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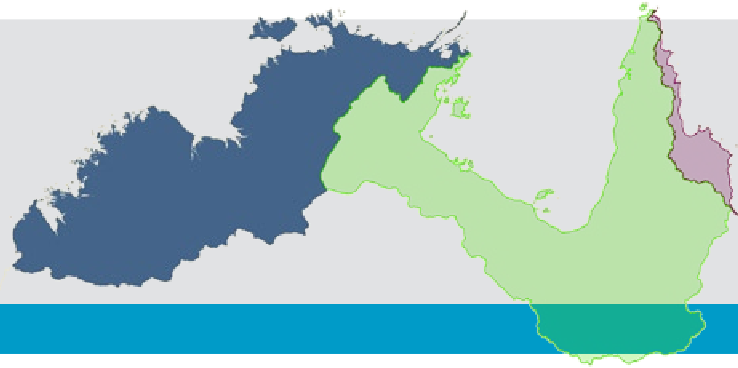
Water in the Timor Sea Drainage Division

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



August 2009

Australian Government
National Water Commission
Raising National Water Standards Program

Acknowledgments

Prepared by CSIRO for the Australian Government under the Raising National Water Standards Program of the National Water Commission (NWC). Important aspects of the work were undertaken by the Western Australia Department of Water (DoW); the Northern Territory Department of Natural Resources, Environment, The Arts and Sport (NRETAS); the Queensland Department of Environment and Resource Management (QDERM); the New South Wales Department of Water and Energy; Sinclair Knight Merz; Environmental Hydrology Associates and Jolly Consulting

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 Scientists (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.

Citation

CSIRO (2009). Water in the Timor Sea Drainage Division. Summary of a report to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project. CSIRO, Australia. 12pp

Publication Details

ISSN 1835-095X

> Cover photographs: (left) Fitzroy River at Fitzroy Crossing, WA.
Courtesy of the Western Australia Department of Water.
(right) Katherine River, NT.
Courtesy of CSIRO Sustainable Ecosystems.

The Timor Sea Drainage Division

The Timor Sea Drainage Division (Figure 1) includes most of the Top End and the Kimberley, and covers an area of approximately 564,600 km^2. Much of the landscape forms a patchwork of harsh, dry escarpments and tablelands, and low-lying river flats. It is hot and dry during the dry season from May to October and often flooded during the wet season. Streams generally run west to the Indian Ocean or north to the Timor Sea and can be very large by Australian standards. On a streamflow volume per area basis, it is the second wettest drainage division in Australia (after the Tasmania Drainage Division).

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

- Fitzroy (WA)
- Kimberley
- Ord-Bonaparte
- Daly
- Van Diemen
- Arafura

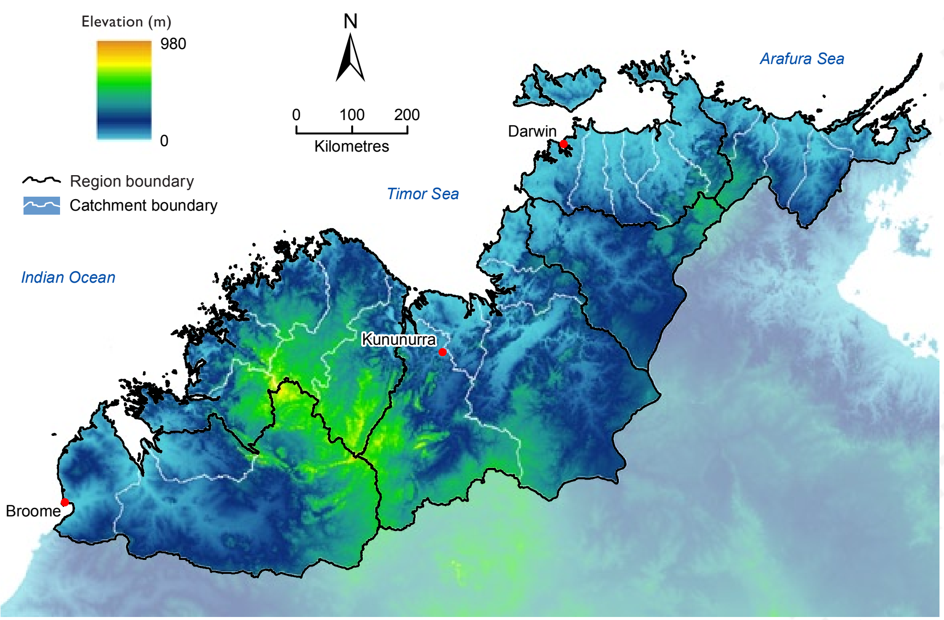
The large river systems – the Ord, Victoria, Daly and Fitzroy – have relatively low gradients; they mainly drain expansive savannah woodland plains and form extensive floodplains and coastal wetlands. The Kimberley in the south-west and Arnhem Land in the north-east have short river basins with high gradients. Most rivers drain to coastal floodplains and wetlands, although the rivers of the Kimberley dissect the coastal landscape draining to an extensive archipelago of coastal islands. Relatively shallow seas result in low wave energy and large tidal ranges.

