VOLUME 1

WATER RESOURCES OF THE TIWI ISLANDS:

MAIN REPORT

Water Fall at Pickertaramoor, Takamprimili Creek

ISBN 0 7245 4848 3
Report Number: 26-2003D

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Northern Territory Government
Department of Infrastructure, Planning and Environment

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND ENVIRONMENT
NATURAL SYSTEMS DIVISION

Report Number: 26-2003D

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ISBN 072454848-3
9 780724 548484

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COMMONLY USED ABBREVIATIONS

ADWG	Australian Drinking Water Guidelines
AHD	Australian Height Datum
BGL	Below Ground Level
$CaCO_3$	Calcium Carbonate
DLPE	Department of Lands, Planning and Environment
EC	Electrical conductivity
GIS	Geographical Information System
km	kilometres
L/s	litres per second
m	metres
m^3	cubic metres (1 m^3 = 1000 litres)
mg/L	milligrams per litre
mm	millimetres
NLC	Northern Land Council
NLP	National Landcare Program
CNR	Conservation and Natural Resources Group (the former 'Water Resources' is now part of this group)
NT	Northern Territory
RN	Registered Number (referring to bore)
TDS	Total dissolved solids (in mg/L)
μS/cm	microSiemens per centimetre (units of Electrical Conductivity or EC)

NOTE

Words in *italics* are defined in **APPENDIX A: GLOSSARY OF TERMS**.

EXECUTIVE SUMMARY

The water resources of the Tiwi Islands were mapped, described and evaluated, incorporating the traditional knowledge of the Tiwi people in regards to their water resources.

A set of decision-making tools comprised of reports, maps and an interactive CD-ROM was developed as a result of the study. An effort was made to compile and present the results in a way that can be used by individuals without a scientific or technical background. It is hoped that the results of this study may be easily understood and effectively applied by the Tiwi people, their community leaders and the Tiwi Land Council.

A series of maps was prepared, which shows the distribution of hydrographic data, regional aquifers, Aboriginal place-names and sites associated with traditional knowledge of water. This map series, detailed below in Table 1 is also available in hard copy.

Table 1 Map Series

Map Title	Scale	Description
Spring Flow of the Tiwi Islands – Map 1	1:250,000	Location of springs, bores and hydrographic sites and information
The Water Resources of the Tiwi Islands – Map 2	1:500,000	Shallow aquifers, deep aquifers and sandstone thickness
The Traditional Knowledge of Water – Map 3	1:250,000	Satellite image showing main features of traditional significance
Project Poster	1:250,000	The Tiwi Islands Water Study; Learning About Water

The other products available from this study are three hard copy reports. The reports are in three volumes as follows:

Table 2 Reports

Title	Description
Volume 1 - *Water Resources of the Tiwi Islands, Main Report*	The main report on the regional hydrogeology and water resources
Volume 2 - *Water Resources of the Tiwi Islands, Aboriginal Knowledge*	Traditional knowledge, place names and stories about water
Volume 3 - *Water Resources of the Tiwi Islands, Technical Report*	A detailed listing of pre-existing and new technical data collected during the study

The CD-ROM has been created to be interactive. It can be viewed on any computer with a *Microsoft Windows* operating system. The CD-ROM is comprehensive and includes regional Geographic Information System (GIS) data, regional base maps, hydrographic data, photos and the traditional knowledge map with Tiwi place-names.

The Natural Systems Division of the Conservation and Natural Resources Group, NT Department of Infrastructure, Planning and Environment holds the reports, maps and CD-ROM. Information regarding the availability of the results of this study is located inside the front cover of this report.

PART 1. INTRODUCTION

Prior to this investigation, it was identified that the existing information was inadequate to properly manage the land and water resources of the Tiwi Islands. Funding was obtained through the National Heritage Trust, to carry out the three-year water resource investigation on Melville and Bathurst Islands. Additional funding was provided through the Northern Territory Government, ATSIC and the TLC. The project was managed through the Water Resources Assessment Branch, Natural Resources Division (NRD) of DIPE.

The partners in this study were the National Heritage Trust (NHT), the Department of Infrastructure, Planning and Environment (DIPE), the Aboriginal and Torres Straight Islander Commission NT (ATSIC) and the Tiwi Land Council (TLC). The main recipients of the information and the primary clients during the study were the Tiwi people and the Tiwi Land Council.

The investigation began as a desktop study to collate and analyse the existing data, reports and maps. The desktop study was followed by community consultation to further identify the regional information needs and water resource issues. The process involved community meetings to introduce the project objectives and to gain assistance from community leaders, elders and community managers. The preliminary consultation was followed by three seasons of data collection and fieldwork.

Standard water resource survey techniques were applied to assess both the surface water and *groundwater* resources. The *hydrographic* surveys involved the collection of stream flow data, rainfall data and water chemistry sampling. Further data on the resource was collected through *geophysical* surveys, assessment drilling and test pumping. The surveys made use of satellite imagery, topographic maps, geologic maps and draft base maps.

Base maps depicting existing hydrographic data were developed and presented to local community councils and the Tiwi Land Council. The maps proved to be an effective tool in presenting the project objectives and outputs. The maps were presented during community consultations throughout the various stages of the investigation. Base maps were made available to traditional owners and to various government representatives who were working in the area.

During the collection of scientific data, traditional knowledge about the region and the water resources was also collected. The objective was to integrate the scientific knowledge with the traditional knowledge to produce a series of maps and reports for use by traditional owners. The process began with the identification of traditional landowners through council meetings and personal communication. During this time, contacts and friendships were made that helped the project staff in recording water stories and traditional place names.

Draft maps with tribal boundaries and place names in the Tiwi Language were created and shown to traditional owners. The maps were effective in helping to collect information from the elders during trips in the bush. The use of *satellite images* was also found to be effective in the location of traditional places not visited for many years. During bush trips, water stories were also collected and have been included in the traditional knowledge report.

1.1 Location and Access

The Tiwi Islands, which comprise Bathurst and Melville Island, are located 60 km north of the city of Darwin in Australia's Northern Territory (Figure 1).

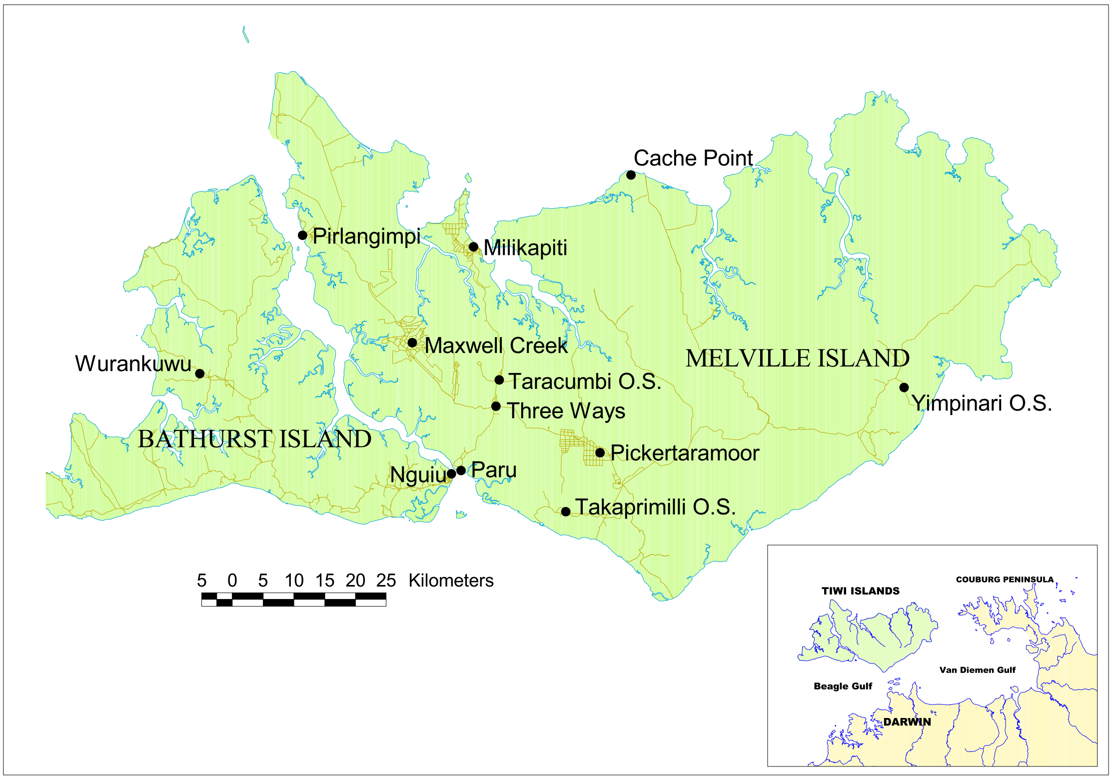


Figure 1 **Location map of Melville and Bathurst Islands**

The Islands are also 300 km to the south of the nearest Indonesian island of Pelau Slaru. Melville Island is the larger of the two islands with an area of 5,700 km^2, whereas Bathurst Island is 1,600 km^2.

Access to the islands is limited to daily flights on small charter services operating out of Darwin. There are regularly scheduled flights through the charter services to Nguiu on Bathurst Island and to Pirlangimpi and Milikapiti on Melville Island. Freight is typically transported to the islands through local barge services based in Darwin. The Tiwi Barge Services operates on a weekly schedule to Nguiu, Port Hurd, Pirlangimpi (Garden Point) and Milikapiti (Snake Bay). The barges do not offer passenger services. Any visitors to the islands must obtain a permit before arrival. The permits can be obtained from the Tiwi Land Council offices in Darwin.

1.2 The Tiwi People

Melville and Bathurst Islands are held by the Tiwi Islands Aboriginal Land Trust. The population of both islands, recorded during the 2001 Census was 2,360 people. Nguiu, with a population of about 1,410 is the largest community centre. The smaller communities of Milikapiti and Pirlangimpi have populations of 491 and 365, respectively. Most of the inhabitants of the Tiwi Islands live in these three main communities and the four outstations at Wurankuwu, Takamprimili, Taracumbi and Yimpinari. Aside from the communities and outstations, the vast majority of both Melville and Bathurst Islands are uninhabited.

Between 18,000 and 20,000 years ago the last age of *glaciation* was coming to completion. At that time, the sea level was approximately 130 m below its current level. The Tiwi Islands were linked to the mainland and the Aboriginal people of the mainland were able to migrate northward on foot. The melting of the glacial ice sheets began 18,000 years ago and caused a major *transgression* (rise) of the seas over a 10,000-year period of time. During the *transgression*, the people who made this area their home remained on the newly formed islands as the seas rose around them. About 7,000 years ago, the sea had reached its present level and the Tiwi Islanders became isolated from the Aboriginal people of the mainland.

The Tiwi people have long considered themselves to be different from the inhabitants of the mainland. They do not consider themselves to be “Aboriginal”; instead they consider themselves as being uniquely “Tiwi”. Tiwi isolation from the mainland resulted in the development of distinctive features in their artistic expressions, such as carved totem poles and grave posts. Although isolated from Aboriginal people of the mainland, the Tiwi Islanders were visited by outsiders who further influenced their unique characteristics.

Like many Aboriginal centres along the northern coast of Australia, early Macassans and Japanese pearl fisherman visited the Tiwi Islanders. The influence of the Macassans and Japanese can be seen in the facial features of the Tiwi People and of those Aboriginal descendants who lived along the northern coast of the mainland.

The first recorded visit by Europeans was on 30 April 1705 by the Dutch under the command of Maarten van Delft. The first attempt at European settlement was the establishment of Fort Dundas by the British in 1824, which was abandoned after four years. The first permanent settlement by Europeans was by Father Francis Xavier Gsell who established the first Roman Catholic mission at Nguiu on Bathurst Island in 1911.

1.3 Climate

The climate of the Tiwi Islands is tropical and *monsoonal* with a hot and humid wet season from October to April. This is followed by a pleasant, relatively cooler dry season from May to September. During the wet season, the temperature ranges from 26.7 to 32.2 ^{o}C and during the dry season from 21.1 to 26.7 ^{o}C.

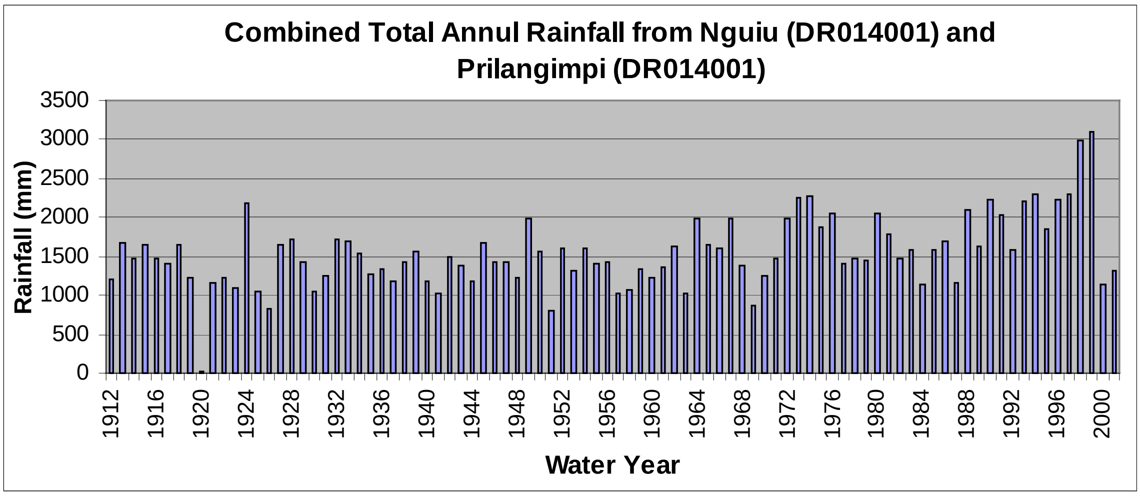


Figure 2 Total Annual Rainfall (Nguiu and Pirlangimpi)

The rainfall data from gauging stations in Nguiu and Pirlangimpi has been combined to create a continuous record of total annual rainfall between 1912 and 2003 (Figure 2). The average monthly rainfall data for Pirlangimpi is shown in Figure 3. Precipitation occurs almost exclusively during the wet season and the average annual rainfall for both islands is 1500 millimetres (Moser, 1994; Yin Foo, 1992; Chin, 1991). The peak monthly average rainfall ranges from about 420 millimetres in the wet season to a negligible amount in the dry season.

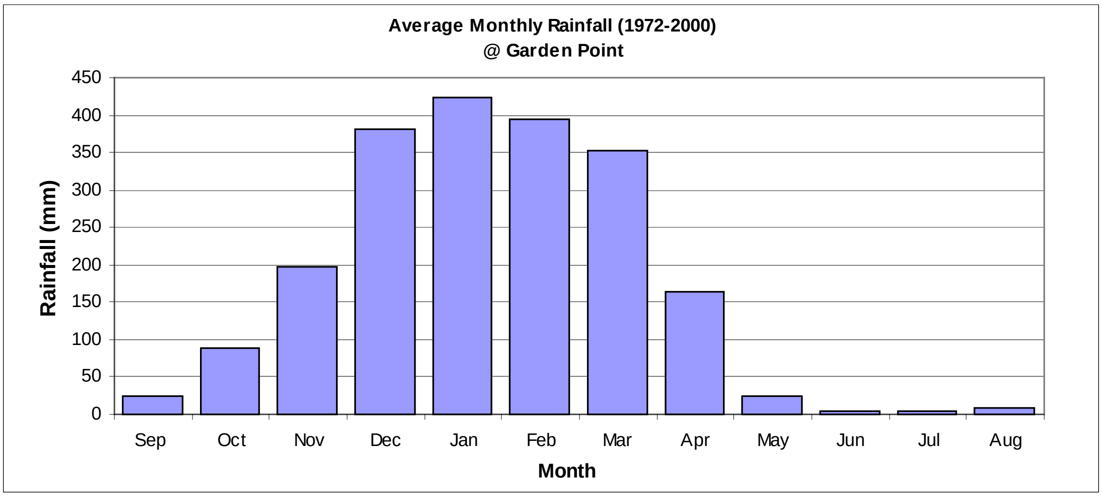


Figure 3 **Average Monthly Rainfall at Pirlangimpi (Garden Point)**

1.4 Geology

The then Department of Natural Resources, Bureau of Mineral Resources, Geology and Geophysics, Northern Territory completed the mapping of the Tiwi Islands in 1976. The area is covered by two 1:250,000 scale maps titled “Melville Island, Sheet SC 52-16” and “Bathurst Island, Sheet SC52-15”. The maps are accompanied with explanatory notes titled: “Bathurst and Melville Island, Northern Territory” by R. J. Hughes.

Figure 4 is a schematic of the stratigraphy of the Tiwi Islands. The oldest geologic formation is the Proterozoic aged basement that consists of igneous and metamorphic rocks. Overlying the basement is a thick sequence (700+metres) of Cretaceous aged sediments, which form the Bathurst Island Formation. At the base of the sequence are the Mullaman Beds (Klm), which consist of sandstone and shale. The Mullaman Beds are not exposed on the Tiwi Islands.

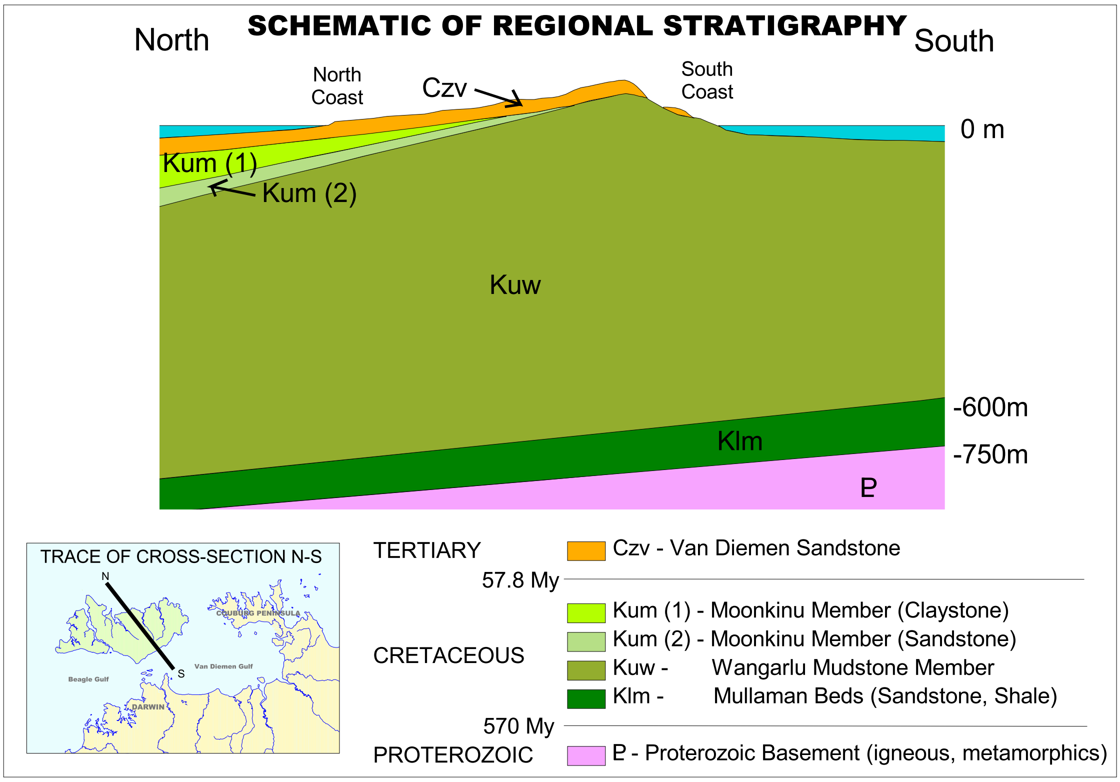


Figure 4 Regional Stratigraphy

Above the Mullaman Beds is a thick layer of mudstone called the Wangarlu Member (Kuw). This is the oldest unit that outcrops on the Tiwi Islands and is comprised of *mudstone* and *siltstone*. The Wangarlu Member underlies all of the islands from approximately sea level to a depth of about 500 metres. The Wangarlu Mudstone is typically seen in drill cuttings as a sticky to firm, grey clay. Surface expressions have been observed in the grey clay, which is exposed at low tide along the south-facing beach behind the council offices in Nguiu.

Lying on top of the Wangarlu Member is the Moonkinu Member, which was deposited, in a shallow marine environment during a period of sea *regression* (Forsci, 1999; Chin, 1991; Hughes, 1976). This unit consists of fine to very fine *sandstone* with interbeds of grey carbonaceous mudstone and siltstone (Chin, 1991; Hughes, 1976). In boreholes it has been described as interbedded grey *claystone*, *siltstone* and sandstone. Along the beach at Milikapiti, a small section of this unit has been highly weathered into a hard, dark brown, indurated mudstone. There is a sandstone horizon within the Moonkinu Mudstone that has been found to be water bearing and is considered to be a regional, deep *confined aquifer*.

Following the deposition of the Cretaceous aged sediments, there was a long period of erosion during which much of the sediments in the Bathurst Island formation were worn down and eroded. Following this period of *erosion, deposition* occurred, during which the Van Diemen Sandstone was laid down. The Van Diemen sandstone was formed as a result of the *weathering, erosion* and *transportation* of sediments from the ancient highlands located on what is now the mainland. This formation has been described in detail during previous investigations as a fine to medium grained *quartzose* sandstone that has formed along coastal areas dominated by stream flow and tidal action (Moser, 1994; Yin Foo and Morretti, 1992; Chin, 1991; Britten, 1988; Hughes, 1976). The sandstone is typically seen in drill cuttings as white, tan, yellow, brown, purple, red, soft, very fine grained, clayey sandstone.

