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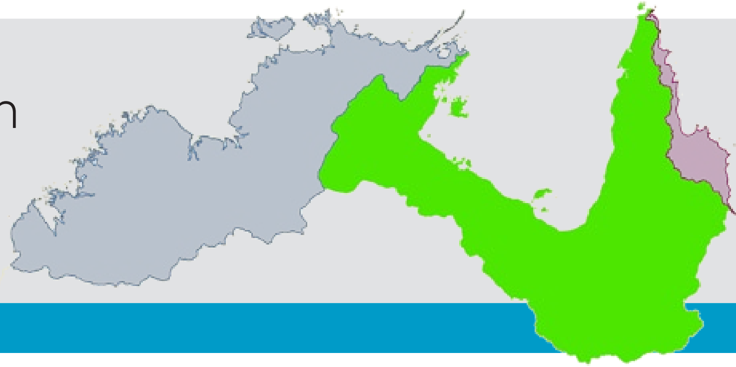
Water in the Gulf of Carpentaria Drainage Division

Summary of a report to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project



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Australian Government
National Water Commission
Raising National Water Standards Program

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The Project was guided and reviewed by a Steering Committee (Kerry Olsson, NWC – co-chair; Chris Schweizer, Department of the Environment, Water, Heritage and the Arts (DEWHA) – co-chair; Tom Hatton, CSIRO; Louise Minty, Bureau of Meteorology (BoM); Lucy, Vincent, Bureau of Rural Sciences (BRS); Tom Crothers, QDERM; Lyall Hinrichsen, QDERM; Ian Lancaster, NRETAS; Mark Pearcey, DoW; Michael Douglas, Tropical Rivers and Coastal Knowledge (TRaCK); Dene Moliere, Environmental Research Institute of the Supervising Scientist (*eriss*); secretariat support by Angus MacGregor, DEWHA) and benefited from additional reviews by a Technical Reference Panel and other experts, both inside and outside CSIRO.

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> Cover photographs: (left) Sun setting on cattle amongst the spinifex near Hughenden, QLD. Courtesy of CSIRO Land and Water. (right) Robinson River, 2008. Courtesy of NRETAS.

The Gulf of Carpentaria Drainage Division

The Gulf of Carpentaria is the large, shallow sea enclosed on three sides by northern Australia, and bounded on the north by the Arafura Sea. The land bordering the Gulf is generally flat and low-lying. To the west are Arnhem Land and the Top End, to the east Cape York Peninsula. The area to the south is known as the Gulf Country or simply the Gulf. In the Gulf Country, there are no mountains to restrict rainfall to the coastal band. The transition from the profuse tropical growth of the seaside areas to the arid scrubs of central Australia is gradual.

A large portion of the region comprises floodplains, with very low relief (Figure 1), resulting in significant tidal inundation during the wet season. The Gulf of Carpentaria Drainage Division covers approximately 647,000 km^2.

For this project, river basins were grouped into six regions. From west to east, these are:

- Roper
- South-West Gulf
- Flinders-Leichhardt
- South-East Gulf
- Mitchell
- Western Cape

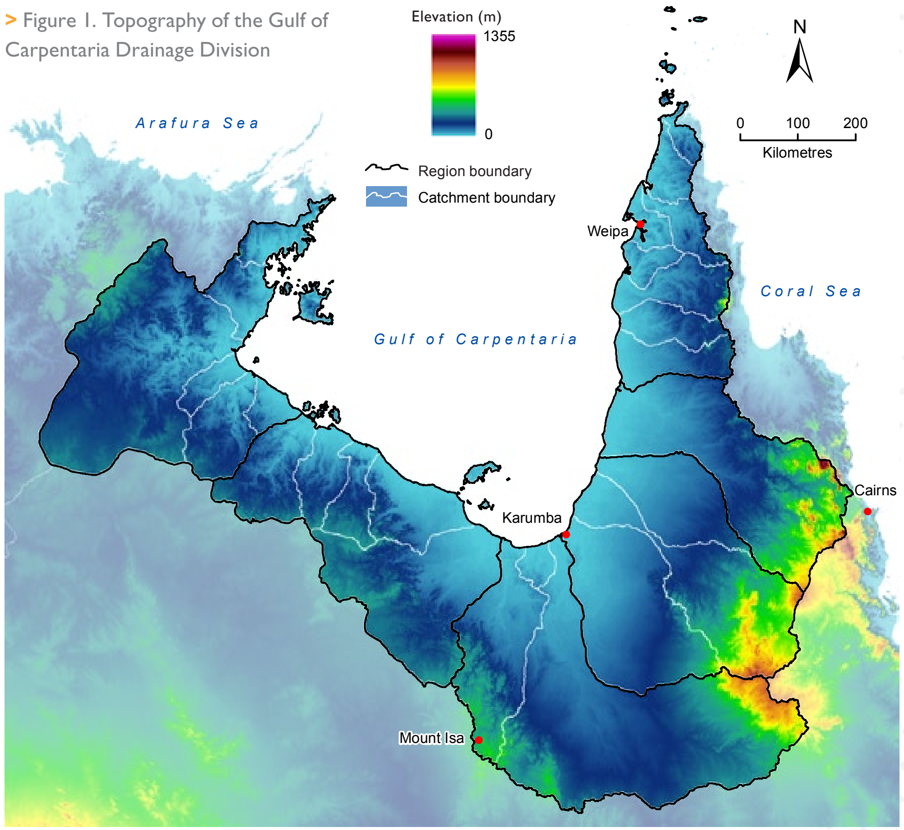
The climate is hot and humid with two seasons per year. The dry season runs from about May to October; the wet season from November to April. Almost all rainfall is compressed into two or three months, and during this period many low-lying areas are flooded.

Wet seasons are hot and humid with maximum temperatures around 33 to 36 °C in January. During the wet season, the region is one of the cloudiest of the north, even though there is an average of seven to eight hours of sunshine each day.