The climate is predominantly tropical, with high temperatures year-round (averaging 28°C) and high, yet very seasonal, rainfall. Rainfall decreases away from the coast, ranging from 1687 mm/year in the north to 383 mm/year in the south. Almost all rain falls during the wet season, from November to April. To the south, the climate becomes hotter and more arid and rainfall becomes less seasonal.

Historical (1930 to 2007) mean annual rainfall across the drainage division is 868 mm with high year-to-year variability. Historical mean annual potential evapotranspiration is 1979 mm. On an average annual basis, the drainage division can be described as being 'water-limited' i.e. the mean annual potential evapotranspiration exceeds the mean annual rainfall.

Tropical savannah along and inland from the coast gradually changes to open savannah towards the south. The vegetation has adapted to cyclical conditions resulting from the strong seasonality of highly intense rainfall and the corresponding strong seasonality of streamflow. Only small areas of the division have been cleared (<1 percent) or are used intensively. Native vegetation cover and condition has been extensively affected by grazing pressure, altered fire regimes and weeds, with complex interactions between the three processes. An increased incidence of introduced grass species and an increasing intensity and frequency of fires is observed in some areas.

> Figure 1. Topography of the Timor Sea Drainage Division showing project regions (black lines) and river basins (white lines)



The dominant land use is grazing, with large areas of nature conservancy and areas under Indigenous use. Extensive areas of highly productive seasonal coastal wetlands support important prawn and finfish fisheries.

The drainage division has a great diversity of freshwater fish species, with almost 100 different species recorded (27 of them endemic to the division). The variety of bird life, both resident and migratory, is without parallel.

The population is sparse, with most people living in either Darwin or Broome. Around 30 percent of the population are Indigenous.

Because of the low population density, much of the native vegetation in the drainage division remains relatively intact. Key environmental issues include land clearing, rapid population growth and the lack of a sustainable fire-management policy.

Wetland assets include lakes, mangroves, areas subject to inundation, saline coastal flats, watercourses and swamps. Eight wetlands are classified as 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.

Rivers that flow year-round 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.

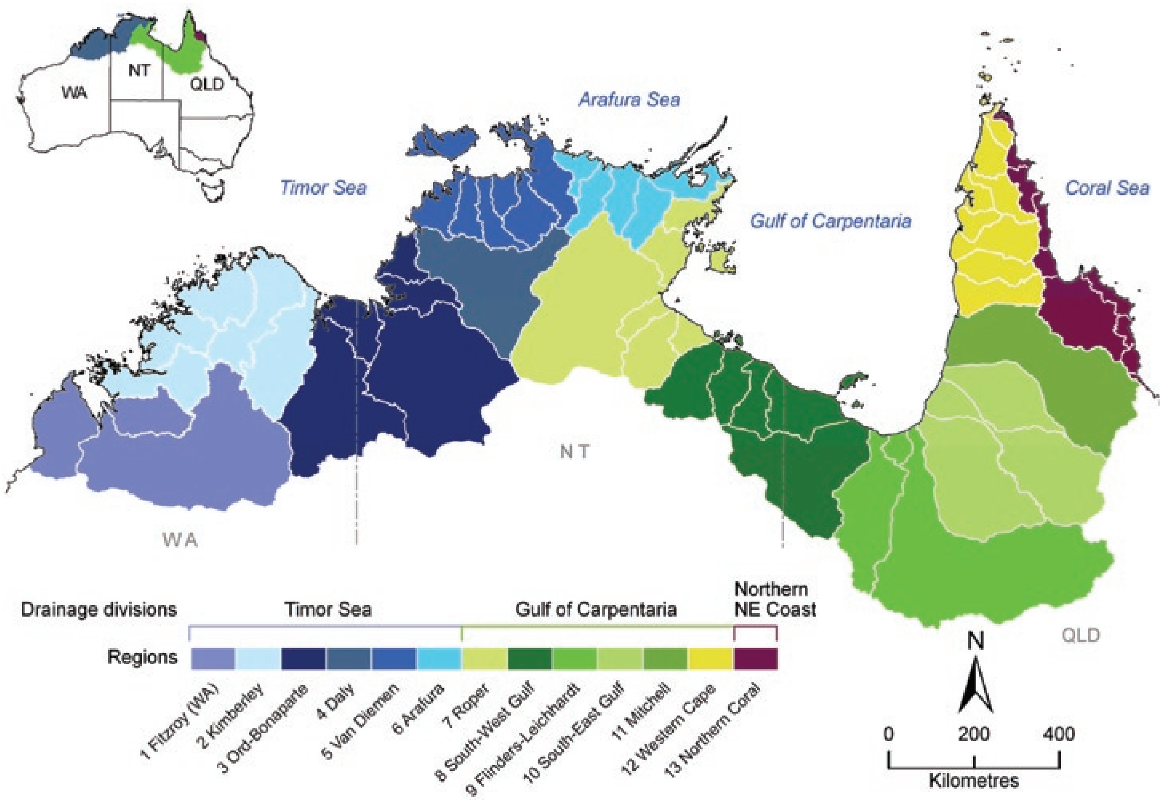
The term 'development' refers to the use of surface water and groundwater supplies. This assessment assumes that all current entitlements are being fully used and, where possible, actual use is also assessed.