The sandstone covers most of Melville and Bathurst Islands and varies greatly in thickness. In the areas of gently undulating terrain, the thickness is about 20 to 30 metres. Where the higher ridges have formed along the southern parts of both islands, the thickness reaches 60 metres. The top of the Van Diemen Sandstone has typically been weathered to an iron rich, porous layer of *laterite*. Both islands are typically covered with a discontinuous layer of laterite, which can be up to 10 metres thick. Where present, the laterite has varying degrees of *permeability*. The base of the Van Diemen Sandstone follows the ancient *erosional surface* of the Cretaceous sediments and dips gently to the northwest.

When exposed at ground level, the sandstone is sometimes very hard and forms the cliffs along the road between Three Ways and Tinganoo Bay. At other locations along the northern coast, it can be seen as a 2 to 10 metre cliff, consisting of soft to hard, very fine-grained sandstone. The Van Diemen Sandstone has been identified as the regional, shallow, *unconfined aquifer* on Melville and Bathurst Islands.

Much of the lower lying, undulating plateaus and sand plains are covered with more recent *Quaternary* aged alluvial sediments. These units will typically consist of silt, sand and gravel.

1.5 Landforms

Different types of landforms are the result of the interaction of the underlying rock types and climate over many millions of years. Most of the Tiwi Islands consists of gently undulating country with elevations of less than 50 metres above sea level (Forsci, 1999). The higher country on Bathurst Island reaches elevations of 100 metres, while on Melville Island the maximum elevation is about 140 metres above sea level (Figure 5).

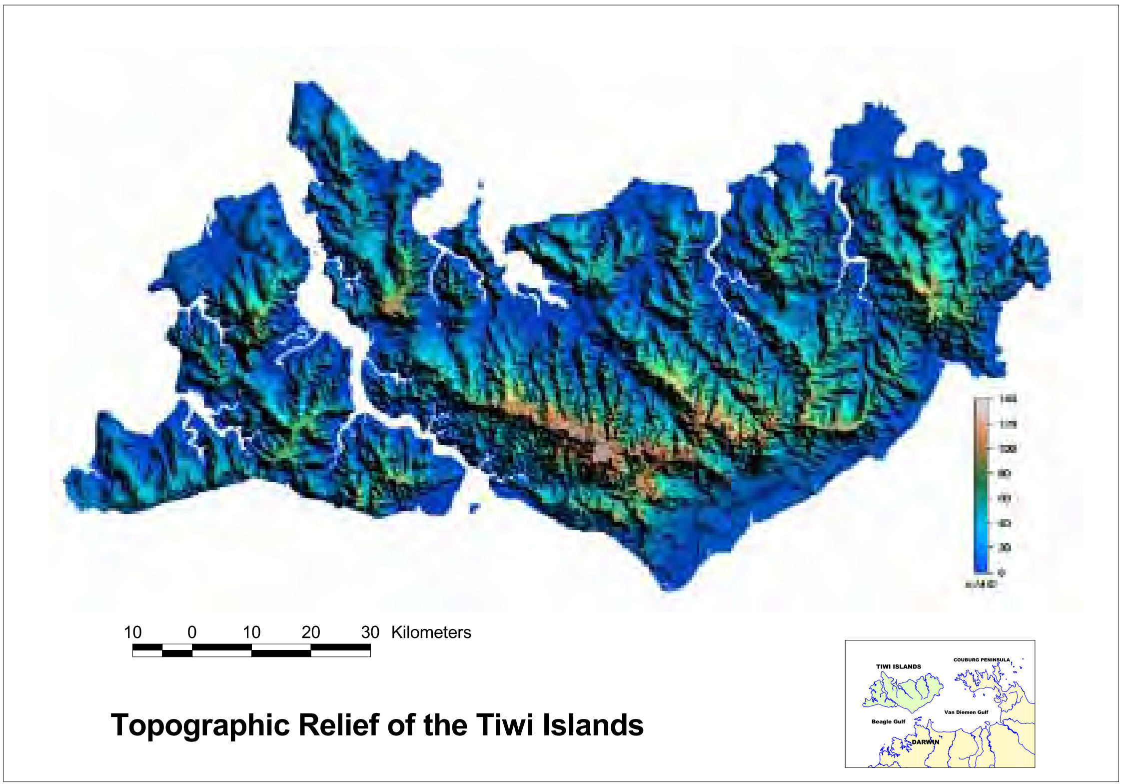


Figure 5 Digital Elevation Model of Topography

The three main *physiographic units* (Chin, 1991; Hughes, 1976) of the Tiwi Islands are:

1) Low dissected plateaux and undulating laterite rises;

2) Northern and inland sand plains; and

3) Coastal (flood) plains.

The southern portion of Melville Island and most of Bathurst Island consists of undulating laterite rises and *dissected plateaux*, which have formed over the Van Diemen Sandstone (Hughes, 1976). Examples of this terrain can be seen in the high country along the road between Cape Fourcroy and Nguiu Farm; and along the road between Pickertaramoor and Tinganoo Bay. These areas are typically of higher elevation and are the *erosional remnants* of the pre-existing *Tertiary* land surface. The older topography is preserved due to the formation of the more resistive laterite capping and the localised hardening of the sandstone surface. More recent *alluvium* fringes these dissected plateaux regions, which give way to yellow and red sandy plains to the north.

The northern and inland sand plains have formed as a result of the northerly erosion and dissection of the sandstone plateaux to the south. The sand plains make up a majority of the northern portion of Melville Island. The sand plains have formed over the Van Diemen sandstone, which dips gently to the north. The sand plains have recent alluvial deposits, which have formed as a result of the *weathering* of the Van Diemen Sandstone.

The coastal plains are typically low lying country and flood plains, which are subject to tidal inundation and seasonal flooding. Examples of this country can be seen as the mangrove flats and floodplains, which fringe the *marine estuaries* of the major rivers and creeks on both Melville and Bathurst Islands.

1.6 Water Use

The communities of Nguiu, Milikapiti and Wurankuwu have designated borefields for domestic water supply. The community of Pirlangimpi draws its drinking water from Blue Water Creek. Milikapiti and Nguiu communities make use of old test bores to irrigate market gardens.

Monthly consumption records for Nguiu, Pirlangimpi and Milikapiti were obtained from the Power and Water Corporation, Rural Services Division, Darwin. The total consumption from January 1999 to December 2001 was calculated and divided by the total number of days to generate a production rate in terms of litres consumed per day for this three-year period. From this estimate, and the current population of each community, a rate of consumption for each community (litres/person/day) was calculated. The water consumption for each community is summarised in Table 3. The calculations shown in Table 3 do not include the irrigation of market gardens or industrial use.

Table 3 Production and Usage estimates, 1999-2001*

Community	Population	Water Consumption (Litres/Day)	Usage (L/person/day)
Nguiu	1,410	820,000	582
Milikapiti	491	492,000	1,000
Pirlangimpi	365	405,000	1,110

* Production figures for Wurankuwu (population 90) are not available.

The discrepancies in the total consumption per capita for each community may indicate varying degrees of use efficiency in the home. Discrepancies may also reflect inaccuracies in the 2001 population Census.

Outside of the main communities, there are only a handful of outstations, tourist operations and dry season bush camps. The outstations of Taracumbi, Takamprimili and Yimpinari were previously dependent on surface water, but have recently converted to *groundwater* bores for domestic production. Consumption estimates for outstations is not available.

There is a small production bore available for communal use at the popular bush camp of Wuluwunga, located about 18 kilometres north of Pirlangimpi. This is the only bush camp that has access to a bore for communal water supply. All other bush camps depend on small springs and creeks for their water supplies.

The tourist operation at Araliyuwu Creek (Jesse Creek) depends on rainwater and the water pumped from a *soak* about 5 kilometres inland. The barramundi farm at Port Hurd is fully dependent on rainwater. In 1998, a *soak* that had previously been used as a temporary water supply was degraded by a tidal surge related to Cyclone Thelma. The soak was subsequently abandoned.

PART 2. THE WATER CYCLE

To understand the *groundwater* and surface water systems, it helps to have an understanding of the water cycle (see Figure 6). When rain hits the ground, some of it runs off into streams and creeks (*surface runoff*), some *evaporates* and some seeps into the ground (*infiltration*). The amount of water that *infiltrates* depends on many factors, including the soil and rock type, the slope and the intensity and duration of rainfall. Of the water that *infiltrates*, some will *evaporate* or be taken up from the soil and used by vegetation (e*vapotranspiration*) and the rest will move downwards until it reaches the *water table* to become *groundwater*. The process of adding water to the *groundwater* system is called *recharge*. *Porous* rocks and soil allow the *groundwater* to slowly move from high areas to low areas, usually *discharging* to the surface at some point. If a useful amount of water can be extracted from a rock unit, then it is referred to as an *aquifer*.

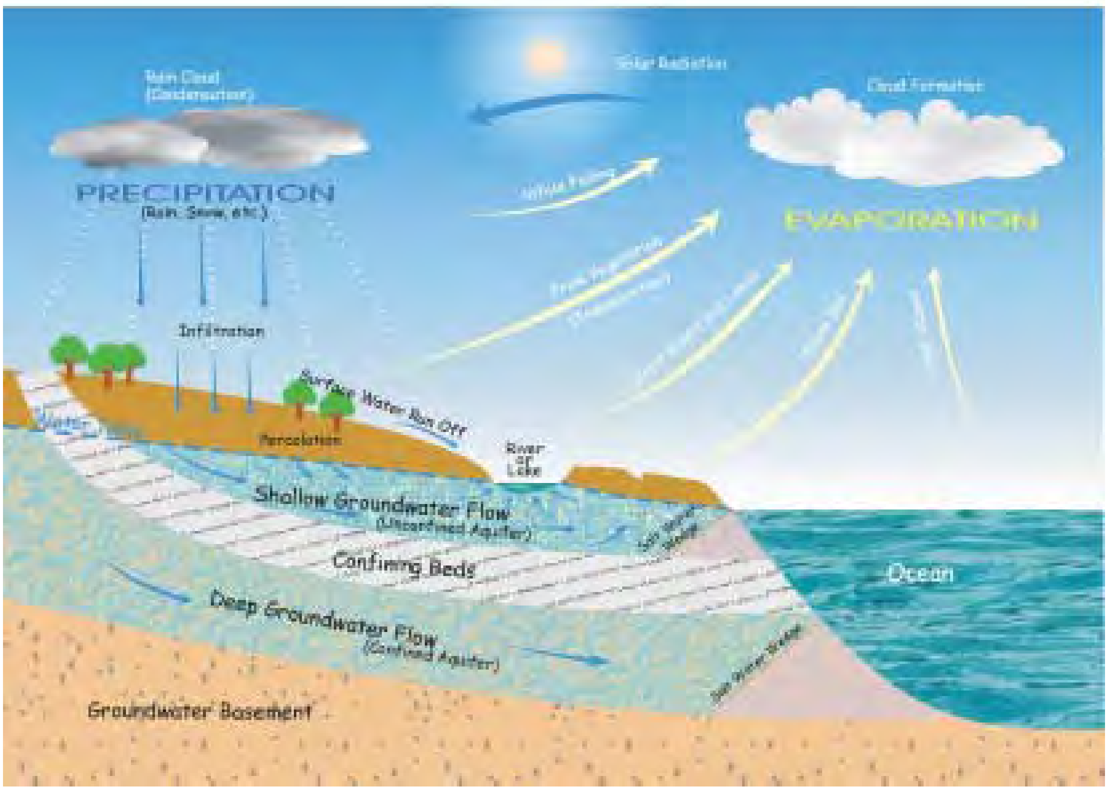


Figure 6 Components of the Water Cycle

Recharge occurs only in the wet season when rainfall intensity and duration is sufficient. During the wet season, *groundwater* levels rise, while in the dry season they fall. The amount and rate at which the *groundwater* levels rise and fall depends on the type, size and other physical properties of the *aquifer* as well as the amount of *recharge*.

DIPE has monitored the change in *groundwater* levels in many *aquifers* throughout the NT over many years. *Groundwater* levels are collected by measuring the depth of the *water table* in *observation bores*. Changes in the water table demonstrate the effects of recharge during the wet season and discharge during the dry season. Knowing how an *aquifer* responds to *recharge* and dry season water level changes can help us determine how much *groundwater* the bore will *yield* and how the *water table* levels will change in response to pumping.

PART 3. GROUNDWATER

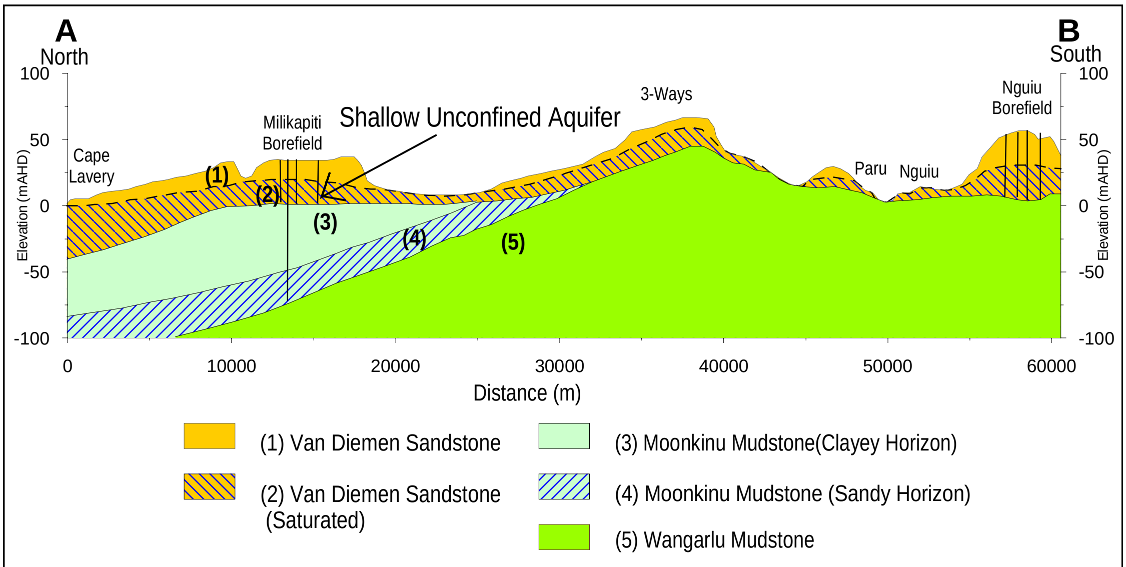
There are two regional aquifer systems on the Tiwi Islands as shown on *Map 2 – Water Resources of the Tiwi Islands*. The first aquifer has been defined as being “shallow and unconfined”, whereas the second regional aquifer is “deeper and confined”.

3.1 Regional, Shallow, Unconfined Aquifer

The shallow aquifer system consists of the Van Diemen Sandstone and the overlying laterite and alluvium. A detailed geologic cross section of Melville Island highlighting the occurrence of the shallow Van Diemen Sandstone aquifer is shown in Figure 7.

3.1.1 Aquifer Characteristics

The Van Diemen Sandstone is described as a brown, tan, purple and white *friable* medium to coarse-grained quartz sandstone with a clayey *matrix*. Considering that the thin alluvial cover is sometimes negligible, the regional shallow aquifer will be referred to as the Van Diemen Sandstone during further discussions.



Adapted from Geological cross-section E-F, Map 2-Water Resources of the Tiwi Islands

Figure 7 Geological Cross-Section of the Shallow Unconfined Aquifer.

Figure 7 distinguishes between the “saturated” and the “unsaturated” parts of the Van Diemen Sandstone. There is typically a 10 to 30 metre layer of unsaturated Van Diemen Sandstone overlying the saturated portion. It is the saturated portion of the sandstone that is water bearing and the primary target for production bores.

3.1.2 Aquifer Extent and Thickness

This regional aquifer covers most of Melville and Bathurst Island. The extent and estimated thickness of the shallow aquifer (Van Diemen Sandstone) is shown in Figure 8. The Van Diemen Sandstone has higher production potential where the thickness is greater than 20 metres. The maximum thickness of the Van Diemen Sandstone is approximately 70 metres.

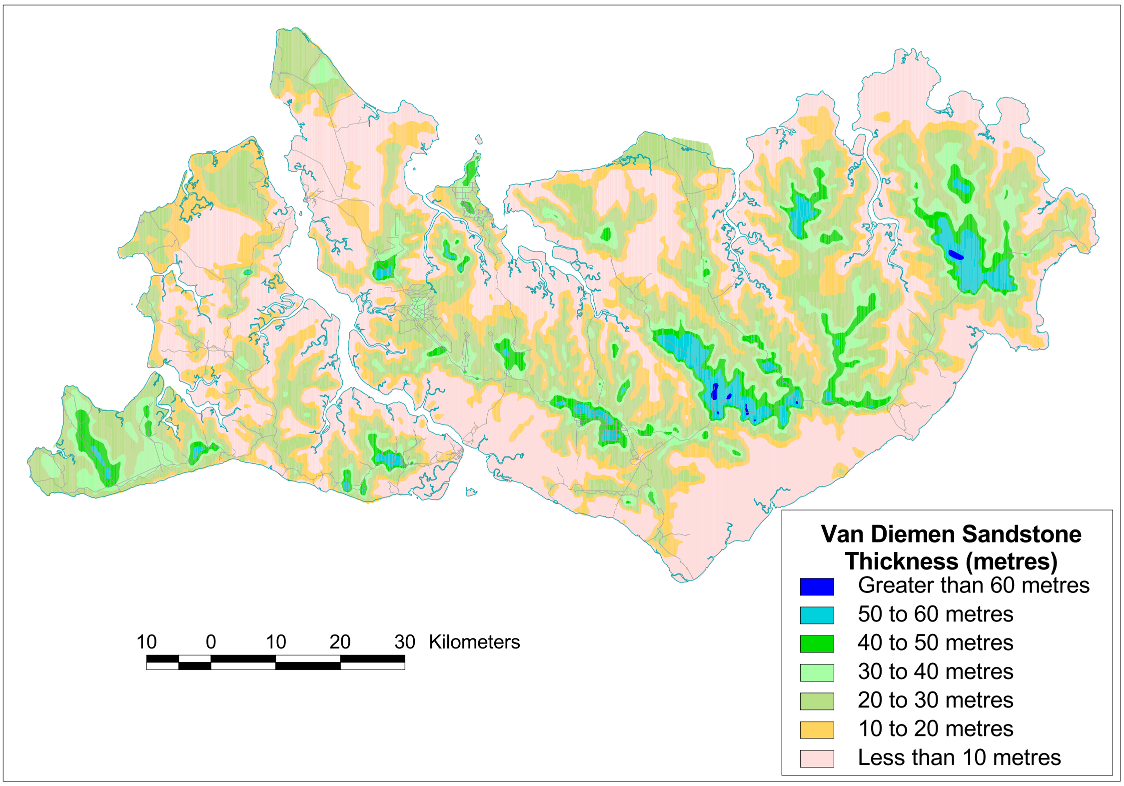


Figure 8 Van Diemen Sandstone - Thickness

3.1.3 Aquifer Potential and Estimated Yield

The indicative yield of the shallow *unconfined* aquifer is available in hard copy and in digital form in *Water Resources of the Tiwi Islands – Map 2*. This information has been summarised in Figure 9. The regional, shallow aquifer yield has been classified as follows:

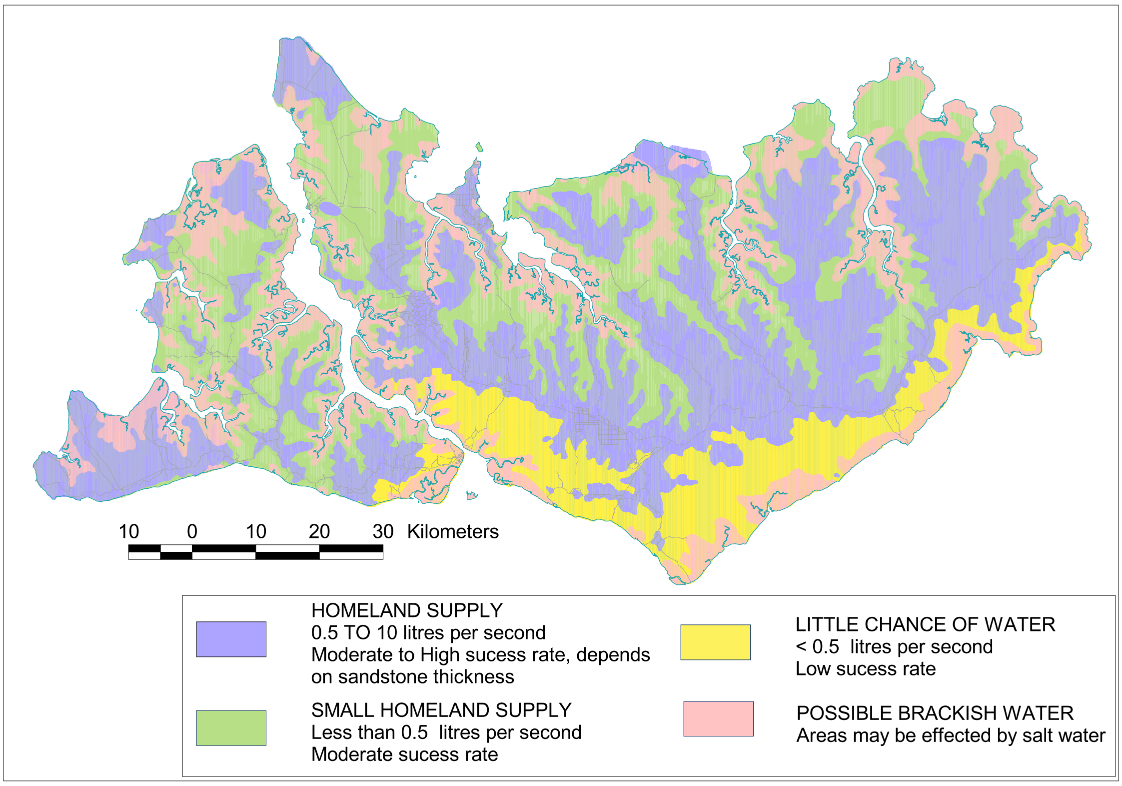


Figure 9 Shallow Unconfined Aquifer Potential

HOMELAND SUPPLY

A homeland supply has enough water for a community or major outstation. The **blue** areas in Figure 9 show where there is a moderate to high success rate of drilling a bore that can yield from 0.5 to 10 litres per second. The success rate and final production yield of the bore is highly dependant upon the thickness of the Van Diemen Sandstone. The thicker the section of fully saturated aquifer, the better the chances of successfully drilling a bore with a homeland supply. Refer Figure 8 which shows the thickness of the Van Diemen Sandstone on Melville and Bathurst Islands.