Dry season rainfall can be associated with the moist trade winds being uplifted over the coast. Temperatures are moderate in the dry with July average minimums dropping to about 21 °C in the north and 14 °C in the southern inland areas.

The climate gradients are aligned with the coast, decreasing north to south. Mean wet season rainfall ranges between 1800 mm in the north up to 300 mm in the south with moderate to high variability year-to-year.

> Figure 1. Topography of the Gulf of Carpentaria Drainage Division



The equatorial savannah climate in the far north gradually changes southwards into tropical savannah, then grasslands, with small areas of rainforest and subtropical climate along the Great Dividing Range in the east. The far south gradually changes to desert.

Gulf Country rivers, though mostly fairly short, tend to be very large by Australian standards and carry a quarter (about 90,000 gigalitres) of the continent's total yearly streamflow. Most rivers, however, flow only during the short wet season.

Pastoralism is the dominant land use. There are significant areas of nature conservation, Indigenous land use and forestry. Most income is generated by mining; large mines in the region include the Mount Isa Copper Mine, the McArthur River and Century lead-zinc mines and Weipa bauxite mines. The fishing industry is also a major employer, with prawn and finfish industries supported by the extensive coastal wetlands and shallow coastal waters.

Less than one percent of the drainage division has been cleared or is used intensively. Grazing pressure and fire regime strongly affect native vegetation cover and weeds significantly influence native vegetation condition. Buffel grass, a pasture species, is changing the composition of native grasslands and increasing fire intensity.

The population of the division is reasonably sparse with most people living in the mining town of Mount Isa. The Indigenous population is a significant component (>25 percent) of the population.

Key environmental issues for the division are the sustainable management of grazing and fishing and the management of mining water.

The drainage division supports a diverse array of vertebrate species, though it does not have the high levels of vertebrate biodiversity seen in the bordering higher-rainfall Timor Sea and North-East Coast drainage divisions. It has three endemic freshwater fish species and no endemic birds.

Wetland assets include lakes, mangroves, areas subject to inundation, saline coastal flats, watercourses and swamps. There are no Ramsar Convention sites. All of the drainage division's wetlands are important for ecological reasons or because they have historical significance or high cultural value, particularly to Indigenous people.

During the dry season, rivers have little rain water to ensure a continuous flow. So all perennial rivers and perennial springs are important sources of water, and most are also sacred sites.

The Northern Australia Sustainable Yields Project

The National Water Commission – on behalf of the Council of Australian Governments and in consultation with the Australian Government Department of the Environment, Water, Heritage and the Arts – commissioned CSIRO to assess the water resources of northern Australia, covering the Timor Sea and Gulf of Carpentaria drainage divisions and that part of the North-East Coast Drainage Division that lies north of Cairns.

Building on the success of the Murray-Darling Basin Sustainable Yields Project (completed in 2008), the Northern Australia Sustainable Yields Project has developed methods to assess water resources – surface water and groundwater – under four scenarios:

A. historical climate (1930 to 2007) and current development

B. recent climate (1996 to 2007) and current development

C. future climate (~2030) and current development

D. future climate (~2030) and future development.

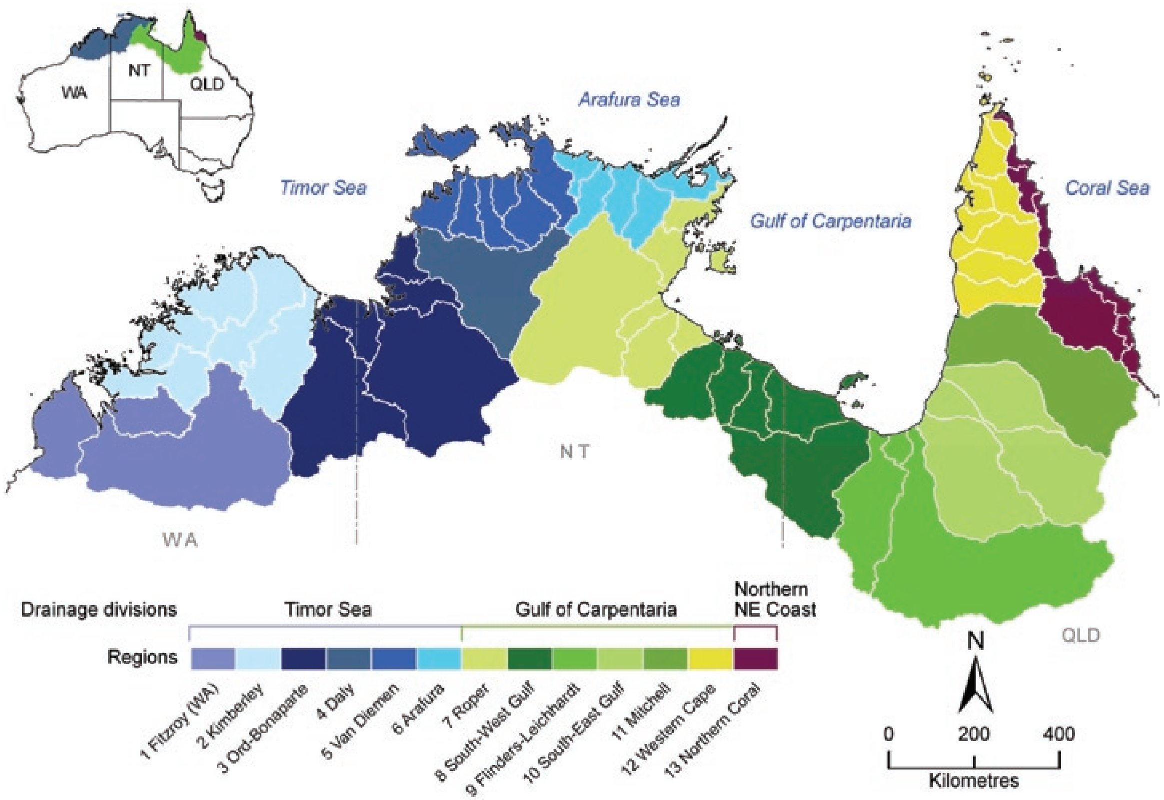
The term 'development' refers to the use of surface water and groundwater supplies. This assessment assumes that all current entitlements are being fully used and, where possible, actual use is also assessed.