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 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 (26 river basins) of the Timor Sea Drainage Division. Separate summary reports are available for the Gulf of Carpentaria 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 Timor Sea Drainage Division

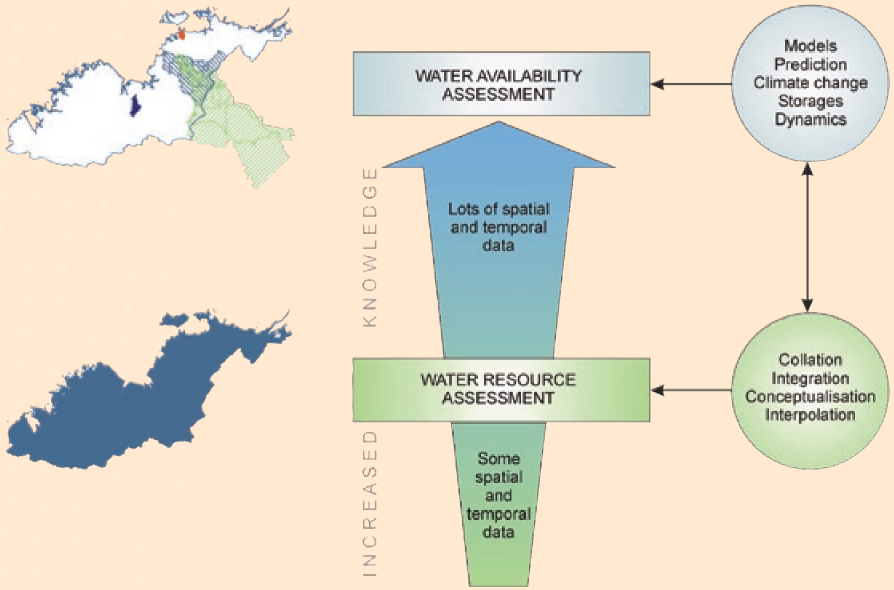
A **water resource assessment** (Figure 3) has been achieved for all regions of the Timor Sea Drainage Division. This identifies how much water there is, in all its guises, at any given location, at any given time within the constraints of the current data.

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.

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 Timor Sea Drainage Division, there are three surface water models and two groundwater models that are suitable for regional-scale water availability assessment. The Darwin River Dam of the Van Diemen region, the Daly River basin, and the Lower Ord catchment downstream of Lake Argyle have calibrated surface water models. The Darwin Rural Area-McMinn's-Howard East part of the Van Diemen region and the Katherine-Douglas-Daly areas of the Daly region have numerical groundwater models (Figure 3).

Key finding 1

Water availability assessments can be made for parts of key catchments



> Figure 3. The levels of water assessment capability for the Timor Sea 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