In areas where the thickness of the Van Diemen Sandstone is greater than 40 metres, there is a good chance of drilling bores that can yield between 5 and 10 litres per second. An example of this would be the borefield at Milikapiti where the Van Diemen Sandstone is about 50 metres thick. Of the 50 metres, about 40 metres are saturated. Bores completed in the saturated thickness have reported yields of 3 to 5 litres per second. It is speculated that with better bore construction, higher yields of up to 10 litres per second may be possible.

Another example is the Nguiu borefield, where the full thickness of Van Diemen Sandstone is 60 to 70 metres. In this case, the fully saturated portion of the Van Diemen Sandstone was about 40 metres thick. Existing production bores yield from 3 to 8 litres per second, but improved construction methods could prove increased production rates of 10 to 15 litres per second.

In areas where the thickness of the aquifer is less than 40 metres, bore yields are typically less than 5 litres per second. Examples of this would be the supply bores at Three Ways, Yimpinari, Taracumbi and Takamprimili outstations. The bores were successfully completed in the shallow aquifer where the thickness of the Van Diemen sandstone is limited to about 20 or 30 metres. The total thickness of the saturated aquifer was about 10 metres. Reported yields ranged from 0.8 litres per second (Takamprimili) to 5 litres per second (Three Ways).

SMALL HOMELAND SUPPLY

The **green** areas in Figure 9 indicate where there is a moderate success rate in drilling a successful bore. The expected yields would be less than 0.5 litres per second. In these areas, the thickness of sandstone is typically between 10 and 20 metres. The saturated thickness would be less than 5 or 10 metres.

LITTLE CHANCE OF WATER

The region marked **pale yellow** on the map and in Figure 9 indicates the areas that are underlain by the Wangarlu (mudstone) Member. Throughout the south facing slopes of Melville Island, there are scattered ridges and hills of Van Diemen Sandstone. When present, the thickness is typically limited to about 10 metres. Local springs that discharge from the thin remnants of Van Diemen Sandstone typically dry up by the middle or end of the dry season. The success rate of drilling a producing bore is very low. Assessment drilling in 2000 (near Paru) resulted in the construction of production bores that could only produce 0.1 litres per second. This area is not a reliable source of either surface or ground water.

POSSIBLE BRACKISH WATER

The areas marked with pale pink show where the groundwater might be brackish due to the effects of saltwater intrusion. These areas are low lying and are also susceptible to the effects of cyclonic storm surges. The degradation of the soak at Barra Base is a good example of this occurrence. Bores located within a kilometre of the coast or the maximum extent of tidal inundation may be brackish.

3.1.4 Groundwater Quality

In most cases, the water from the shallow aquifer is considered to be of good quality. The exceptions are bores drilled near the marine environment where saltwater intrusion may be a factor.

3.2 Regional Deep, Confined Aquifer

The second regional aquifer on the Tiwi Islands is a deep, confined sandstone aquifer within the Moonkinu Member of the Bathurst Island Formation. The deep aquifer is separated from the shallow aquifer by a *confining layer* that consists of a relatively *impermeable* claystone and siltstone (Figure 10).

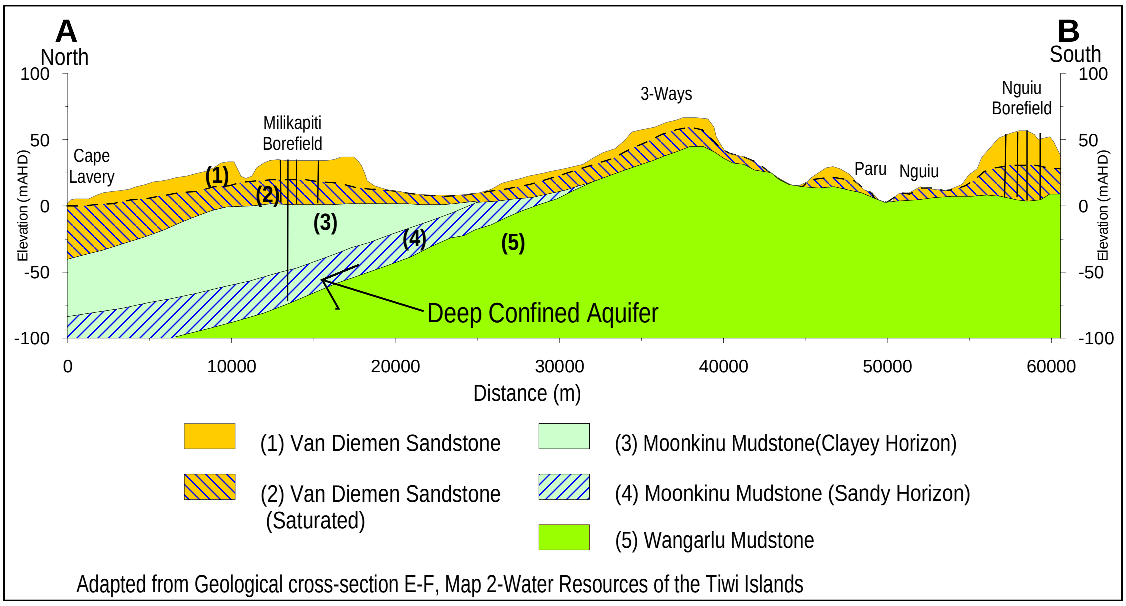


Figure 10 Geological Cross-Section of the Deep Confined Aquifer

3.2.1 Aquifer Characteristics

The aquifer is comprised of grey sandstone with thin interbeds of grey siltstone and claystone. The aquifer is approximately 30 to 60 metres thick and dips gently to the northwest.

3.2.2 Aquifer Extent

The regional extent and predicted depth to the top of this unit (relative to mean sea level) is depicted in Figures 10 and 11. In general, the sandstone is at about sea level near the middle of Melville Island and dips gently to the northwest. At Milikapiti, the top of the aquifer has dipped to a depth of 90 metres below sea level and is 30 to 50 metres thick.

3.2.3 Deep Aquifer Yield

The deep aquifer has been identified at 4 locations on the Tiwi Islands: Milikapiti, Cache Point, Wurankuwu and Maxwell Creek (Figure 11).

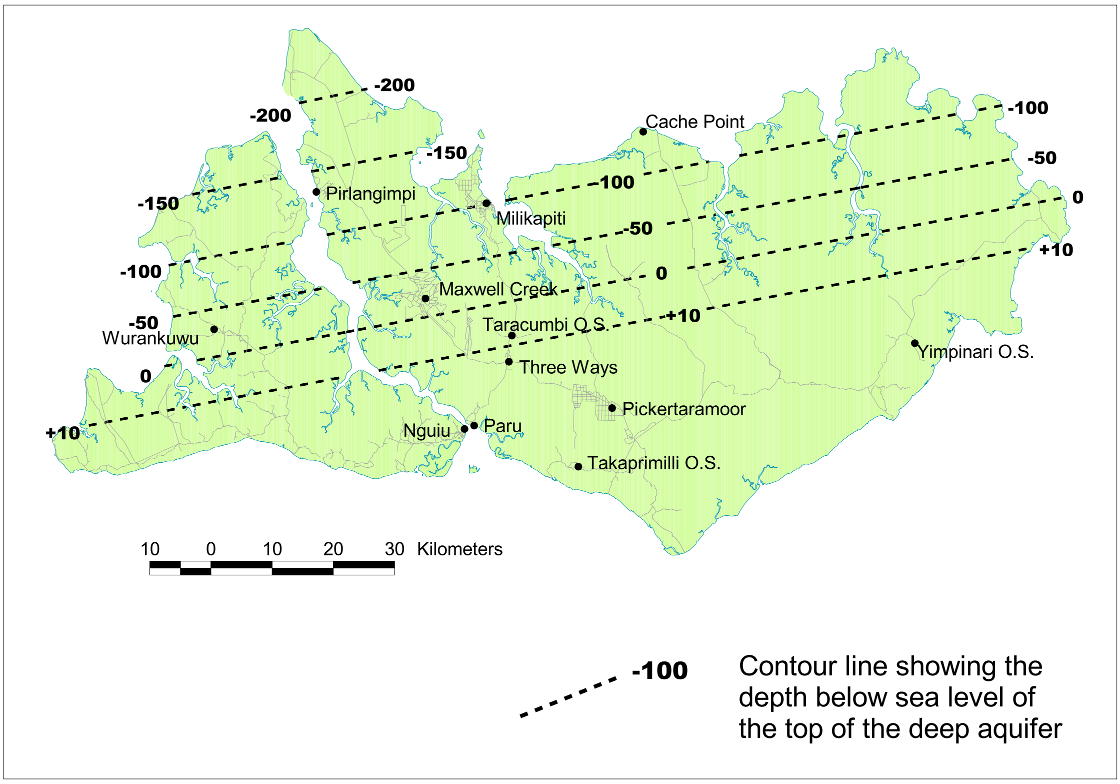


Figure 11 Deep Confined Aquifer Occurrence and Depth

At Milikapiti, a single bore (RN027923) has been completed in a sandstone horizon between 90 and 120 metres below sea level. The bore has been rated at 4 litres per second, but construction methods were a limiting factor in bore performance. The deep aquifer may be capable of producing higher yields.

Assessment drilling in 2000 was conducted at a site about 25 kilometres south of Cache Point. A single bore (RN032881) was successful in locating a deep, sandstone layer between 110 and 150 metres below sea level. The sandiest horizon was found to be between 130 and 150 metres below sea level. The bore could not be yield tested, but the resistivity and gamma bore hole logs indicated that the sandy horizon was water bearing and that the water was fresh.

At Wurankuwu, two bores (RN029293, RN029295) were constructed in the deep sandstone aquifer between 35 and 55 metres below sea level. Assessment bore RN029293 was airlifted at 3 litres per second and pump tested at 2 litres per second. Production bore RN029295 was pump tested at 4.5 litres per second, but step test results indicated that the bore could have been pumped at significantly higher rate (6-8 litres per second). The recommended pumping rate was limited to 2 litres per second to avoid saltwater intrusion.

Further assessment drilling in 2000 identified a portion of the deep aquifer at Maxwell Creek extending from 10 metres above sea level to 35 metres below sea level. Bore RN032887 was airlifted at only 5 litres per second due to bore construction limitations (4 inch diameter). It is speculated that a larger diameter bore (6 to 8 inch) may produce up to 10 litres per second.

Testing results of the deep aquifer are inconclusive and the production potential is unknown. Previous testing indicates that the aquifer may be high yielding (greater than 10 litres per second) and that further investigation is warranted.

3.2.4 Deep Aquifer Water Quality

At Milikapiti, Wurankuwu, and Maxwell Creek, the water produced from the deep sandstone horizon in the Moonkinu Member is of good quality. The bore at Cache Point could not be sampled due to borehole instability. The *resistivity* and *gamma* logging of that bore was very similar to the geophysical logs in the deep sandstone at both Milikapiti and Wurankuwu. This comparison would indicate that the water of the deep aquifer at Cache Point was also fresh.

3.2.5 Regional Groundwater Hydraulics

Pump testing of production bores in Milikapiti, Nguiu and Wurankuwu resulted in the estimation of aquifer parameters (Moser 1994; Yin Foo 1992; Chin 1991). The parameters quantify the aquifer ability to store and produce water. The main parameters which best describe the aquifer are the storage coefficient (confined), specific yield (unconfined) and transmissivity. Representative aquifer parameters for the shallow and deep aquifer systems are summarised in Tables 4 and 5.

Table 4 Aquifer parameters in the Shallow Aquifer System

Bore Field	Specific Yield (SY) (Unconfined)	Transmissivity (T) m^2/day
Milikapiti	0.1	200
Nguiu	0.1	110
Wurankuwu	0.1	50

Table 5 Aquifer Parameters in the Deep Aquifer System

Bore Field	Storage Coefficient (Confined)	Transmissivity (T) m^2/day
Milikapiti	n/a*	60
Wurankuwu	0.0001	300

*n/a: The data is not available

3.3 Groundwater Monitoring

The measurement of water levels in designated monitoring bores helps to determine how the aquifer water table changes with time. Water levels in most bores were recorded immediately after construction. Certain bores are constructed as designated monitoring bores and water levels are measured periodically. These measurements can be made either by hand or by using an automatic *logger* that gives continuous measurements of water level at specific periods of time or after a pre-determined change in level.

The borefields in Milikapiti and Nguiu have had designated monitoring bores since the borefields were first developed. Nguiu and Milikapiti have a total of 52 monitoring bores. Water level measurements were made by DLPE staff or by the essential services officer under contract by the Power and Water Authority.

Prior to this investigation, monitoring bores in Milikapiti and Nguiu were measured on a monthly basis from 1988 to 1995. From 1996 to the beginning of this project in 2000, the monthly monitoring of these bores was abandoned. For a 5-year period, the water levels were only measured every 6 or 12 months. Water levels were measured several times a year from 1999 to 2003 as part of this water resource investigation. To properly assess the status of the water resource, it is important that water level monitoring on the borefields is done on a monthly basis.

Figure 12 is a hydrograph from a bore at Nguiu that was monitored on a monthly schedule. Figure 13 is a hydrograph of total annual rainfall at Pirlangimpi. It is important to note that between 1995 and 2000 there was an increase in total annual rainfall above the regional average of 1500 mm. As a result, the water levels in the monitoring bores began to rise. In this case, the rise from 1995 to 2000 was about six metres. By 2000, the regional aquifer water levels were higher than had been recorded for 15 years. Subsequently, many of the springs and creeks showed higher than average flow rates.

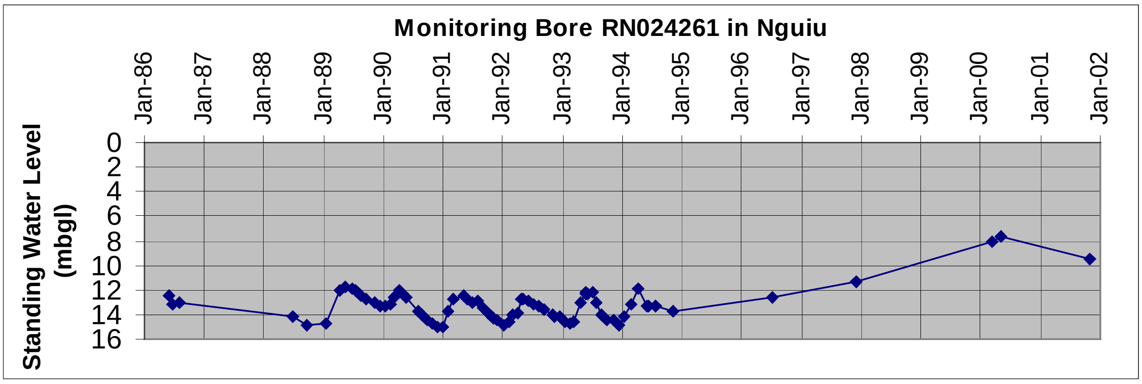


Figure 12 Bore Water Levels at Nguiu

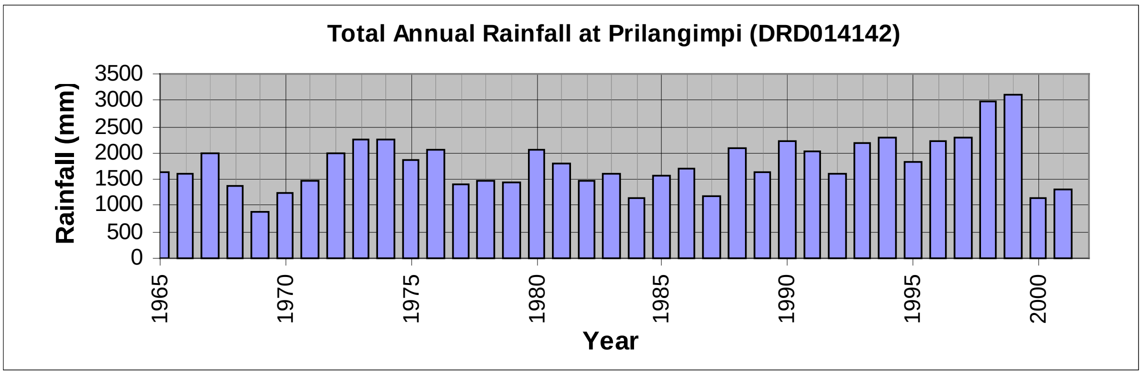


Figure 13 Total Annual Rainfall, Pirlangimpi

Additional monitoring data outside of the designated bore fields was collected during the course of this investigation. Monitoring bores at Yimpinari, Three Ways, Taracumbi Outstation, Maxwell Creek and Garden Point were constructed as part of the assessment-drilling program in 2000. The bores at these locations were either equipped with automatic loggers or had periodic measurements made by hand from 2000 to 2002.

The data has been stored in the HYDSYS database that is maintained by the Natural Systems Division of DIPE. All of the monitoring data from HYDSYS has been made available on the CD-ROM that includes this report.

3.4 Groundwater Quality (Shallow Aquifer)

Representative examples of groundwater quality sampling are shown in Table 6. The water from the borefields in Nguiu and Milikapiti is of very high quality (RN027922 and RN021793). This is known to anyone who lives on the islands or who has visited and experienced the fresh taste of “Tiwi Water”. With the exception of *pH*, the water in the shallow and deep aquifers are within the Water Quality and Monitoring Guidelines as outlined in *the Australian and New Zealand Guidelines for Fresh Water Quality (*ANZECC, 2002*)*. . A table of minimum allowable characteristics and inorganic chemicals is provided in APPENDIX B. Water sampling of all outstations and community bores indicate that groundwater quality is within the national guidelines.

Chemical sampling during previous studies has been well documented (Moser 1994; Yin Foo and Morretti 1992; Chin 1991) and indicates that the water quality of the groundwater on the Tiwi islands is typical of other groundwater sources in the Top End.

Water quality is very much affected by the interaction between the groundwater and the aquifer material. As the rainwater percolates into the ground, it reacts with the aquifer material. Over time, this interaction may change the chemical composition of the water.

On the Tiwi Islands, the aquifers are made up of sandstone with layers of silt and clay. The sand grains are made of silica and do not react readily with the water, nor do the clay layers, which are relatively *inert*. As a result, the water in the sandstone is not that much different from the rainfall that *recharges* the *aquifer* each year.

The quality of water can be described chemically by many constituents that are analysed in a laboratory. Some of the more basic properties of water that help to determine the quality of water are pH, alkalinity, hardness and salinity (TDS).

The *pH* is a measure of the hydrogen ion concentration in water. Rainwater contains varying amounts of gasses such as carbon dioxide and sulfur dioxide. When rainwater comes in contact with the ground surface, it may react with organic material, which results in a further increase in these gases. As a result, the pH of most rainwater is below 7 (acidic) and is considered to be corrosive to iron roofs and equipment. Water with a *pH* of less than 7 is usually corrosive, whereas a pH of greater than 7 is considered to be *alkaline*. Water from the shallow *aquifer* typically has a *pH* between 4 and 6, which is suitable for drinking water, but is considered to be corrosive to metal pipes and fittings.

With a low *pH*, the water is also low in *alkalinity,* with recorded levels of less than 10 milligrams per litre. Water which has a high alkalinity (>100 milligrams per litre) may tend to cause scaling and deposits to form on water pipes, tea kettles and other surfaces. This is not a problem in Milikapiti or Nguiu.

Table 6 Examples of Water Quality Analysis for Tiwi Island Borefields

Bore RN	Date of Sample	pH	EC (µS/cm)	Total Dissolved Solids	Sodium, Na	Potassium, K	Calcium, Ca	Magnesium, Mg	Iron (Total), Fe	Total Hardness	Total Alkalinity	Silica, SiO2	Chloride, Cl	Sulphate, SO4	Nitrate, NO3	Bicarbonate	Fluoride, F
				(mg/L)													
Wurankuwu: Mookinu Mudstone (Deep Aquifer)																	
29292	Jun-94	6	20	46	2	<1	<1	<1	1.9	<1	5	11	6	1	<1	6	<0.1
Milikapiti: Van Diemen Sandstone																	
27922	Dec-91	5.6	40	32	5	<1	2	1	0.1	9	5	12	9	<1	1	6	<0.1
Milikapiti: Van Diemen Sandstone, Bore located on Karslake Peninsula, Saltwater intrusion causes high EC																	
27858**	Nov-91	4.9	1905	990	319	3	8	36	1.7	168	2	18	584	17	<1	2	0.2
Milikapiti: Mookinu Mudstone (Deep Aquifer)																	
27923*	April-94	6.8	192	125	13	6	3	2	0.4	16	71	18	13	12	1	86	0.6
Nguiu: Van Diemen Sandstone																	
21793	Dec-82	5.4	31	26	4	<1	1	<1	0.4	3	2	12	8	<1	<1	3	<0.1

Water with an abundance of dissolved minerals is considered to be “hard”. Water with a high dissolved mineral content can be found in Darwin or Katherine where the aquifers are dolomite or limestone. When water is considered to be hard, there will be a difficulty in making suds from soap. Soft water has the opposite effect. The water on the Tiwi islands is considered to have a relatively low hardness.