Potential changes in flow regime at sites of important environmental assets were identified; these sites are often also important social and cultural sites. The strongly seasonal climate characteristics of northern Australia were considered. Surface–groundwater interactions were investigated. Current water storages and storage options were assessed, including groundwater storage, under the different scenarios. New storage sites and storage-yield reliabilities, however, were not assessed.

This project marks the first time a consistent, robust and transparent assessment has been carried out across the three jurisdictions of northern Australia, and the first time that models have included an assessment of possible future climate implications. It constitutes the first activity under the Australian Government's Northern Australia Water Futures Assessment and provides critical information for the Northern Australia Land and Water Taskforce.

This project was a desktop study. While no new data were collected, new data were generated through numerical modelling using existing data as a base, and new interpretations of existing data were undertaken.

Assessments and reporting have been made at the region scale, with regions ranging from 45,000 km^2 to 165,000 km^2, and comprising one or more river basins. Thirteen regions are defined for this purpose (Figure 2). This report summarises the results of investigations across the 6 regions (29 river basins) of the Gulf of Carpentaria Drainage Division. Separate summary reports are available for the Timor Sea and Northern North-East Coast drainage divisions, and for the entire project area. Detailed assessments for each region are included within the full Division reports.



> Figure 2. Reporting regions for the Northern Australia Sustainable Yields Project. White lines delimit the river basins

Assessing water resources in the Gulf of Carpentaria Drainage Division

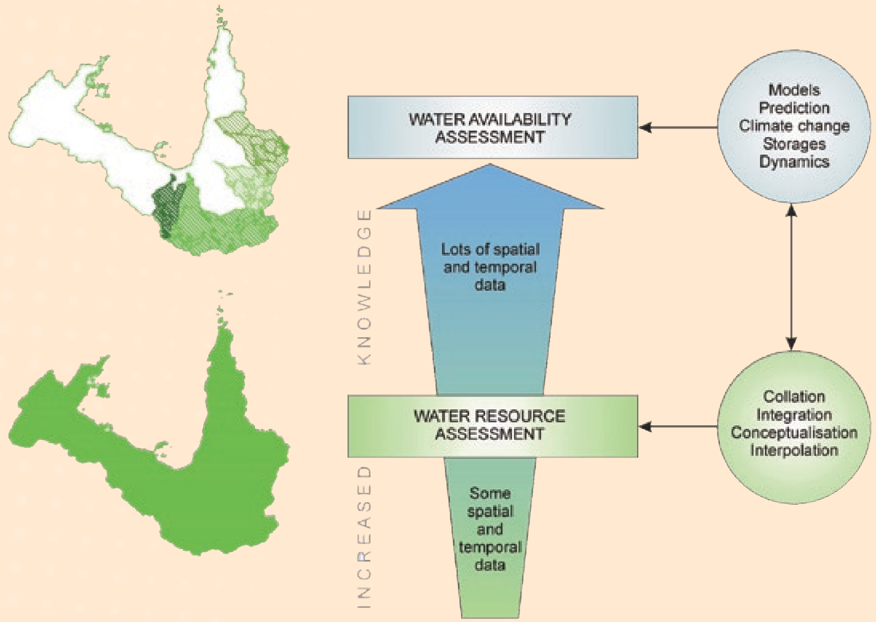
A **water resource assessment** (Figure 3) has been achieved for all regions of the Gulf of Carpentaria Drainage Division. This identifies how much water there is, in all its guises, at any given location, at any given time within the constraints of the current data.

Climate data (rainfall, sunshine, temperature, relative humidity) and landscape information are available; and surface and groundwater monitoring data were gathered to make an informed assessment of components of the hydrological cycle. The climate data were used to model runoff and diffuse groundwater recharge.

Key finding 1

Water availability assessments can only be made for parts of key catchments

A **water availability assessment** can be achieved where detailed numerical river systems and groundwater modelling is possible, information on storage and release potential is available, or where no surface water regulation exists. The aim of a water availability assessment is to determine the amount of water that could be diverted or extracted from each source, at any given location, at any given time. In the Gulf of Carpentaria Drainage Division, there are river systems models for large parts of the Mitchell, South-East Gulf and Flinders-Leichhardt regions, which have been developed to distribute estimated water resources using historical hydrological data (Figure 3).



> Figure 3. The levels of water assessment capability for the Gulf of Carpentaria Drainage Division. Shaded areas of the map have enough information and models to carry out the labelled level of assessment