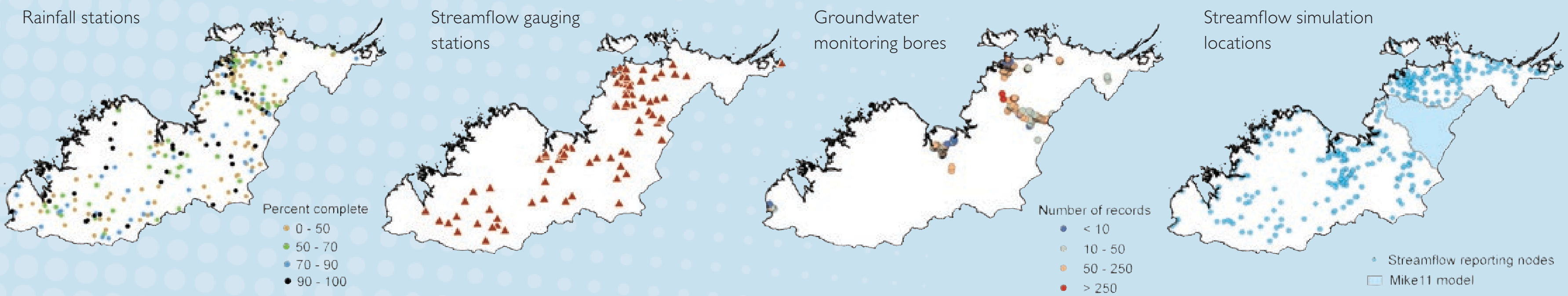
Integral to this project is the identification of gaps in data, information and knowledge. A key limitation on the project lay in the lack of water-related data for northern Australia.

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 current rainfall stations, streamflow gauging stations, groundwater monitoring bores and streamflow simulation locations in the Timor Sea Drainage Division

An extreme climate

The Timor Sea Drainage Division receives substantial rainfall each year. An average 504,000 GL (equivalent to 45 times the capacity of Lake Argyle, or 1000 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 (244,000 GL) the mean amount; the wettest year, 2000, received nearly twice as much (820,000 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 Fitzroy (WA) region in the south-west is double that in the Van Diemen region in the north.

Key finding 3

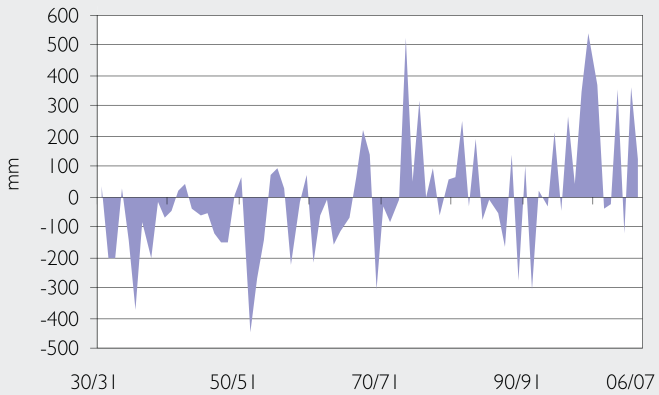
There is high inter-annual climate variability

