Water in the Northern North-East Coast Drainage Division

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

August 2009
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The Northern North-East Coast Drainage Division

The northern part of the North-East Coast Drainage Division consists of nine river basins, the largest being Normanby at just under 25,000 km$^2$, and the rest around 3,000 km$^2$. The coast rises steeply to the Great Dividing Range (Figure 1) and the region receives substantial rainfall where air is forced to rise over the range, in addition to the seasonal monsoonal and trade wind-derived rain.

For this project, the drainage division comprises just one region – the Northern Coral region. The climate is tropical with high temperatures year-round (averaging 28 °C) and high, yet very seasonal, average rainfall of 868 mm/year (1930 to 2007), with climate gradients aligned with the east coast. Rainfall averaged over the water year (September to August) ranges from 600 mm at most inland sites, to some of the highest rainfall sites in Australia situated in the south-east corner of the area, with annual rainfall in excess of 2400 mm.

A distinct wet season extends from November to April when rainfall averages around 206 mm/month. In the dry season (May to October) an average of only 18 mm/month is received. Ninety-two percent of annual rainfall falls during the wet season. The highest annual rainfall for the project area was 2143 mm in 1974 and the lowest was 769 mm in 1961.

Further to the south-west of the area, the climate becomes hotter and more arid and rainfall becomes less seasonal. In the south of the area this gives rise to an east–west gradient in annual rainfall, ranging from 1687 mm in the east to 383 mm in the west.

On an annual scale, the project area can be described as being ‘water-limited’ i.e. the mean annual potential evapotranspiration (1853 mm) exceeds the mean annual rainfall (1338 mm).

The vegetation has adapted to cyclical conditions resulting from the strong seasonality of highly intense rainfall and the corresponding strong seasonality of streamflow. The far south-east, however, does receive more rainfall on average during the year than can be potentially evaporated, and a small region of wet tropics exists in this area.

Wetland assets present in the region include lakes, mangroves, areas subject to inundation, saline coastal flats, watercourses and swamps. All of the division’s wetlands are important for ecological reasons or because they have historical significance or high cultural value, particularly to Indigenous people, or a combination of these reasons.

Many of the larger rivers in the region stop flowing during the dry months.

> Figure 1. Topography of the northern North-East Coast Drainage Division
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
B. recent climate
C. future climate and current development
D. future climate 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 a single region defined for the Northern North-East Coast Drainage Division. Separate summary reports are available for the Timor Sea and Gulf of Carpentaria drainage divisions, and for the entire project area. Detailed assessments for each region are included within the full Division reports.
Assessing water resources in the Northern North-East Coast Drainage Division

A water resource assessment (Figure 3) has been achieved for the Northern Coral region of the Northern North-East Coast 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 Northern Coral region, there is currently no requirement for these models (Figure 3).

Key finding 1
Only a water resource assessment has been made for the region.

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.

Rainfall stations

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Streamflow gauging stations

Groundwater monitoring bores

Streamflow simulation locations

> Figure 3. The levels of water assessment capability for the Northern North-East Coast Drainage Division. Shaded areas of the map have enough information and models to carry out the labelled level of assessment.

> Figure 4. Location of rainfall stations, streamflow gauging stations, groundwater monitoring bores and streamflow simulation locations in the Northern North-East Coast Drainage Division.
An extreme climate

The Northern North-East Coast Drainage Division receives substantial rainfall each year. An average of more than 60,000 GL (equivalent to 6 times the capacity of Lake Argyle, or 120 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, 1961, received only 35,000 GL, while the wettest year, 1974, received over 100,000 GL. Averages belie this variability and a single extremely wet year can dramatically increase the long-term average.

More than 92 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 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 3
There is high inter-annual climate variability

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 Northern North-East Coast Drainage Division

> Figure 6. Spatial distribution of historical mean annual, wet-season and dry-season rainfall and potential evapotranspiration, and their difference (rainfall less potential evaporation) across the Northern North-East Coast 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, but in contrast to the rest of northern Australia, most headwaters also receive substantial rain, due to strong effect of the Great Dividing Range, the importance of cyclonic rain and the relatively short distance from coast to drainage divide (Figure 7). Rivers are short and runoff is rapid and streamflow is intense.

About 17,000 GL of surface flow is generated each year and this constitutes a high proportion of rainfall (spatially between 10 and 50 percent) relative to other regions. Large storages would be 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.

Key finding 5
Most rain, and runoff, occurs near the coast, not in the rivers’ headwaters

Key finding 6
There are significant constraints on the viability of surface water storages

Key finding 7
Most catchments have largely unimpeded flow

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 region. The region has 6 river basins that are either declared or potential wild river areas. 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.
Water in the Northern North-East Coast Drainage Division

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.

The Gilbert River Formation (and equivalents) of the Great Artesian Basin may potentially provide opportunities for medium-scale groundwater developments (i.e. 10 to 100 GL/year). There is large uncertainty, however, about the volumes of water that could be developed. Further inland, groundwater from the Great Artesian Basin is the most important source of dry season flow in rivers, and supports 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.

Recharge 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.

Key finding 8
Perennial river reaches have high cultural, social and ecological value

Key finding 9
Inland perennial rivers are sustained by point discharge of groundwater

Key finding 10
Shallow groundwater provides opportunities for development, but its dynamic behaviour poses risks of impacting local streamflow

Key finding 11
The Great Artesian Basin aquifers may support further development, but safe extraction yields have not been determined
So, rivers may recharge aquifers during the wet months, while discharging groundwater may keep rivers flowing during the dry months.

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.

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.

Across the nine river basins in the Northern North-East Coast Drainage Division, 18 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 12
There is little potential for increased groundwater storage.

Key finding 13
Floods are essential to sustain ecosystems, but there are no ecosystem response indicators for changes to flow regimes.

Key finding 14
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 had very similar average rainfall compared to 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 climate of the recent past is neither indicative of historical conditions, nor the possible range of future conditions.

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 four 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 10. Historical annual rainfall (blue) and modelled runoff (orange) averaged over the Northern North-East Coast Drainage Division. The trend line indicates longer term variability; highest and lowest rainfall years are indicated.

> 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

There are currently no water plans for the Northern Coral region, though the southern catchments have plans proposed. No significant water-related development is expected, except very locally (for example, to meet the urban water requirements in the Mossman-Port Douglas area). Modelling suggests significant impacts at the region scale are unlikely. Locally any changes may be important, especially where critical surface–groundwater interaction takes place.

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.

Key finding 17
Planned development will have minimal regional water resource consequences, but may have local impact.

> Daintree River Estuary at Cape Kimberley, QLD. 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.

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