Data, information and knowledge gaps

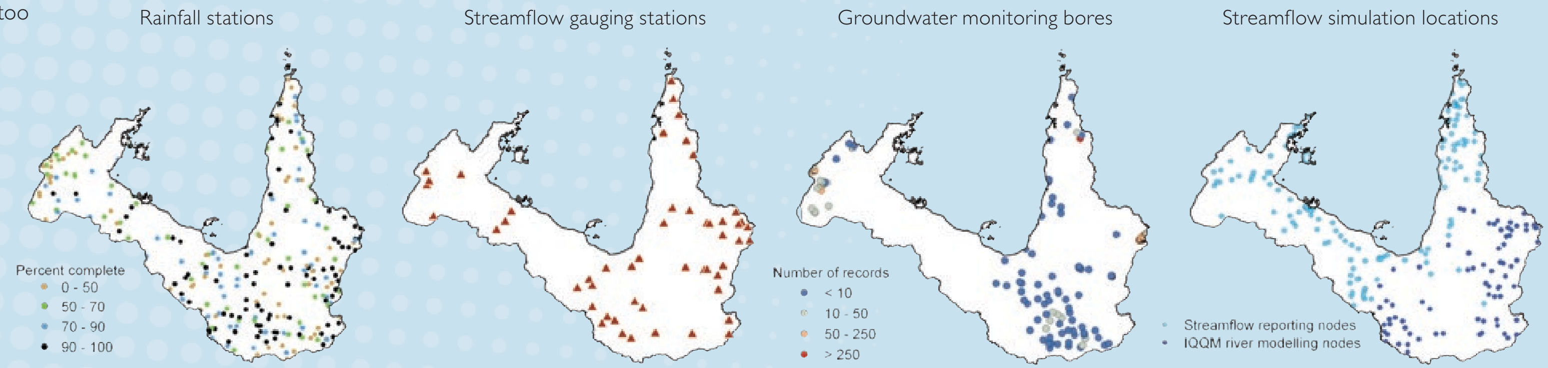
Integral to this project is the identification of gaps in data, information and knowledge. A key limitation on the project lay in the lack of water-related data for northern Australia.

Climate analyses were restricted to the 77 years from 1930 to 2007; prior to this there are too many gaps to allow a contiguous analysis. Even today, there are still considerable spatial gaps in rainfall data that restrict detailed analysis, particularly in the important headwater regions (Figure 4).

Streamflow gauging stations and reliable groundwater monitoring bores are sparsely located and the level of confidence in low-flow records at many gauging stations is poor. The paucity of flow data greatly inhibits the potential to assess the linkages between ecological systems and flow regime. Data are especially sparse in floodplain regions where maintenance of recording equipment is difficult. Surface water modelling has had to rely heavily on streamflow data from the 1970s and 1980s. Only a few locations have streamflow data extending back to the 1950s and in recent years many gauging stations have closed. Groundwater information is locally available, but large areas remain devoid of any quantitative groundwater data.

Key finding 2

There is a paucity of quality data for water resource accounting



> Figure 4. Location of rainfall stations, streamflow gauging stations, groundwater monitoring bores and streamflow simulation locations in the Gulf of Carpentaria Drainage Division

An extreme climate

The Gulf of Carpentaria Drainage Division receives substantial rainfall each year. An average of more than 510,000 GL (equivalent to 46 times the capacity of Lake Argyle, or 1200 Sydney Harbours) of rain fell across the drainage division each year between 1930 and 2007. From year to year, however, there is great variability in this amount (Figure 5). The driest year, 1952, received only half (251,000 GL) the mean amount; the wettest year, 1974, received twice as much (1,057,000 GL). Averages belie this variability and a single extremely wet year can dramatically increase the long-term average. This variability increases away from the coast and towards the south: year-to-year variability of rainfall in the Flinders-Leichhardt region in the south is twice that of the Western Cape region in the north.

Key finding 3

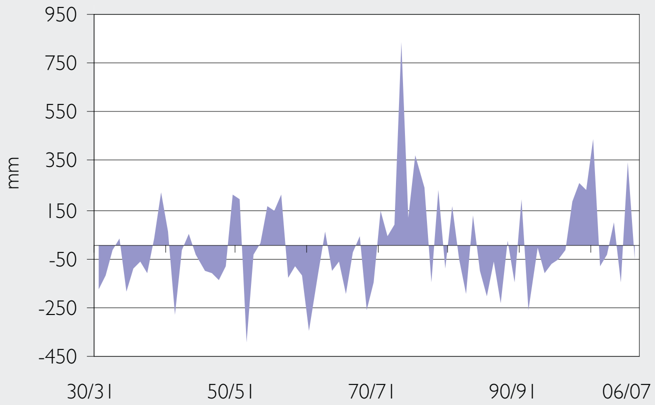
There is high inter-annual climate variability