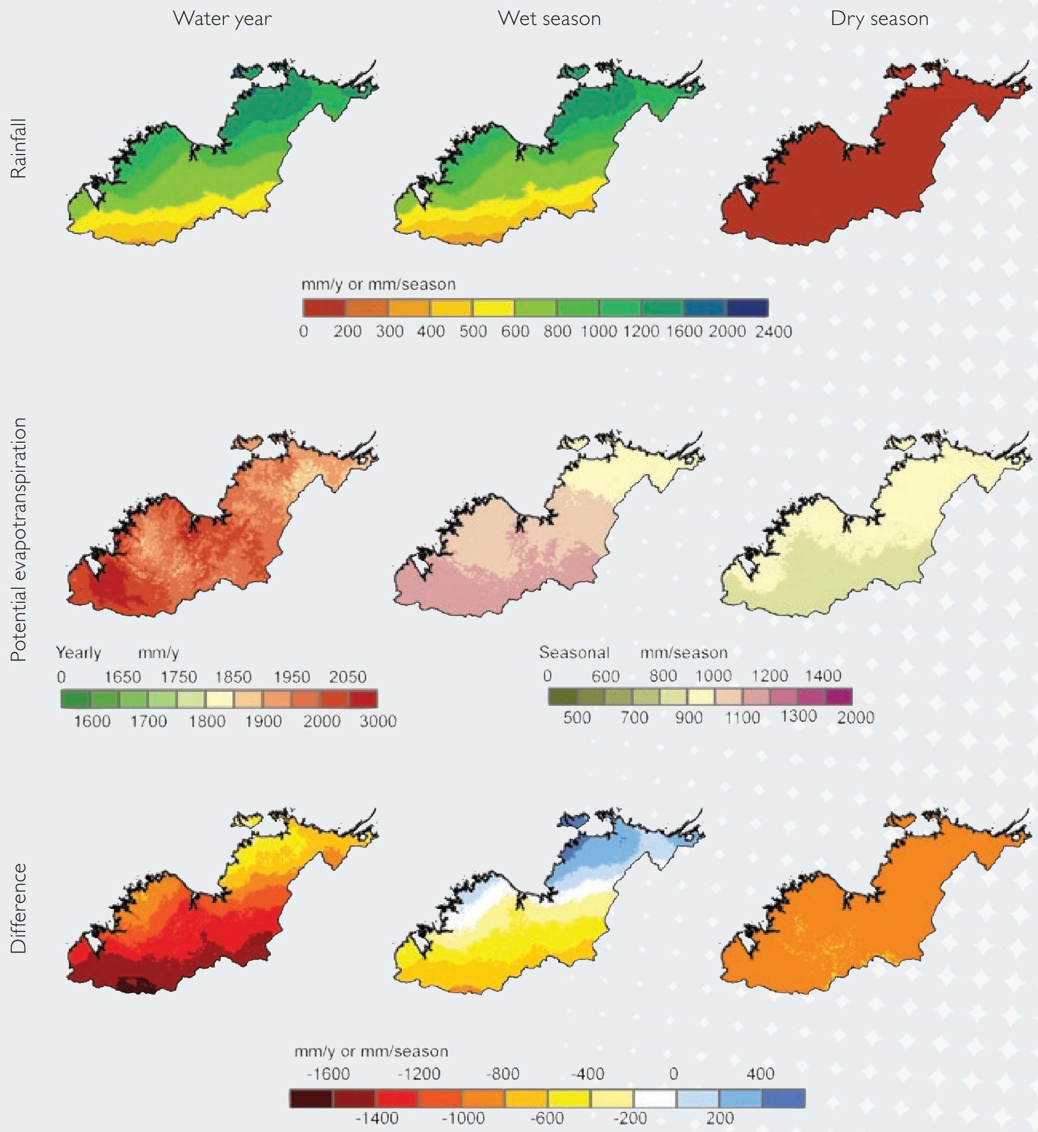
More than 95 percent of annual rainfall falls between November and April, with three to six months receiving little or no rain at all. The potential for evaporation and for plant transpiration ('potential evapotranspiration') is high throughout the year. On average, for ten months of the year potential evapotranspiration is greater than the amount of rainfall received. During a few months in the wet season, daily rainfall can exceed potential evapotranspiration and this drives the seasonal stream flow. 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 Timor Sea 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 Timor Sea Drainage Division water year: 1 September to 31 Augus; 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 40 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.

Key finding 5

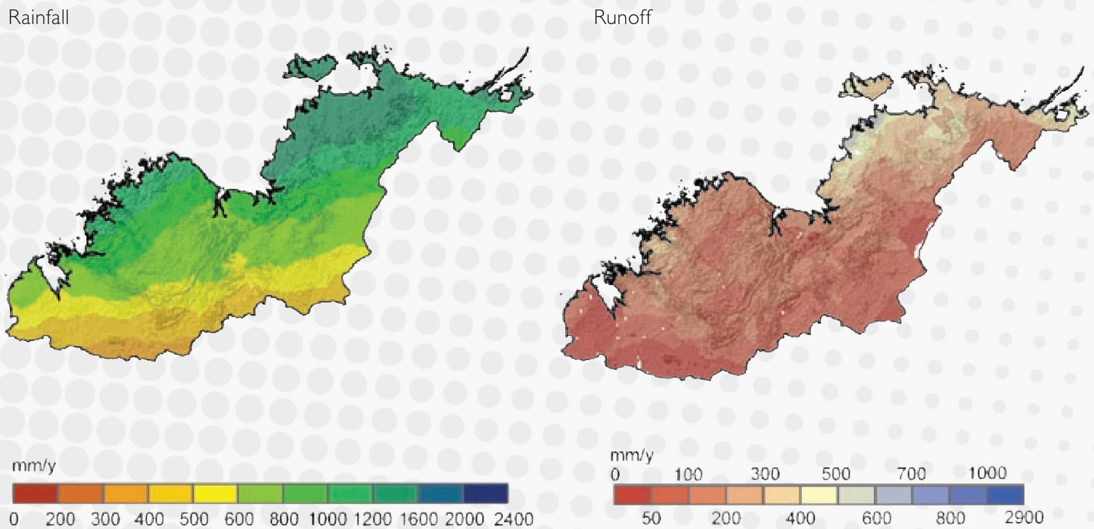
Most rain, and runoff, occurs near the coast, not in the rivers' headwaters

This pattern of runoff combines with the generally low relief of 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 and possible locations have already been identified by jurisdictions.

The Van Diemen region – the catchments surrounding Darwin – has a combination of high rainfall and adequate relief and additional potential storages have been identified. Their likely development, however, is beyond the time frame of this study (i.e. beyond 2030).