Salinity is a function of the amount of dissolved salts in solution. During the interaction of rainwater with some the aquifer materials, minerals are dissolved by the water and form salts in solution. This causes an increase in the salinity of the water. Salinity can be expressed in terms of *Electrical Conductivity* (EC) with units of µS/cm (microSiemens per centimetre). Another way to express salinity is by the concentration of Total Dissolved Solids (TDS). To determine this, a water sample is evaporated and the weight of the remaining solids is measured. The units for TDS are in milligrams per litre. Salinity is usually expressed as either TDS or EC.

The groundwater on the Tiwi Islands has low salinity with electrical conductivities of less than 50 microSiemens per centimetre and Total Dissolved Solids of less than 70 milligrams per litre (Chin 1991). The exception is likely to be in areas near the coast where saltwater intrusion may be a consideration. During assessment drilling in Milikapiti (Chin, 1991), *brackish* water with EC measurements of 1905 to 5470 microSiemens per centimetre were sampled (Table 6, RN027858). The standing water level was at sea level and the aquifer was affected by saltwater intrusion.

3.5 Groundwater Quality (Deep Aquifer)

Water quality in the deeper aquifer (Table 6, RN27923) differs from the shallow aquifer due to a difference in the aquifer material and the length of time that the water has been in contact with the formation. The deeper aquifer sampled in Milikapiti has a neutral pH of 7, which is due to the presence of carbonate in the aquifer material when the sandstone was deposited (Chin, 1991). The *carbonate* acts as a buffer to make the water less acidic. Conversely, the alkalinity is much higher and has been reported to be between 65 to 100 milligrams per litre (Chin 1991). The electrical conductivity is similar to that of the shallow aquifer and is less than 200 microSiemens per centimetre. The blending of water from the deeper aquifer in Milikapiti with the shallow aquifer may help to raise the pH of the water supply.

Groundwater samples have been collected from numerous bores throughout the region during this study and during previous investigations. A full listing of the detailed chemical data from several hundred water chemistry samples are available on the CD-ROM.

PART 4. SURFACE WATER

4.1 Surface Water Catchments

A surface water *catchment* describes a basin and stream system that includes all the upstream land and surface area that drains into a specific river or stream. A topographic *divide* defines the catchment area boundary. The divide is a line passing through the highest points between two neighbouring steam systems or basins.

DIPE has divided the Northern Territory into a series of regional surface water catchments. Both Melville and Bathurst Islands are catchment 816 in this network. As part of this investigation, the Tiwi Islands were subdivided into a series of smaller catchments for each of the larger river systems. The sub-catchments are shown below in Figure 14.

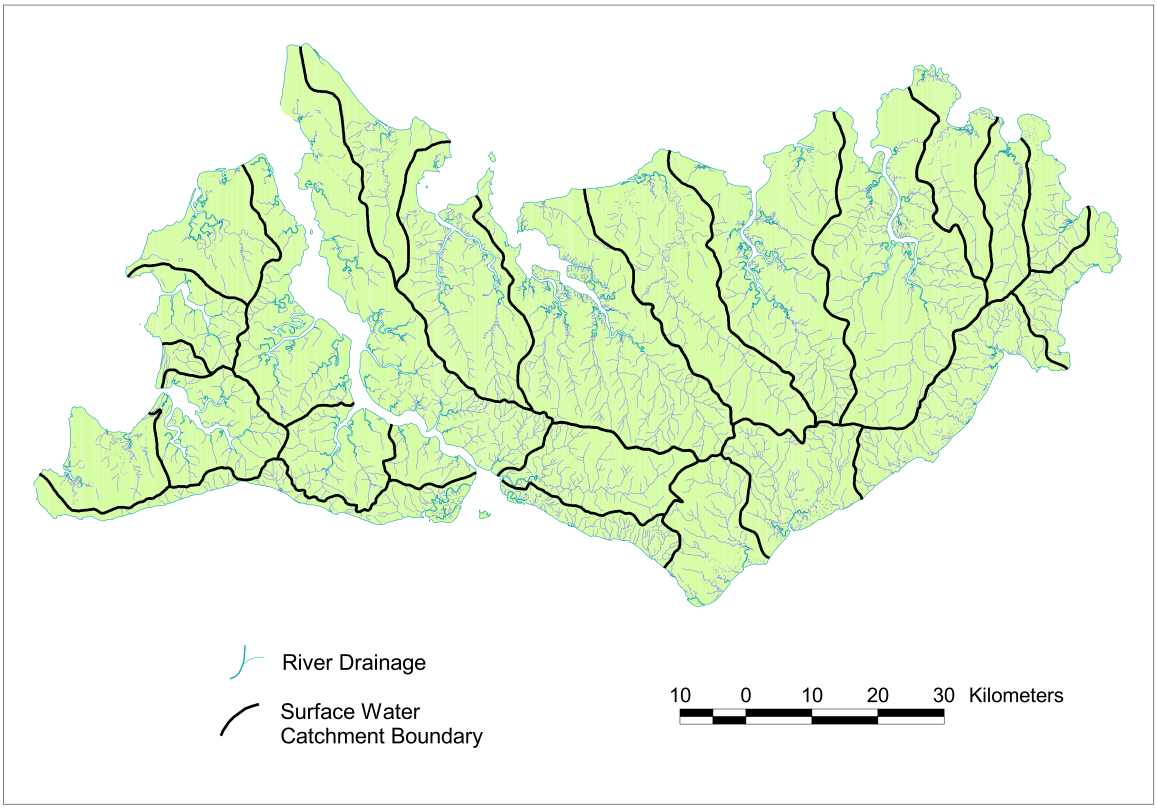


Figure 14 Surface Water Catchments

4.2 Stream Flow Monitoring

There are a total of 68 measurement sites on the Tiwi Islands as shown below in Figure 15. During the investigation, stream flow measurements were collected at 54 of those sites. All of the sites have “spot” readings that represent the flow volume at a single instant in time. Many of these stations have repeated measurements that date back to the 1960s.

During the investigation (2000-2002) the groundwater levels were higher than normal due to increased rainfall between 1997 and 2000. As a result, the flow measurements during the investigation are higher than normal flow rates.

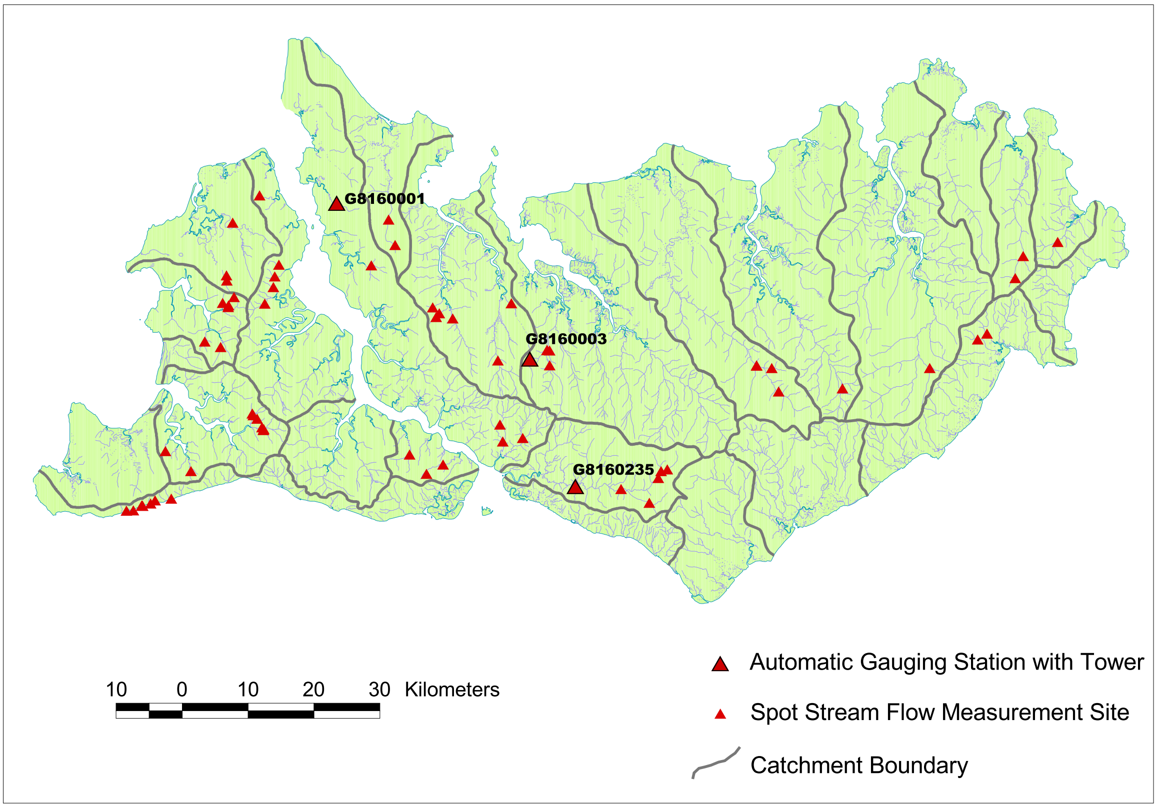


Figure 15 Stream Flow Measurement Sites

There have been three “dedicated” gauging stations on Takamprimili Creek, Blue Water Creek and Taracumbi Creek (Figure 15). The stations have “gauging towers” that house instruments and measuring equipment (Figure 16). The towers are equipped with automatic loggers that measure continuous changes in water level throughout the year.

A survey of the shape of the streambed, or section, allows for the development of a rating curve. The curve equates a certain rise in the height of water in the stream to the flow. It is a function of the cross sectional area of the stream channel.

Figure 16 Gauging Tower at Blue Water Creek

The three dedicated gauging stations were established in the 1960s, but were subsequently abandoned in 1986. As part of this investigation, the gauging stations were made operational and automatic loggers were installed in each. During automatic logging, spot measurements were also made periodically to assist in the creation of a new rating curve. The spot measurements were made with the use of a (Pygmy) current meter. The stream flow data collected during this investigation and all of the historic flow measurement data is available on the CD-ROM that includes this report.

4.3 Rivers and Streams

The rivers and streams have their highest flows during the wet season when flow is dominated by rainfall "*runoff*". Figure 17 is a graph of the total monthly rainfall at Pirlangimpi between January 1980 and January 1983. Figure 18 is a hydrograph of creek flow versus time at Blue Water Creek during the same period. By the end of the wet season, surface flow is sourced from springs and the drainage of the shallow aquifer along the course of the stream. When the flow in the streams is dominated by the drainage of groundwater, this is known as "*base flow*". The components of flow, which are attributed to runoff and baseflow, are shown in Figure 18.

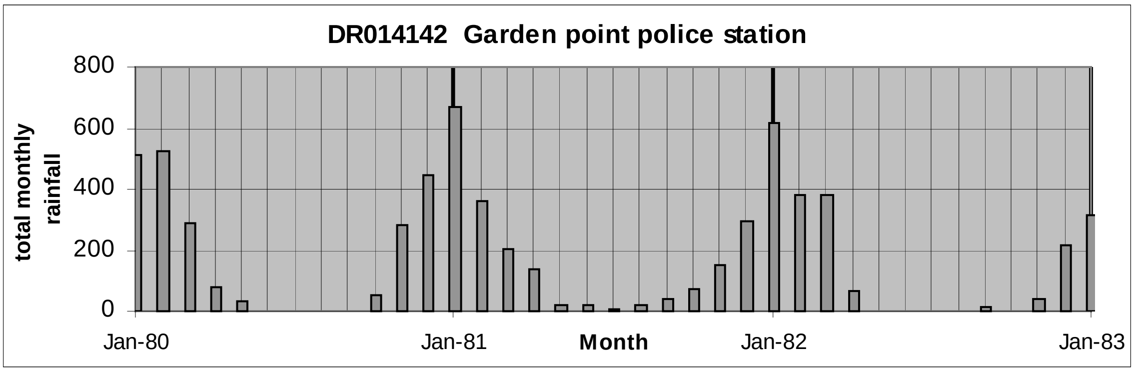


Figure 17 Total Monthly Rainfall data from Garden Point Police Station

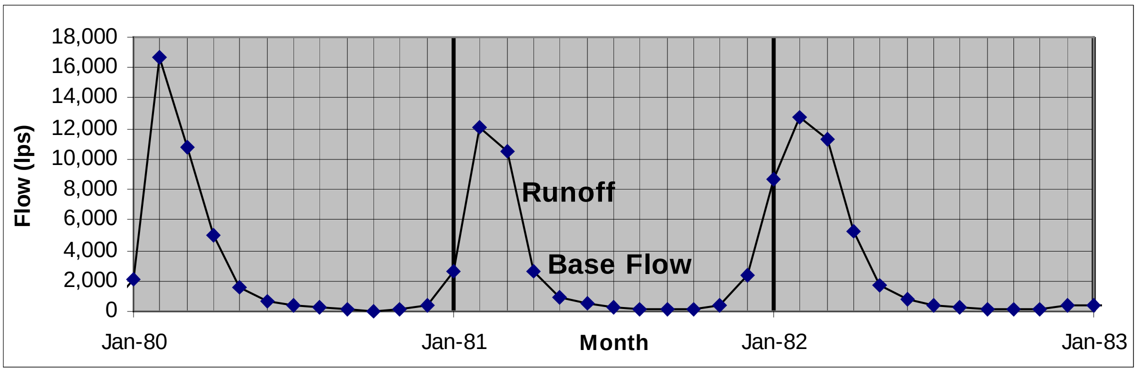


Figure 18 Flow Volume in Blue Water Creek

4.4 Spring Flow

Figure 19 shows the volume of base flow at surface water monitoring sites as measured at the end of the dry season 2001. By the end of the dry season, many of the smaller springs in the higher elevations have dried out. By this time, only the larger springs still flow (ie. Takamprimili and Taracumbi) or those springs and seeps in areas of lower elevation. The volume of flow from the bigger springs is related to the saturated thickness of the Van Diemen Sandstone from which the water drains.

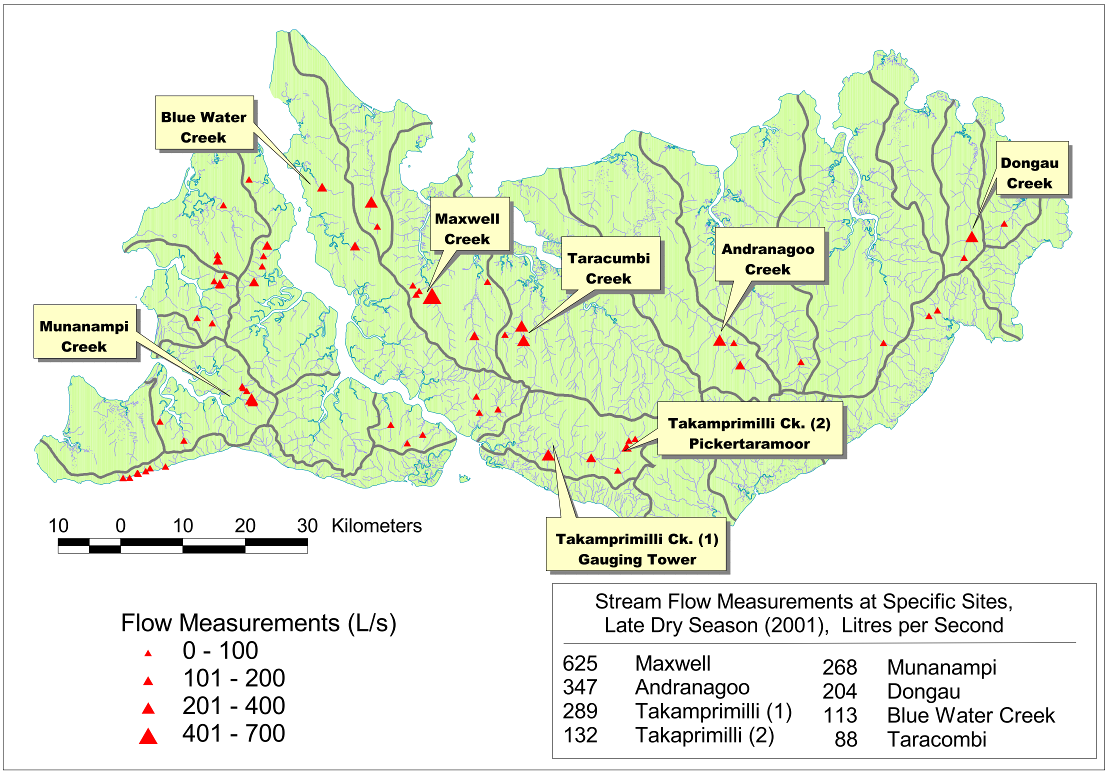


Figure 19 Stream Flow at the end of the Dry Season, 2000-01

Many of the springs in the southern side of Melville Island dry up by the end of the dry season. In this area, the sandstone is very thin (<20 metres) and drains rapidly at the end of the wet season. The small rivers and creeks on the northern half of Melville Island tend to flow longer due to the greater thickness of sandstone. In many cases, only the larger springs still flow by the end of the dry season. The creeks at Pickertaramoor (Takamprimili), Taracumbi, Maxwell Creek and Blue Water Creek have measurable flows in September and October. In all of these cases, the streams are fed by springs, which drain from the regional shallow aquifer, the Van Diemen Sandstone.

4.5 Minimum Flows and the Rainfall Record

It should be noted that the spring flows measured during the investigation represent higher than normal flows. This is due to the wetter than average wet seasons between 1995 to 2000.

Figure 20 is a hydrograph showing minimum stream flows for three creeks with long term records: Blue Water Creek, Taracumbi Creek and Takamprimili Creek. The data shows the minimum flows that were measured at the end of the dry season. These measurements were typically taken in September or October, before rainfall and runoff had any long-term effect on creek flow. The flow hydrographs show that high flows were recorded from 1975 to 1977 and again from 1999 to 2002.

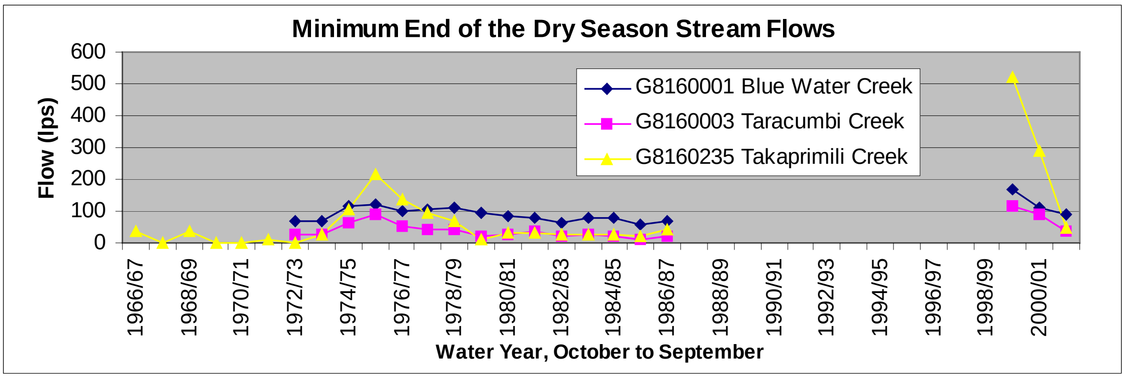


Figure 20 Hydrograph of Minimum Flows, 2000-01

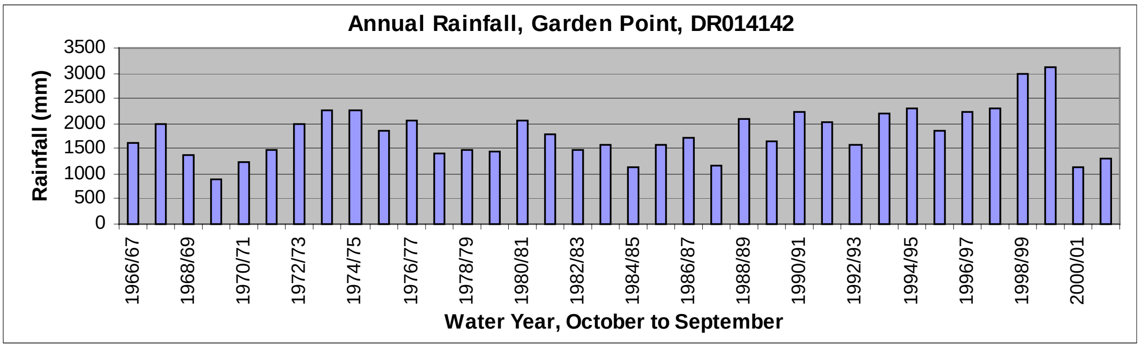


Figure 21 Total Annual Rainfall, Pirlangimpi

Figure 21 is a hydrograph showing total annual rainfall for the *water year*. In the NT, the water year extends from 1 October to 30 September of the following year. Between 1972 and 1977, the total annual rainfall was above the average of 1500 millimetres. The flow hydrograph shows a corresponding increase in minimum flows. Between 1978 and 1993, the annual rainfall fluctuated around the average of 1500 millimetres. The flows shown in Figure 20, correspondingly, represent average annual flows at the end of the dry season.