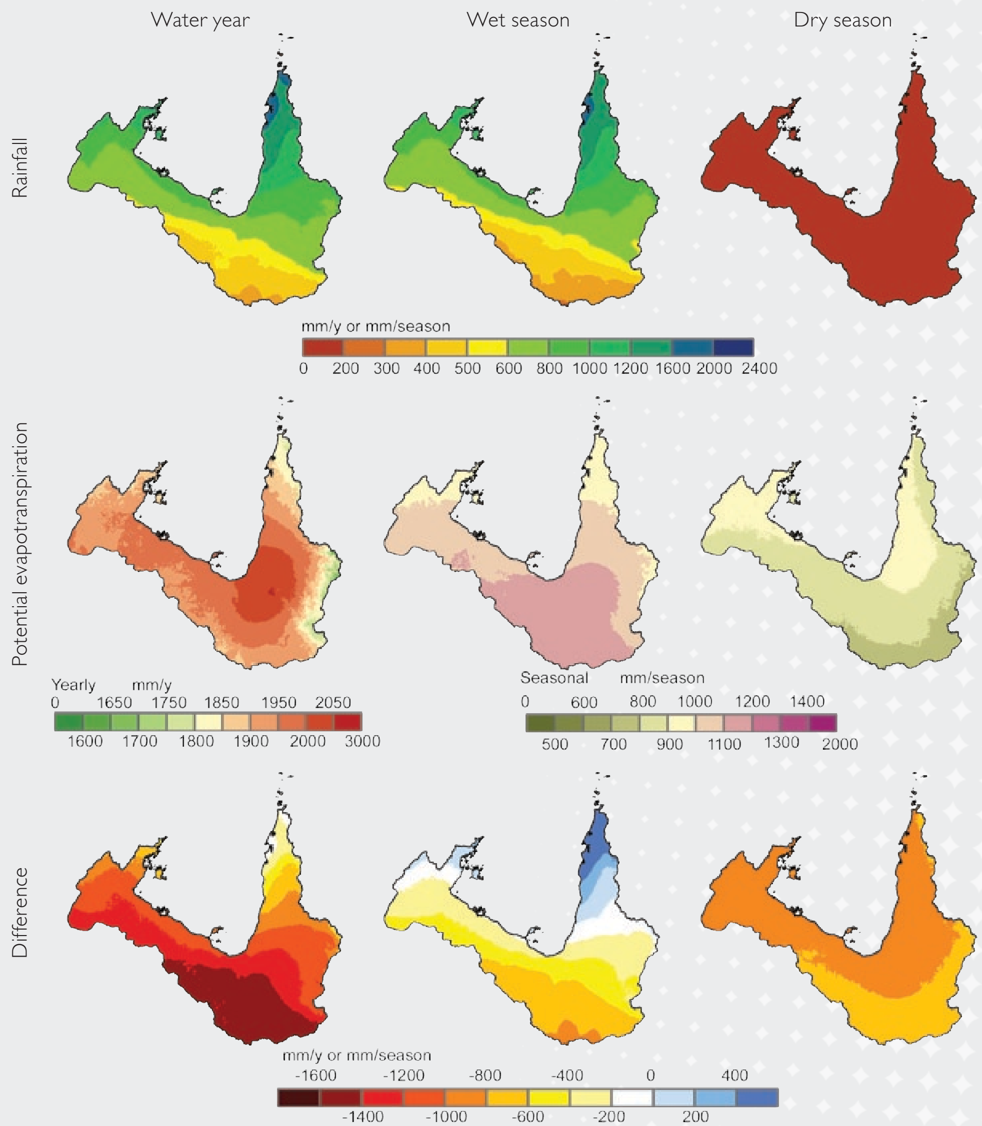
More than 94 percent of annual rainfall falls between November and April, with three to six months receiving little or no rain at all. The potential for evaporation and for plant transpiration ('potential evapotranspiration') is high throughout the year. On average, for ten months of the year potential evapotranspiration is greater than the amount of rainfall received. During a couple of months in the wet season daily rainfall can exceed potential evapotranspiration and this drives the seasonal streamflow. On an annual basis, however, rainfall is insufficient to meet evaporative demand and the landscape may be described as water-limited (Figure 6).

Key finding 4

The climate is extremely seasonal and the landscape may be described as annually water-limited

> Figure 5. Annual historical rainfall divergence (mm) from the historical mean, averaged over the Gulf of Carpentaria Drainage Division





> Figure 6. Spatial distribution of historical mean annual, wet-season and dry-season rainfall and potential evaportransporation, and their difference (rainfall less potential evaporation) across the Gulf of Carpentaria Drainage Division
water year: 1 September to 31 August; wet season: 1 November to 30 April; dry season: 1 May to 31 October

Historical and current water resources

Surface water

Most rain falls near the coast, on the estuaries, not in the rivers' headwaters (unlike, for example, the Murray-Darling Basin). Both rainfall and runoff decrease away from the northern coast. Runoff varies from 60 percent to less than 3 percent of rainfall from north to south (Figure 7) and generates on average about 90,000 GL of streamflow across the drainage division each year. (This compares to 95,600 GL reported by the jurisdictions for the National Land and Water Resources Audit).

Key finding 5

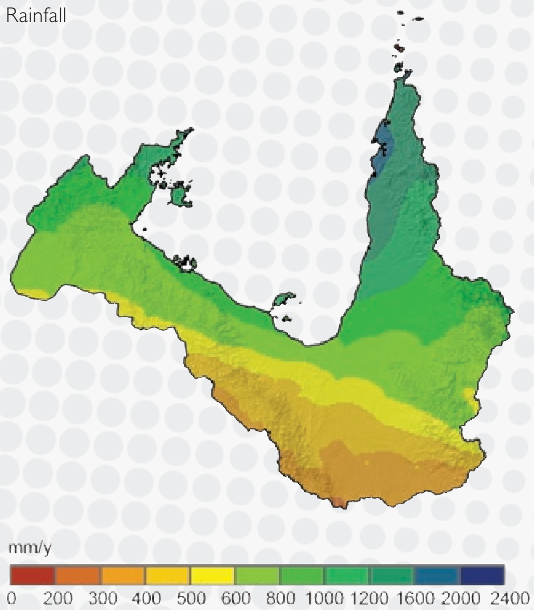
Most rain, and runoff, occurs near the coast, not in the rivers' headwaters

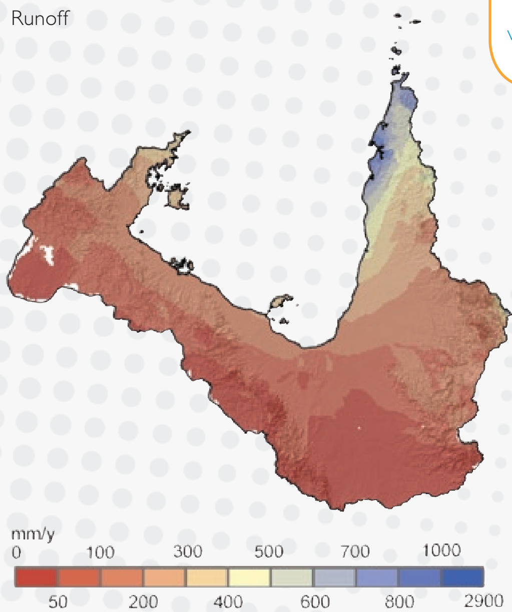
This pattern of runoff combines with the generally low relief for much of the coastal region to provide little opportunity to increase surface storages. Opportunities occur mainly in the upper reaches of catchments. In these areas, however, rainfall is lower and more sporadic, and potential evapotranspiration is higher. Large storages are needed to compensate for evaporative losses and storage volumes need to be much larger than they would need to be in southern Australia, all things being equal. There are few opportunities to increase surface water storage that satisfy all these requirements, and possible locations have already been identified by jurisdictions.

