment. There is currently virtually no dryland production of food or fibre for human consumption.

A wide range of crops is potentially suited to dryland production in the Flinders catchment.

- Crops – including cotton, maize, mungbean, sorghum (grain), chickpea and lablab – can potentially produce profitable yields in favourable seasons. Crops – such as soybean and sugarcane – will grow in favourable conditions but are less promising.

High rainfall variability means that continuous year-on-year dryland cropping is unlikely to be possible in the Flinders catchment. Opportunistic cropping, pursued in years in which the late wet-season soil profile contains sufficient soil water and the outlook for more rainfall is positive, is likely to provide the most profitable and sustainable approach to dryland cropping.

- Analysis of farm gross margins indicates that for dryland crops grown in the Flinders catchment, break-even crop yields could be expected approximately eight years in ten for short-season dryland crops such as mungbean; approximately two years in ten for dryland crops such as sorghum (grain) and chickpea; and approximately one year in ten for crops such as maize and dryland cotton.

Dryland cropping in the Flinders catchment can potentially provide a significantly greater, though much less reliable, source of agricultural production than irrigated cropping.

- If the approximately 8 million ha of at least moderately suitable arable soil in the Flinders catchment were, by way of example, devoted to dryland sorghum (grain), median potential regional production of around 18.4 megatonnes and a gross value of production of $4,232 million is theoretically possible. Actual yields would be lower and would vary significantly from year to year. Furthermore, annual variability is likely to place economic limits on the area of dryland agriculture, as are the challenges of managing large tracts of cleared but uncropped soil.

Dryland cropping is likely to comprise a component of irrigated farming systems, because the water available to irrigate crops is likely to vary significantly from year to year.

- Because there is far more irrigable soil in the Flinders catchment than there is water to irrigate it, decisions about the most efficient and cost-effective use of limited irrigation water will need to be made at combinations of regional, farm and paddock scale. From year to year, this will see farmers making decisions about the relative areas of irrigated and dryland cropping and full or partial irrigation employed on their farms.
Opportunistic dryland cropping in the Flinders catchment is favoured by the fact that information about cropping opportunity and risk is available at the time of planting. This makes it possible to reduce production risk associated with inter-annual variation in rainfall, in a given year. This only partially addresses the business risks associated with intermittent opportunistic cropping because capital, plant and equipment will be under-utilised in drier years.

- January is the sowing time at which optimum yields for many crops are achieved. It is also the time at which the season’s water supply can be most reliably assessed. Stored soil water is readily apparent and the prospects of future rainfall can be assessed with some degree (65%) of confidence.

- This is an enabler of cropping in a highly variable environment, as it permits growers to distinguish the years in which they are most likely to make a profit from the years in which they are least likely to make a profit. Risk of crop failure from lack of moisture is reduced, saving heavy losses in both agronomic (seed, fertiliser, fuel) and financing (borrowing) costs.

- On the other hand, wet-season cropping is attended by considerable risk because of potential difficulties with access to paddocks, trafficability and waterlogging of immature crops.

Irrigated cropping in the Flinders catchment currently comprises approximately 500 ha of mixed crops. There is potential to expand irrigated agriculture, on the scale of the Ord River Irrigation Area. The addition of 20,000 ha of irrigated agriculture in the Flinders catchment would increase the irrigated area of northern Australia by approximately 15%.

A wide range of crops is potentially suited to irrigated production in the Flinders catchment.

- Crops – including cereals, pulses, forages, vegetables and perennials as well as industrial crops such as sugarcane and cotton – are all well adapted to irrigated production in the climate of the Flinders catchment.

- Intensive horticultural production of annual crops – such as capsicum, chilli, cucurbit, eggplant, sweet corn, tomato, melon and strawberry – is possible and may enable growers to exploit higher prices made possible by harvesting in the off-season of most of Australia’s production areas.

- The predominantly cracking clays of the Flinders catchment are not well suited to growth of many perennial crops, for which the soil’s shrink–swell cycle can cause root shear if irrigation is not used to maintain consistent levels of soil moisture.
A wide range of crops is potentially profitable when grown under irrigation in the Flinders catchment.

- For most crops, median yields under irrigation are 30 to 50% higher than ‘break-even’ yields (the yield required to return a positive gross margin). For some crops (industrial crops such as cotton processed locally), median yields under irrigation are two to three times that required to break even.

- Profitability of industrial crops (such as cotton and sugarcane) is compromised by the cost of transport to distant processing facilities.

Irrigated cropping in the Flinders catchment has the potential to significantly increase food and fibre production in northern Australia.

- If on-farm dams were able to supply 175 GL to crops, it would be possible to irrigate with 70 to 80% reliability, for example, more than 40,000 ha of sorghum (grain), potentially producing more than 345,000 tonnes of grain with a gross value of more than $79 million. Actual yields would, for a variety of reasons, frequently fall below this potential.