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 Timor Sea Drainage Division overlaid on a relative relief surface

Diversions

The majority of rivers in the drainage division have little or no regulation. The few regulated rivers have a high level of regulation and this has had local consequences to flow regimes downstream of regulation structures. Of note are the Ramsar-listed sites of Lake Argyle and Lake Kununurra, created through regulation of the Ord River.

Key finding 7

Most catchments have largely unimpeded flow

The surface waters of the Lower Ord system provide water for irrigation, hydropower and the environment. The level of use of water diverted for irrigation is low, but hydropower demand can require release of more than half of all inflows to Lake Argyle.

Surface water – groundwater interaction

High evaporation rates and a 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

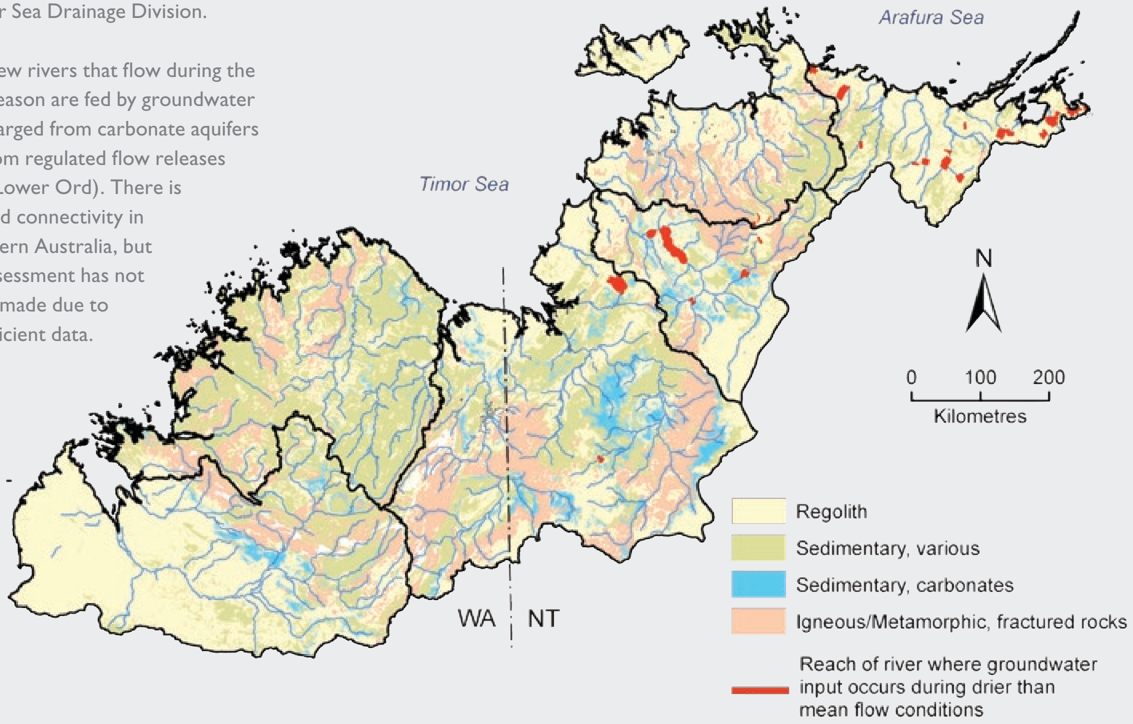
Critically, the inland rivers that flow through the dry season are sustained by localised groundwater discharge—discharge occurs where streams cross outcrops of shallow aquifers, or in high-rainfall areas where rejected recharge (from aquifers that fill to capacity) keeps the river flowing (Figure 8). 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 Timor Sea Drainage Division.

The few rivers that flow during the dry season are fed by groundwater discharged from carbonate aquifers or from regulated flow releases (e.g. Lower Ord). There is limited connectivity in Western Australia, but an assessment has not been made due to insufficient data.



Groundwater

Water tables in shallow aquifers respond dramatically to the seasonal rains, some rising by more than 15 metres each year. Many aquifers fill to capacity, and drain slowly during the dry season. The shallow aquifers generally have good quality water, reflecting the annual fill-and-spill cycle, and can provide 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 shallow systems have lower extractable yields than deeper, more regional groundwater systems, and there is a risk of extraction reducing streamflow of local rivers that rely on groundwater input.

Key finding 10

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

The extensive aquifers of the Tindall Limestone around Katherine and the Oolloo Dolostone in the Douglas-Daly area, for example, may support use of over 100 GL/year. These aquifers, however, are also commonly the primary sources of water that keeps local streams flowing year-round; so groundwater extractions adjacent to streams may need regulation to ensure groundwater input to streamflow does not fall below critical limits. Monitoring and models are vital to help constrain levels of extraction.