Parts of the headwaters of the river basins in the north and east of the drainage division also receive sufficient rainfall to generate flows in the Mitchell and Western Cape regions (Figure 7) yet these areas also have low relative relief.

Key finding 6

There are significant constraints on the viability of surface water storages





> Figure 7. Spatial distribution of historical mean annual rainfall and modelled runoff across the Gulf of Carpentaria Drainage Division overlaid on a relative relief surface

Diversions

The majority of rivers in the drainage division have largely unimpeded flow. This is reflected in the large number of wetlands registered in the Directory of Important Wetlands, the proposed Heritage listing of Cape York Peninsula and the Wild Rivers legislation adopted across many rivers of the drainage division. A wild river declaration preserves a wild river's natural values by regulating development within the wild river and its catchment area, and by regulating the taking of natural resources from the area. The few regulated rivers generally have a high degree of regulation and these have had local consequences to flow regimes downstream and around regulation structures.

Key finding 7

Most catchments have largely unimpeded flow

Surface water – groundwater interaction

The high evaporation rates and long dry season mean that very few rivers—indeed, very few river reaches— flow year-round. Those that do are highly valued. Values are often environmental, cultural, social and developmental, and are intertwined. These perennial river reaches support endemic ecosystems, provide tourism and fishing opportunities and have high spiritual significance for Indigenous and non-Indigenous people alike.

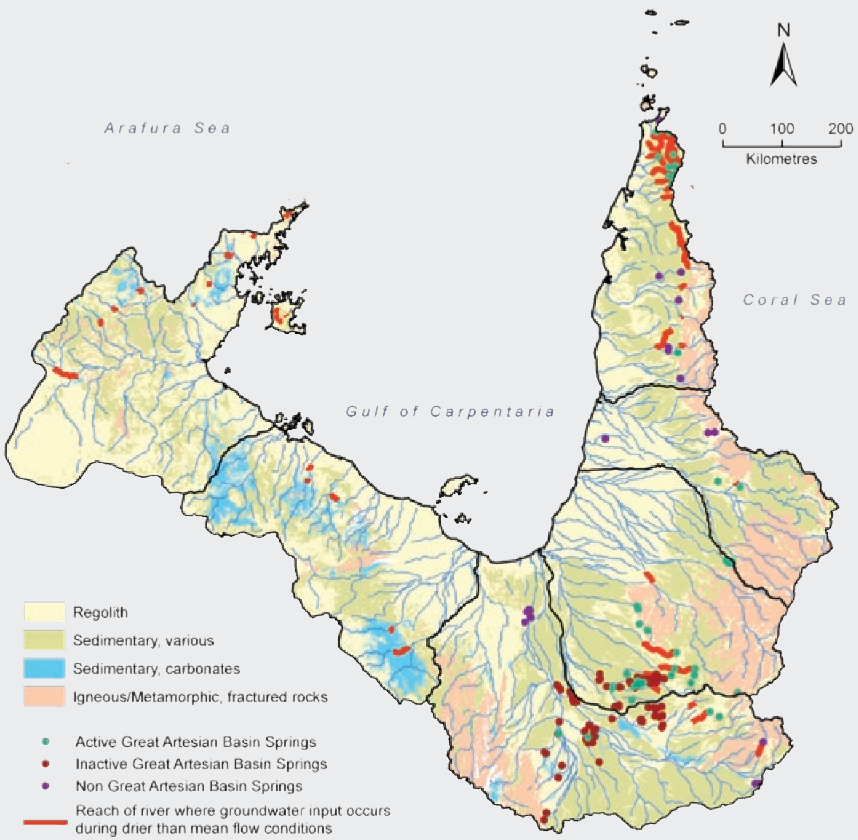
Key finding 8

There are very few perennial river reaches and these have high cultural, social and ecological value

Critically, the inland rivers that flow through the dry season are sustained by localised groundwater discharge—discharge occurs where streams cross outcrops of shallow aquifers, or where deeper artesian waters puncture the landscape, generating springs (Figure 8). These localised points of discharge are few and the risk of impact from development is high. In these environments, ecosystems have adapted to streamflow conditions that are rainfall-dependent in the wet season and groundwater-dependent in the dry season.

Key finding 9

Inland perennial rivers are sustained by point discharge of groundwater



> Figure 8. Surface–groundwater connectivity in the Gulf of Carpentaria Drainage Division. The few rivers that flow through the dry season are related to discharge either from Great Artesian Basin aquifers in the east, or carbonate aquifers in the centre and west

Groundwater

Water tables in shallow aquifers respond dramatically to the seasonal rains, often rising several metres each year. Many shallow aquifers fill to capacity, and drain slowly during the dry season.

Shallow groundwaters generally have good quality water, reflecting the annual fill and spill cycle, and can be good supplies of potable water. Extractable yields are determined by the extent to which these dynamic systems can recover each year. The annual natural rise and fall of water levels, however, means these systems have lower extractable yields than deeper, regional systems or the confined aquifers of the Great Artesian Basin and there is risk to reducing any streamflow of local rivers reliant on groundwater input.

Key finding 10

Shallow groundwater provides opportunities for development, but its dynamic behaviour poses risks of impacting local streamflow

Deep groundwater supplies of the Great Artesian Basin are a potential additional source of water within the drainage division. There is already significant extraction for stock and domestic purposes, and the resource may support further use, but more monitoring of groundwater dynamics is needed to determine safe extraction levels.

Key finding 11

The Great Artesian Basin aquifers may support further development, but safe extraction yields have not been determined

The Great Artesian Basin aquifers likely discharge beneath the Gulf of Carpentaria; the consequences of this discharge to the marine environment have not been investigated.

Further inland, groundwaters from these aquifers are the most important source of dry season flow in rivers, and support numerous artesian springs (Figure 8).