- While combined on-farm storage of 350 GL could be used to irrigate one low-water-use crop annually, a potential farming systems scenario would see year-round irrigation of a range of crops in rotation (e.g. cotton, sorghum and peanuts). If this were to occur, a significantly smaller area of land (probably of the order of 10,000 to 20,000 ha) could be irrigated with available water. The precise area under irrigation will, in any year, vary depending on factors such as irrigation efficiency, water availability, crop choice, the balance between single and double cropping, and risk appetite – each of which may vary depending on circumstances particular to a given farm enterprise.

- The distributed nature of offstream storages may increase costs associated with transport and processing of agricultural products compared with a large and more centralised dam-based irrigation development.

Economic returns on irrigated and dryland agriculture are maximised when crops approach their full yield potential.

Yields harvested on-farm are highly dependent on the critically important – yet difficult to define – trait of ‘management skill’, the process by which the best decisions and actions occur at the best time. This grows with experience and, until it reaches a high level, the challenges associated with the relative lack of cropping experience in the Flinders catchment should not be underestimated.

The ability to enact farm decisions in the most timely manner can be impaired by the extremes of climate in the Flinders catchment. Protracted wet periods, for example, may prevent sowing and other farm operations from occurring at their optimum time, reducing crop yield and profits. This may be a particular challenge given the predominance of cracking clay soils in the Flinders catchment.

Until a pool of expertise develops and is efficiently able to anticipate challenges, actual crop yields would be expected to be significantly lower than potential crop yields. The difference between actual and potential yields, often referred to as the ‘yield gap’, usually closes slowly over time, and this needs to be factored into individual enterprise plans and cash flows.
Flooding

The coastal floodplains of the Flinders catchment are amongst the most frequently and extensively flooded parts of Australia. Floods regularly cover large areas of land that may extend many hundreds of kilometres inland. Floods play a range of constructive and destructive roles.

While large areas of potential agricultural soil are not regularly flooded, those parts of the Flinders catchment that are most flood prone are amongst those where soils are the most agriculturally suitable.

- Soils with a potential secondary salinity risk are widespread in the Flinders catchment. Potential agricultural soils that have a low risk of secondary salinity are most likely to be found in the parts of the catchment that flood most regularly.
- The mid to lower reaches of the Flinders catchment are very flat (with a slope less than 1:50,000) so flood water drains slowly, increasing the risk to agricultural production and damage to plant, equipment and infrastructure.

Flooding is ecologically critical because it connects offstream wetlands to the main river channel and connects and cleanses waterholes that sustain biodiversity during the dry season.

- The high biodiversity found in many unregulated floodplain systems in northern Australia depends largely on ‘flood pulses’ that allow fauna and nutrients to be exchanged between the main channel and coastal wetlands (tidal and freshwater). Reductions in floodplain inundation would result in appreciable decreases in aquatic and marine productivity.
- The Flinders catchment hosts two wetland aggregations that are recognised in the national Directory of Important Wetlands: the Southern Gulf Aggregation (545,353 ha) near the mouth of the Flinders River and Lignum Swamp near Julia Creek.
- The Flinders River estuary is adjacent to the Morning Inlet – Boyne River Fish Habitat Area, which has been declared to protect recreational, commercial and Indigenous fishing interests.

- The volume and velocity of ‘first-flush’ floods events is critical in renewing water quality and volume of streams and waterholes, so has significant ecological value. A set of rules on what constitutes the first flush and how much water is required to pass in order to renew the aquatic system is very difficult to determine but is critical to water resource planning.

Floods are economically critical because they underpin the health of the Gulf of Carpentaria fisheries.

- There is a strong positive relationship between streamflow and fishery catches, especially for species of commercial and recreational importance. Prawn landings in the Gulf of Carpentaria prawn fishery are strongly related to wet-season flows from the Gulf rivers.

Construction of the most promising water storages in the Flinders catchment would have a minor effect on inundation of the Flinders floodplain during most flood events.

- Construction of offstream storages capable of impounding 350 GL would, in the Flinders catchment, reduce floodplain inundation during ‘low flood’ years and would have a minor impact on floodplain inundation during ‘average’ and wet years.
Distance from the farm gate to agricultural processing plants places a significant cost burden on industry in the region.

Abattoirs at Townsville, Rockhampton and Biloela are the only export-certified abattoirs in north Queensland; no substantial inland beef processing plants serve northern Australia.

The sugar mill nearest the Flinders catchment is in the Burdekin, a road trip of 520 km from Richmond. The cotton gin nearest the Flinders catchment is in Emerald, a road trip of 780 km from Richmond.

Major sealed roads within the Flinders catchment (such as the Flinders Highway) can be closed by rain or flooding for as many as 30 days each year, although closures of one to five days each year are most common.

Pastoral enterprises of the Flinders catchment require access to new skills and services, and new people, to support the transition to irrigated cropping.

The skills and services required to support pastoralism differ significantly from those required to support intensive irrigated crop production. Prospective irrigators will require expertise and advice regarding regulatory and legal matters as well as specialist technical soil management and irrigation expertise. Implementing irrigation will require agronomy services; equipment suppliers and repairers; input suppliers; and ongoing and timely access to skilled labour. In the first instance these would have to be ‘imported’.