There was a second series of higher than average rainfall years beginning in 1994 and extending to the end of 2000. In addition, the total annual rainfall between 1998 and 2000 peaked out at about 3000 mm for each rain year. Correspondingly, there was a large increase in the end of dry season stream flow as shown in Figure 20. By 2002, total annual rainfall was below normal levels.

It is interesting to note that in 2002, river flows reduced to levels more representative of the average annual flow values recorded between 1978 and 1987. The flows recorded at the end of the dry season represent base flow to creeks that drain directly from the regional sandstone aquifer. The aquifer had reached a level of high saturation by the end of 2000.

It took about 2 years for the regional system to drain and equilibrate to levels of saturation more representative of average base flows recorded between 1978 and 1987.

4.6 Regional Surface Water Quality

A total of 29 surface water sites on Melville and Bathurst have been sampled for water quality. The surface water samples have had standard and *bacteriological analysis* and additional analysis in regards to *nutrients* and *trace metals*. The data from the full set of analyses are available on the CD-ROM.

In general, surface water chemistry is similar to that of the groundwater from which it is sourced. Analysis for electrical conductivity, total dissolved solids, pH, total hardness and alkalinity are similar to those reported for the shallow aquifer in Table 6.

During a river health study of Takamprimili Creek (Suggit and Edwards, 1997) the pH was found to increase from 4.6 at the headwaters to 6.4 at the tidal limit near the gauging station. This could be due to natural degassing of carbon dioxide in the open creek system. The investigators commented that this has also been noted in Rapid Creek in Darwin. Since this is probably a natural process, it is not considered to be a river health issue.

Takamprimili Creek was found to be in good health after general water chemistry, nutrient and metals analysis. The macroinvertebrate population was similar to fauna found in other Top End creeks. This is an important conclusion, considering that the headwaters of Takamprimili Creek were the centre of a major forestry operation, which ended in the 1990s.

One detrimental impact to the Takamprimili Creek system was reported as a localised increase in turbidity due to the wallowing of buffalo. This led to an increase in turbidity and an increase in nutrients due to the introduction of buffalo faeces. Blue Water Creek is particularly vulnerable to similar bacteriological contamination (Tysen, 1994) during times of high flow. On Bathurst Island, where there are no buffalo, the feral pigs have a similar impact on the environment.

The other potential impact on regional water quality is the introduction of suspended solids to creek systems as a result of major road works. Similarly, current land clearing for forestry operations has the potential to impact on the turbidity and sediment loads in regional drainages. These impacts are management issues that are being addressed by the traditional owners and the Tiwi Land Council.

PART 5. GROUNDWATER AND SURFACE WATER INTERACTION

5.1 Recharge to the Shallow, Unconfined Aquifer

Recharge to the shallow Van Diemen Sandstone aquifer is through direct infiltration during localised rainfall events in the wet season. Figure 22 shows the relationship between rainfall and seasonal water level fluctuation in the shallow aquifer between Three Ways and Taracumbi Outstation.

At Three Ways, an automatic logger was installed in bore RN008437 in January 2001. The aquifer at this site is 25 metres thick. A rain gauge (R8160008) was installed a few metres from the bore in October of the same year. The hydrographs are for the period from May 2001 to October 2002.

An automatic logger was installed in the gauging station at Taracumbi Creek, located approximately 5 kilometres down slope (north) from the monitoring bore. The hydrograph showing the volume of stream flow is for the same period.

There was a delay of three months between the first rain event in October and the rise in water levels in the bore in the beginning of January. It appears that the regional shallow aquifer requires a series of rain events before there is sufficient aquifer saturation to affect the water table. In this case, there was a cumulative total of 700 millimetres of precipitation before the first increase in the water table in January.

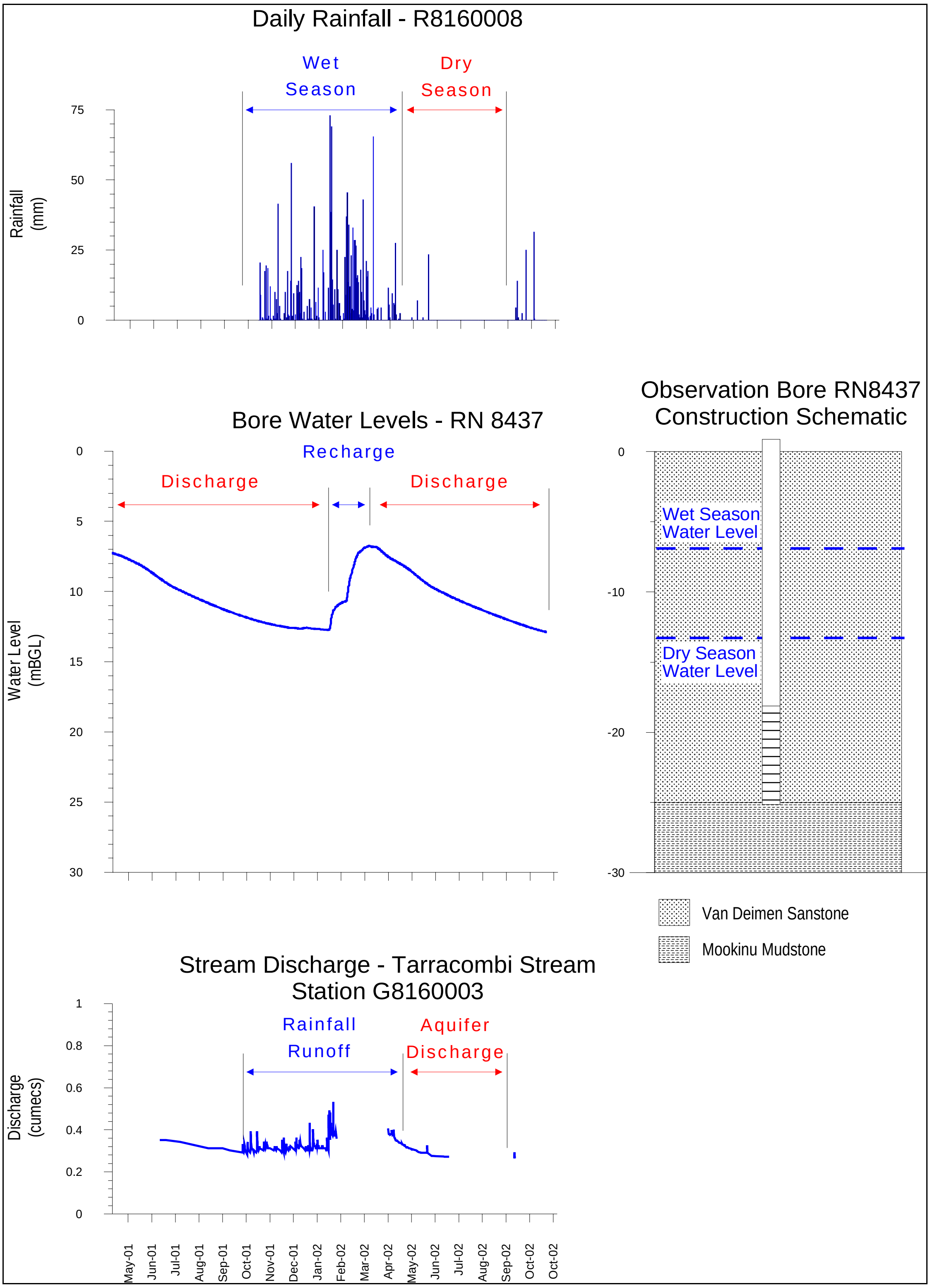


Figure 22 **Rainfall, Water Levels and Stream Flow from Three Ways and Taracumbi Creek**

Following the wet season, the water drains from the aquifer to feed the surrounding creeks and springs. The slope of the hydrograph during drainage, or the *recession curve*, becomes shallower as the rate of drainage reduces. The earlier portion of the recession curve represents the short-term storage and the annual recharge volume of the aquifer. The slower draining water represents the base flow drainage of the aquifer, or the long-term storage. Each year, the aquifer is recharged through precipitation and subsequently drains to the surrounding springs and creeks. The shape of the recharge and recession curve for bore RN008437 is similar to monitoring bores in the Milikapiti and Nguiu borefields.

Figure 23 shows a similar monitoring arrangement near Yimpinari Outstation.

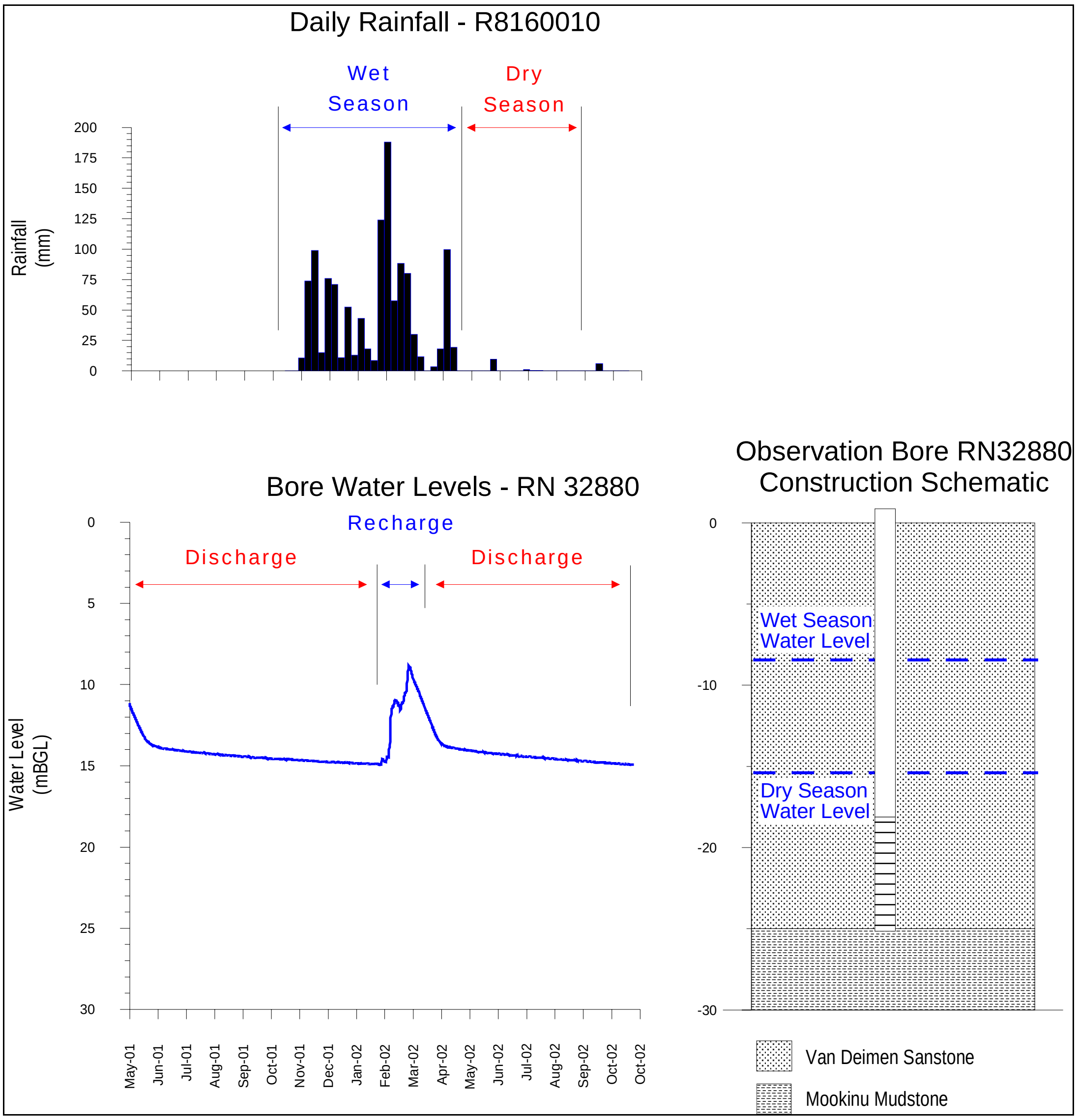


Figure 23 **Rainfall and bore water levels near Yimpinari Outstation**

A monitoring bore was constructed in October 2000 (RN032880) and an automatic water level logger was installed at the end of December 2000. The aquifer at this site is also 25 metres thick. A rain gauge was installed beside the bore in September of 2001 (R8160010). The *hydrographs* in Figure 23 are for the period from May 2001 to October 2002.

Similar to the recharge at Three Ways, there is a delay of three months between the first rain event in November and the rise in water levels at the beginning of February. In this case, there was a cumulative total of 616 millimetres of precipitation before the first increase in the water table was recorded.

The rise in mid-February corresponds well to a large rain event at that time. A second rise at the end of February corresponds to another significant rain event in the middle of February. It appears that about 616 millimetres of rain is required before the effects of recharge can be measured in the aquifer. The water table response lags behind the rain event by a couple of weeks. Similar to the monitoring bore at Three Ways, the total thickness of *unsaturated aquifer* above the late dry season water table was about 15 metres.

Following the wet season, the water drains fairly rapidly from the shallow portion of the aquifer as can be seen from the steep slope of the *recession curve* between the beginning of March and the beginning of April. By mid-April, the rate of drainage has reduced considerably. The rapid drainage at this location is due to various factors, such as the limited lateral extent of the aquifer and proximity of local creeks (drains). Another explanation may be bore construction whereby drainage from the bore is limited when the water table reaches a certain head. In general, the shape of the recession curve is not typical of other aquifer responses seen in the regional shallow aquifer.

Figure 24 shows monthly monitoring data from a bore in the Nguiu Borefield. Figure 25 is a hydrograph of total monthly rainfall at Pirlangimpi. Both hydrographs are for the period from January 1989 to January 1995.

The cyclic nature of the annual recharge to the aquifer and discharge from the aquifer is clearly shown. As previously discussed, a few months of precipitation are required before there is sufficient recharge to cause a rise in the water table. The shape of the water level hydrograph is similar to other bores in both the Milikapiti and Nguiu borefields.

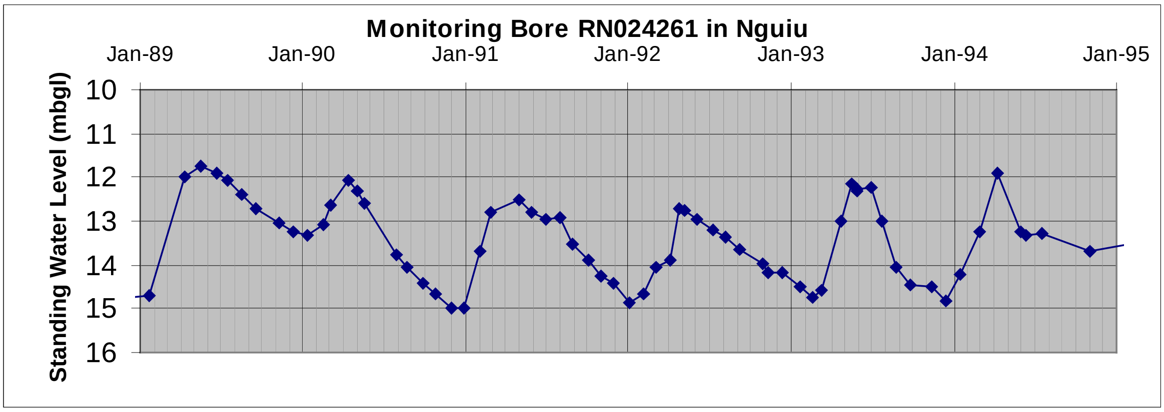


Figure 24: **Monthly Monitoring Bore Data, Nguiu**

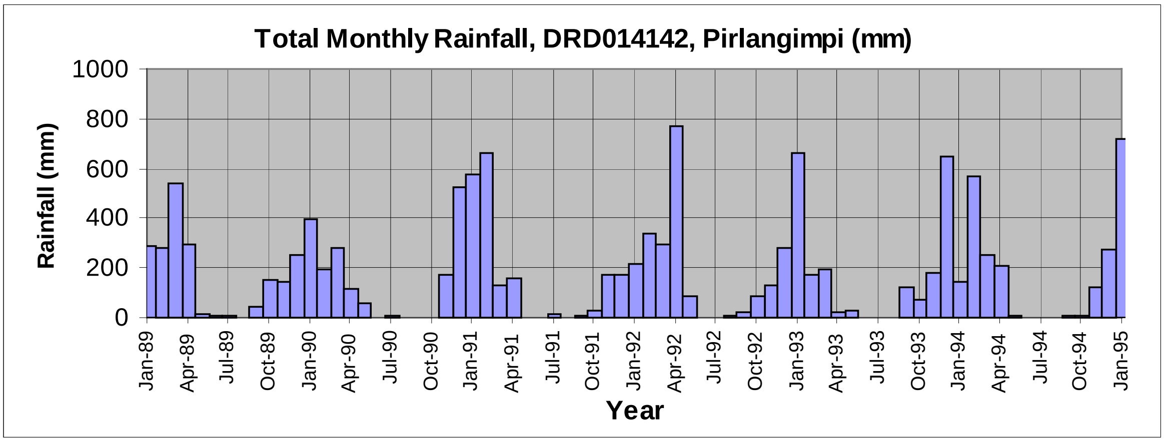


Figure 25: **Total Monthly Rainfall, Pirlangimpi**

5.2 Recharge to the Deep, Confined Aquifer

A cross-section of the deeper, confined aquifer and the current zone of recharge are shown in Figure 26. Recharge into the lower portions (100 metres below sea level) of the aquifer is not well understood. If recharge occurred to the formation as it was being deposited, the water quality would have been brackish. This is due to the fact that the Moonkinu Mudstone was deposited in a predominantly marine environment. A second possibility is the recharge took place between 20,000 and 7,000 years ago when the sea level was lower. For this scenario, the location of the deep point of discharge and/or through flow is unknown and not fully understood.

At present, recharge is occurring at the point where the deep aquifer is in contact with the overlying Van Diemen Sandstone. Much of the locally recharged water to this zone would be discharged to the surrounding creeks and springs at sea level.

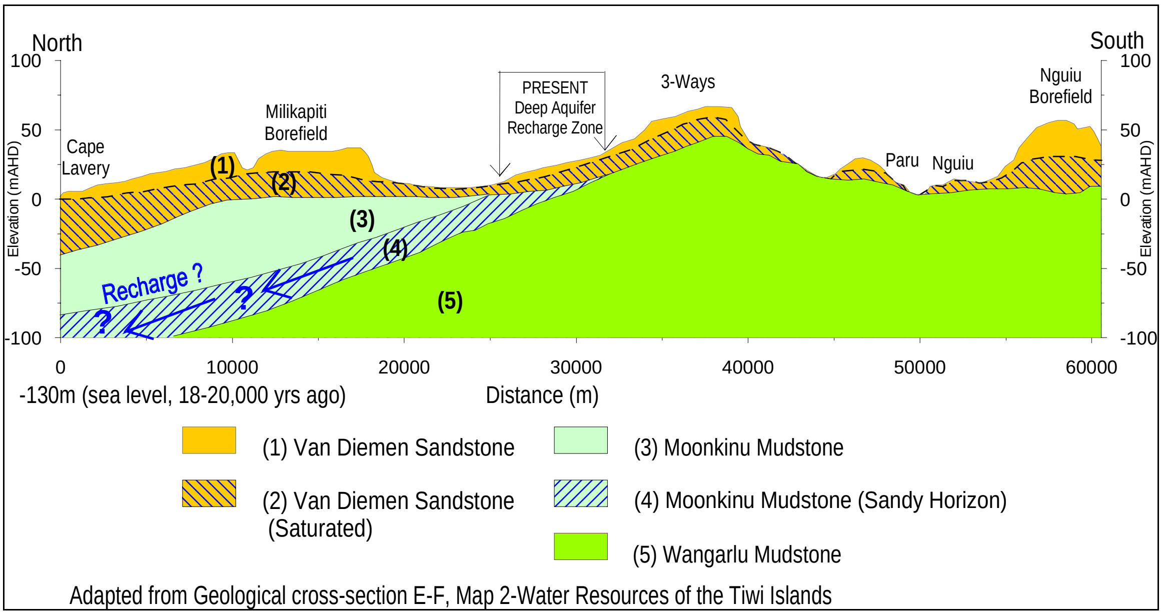


Figure 26 Recharge to the Deep Aquifer

PART 6. ABORIGINAL KNOWLEDGE

A key element of this study was the integration of traditional knowledge about water with the technical understanding of the water resource. Throughout the investigation, information was collected from traditional owners in the form of water stories, traditional place names and personal observations about the occurrence of water. The information has been presented in a traditional knowledge map and accompanying report. A full accounting of the methods used to collect traditional knowledge and the information collected are covered in detail in *Volume 2: Water Resources of the Tiwi Islands, Aboriginal Knowledge.*

The traditional owners and elders of the Tiwi Islands have given the project team permission to publish some of the place names on the final maps for public use. The map and report can be viewed and reproduced from the CD-ROM.

PART 7. WATER RESOURCE MANAGEMENT ISSUES

7.1 Sustainable Development

All State, Territory and Commonwealth governments recognise the importance of working in partnership with landcare groups, industry, traditional owners and other key stakeholders in the sustainable development and conservation of natural resources. This management principle seeks to ensure that the health of our land, water and vegetation are balanced with regional aspirations for long term productivity and prudent use of the resource for generations to come.

Thus far, the level of development on the Tiwi islands has not caused any undue concern as to the health and sustainability of the water resources. The growth in the populations of Nguiu, Milikapiti, Pirlangimpi and Wurankuwu may require the upgrading of and increase access to the water supply. These situations can be addressed when the time comes and the adequate measures taken at that time. At this time, there is no need for concern in regards to community water supplies.