Groundwater recharge rates are variable across the landscape, and depend on soil type, vegetation and topography as well as rainfall amount and other climate variables. The complex interplay between these parameters means there is not always a direct correlation between rainfall and groundwater recharge rates. Modelling indicates that rainfall regime (rain per rain day, number of rain days) is critical, and lower total rainfall might still result in higher recharge. Pathways for water infiltration to water tables can be complex and may change in importance through the year. So, rivers may recharge aquifers during the wet months, while discharging groundwater may keep rivers flowing during the dry months.

Key finding 12

Groundwater recharge is complex and not directly proportional to rainfall

Groundwater data are very sparse for most aquifers across the drainage division and there are large uncertainties regarding the volumes that might be safely extracted. This uncertainty is greater than the variability inherent in any possible changes expected due to climate change. Increased extraction will have consequences downstream that currently cannot be fully evaluated.

There is little potential to replenish shallow aquifers artificially ('managed aquifer recharge'). Shallow aquifers fill and spill with the seasons, and the time when they have capacity to accept more water coincides with the time when there is little surface water available. In addition, much of the terrain has a hard crust (laterites) restricting the ability to use infiltration pits. More expensive injection wells would be required, reducing the economic viability.

The large areas of carbonate aquifers across the east of the drainage division develop karst features and sinkholes and are important channels for water to penetrate the ground.

Key finding 13

There is little potential for increased groundwater storage

Floods, flows and ecology

Floods are vital for ecosystems, flushing nutrients into the near-shore marine environment and providing vast on-shore breeding grounds. Flooding across floodplains also fills hollows and pools that persist through the dry season, sustaining vital ecosystems until the next wet season.

Key finding 14

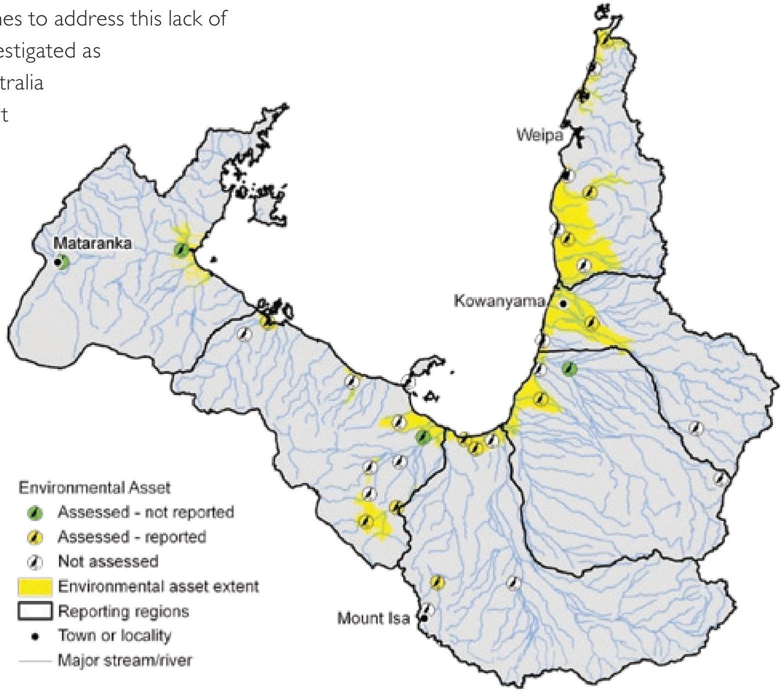
Floods are essential to sustain ecosystems, but there are few ecosystem response indicators for changes in flow regimes

Across the 29 river basins in the Gulf of Carpentaria Drainage Division, 35 sites on the Directory of Important Wetlands were examined (Figure 9). None have ecosystem response indicators against which to judge whether a change in flow would be detrimental to the ecosystem. Approaches to address this lack of information are being investigated as part of the Northern Australia Water Futures Assessment Ecological Program.

There is still a general lack of data on quantitative relationships between flow and specific ecological entities (e.g. macrophyte populations, fish passage, faunal and floral habitats), so the consequences of flow changes for ecological systems are largely unknown.

Key finding 15

The consequences of flow changes on ecological systems are largely unknown



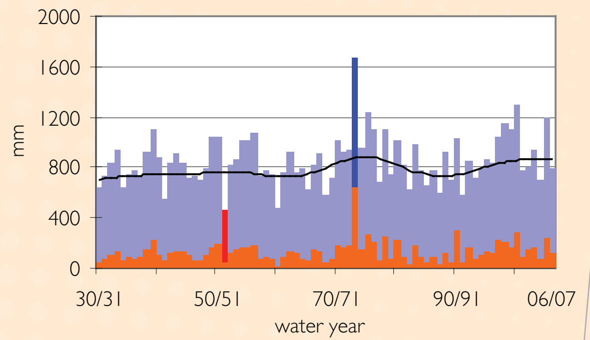
> Figure 9. Environmental assets assessed during this project. At yellow coloured sites we have sufficient confidence in flow regimes to report one or more flow metrics

Historical and recent climate trends

Historical (1930 to 2007) climate records indicate a slight increase in rainfall intensity (rain per rain day) in the drainage division and that the recent past (1996 to 2007) has been 19 percent wetter than the previous 66 years (Figure 10). The recent past does not, however, have the full range of climatic variability seen in the historical record; neither does it have the extremes of possible future conditions. So there is considerable risk in using recent past conditions to guide future water planning. A single very wet year can significantly bias the long-term mean.