Notably, where water allocation plans are being implemented or developed in the Northern Territory – such as for the Tindall Limestone around Katherine, the Oolloo Dolostone around Daly and the Darwin-Howard East area – all are resulting in caps to groundwater extraction.

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 11

Groundwater recharge is complex and not directly proportional to rainfall

Groundwater data is 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 groundwater extraction will have detrimental consequences on both groundwater levels and flows in nearby rivers, 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.

Key finding 12

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 fills hollows and pools that persist through the dry season, sustaining ecosystems until the next wet season.

Key finding 13

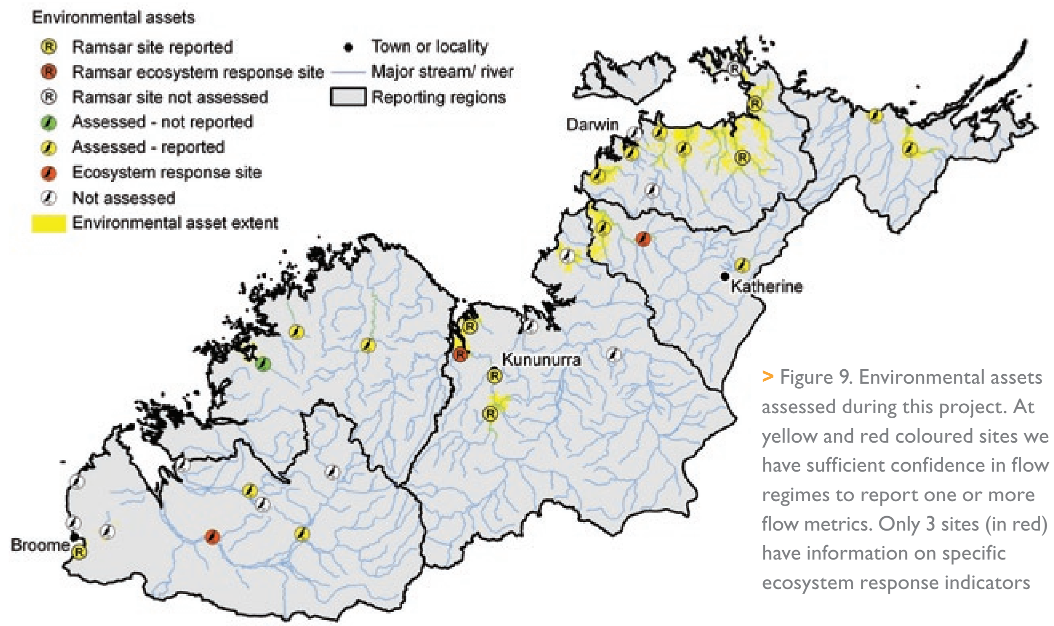
Floods are essential to sustain ecosystems, but there are few ecosystem response indicators for changes in flow regimes

Across the 26 river basins in the Timor Sea Drainage Division, 34 sites on the Directory of Important Wetlands were examined (Figure 9). Only three of these have ecosystem response indicators against which to judge whether or not 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.

The Ord-Bonaparte, Daly and Fitzroy (WA) regions have sufficient research for the development of site-specific ecological flow metrics against which changes to flow regime can be assessed; this is a rarity for northern Australia. Despite the existence of these metrics, for some environmental assets 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 14

The consequences of flow changes on ecological systems are largely unknown



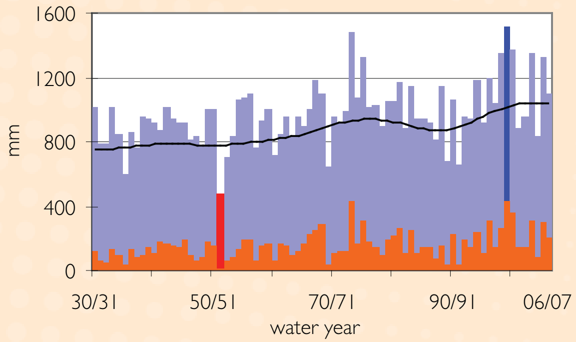
> Figure 9. Environmental assets assessed during this project. At yellow and red coloured sites we have sufficient confidence in flow regimes to report one or more flow metrics. Only 3 sites (in red) have information on specific ecosystem response indicators

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 30 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 15

The wetter climate of the past decade 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 Timor Sea Drainage Division