7.2 Environmental Protection

Threats to the municipal water supply have been addressed during the development of the borefields in Nguiu, Milikapiti and Wurankuwu. Standard methods of bore construction were used to ensure that the possibility of contamination was minimal. The accepted practice of applying a minimum separation of supply bores from sources of contamination has been strictly adhered to.

Care should be taken in the placement of future rubbish tips; horticultural gardens, fuel storage and chemical supply depots near the current borefields. This principle has been applied in each community and the risk of contamination to municipal supply bores is minimal.

It is recommended that a hydrogeologist be consulted in future when the placement of any facility on or near the present borefield (where contamination of the aquifer from surface pollution is an issue) is considered.

7.3 Groundwater Dependent Ecosystems

The importance of protecting the environment cannot be overstated and is a driving issue behind the water management strategies presently being developed nationally. It is recognised that certain plants, animals, and ecosystems rely on water from groundwater sources. This is certainly an issue on the Tiwi Islands as all of the freshwater springs are maintained by groundwater through the dry season. In areas of development, it is important that groundwater-dependant ecosystems be identified where current use may impact on either the quantity or quality of water.

Presently, the volume of use from the municipal borefields has not caused any noticeable impact on areas of environmental significance. It would be prudent, in the future, to address this issue when expanding or establishing new municipal bore fields.

Impacts to surface water drainage and freshwater aquatic life may arise in areas where sediment load into the creeks is increased during the wet season. This could arise from improperly managed land clearing. The current land clearing operations at the Sylvatech joint venture on Maxwell Creek have addressed such issues. It is understood that the current soil conservation methodology (engaged by Sylvatech) has been effective in reducing sediment transport.

7.4 Feral Animal Control

The wallowing of uncontrolled buffalo and the digging of feral pigs around springs is impacting on the environment. Any disruption to the stream banks will cause an increase in turbidity and actively erode firm banks into muddy wallows. Feral animal control is an ongoing concern that needs to be managed by the traditional owners and the Tiwi Land Council.

7.5 Protection of Future Borefields

Appendix A provides detailed information and a location map of assessment bores drilled in 2000 outside of Pirlangimpi. These bores indicated that there might be sufficient groundwater in the area east of Pirlangimpi to establish a borefield. Although the present water supply may be adequate and no plans have been discussed to establish a borefield, this area should be protected from any development that may impact on the underlying groundwater supply. Appendix B includes a map showing the location of the assessment bores and the extent of the area that should be protected.

7.6 Protection of Blue Water Creek, Pirlangimpi

Blue Water Creek should be protected from the impacts of development, bacteriological contamination, chemical contamination and the introduction of silt and sediments from roadworks. The community should ultimately give consideration to the development of a borefield to replace the surface water supply.

7.7 Groundwater and Surface Water Monitoring

It is important that the regular monitoring of groundwater levels in and around the present borefields at Nguiu and Milikapiti be continued. At the completion of this water resource investigation in December of 2002, there will no longer be the resources available to continue the monitoring program. The Tiwi Land Council and local community governments could take on the responsibility of developing a monitoring program. The bores only need to be measured every month. A minimum of 10 bores in each of the fields would provide adequate coverage of the resource.

The first step in this process might be to write this responsibility into the contract of the essential services officer in each community to guarantee that funds would be made available for this work. A second step could be to train local assistants in the monitoring procedures. This would continue the monitoring program beyond the extent of the essential services officer’s contract and involve community members.

7.8 Water Use and Public Awareness

Efficient use of water should be a priority in all communities in the Top End. The first step to this process could be to raise the level of education and public awareness about the proper use of water. This may be as simple as developing an educational program for children in the local community schools about the importance of not letting taps run uncontrollably, and the sensible use of water.

PART 8. FURTHER WORK

The information presented to the Tiwi people will assist them in better managing and using their land and water resources. The data from previous investigations and the data collected during this study have been merged to form a comprehensive and complete source of information in regards to regional water resources. It is important to continue the process of data collection, analysis and the further development of an understanding of the nature of the resource. With this in mind, the following work is recommended in the future:

8.1 Groundwater Monitoring

Continued regular monitoring of regional groundwater levels, specifically in the Nguiu and Milikapiti bore fields. It is recommended that the Tiwi Land Council, local community councils and community members take on this responsibility as part of caring for their country.

8.2 Surface Water Monitoring

Automatic loggers at the stream flow stations at Blue Water Creek, Taracumbi Creek and Takamprimili Creek were installed during this study. At the end of the study, the loggers were subsequently removed. It is recommended that the gauging stations be reactivated at the three designated stream flow gauging sites.

Maxwell creek has the highest measured flow volume on both Melville and Bathurst Island. It is also at the centre of extensive forestry activity. It is highly recommended that an automatic flow monitoring station be constructed on Maxwell Creek.

8.3 Environmental Monitoring

Environmental monitoring of surface water and ground water sites in regards to the current forestry project should be started and maintained as a joint project between the Tiwi Land Council and Sylvatech Pty Ltd.

8.4 Environmental Flow Studies

Determination of environmental flows to many of the unique wetlands and rainforests. This will allow for the better understanding of the water resource that maintains these areas.

8.5 Hydrographic Rating Curves

The rating curves for the above mentioned stream gauges require a full analysis and recalculation of a new rating curve. It is recommended that the Hydrographic and Drilling Section, Natural Systems Division of the DIPE undertake this work.

8.6 Spring Flow Studies

Further investigation of stream flow and spring discharge on Melville and Bathurst Islands should be continued. Future hydrologic studies could further define the perennial or ephemeral nature of many of these springs.

8.7 Pirlangimpi Borefield Investigation and Protection

An area located 3 kilometres east of Pirlangimpi may be the site of a future borefield for the community of Pirlangimpi. Further studies are required to quantify the potential resource as a supplementary water supply for the community. Development of the community may require an increase in the local water supply.

8.8 Recharge and potential yield of the Deep Regional Aquifer

The recharge mechanism and the production capabilities of the deep aquifer are poorly understood. It is recommended that further investigation be carried out to better define the hydrogeology of this considerable resource. In particular, age dating of the water from the deep supply bore at Milikapiti would help to determining the source of recharge water.

8.9 Traditional Knowledge

The traditional place names and the location of those sites have been recorded to as accurate an extent as time allowed. The map which accompanies the report, should be regarded as a draft version. The Tiwi people may wish to review and update the map as part of their traditional heritage.

PART 9. WATER RESOURCE DATA

The final products of this study are a series of hard copy maps, hard copy reports and an interactive CD-ROM. All of the hard copy maps and reports are available in digital format on the CD-ROM. The CD-ROM has instructions on how to print the maps and reports.

In addition to the maps and reports, the CD-ROM has a wealth of information in regards to hydrographic data and Geographical Information System (GIS) files. All of the data is in the Universal Transit Meridian (SUTM52) coordinate system and the datum is the Australian Geodesic Datum from 1966 (AGD 66). The following data categories are available on the CD-ROM:

Bore Details	Rainfall Measurements
Site Locations	Groundwater Chemistry
Water Level Data	Surface Water Chemistry
Stream Flow Measurements	Traditional Name Places

To obtain hard copy reports, maps and/or the CD-ROM, contact Daryl Chin, Manager of Spatial Data Mapping (Palmerston Office) of the Department of Infrastructure, Planning and Environment, Fourth Floor, Goyder Centre, PO Box 30, Palmerston, NT 0831, Phone: 08-8999 3603, Fax: 08-8999 3666, e-mail: daryl.chin@nt.gov.au.

PART 10. ACKNOWLEDGEMENTS

The authors would like to thank the following colleagues for their technical assistance and many helpful discussions during the course of this investigation: Peter Jolly, Daryl Chin, Des Yin Foo, Steve Tickell, Danuta Karp, Dave George, Carly Steen and Anh Tho Tien.

The assistance to this project in regards to the cartography, GIS and spatial data analysis from the following individuals is appreciated: Lynton Fritz, Jeff Fong, Bart Edmeades, Rossimah Sinordan, Dave Howe, Jane Hosking and Peter Brocklehurst.

Through the three years of this project there have been numerous individuals who have contributed in the bush during data collection, assessment drilling, hydrographic surveys and the ultimate analysis of that data. The following individuals are acknowledged for their contributions: Gary Willis, Paul Schober, Roger Farrow, Errol Kerle, Ursula Zaar, Mark Ballard, Ian Gillespie, Seamus May, Jimmy Bilich.

The authors would also like to thank the following members of the Tiwi Land Council, and the local community councils of Nguiu, Milikapiti and Pirlangimpi for their assistance during the initial phases of this project and the many visits to the islands: John Hicks, Kate Hadden, Brian Miller, Gibson Farmer, Bill Bremmer, Bob Copin, Cyril Rioli Jr., Andrew Veal, Tanya Woodcock, David Moore, Graham Feegan, Rory Leach, Laurence Liddy and Carly Devenport.

Without the assistance of the following traditional owners, much of the field work would not have been possible: Marjorie Liddy, Gabby Leache, Cyrol Rioli, Bernard Tipiloura, Robert Tipungwuti, Justin Puruntatameri, Jedda Mangatopi, Mark Mangatopi and Happy Cook.

Special thanks to Christine Long for critical review and editing of the final document.

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APPENDIX A: GLOSSARY OF TERMS

Alluvium: The sediments laid down by rivers, flood plains, estuaries and mountain slopes (clay, silt, sand and gravel).

Airlift Yield: Approximate measurement of aquifer / bore yield determined by forcing compressed air into a bore and lifting the static head of water to the surface.

Aquifer: A body of rock, which is sufficiently permeable to conduct groundwater and to yield useable quantities of groundwater to bores and springs.

Baseflow: The groundwater contribution to stream flow. Baseflow often maintains the flow in a stream through the dry season.

Bacteriological Analysis: Water quality sampling to determine is water is impacted by septic systems. Coliform Bacteria is usually the biggest concern.

Basal Layer: Typically referring to the bottom part of a rock layer or geologic formation.

Brackish: The slightly salty quality of water that may result from the mixing of fresh water with seawater.

Carbonate (rock): A rock which is made up of calcium carbonate ($CaCO_3$), such as limestone or dolomite.

Catchment: A basin and stream system that includes all the upstream land and surface area that drains into a specific river or stream.

Confined aquifer: An aquifer that occurs beneath an impermeable layer which confines the water and subjects it to a pressure higher than atmospheric.

Confining Layer: A rock unit typically made up of claystone or siltstone that confines or "caps" a water-bearing unit beneath.

Cretaceous: A geological time period from 65 to 144 million years ago. This is the age of the Wangarlu Member and the Moonkinu Member of the Bathurst Island Formation.

Current meter: A device for measuring water velocity, consisting of a propeller that turns at a rate dependent on the water's velocity. Tables are available to convert the number of turns over a period of time to water velocity.

Deposition: The lying down of loose material (clay, sand, silt or gravel) as a result of the breaking down (erosion) of other rocks.

Dissected Plateaux: A flat lying area of higher elevation that has been cut up and eroded by rivers and streams that drain off of the high ground.

Discharge: The draining of the shallow sandstone aquifer to specific springs and along the main stream course where the water table meets the land surface**.**

EC: Electrical conductivity, the ability of water to conduct electricity. It is directly related to the salt content of the water. EC is measured in microSiemens per centimetre, μS/cm.

Environmental Flow: The minimum flow required in a river or stream that is required to sustain the native flora and fauna.

Ephemeral: A creek or river that dries up in the dry season.

Erosion: The break down of rocks by natural processes such as wind, water, heat and mechanical corrosion.

Erosional Remnants: Rocks of a particular type that once covered the area completely but have since been eroded away to leave only isolated hills and escarpments of the original material.

Erosional Unconformity (Disconformity): A surface of erosion that separates younger (over-lying) strata from older (under-lying) strata. In the Tiwi Islands, the surface between the Tertiary aged sediments (Van Diemen Sandstone) and the Cretaceous aged sediments (Bathurst Island Formation) is an erosional unconformity.

Estuary: That part of a river drainage that enters the sea within the limit of tidal action.

Evapotranspiration: That part of the rainfall that is returned to the atmosphere through direct evaporation and by the transpiration of plants.

Friable: A rock that crumbles easily, typically due to poor cementing of the grains.

Gamma Log: A borehole geophysical survey that measures the natural radiation in rocks. The survey typically identifies layers that may be rich in clay.

Gauging station: Site on a stream where direct observation of water velocities, heights and volumes are made and recorded to determine volume of stream flow.

Geology: The science, which studies the earth, the rocks of which it is composed and the changes, which it has undergone or is undergoing.

Geographical Information System (GIS): An organised collection of computer software, data and information designed to capture, store, manipulate and display all forms of geographically referenced information.

Geophysics: The use of specialised surveys that measure the physical characteristics of the earth, such as the resistivity, gravity, density (seismic) and magnetic properties to determine the underlying rock types.

Glaciation: A period during which global temperatures dropped and the ice sheets on the north and south poles spread toward the equator. The result was the locking up of ocean water in ice, causing an overall lowering of sea levels.

Groundwater: That part of subsurface water that is held within porous and permeable portions of the earth.

Groundwater Discharge: The release of groundwater to the surface by seepage, evaporation or transpiration (from plants).

Hardness: A measurement of the level of calcium carbonate in water. It is difficult to make soap suds in water that is considered to be "hard".

Hydrogeologist: A geologist who studies the properties of the earth to determine the relationship between geology, groundwater and surface water.

Hydrograph: A graph that shows water level or stream flow measurements over a period of time.

Hydrographic: The study and measurement of surface water flows, volumes and occurrence.

Impermeable: An impermeable rock or sediment forming a barrier that water cannot pass through.

Laterite: Reddish brown, rocky material that has formed as a result of excessive weathering and leaching in very wet conditions.

Lithologic Contact: The boundary between two different rock types, such as sandstone and claystone.

Matrix: The cementing material that often fills the spaces between sand or gravel grains in a rock.

Monitoring/Observation bore: A bore used for measuring groundwater levels.

Mudstone: A rock type which is a mixture of clay, silt and sand.

Nutrient Analysis: A water quality analysis that is suited for the measurement of chemical components typically associated with agriculture such as nitrogen, ammonia and phosphorous.

Perennial: A stream, lake or waterhole that does not dry up from year to year.

Permeability/Permeable: The characteristic of a rock or soil by which water can pass through.

pdf: “Portable Document File” a file format that allows reports and maps to be viewed using most popular software on a computer.

pH: A measure of the hydrogen ion concentration in water. A low pH is “acidic” and a high pH is “alkaline”. A pH of 7 indicates neutrality - non-corrosive to metal.

Physiographic Unit: A landform with specific characteristics that reflect how the land formed, what it is made up of and what has happened to it after formation.

Potable: Drinking water that is fit for human consumption

Porosity: The percent of total pore space in a rock or soil.

Porous: A material (rock) with continuous pores that allow water and other fluids to be stored or pass through.

Quaternary (Period): The most recent geologic period that spans the time from 1.6 million years ago to present day.

Quartzose (Sandstone) sandstone that is made up primarily of clean well-rounded quartz grains.

Recession Curve: That part of a stream flow hydrograph that represents the component of flow that can be attributed to groundwater drainage.

Recharge: The process by which water is added to and absorbed onto a rock or soil.

Regression (Sea): The contraction of the seas and /or the rise of land that causes sea levels to lower with respect to the land.

Resistivity Log: A bore hole geophysical log that measures the rock's ability to conduct electricity. The log is helpful in determining between water bearing zones that are either fresh or salty.

Runoff: The component of rainwater that is not absorbed onto the ground and flows across the land surface.

Salinity: The measure of the total dissolved solids in water, ie. NaCl (salt).

Saltwater intrusion: Movement of sea water into fresh water aquifers.

Satellite Imagery: Digital 'photographs' taken from satellites orbiting the Earth.

Saturated Aquifer: The portion of the aquifer that is water bearing.

Soak: An area where groundwater is close to the surface most of the year. A pit or shallow well can be dug to pump the shallow water.

Specific Yield: In an unconfined aquifer, it is the volume of water that can be drained from the rock due to gravity. Specific Yield is a unitless parameter.

Spring: Discharge points for groundwater where the water table is close to the ground surface.

Standing Water Level: The depth (metres) to the top of the water table in a bore as measured from the ground surface.

Storage Coefficient: In a confined aquifer, it is the volume of water released from storage due to pumping. The Storage Coefficient is a unitless parameter.

Stratigraphy: The branch of geology that studies and describes the formation, composition, sequence and correlation of stratified rocks, such as: sandstone, siltstone, claystone and limestone.

Sustainable: To use a resource in such a way that the continued use is ensured and the other users of the resource are not adversely impacted.

Tertiary: A geological time period from 1.6 to 66.4 million years ago. This is the age of the Van Diemen Sandstone.

Trace Metal Analysis: Water Quality analysis test for the presence certain chemical components related to mining activity, such as; aluminium, copper, lead, nickel, zinc, chromium and arsenic.

Transgression (Sea): Expansion of the sea, which results in the eventual, rising of sea levels and the submergence of the land.

Transmissivity: The measurement of the ability of a material (aquifer) to allow water to pass through.

Turbidity: Relative measure of the clarity of the water, which is a function of the amount of suspended particles in the water. Muddy and murky water has a high turbidity.

Total dissolved solids (TDS): A measure of the dissolved solids in water expressed as milligrams per litre. High TDS implies that the water will be saline (salty).

Unconfined Aquifer: The upper portion of the aquifer is open to atmospheric pressure. Does not have an impermeable cap to "confine" the aquifer.

Unsaturated Aquifer: That portion of an aquifer that is not water bearing.

Water Cycle: The continuous cycle in nature by which rainfall is ultimately returned to the atmosphere as evaporation and transpiration.

Water Table: The level of water in an unconfined aquifer as measured from the ground surface.

Water Quality: The chemical and biological characteristics of water.

Water Year: In the NT, the water year extends from October to the following September so as to account for the total wet season rainfall.

Weathering: (See Erosion)

Yield: Amount of water, which can be supplied by an aquifer or pumped from a bore over a certain time period.

APPENDIX B: PIRLANGIMPI ASSESSMENT BORES

Pirlangimpi Assessment Drilling and the Location of a Potential Borefield

The Preliminary Water Resource Investigation of the Garden Point Borefield

September to November, 2000

Two bores were drilled outside of Garden Point as part of the assessment-drilling program in 2000 (Figure 27). Bores RN32888 and RN32889 were drilled as assessment bores and were completed as monitoring bores with 100mm (4-inch) PVC casing. Bore RN32888 was equipped with an automatic logger between January 2001 and October 2002. The hydrograph is shown in Figure 28.

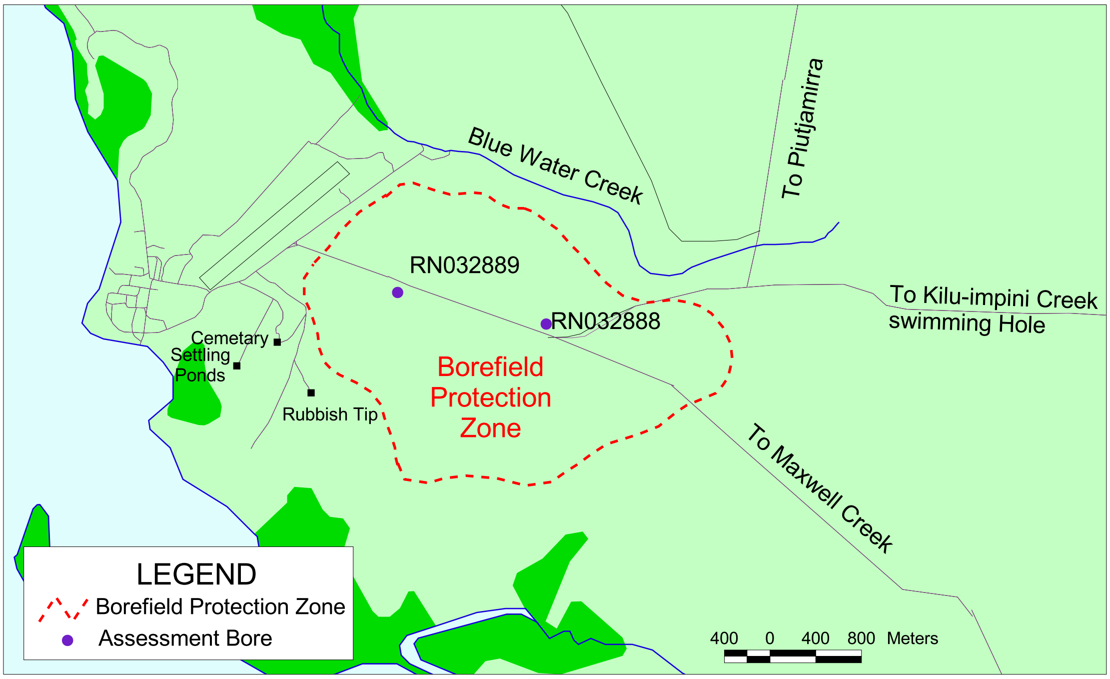

Figure 27 Location of Potential Borefield near Pirlangimpi

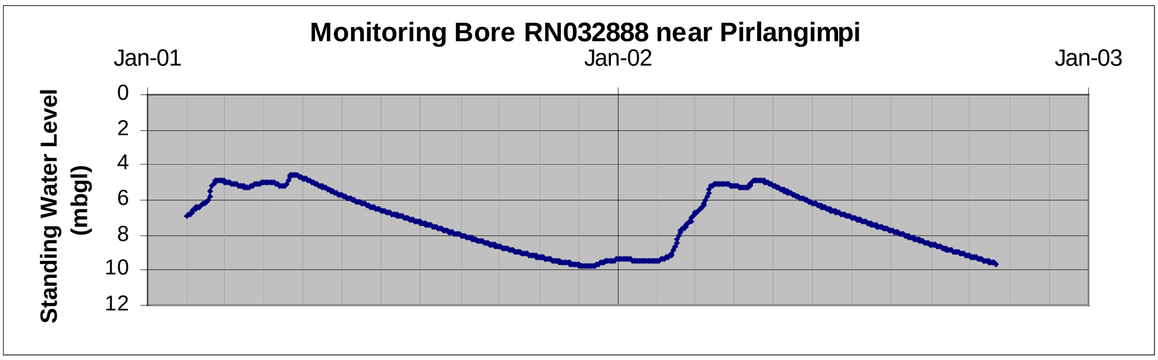

Figure 28 Water Level Data from Bore RN032888

Bore RN32888

Bore RN32888 is further of the two bores from Pirlangimpi. It is located 2.3 km east of the airstrip and is on the northern side of the road leading to Maxwell Creek and Three Ways. Driving from Pirlangimpi, it is 50 metres before the turnoff to the Kilu-Impini water hole.