Key finding 16

The climate of the recent past is neither indicative of historical conditions, nor the possible range of future conditions



> Figure 10. Historical annual rainfall (blue) and modelled runoff (orange) averaged over the Gulf of Carpentaria Drainage Division. The trend line indicates longer term variability; highest and lowest rainfall years are indicated

What the future holds

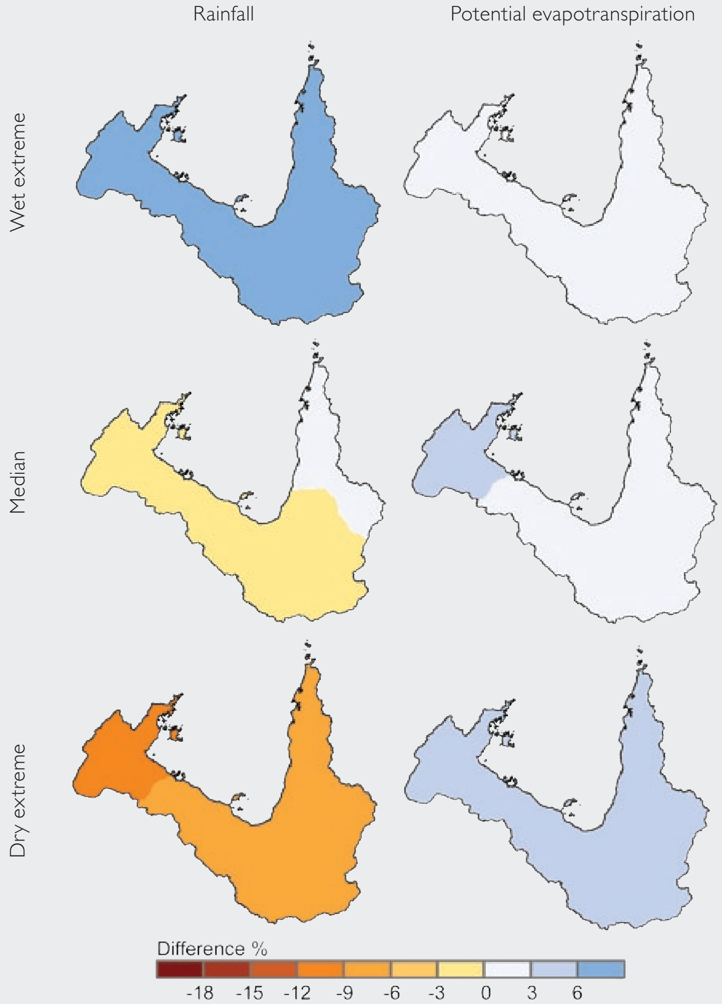
Future climate

Across the drainage division, rainfall in the future (around 2030) is expected to be similar to conditions of the 1990s, within a range of plus ten to minus ten percent (Figure 11). Evaporation rates are expected to be slightly higher, increasing by between one and five percent. Fifteen global climate models were compared. These were recommended by the Intergovernmental Panel on Climate Change in their Fourth Assessment Report in 2007. These models generate a range of possible future conditions based on a range of input assumptions.

This modelling provides confidence at large (regional) scales, becoming less predictive at small (local) scales. So, whilst model results provide a good indication of possible trends, they should not be used to identify local changes.

Key finding 17

Models indicate that future rainfall will be similar to historical averages; potential evapotranspiration may be slightly higher



> Figure 11. Percentage change in future mean annual rainfall (left) and areal potential evapotranspiration (right) derived from future climate simulations (using 15 global climate models and three global warming scenarios) relative to rainfall and areal potential evapotranspiration of the 1990s

Development opportunities and constraints

Existing plans by jurisdictions to increase water use will have little impact on water resources at the river basin scale in the short term (to around 2030). Longer-term impacts may have consequences, however, particularly where groundwater is being extracted. Local consequences may be significant, particularly where groundwater extraction and surface-groundwater interaction is prevalent.

Key finding 18

Planned development will have minimal regional water resource consequences, but will have local impact

Importantly, groundwater takes considerably longer than surface water to move through the landscape. The slower flow times of groundwater compared to surface water mean that groundwater-fed rivers can continue to flow during the dry, but also that any downstream consequences of groundwater extraction may not be realised for many years.

Key finding 19

Groundwater travels much slower than surface water, so responses to any change will be measured in years, not months

Low streamflow conditions may be the most sensitive to modelled climate change. However, the paucity of calibration data provides low confidence in the quantitative assessments of flow regime change, especially for low flow streamflow conditions.

> Minyerri waterhole, NT. Courtesy of NRETAS

About the project

The Northern Australia Sustainable Yields (NASY) Project has assessed the water resources of northern Australia. The project modelled and quantified, within the limits of available data, the changes to water resources under four scenarios: historical climate; recent climate; future climate considering current water use and future climate with potential future water demand. The project identified regions that may come under increased, or decreased, stress due to climate change and increased water use.

The assessments made in this project provide key information for further investigations carried out through the Australian Government's Northern Australia Water Futures Assessment. This initiative aims to develop a knowledge base to inform the development and protection of northern Australia's water resources, so that any development proceeds in an ecologically, culturally and economically sustainable way.

The NASY project was commissioned by the National Water Commission in consultation with the Australian Government Department of the Environment, Water, Heritage and the Arts. This followed a March 2008 agreement by the Council of Australian Governments to undertake comprehensive scientific assessments of water yield in all major water systems across the country and provide a consistent analytical framework for water policy decisions across the nation. CSIRO is also undertaking assessments in south-west Western Australia and Tasmania.

The NASY project was reviewed by a Steering Committee and a Technical Reference Panel. Both include representation from federal and state governments, as well as independent experts.

For further information:

Water for a Healthy Country Flagship
Project Leader
Dr Richard Cresswell
Phone: 07 3214 2767
Email: Richard.Cresswell@csiro.au
Web: www.csiro.au/partnerships/NASY

Northern Australia Water Futures Assessment
Department of the Environment, Water, Heritage and the Arts
Phone: 02 6274 1111
Email: northern.assessment@environment.gov.au
Web: http://www.environment.gov.au/nawfa

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Water in the Gulf of Carpentaria Drainage Division: Summary of a report to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project

This report summarises information from the following report:

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