What the future holds

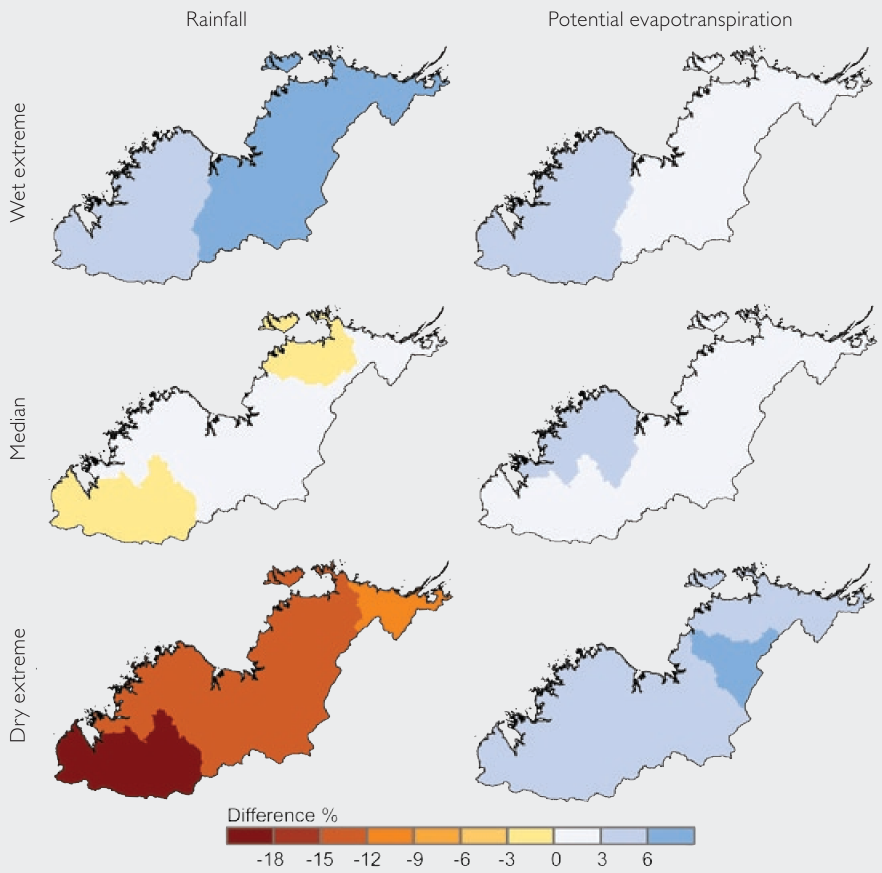
Future climate

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 twenty percent (Figure 11). Evaporation rates are expected to be slightly higher, increasing by between one and six 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 16

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 regional 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 17

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. For example, it will be at least 50 years before the consequences of changing an extraction regime for the Tindall Limestone at Katherine are felt at the Daly River Middle Reaches Wetland, nearly 200 km downstream.

In the Lower Ord system, reliability of surface water supply is expected to be good into the future, unless a dry extreme climate develops. Seasonality of flow has been significantly affected since the Ord River Dam was built and these changes have resulted in a far greater change to downstream flow than is projected from climate change.

In the Daly region, two aquifer systems are under development: the Tindall Limestone is mostly developed in the Katherine area and the Oolloo Dolostone around the Douglas-Daly confluence area to the north-west of the region. Current groundwater extraction is very low, but is expected to increase.

Modelling groundwater extraction at full current entitlements suggests the aquifers should reach a new dynamic equilibrium within ten to 15 years and groundwater levels will be generally comparable to historical levels. Increasing the levels of extraction to reflect potential use in 2030, however, results in generally lower groundwater levels, most notably in the Oolloo Dolostone, with significant impacts on the flow of the lower Daly River and, therefore on associated environmental regimes.

Smaller groundwater developments (10 to 100 GL/year) in the carbonate aquifers in the Darwin Rural Area have reached their extraction limit.

Key finding 18

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

Additional smaller developments might be feasible within the aquifers of the Canning Basin in the south-west of the Timor Sea Drainage Division but more data are required to confirm this.

Even smaller extractions (less than 10 GL/year) are feasible across most of the division, including areas of sandstone aquifers. Many of the shallow groundwater resources, including alluvial aquifers bordering major rivers, are highly dynamic, responding rapidly to seasonal rainfall and river flows.

Low-flow 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.

> Denham River, WA. Courtesy of CSIRO Land and Water

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:

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Water in the Timor Sea 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:

Water in the Timor Sea Drainage Division.: A report to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project. CSIRO, Australia xl+508pp ISSN 1835-095X

This document is printed on recycled paper

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