The average pastoral enterprise in the Flinders catchment supplements family labour with approximately 0.6 full-time equivalent (FTE) staff each year. A 50 ha irrigated forage development is estimated to require approximately 0.5 FTE, while a 1000 ha cotton development is estimated to require 6 FTEs. A 20,000 ha irrigation development would therefore require a minimum of 120 FTEs. Initially these people would need to be ‘imported’ as the requisite skills are not resident and the region’s low unemployment means that there is not an employment pool available.

The Flinders catchment’s social infrastructure requires investment in the event of a large-scale irrigation development.

The population in the Flinders catchment has been declining for at least the last 10 years. As a consequence, some community infrastructure (such as schools and hospitals) would be able to accommodate small to moderate increases in population growth resulting from irrigation development. If significant development were to occur, the concomitant increase in population would require upgrades to existing social infrastructure.

Indigenous people are represented to a greater extent in the Flinders catchment than in the wider Queensland population. While their connections with country have been impacted by historical processes such as forced relocation, significant connections remain. As in the broader community, Indigenous groups have a range of aspirations that relate to the opportunities provided by irrigation development.

Some Indigenous people are focused on opportunities and resources for existing residential populations, while others are focused on resettlement of those currently living elsewhere. Ongoing Indigenous priorities include securing sufficient water to maintain healthy landscapes, but also sufficient water to support current and future Indigenous needs, some of which relate to economic activity such as pastoralism, ecotourism and agriculture. At present, none of the catchment’s Indigenous groups participate in formal water planning processes.

Waterholes in the Flinders catchment are turbid, as a consequence, they are not highly sensitive to changes in water quality associated with sediment or nutrient loads.
Protecting cultural heritage is an Indigenous priority, and two major cultural heritage issues include ongoing damage to known existing sites and lack of documented heritage knowledge about traditional lands. Both hamper Indigenous capacity to respond to current development proposals. This is especially significant given that riverine and aquatic areas are known to be strongly correlated with cultural heritage sites and so the areas of development interest in the Flinders catchment are likely to contain important cultural heritage.

Indigenous people expect that Indigenous water values will be formalised and refined via their involvement in catchment water planning.

**Irrigation development in the Flinders catchment requires management of a number of considerations relating to the aquatic environment.**

Rivers are characterised by their flow regimes, which drive water quality, biodiversity assemblages, aquatic productivity and the physical form of rivers. Relatively minor changes in the amount, timing or location of water flow can significantly affect all of these factors, often unpredictably. Adaptive management is frequently required to address issues as they arise during development. Particular issues relevant to the Flinders catchment include:

- Waterholes in the Flinders catchment are replenished by streamflow rather than groundwater, making flow regimes critical to the ‘health’ of most waterholes.
- Water quality in waterholes declines over the dry season as waterhole temperature rises and oxygen levels drop. The first major flood flush needs to be of sufficient volume and velocity to clean out this ‘stagnant’ water.
- The waterholes of the Flinders catchment are turbid, with high amounts of suspended solids. As a consequence, they are not highly sensitive to changes in water quality – a small change in sediment or nutrient load, from farm runoff for example, makes a smaller difference to the quality of turbid water than of clear water.
- Stream continuity provides connections between the Gulf of Carpentaria and upper reaches of streams. These connections are important because the relatively brief periods during which most streams flow are the times at which inland waterways and the Gulf of Carpentaria stock each other with the fish, energy and nutrients that support the economically significant tourism and fishing industries. Structures that impede water flow – such as dams, weirs and roads – can be located and designed to minimise the extent to which they disrupt stream continuity and fish passage, but at increased cost.

**Irrigation development in the Flinders catchment requires management of a number of considerations relating to the terrestrial environment.**

Promising instream dam sites contain vegetation communities with an ‘of concern’ conservation status that could be inundated following dam construction. Detailed vegetation surveys would be required to support specific dam proposals.

Removal of native vegetation would occur on sites to be irrigated and for associated infrastructure, which would reduce regional plant species richness and impact species for which that vegetation provides habitat. Linear infrastructure (such as roads and channels) tends to have impacts greater than their area would suggest because of their fragmentation and boundary effects.

Irrigation development is likely to increase the risk of wind and water erosion of soils, and the release of sediment, nutrients and agropollutants to the environment. Agronomic and engineering methods can minimise these impacts.

Agriculture necessarily involves the deliberate introduction of novel species to a region, but can also be associated with elevated levels of inadvertent introduction of species via increased traffic and transport. Biosecurity monitoring and management protocols can reduce the likelihood and extent of risk.
Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.

The Flinders and Gilbert Agricultural Resource Assessment was conducted for the Office of Northern Australia in the Australian Government Department of Infrastructure and Regional Development under the North Queensland Irrigated Agriculture Strategy (<http://www.regional.gov.au/ona/nqias.aspx>). The Strategy is a collaborative initiative of the Office of Northern Australia and the Queensland Government. One part of the Strategy is the Flinders and Gilbert Agricultural Resource Assessment, which is led by CSIRO. Important aspects of the Assessment were undertaken by the Queensland Government and TropWATER (James Cook University).

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