The bore was drilled to a total depth of 24.6 metres with polymer fluid. The base of the sandstone was at 23.0 metres. The bore was completed with 100 mm (4 inch) PVC casing. A 6 metre length of the casing was hand slotted between 16 and 22 metres BGL. The bore was constructed for the purpose of assessing the local thickness of aquifer, estimating yield and for future monitoring. The bore is not large enough in diameter to be used as a production bore.

After construction, the bore was airlifted at a rate of 3.5 litres per second for about 1 hour. The water was clear, had a nice taste and an electrical conductivity (EC) of 63 μS/cm. The Standing Water Level was measured at 6.1 metres below ground level on 17 November 2000.

Bore RN32889

Bore RN32889 is located about 1 km east of the airstrip, on the south side of the road to Maxwell Creek. It was drilled to a total depth of 30.6 metres. Polymer fluid was used during drilling and the base of the Van Diemen Sandstone was found to be at a depth of 30.0 metres. Below the sandstone was the grey clay of the Moonkinu Member of the Bathurst Island Formation.

The bore was constructed with 100 mm PVC casing to a total depth of 29.3 metres. A 6 metre length of the casing was slotted by hand between 21 and 27 metres BGL. After construction, the bore was airlifted at a rate of 3.5 litres per second for about 1 hour. The water was clear and had a nice taste. The EC was 120 μS/cm. The standing water level was measured at 10.23 metres below ground level on 17 November 2000.

Bore Field Potential

The bores were only airlift tested for a short time (1 hour) and the yields reported do not necessarily represent the ultimate production potential of the aquifer. The bores were completed with 4 inch PVC. If 8 inch casing and screen had been used, significantly more water may have been possible. It would be necessary to drill larger diameter test bores adjacent to the monitoring bores and run constant discharge pump tests for at least 24 hours. This would provide an accurate estimate of production potential.

It is recommended that the area be tested during future resource investigations as a potential supplementary water supply for Pirlangimpi. It is also recommended that the area surrounding the bores (See Figure 27) should be protected from any development that may pollute the underlying aquifer.

APPENDIX C: LOCATION OF MILIKAPITI MONITORING BORES

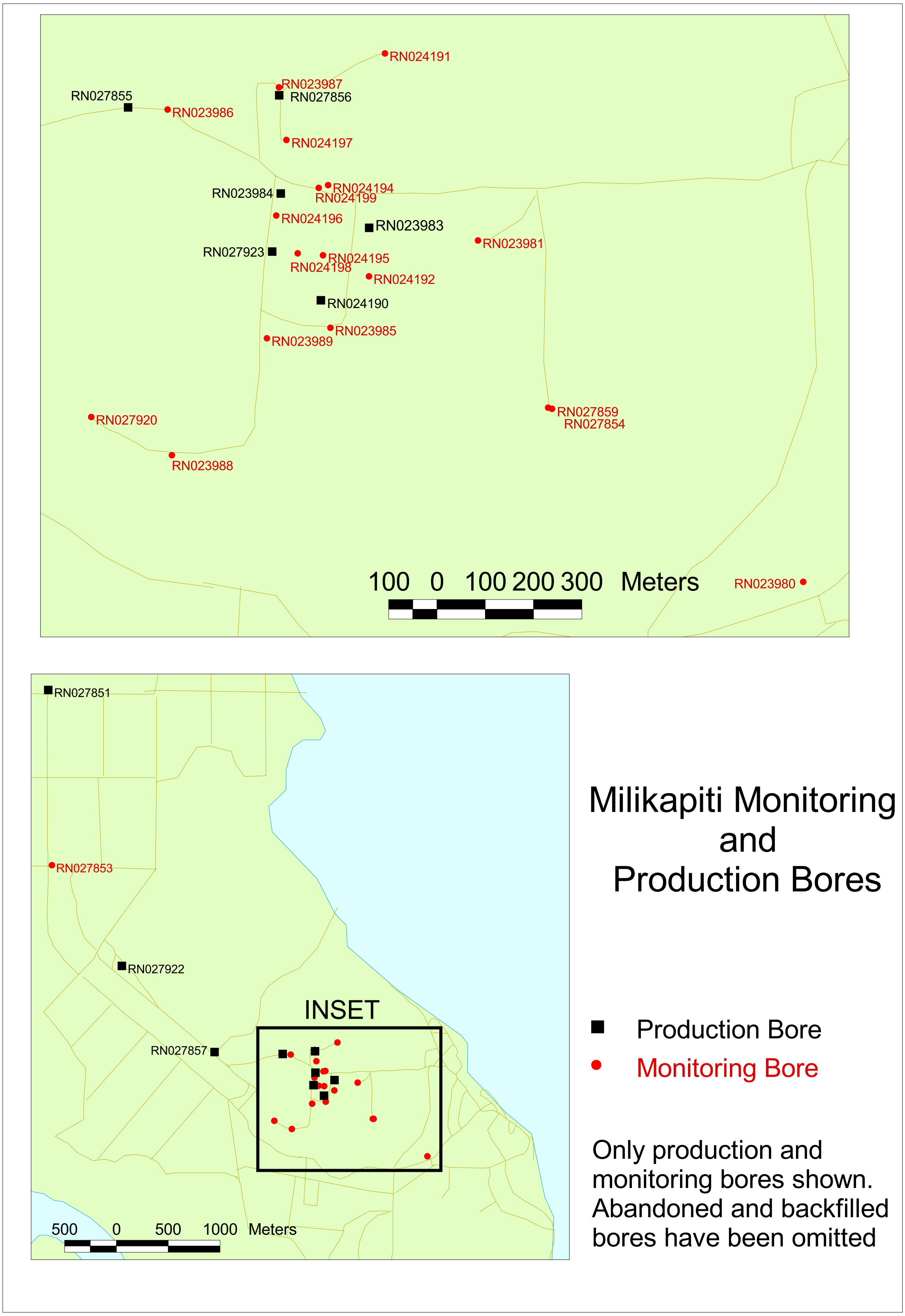

Figure 29 Milikapiti Monitoring Bores

APPENDIX D: LOCATION OF NGUIU MONITORING BORES

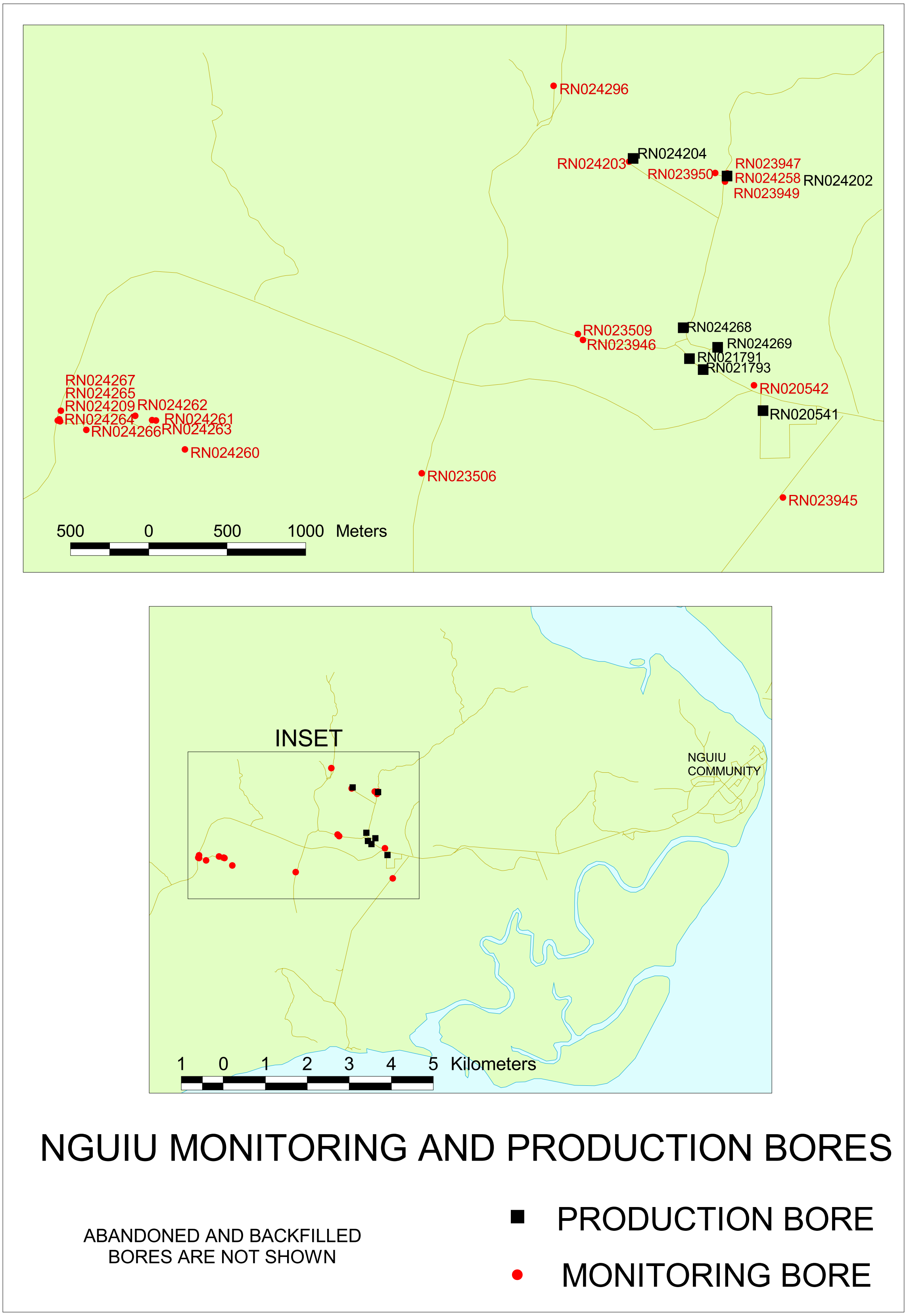

Figure 30 Nguiu Monitoring Bores

APPENDIX E: ANZECC WATER QUALITY STANDARDS, 2002

Based on the Australian Drinking Water Guidelines, National Water Quality Management Strategy, 1996

Guidelines for Physical Characteristics

Characteristic	Health	Aesthetic
Hardness as CaCo3	**	200 mg/L
pH	**	6.5 to 8.5
Total Dissolved Solids	**	500 mg/L
Turbidity	*	5 NTU

Guidelines for Inorganic Chemicals (Values in mg/L)

Chemical	Symbol	Health	Aesthetic
Aluminium	Al	*	0.2
Ammonia (as NH3)	NH_3	*	0.5
Antimony	Sb	0.003	
Arsenic	As	0.007	
Barium	Ba	0.7	
Cadnium	Cn	0.002	
Chloride	NaCl	**	250
Chromium (as Cr(VI))	Cr(VI)	0.05	
Copper	Cu	2	1
Cyanide	CN	0.08	
Flouride	F	1.5	
Hydrogen Sulfide	H^2S	*	0.05
Iron	Fe	*	0.3
Lead	Pb	0.01	
Manganese	Mg	0.5	0.1
Mercury	Hg	0.001	
Molybenum	Mo	0.05	
Nickle	Ni	0.02	
Nitrate	NO_3	50	
Nitrite	NO2	3	
Sodium	Na	**	180
Sufate	SO_4	500	250
Zinc	Zn	*	3

*** Insufficient data to set guideline based on health considerations**

**** No Health-based guideline is necessary**

APPENDIX F: RAINFALL AND STREAM FLOW ANALYSIS (DRAFT REPORT)

Rainfall and Stream Flow Analysis, Anh Tho Tien, 2002 (Draft Report)

RAINFALL AND STREAM FLOW ANALYSIS ON THE TIWI ISLANDS

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND ENVIRONMENT

NATURAL SYSTEMS DIVISION

Technical Report No.: DRAFT, AUGUST 2003

Author: Anh Tho Tien

DIPE, DARWIN NT

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Appendices

A Blud Water Creek

B Taracumbi Creek

C Takaprimilli Creekt

List of Abbreviations

ET	evapotranspiration data (mm)
k'	baseflow recession coefficient
ML	megalitres (10^6 L)
PPT	daily rainfall (mm)
Q_0	discharge in cumecs ($m^3 s^{-1}$) at time $t = 0$
Q_t	discharge in cumecs ($m^3 s^{-1}$) at any given time t (time in days)
R	potential daily recharge (mm)
RE	recharge events (mm)
SMD	end of dry season soil moisture deficit (mm)
SMD_d	soil moisture deficit on day d
SMD_{d+1}	soil moisture deficit on day $d+1$
ΔQ	increases in flow ($m^3 s^{-1}$)

1 Abstract

The aim of this study was to analyse the available rainfall and flow data so that it was in a form that could be used to synthesise historical dry season spring flows for Tiwi Islands creeks and rivers from 1913 to 2000. The synthesised and the actual gauged flows were in good agreement (y = x). For most of the period, groundwater fed flows of Bluewater Creek exceeded 50 L/s, Tarakumby Creek 10 L/s, and Takamprimili River 1 L/s. The maximum spring flows were 200 L/s for Bluewater and Tarakumby Creeks, and 2,100 L/s for Takamprimili River.

2 Background

The Tiwi Islands (7510 km^2), comprising Bathurst and Melville Islands, are both Aboriginal lands (Figure 1.1). The Bathurst and Melville Islands Drainage Basin covers the Surface Water Management Area 816 and the Groundwater Management Unit NT09. The major surface water use is irrigation (30 ML) and urban water supply (180 ML) from Bluewater Creek at Garden Point. About 30% of the area has soils with moderate limitations to agriculture (Chin *et al*., 2000).

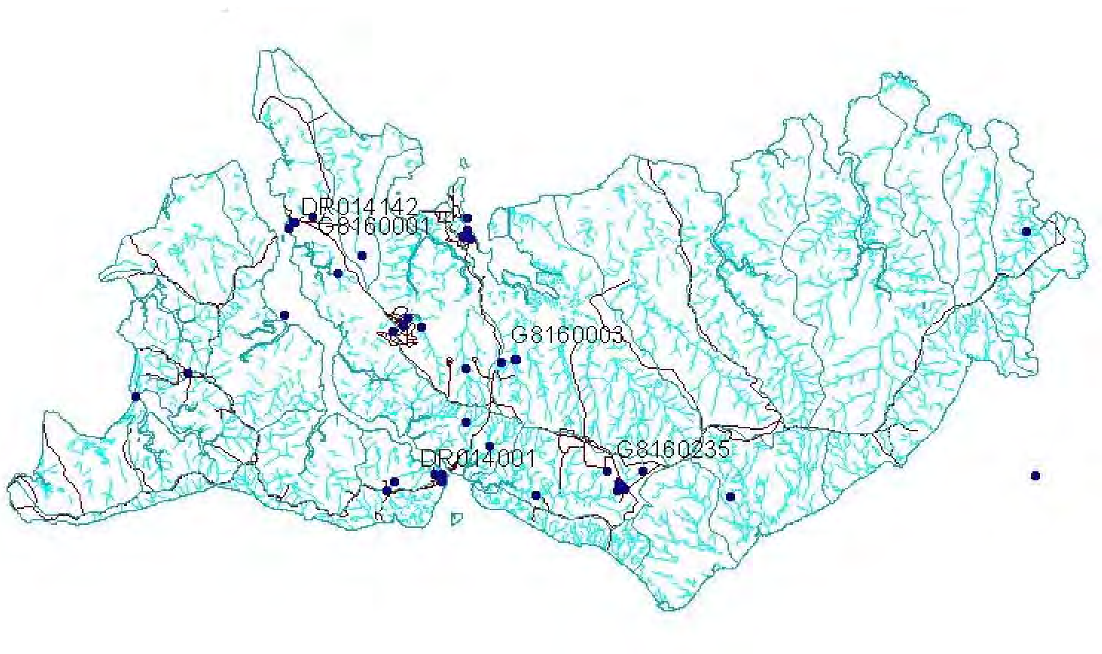


Figure 2.1. Tiwi Islands, SWMA 816 and GMA NT09.

Catchment river road station

An analysis of the rainfall (DR014142) and stream gauging data (G8160001) of Bluewater Creek at Garden Point was made. Although the correlation was moderate (Pearson r = 0.5085), the seasonal trend was identified (Figure 1.2). The analysis was applied to develop relationships between rainfall and groundwater fed flows to predict dry season flows in the absence of detailed low flow gauging.

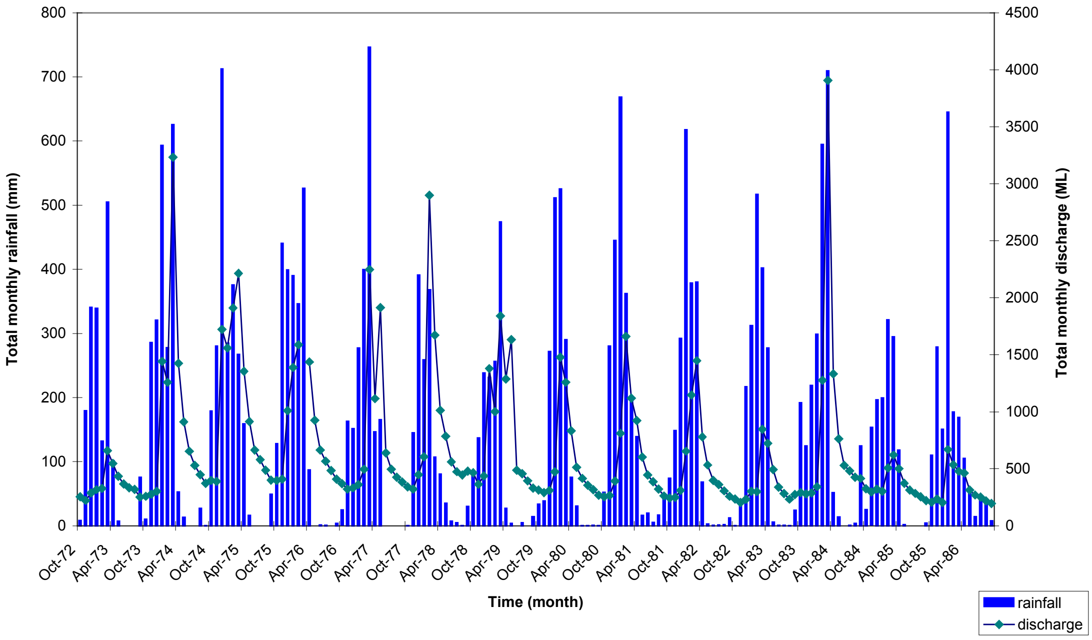


Figure 2.2. Rainfall and discharge at Bluewater Creek (HYDSYS, DIPE).

There were three gauging stations with stage heights that were continuously measured from 1966 to 1986 (Table 1.1). The gauging station G8160001 (Bluewater Creek at Garden Point) was selected as rating curves were developed and stream flow data are available from the hydrological database HYDSYS, which is maintained by the Conservation & Natural Resources Group, NT Department of Infrastructure, Planning & Environment. In general, the quality of the flows was satisfactory (HYDSYS quality code). However, the quality of the available stage data at all sites varied from satisfactory to poor (HYDSYS quality code) (Chin *et al*., 2000).

Table 2.1. Stream flow data (HYDSYS, DIPE).

Station ID	Date		Catch. Area	Runoff (mm)	Rainfall (mm)			Rainfall as Runoff (%)		
	Start	End	(km^2)		mean	max	min	mean	max	min
816001	28/06/66	29/10/86	11.5	690	1987	2433	1440	32	53	18
816003	18/08/66	04/12/86	17.5							
816235	15/08/67	04/12/86	166.0							

The average catchment rainfall and runoff at site G8160001 were calculated (Table 1.2). On average, 30% of rainfall becomes runoff.

Table 2.2. Average catchment rainfall and runoff at site G8160001 (Chin *et al*., 2000).

Financial year	G8160001 Annual stream discharge (ML)	DR014142 Annual rainfall (mm)	Annual runoff (mm)	Runoff / Rainfall ratio
72/73	3421.8	1690.1	297.5	0.18
73/74	9289.5	2255.6	807.8	0.36
74/75	12483.5	2303.5	1085.5	0.47
75/76	14900.9	2432.8	1295.7	0.53
76/77	8975.3		780.5	
77/78	9955.4		865.7	
78/79	8934.0		776.9	
79/80	5442.9	1796.7	473.3	0.26
80/81	7421.9	2187.2	645.4	0.30
81/82	6744.2	2028.3	586.5	0.29
82/83	4602.1	1786.5	400.2	0.22
83/84	9808.6	2230.1	852.9	0.38
84/85	4888.3	1440.1	425.1	0.30
85/86	4140.7	1707.1	360.1	0.21
mean	7929.2	1987.1	689.5	0.32
max	14900.9	2432.8	1295.7	0.53
min	3421.8	1440.1	297.5	0.18

$$\text{Runoff (mm)} = \frac{\text{Stream discharge (ML)}}{\text{Catchment area (km}^2\text{)}}$$

3 Method of synthesis of historical spring flows

Available rainfall and flow data have been used to synthesise historical dry season spring flows at Berry Springs (Jolly *et al*., 2000a), and Katherine and Daly Rivers (Jolly *et al*., 2000b). This enabled estimates of spring baseflow to be made using a long-term rainfall record in the absence of reliable flow gauging. The developed method was applied in order to predict dry season flows on the Tiwi Islands. The different steps included the determination of maximum spring flow and the baseflow recession coefficient from dry season flow data (Section 2.1), potential recharge from rainfall data (Section 2.3), the relationship between recharge events and increase in spring flow (Section 2.4), and the synthesis of spring flows (Section 2.5). The predicted flows were then correlated with actual gauged flows to assess the accuracy of the prediction. The model was then calibrated by adjusting the individual input parameters until a strong correlation between gauged and predicted flows was found.

3.1 Interpretation of dry season flow data

During the dry season, without surface influx, Bluewater Creek is totally fed by groundwater discharge from a sandstone aquifer. The recession portion of the baseflow curve is expressed by an exponential depletion equation (Szilagyi, 1999)

$$Q_t = Q_0 e^{-kt} \qquad \text{(Equation 1)}$$

$$\therefore \quad \ln Q_t = \ln Q_0 - kt \qquad \text{(Equation 2)}$$

$$\text{or} \quad \log Q_t = \log Q_0 - k't \qquad \text{(Equation 3)}$$

$$\therefore \quad k' = \frac{\log Q_0 - \log Q_t}{t} \qquad \text{(Equation 4)}$$

where Q_t is the discharge in cumecs ($m^3\ s^{-1}$) at any given time t, Q_0 is the discharge at time t = 0, k' is the baseflow recession coefficient, and t is time in days. The initial time t = 0 represents the time when the aquifer that feeds Bluewater Creek has been fully recharged in the previous wet season, and Q_0 is then the maximum spring flow. The equation predicts the discharge in the creek at a later point in the dry season, given the flow rate at the current point in time. The equation only applies to dry season aquifer flows with no surface influx. Excessive pumping or early rainfall events will offset the accuracy of the predictions.

The baseflow recession coefficient *k'* and the maximum spring flow Q_0 were determined from hydrographs printed out from HYDSYS, a hydrological database maintained by the Northern Territory Department of Infrastructure, Planning and Environment. The hydrographs at the gauging station G8160001 (Bluewater Creek at Garden Point) were plotted on logarithmic scale from HYDSYS. The gauging performed during the wet season were excluded from consideration because of the impact of rainfall on the surface water flow. The recession equations were determined from the graphs of separate years. The values of the recession coefficients were averaged over the whole data set of hydrographs. The maximum spring flow Q_0 was also estimated from the hydrographs. Visual inspection of the hydrographs showed that the average maximum spring flow that occurs at Bluewater Creek and Tarakumby Creek was 0.2 $m^3 s^{-1}$, and 2.1 $m^3 s^{-1}$ at Takamprimili River.

3.2 Analysis of rainfall data

The rain stations maintained by the Bureau of Meteorology (BOM) and presently active are Cape Fourcroy, Milikapiti, Nguiu Farm, Pirlangimpi, and Takamprimili Creek (Table 2.1).

Table 3.1. Tiwi Islands BOM stations.

Station Number	Station Name	Latitude	Longitude	HYD SYS	Last Inspected	Status
014001	NGUIU	-11.7650	130.6286	yes	03/02/1995	CLOSED
014087	PICKERTARAMOOR	-11.7653	130.8881	yes	03/02/1995	CLOSED
014194	MELVILLE ISLAND	-11.7667	130.6167	yes		CLOSED
514056 R8160007	SNAKE BAY	-11.4167	130.6667	yes		CLOSED
200731	CAPE FOURCROY	-11.7917	130.0194	no	18/11/1999	OPEN
014103	MILIKAPITI	-11.4258	130.6758	yes	02/11/1992	OPEN
014142	PIRLANGIMPI	-11.4030	130.4169	yes	14/12/2000	OPEN
014288	NGUIU FARM	-11.7797	130.5572	yes	08/11/1996	OPEN
514015 R8160235	TAKAMPRIMILI CK.	-11.7667	130.8833	yes		OPEN

The correlation coefficient $r = \pm 1$ shows a perfect linear relationship and decreases towards $r = 0$ where there is no relationship. A strong correlation is observed when $r \to 1$ and no correlation exists when $r \to 0$. Darwin and Tiwi Islands rainfall data were strongly correlated:

- r = 0.8648 between the Darwin Post Office Rainfall Station DR014016 and the Bathurst Island Mission Rainfall Station DR014001 for the period 1913 to 1942 (Figure 2.1), and
- r = 0.8753 between the Darwin Airport Rainfall Station DR014015 and the Bathurst Island Mission Rainfall Station DR014001 for the period 1941 to 1995 (Figure 2.2).

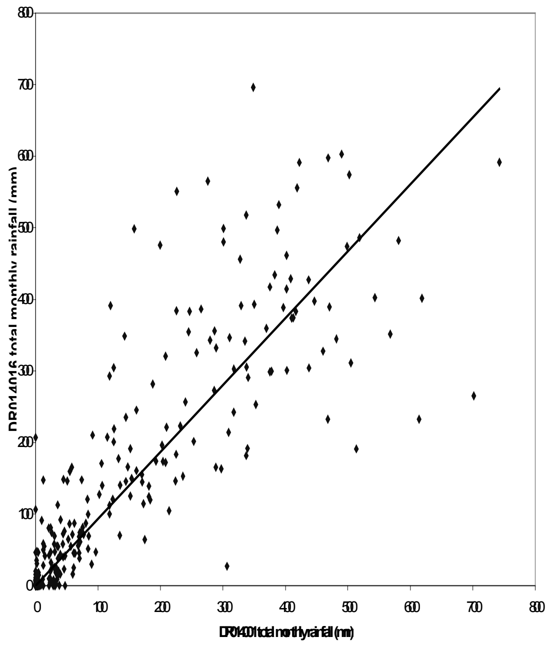


Figure 3.1. Correlation between the Darwin Post Office Rainfall Station DR014016 and the Bathurst Island Mission Rainfall Station DR014001 for the period 1913 to 1942 (HYDSYS, DIPE).

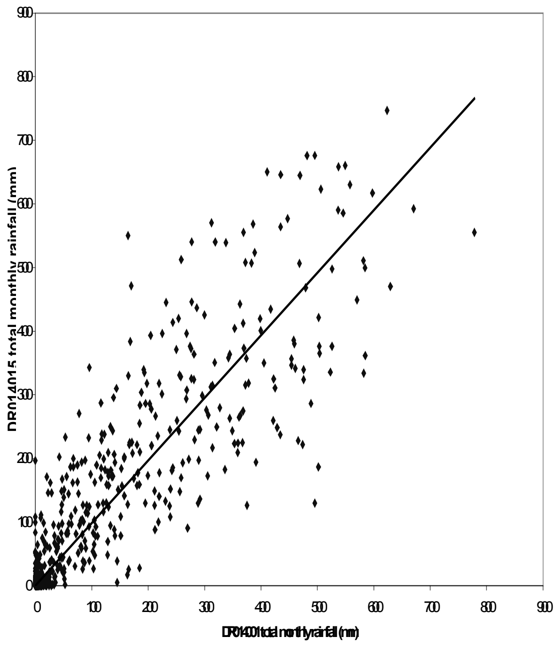


Figure 3.2. Correlation between the Darwin Airport Rainfall Station DR014015 and the Bathurst Island Mission Rainfall Station DR014001 for the period 1941 to 1995 (HDYSYS, DIPE).

However, the rainfall data from the Bathurst Island Mission Rainfall Station DR014001 showed a stronger correlation with the other rainfall stations on Tiwi Islands for their whole period of record (Figure 2.3):

- r = 0.9188 (DR014087, Pickertaramoor, 1964 – 1989);
- r = 0.8939 (DR014103, Snake Bay, 1963 – 1979);
- r = 0.8995 (DR014142, Garden Point Police Station, 1963 – 2000); and
- r = 0.9447 (DR014194, Melville Island, 1912 - 1917).

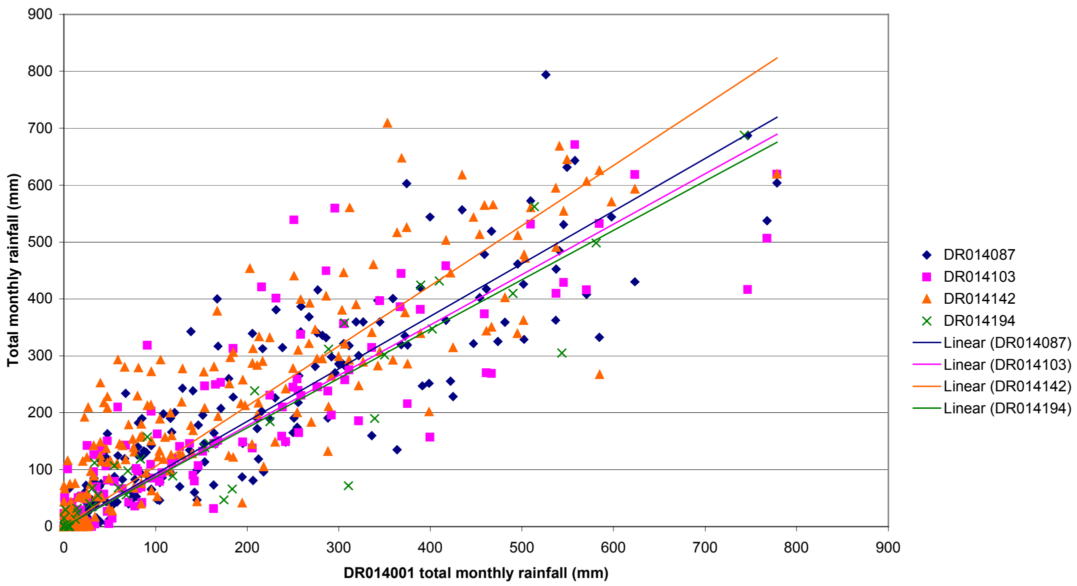


Figure 3.3. Relationships between rainfall stations in Tiwi Islands (HYDSYS, DIPE).

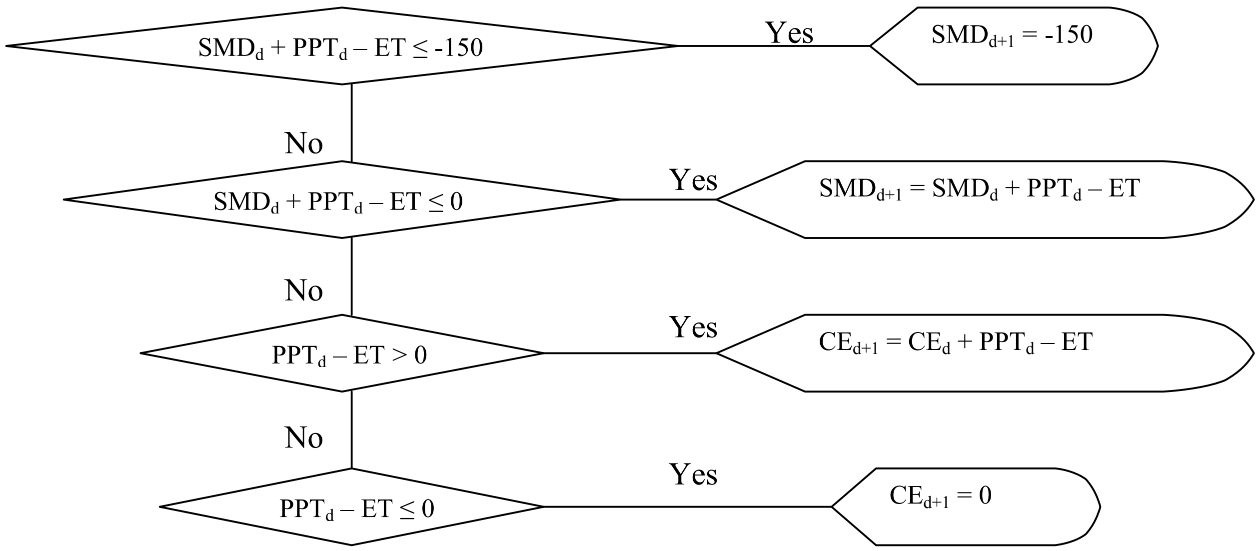
Therefore, the Bathurst Island Mission Rainfall Station DR014001 rainfall data were used in this study for their longer period of record from 1913 to 1995. From the water year 1989/1990 onwards, the rain data at DR014001 were unreliable due to missing days during the wet season. There was a strong correlation (r = 0.8995) between the Bathurst Island Mission Rainfall Station DR014001 and the Garden Point Police Station Rainfall Station DR014142 rainfall data during the 32 year period when both stations were in operation (1963 – 1995) (Figure 2.3). A complete record of rainfall from 1913 to 2000 was constructed by combining both data sets: DR014001 rainfall data from 1913 to 1989, and DR014142 rainfall data from 1989 to 2000.

3.3 Relationship between rainfall and potential recharge

Potential recharge was calculated from daily rainfall (*PPT*), end of dry season soil moisture deficit (*SMD*) and evapotranspiration (*ET*) data, all in mm. All rainfall records were extracted from HYDSYS.

The vegetation types on the Tiwi Islands are similar to those on the mainland (e.g. Howard East), with tropical eucalypt forests and woodlands (PWCNT, 1998). Therefore, an end of dry season soil moisture deficit of 150 mm (Cook *et al.*, 1998) and an evaporation rate of 7 mm day^{-1} (Hutley *et al.*, 2000) were chosen for the calculations.

When it rains, the amount of rainfall that is not intercepted, evaporated or become runoff eventually infiltrates and reduces the soil moisture deficit. If sufficient rain occurs to make up the soil moisture deficit and satisfy evapotranspiration, then soil moisture deficit becomes zero. Any excess rainfall above this required amount then infiltrates and potentially recharges the aquifer. The soil moisture deficit (*SMD*) or cumulative excess (*CE*) was calculated using the following conditions, where d = day:



- If $SMD_d + PPT_d - ET \leq -150$ then the soil moisture deficit on the following day was set to –150 as no more water could be taken out of the soil.
- Else $SMD_d + PPT_d - ET > -150$ and if $SMD_d + PPT_d - ET \leq 0$ then the soil moisture deficit on the following day was $SMD_d + PPT_d - ET$.
- Else $SMD_d + PPT_d - ET > 0$. In this case the soil moisture deficit was fully satisfied and SMD_d was set to 0. The cumulative soil moisture excess (*CE*) that

potentially contributed to recharge was calculated. If $PPT_d - ET > 0$ then the cumulative excess on the following day was $CE_d + PPT_d - ET$.

- Else if $PPT_d - ET \leq 0$ then the cumulative excess on the following day was set to zero.

The daily potential recharge (*R*) was then calculated.

- If the cumulative excess CE ≥ 0, then R = PPT – ET.
- Else CE < 0. In this case the soil moisture deficit was considered.
- If SMD + PPT – ET > 0 then R = SMD + PPT – ET.
- Otherwise R = 0.

The recharge events were used to calculate predicted flows (Section 2.5). Each water year (Oct 1 to Sept 30) is comprised of separate recharge events of varying intensities and duration. Each recharge event is defined by a series of consecutive days of potential recharge. The date associated with each recharge event was defined as the day prior to the first daily record of rainfall. Annual potential recharge is the sum of each recharge event. The correlation between annual rainfall and annual potential recharge was determined.

3.4 Relationship between recharge events and increases in spring flow

Each recharge event (*RE*) relates to an increase in flow (*ΔQ*). The increases in flow were determined using hydrographs and plotted against corresponding recharge events. The slope of the graph shows the relationship between recharge events and increases in flow, defined by the equation

$$\Delta Q \text{ (m}^3 \text{ s}^{-1}) = a \text{ (}10^{-3}\text{mm s m}^{-2}) \; RE \text{ (mm)}$$

The change in flow in Bluewater Creek and Tarakumbi Creek relating to recharge events was (Figure 2.4)

$$\Delta Q \text{ (m}^3 \text{ s}^{-1}) = 0.0011 \text{ (}10^{-3}\text{mm s m}^{-2}) \; RE \text{ (mm)}$$

The change in flow in Takamprimili River relating to recharge events was (Figure 2.5)

$$\Delta Q \text{ (m}^3 \text{ s}^{-1}) = 0.004 \text{ (}10^{-3}\text{mm s m}^{-2}) \; RE \text{ (mm)}$$

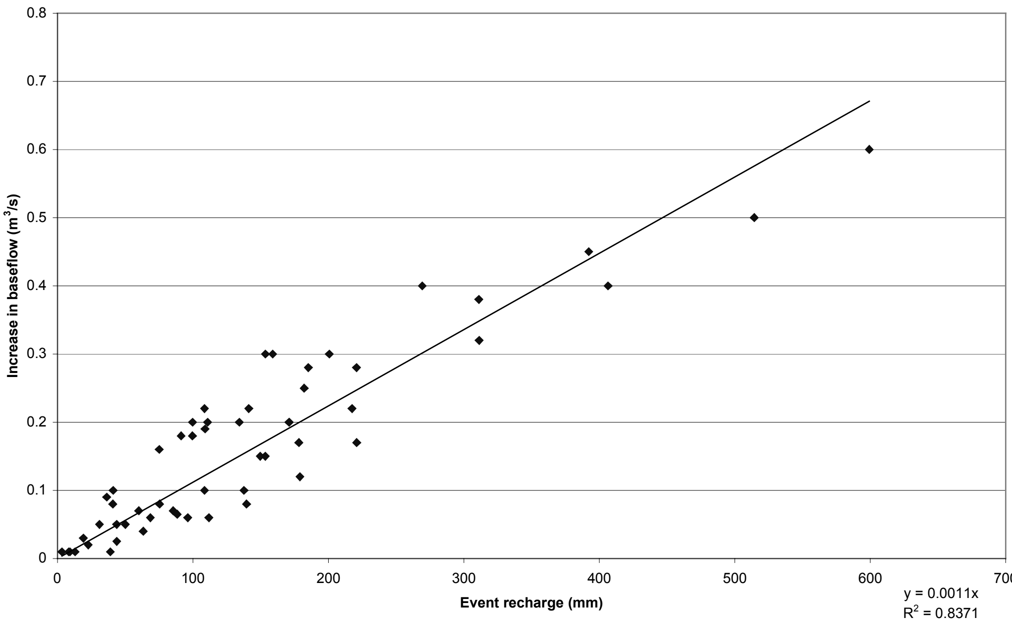


Figure 3.4. Relationship between event recharge and increase in baseflow, 1972-1986.

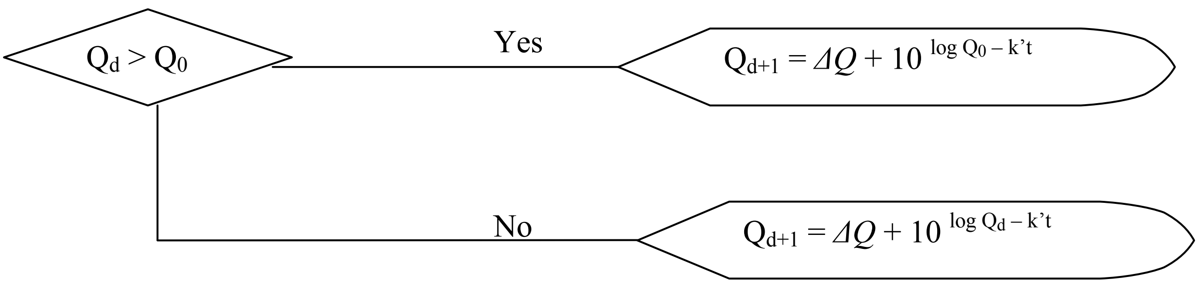
3.5 Synthesis of historical spring flows

Equation 3 from Section 2.1 was used to synthesise historical spring flows from the Bathurst Island Mission rainfall record as follows:

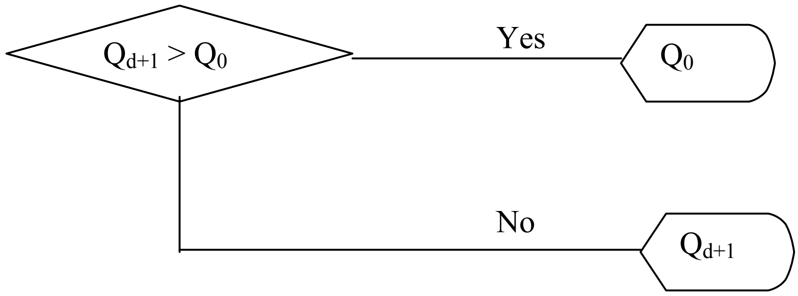
$$\log Q_t = \log Q_0 - k't$$

$$\therefore \qquad Q = 10^{\log Q0 - k't}$$

The relationship derived in Section 2.4 was applied to each individual recharge event in the rainfall record in order to calculate the predicted change in baseflow (ΔQ). The baseflow recession coefficient (k') and the maximum spring flow (Q_0) determined in Section 2.1 were used in Equation 3 to synthesise springflows. Springflows were calculated for the end of Dry season, for days when gauging were taken and for the day before each recharge event.



The recharge was rejected as overland flow when the aquifer was full. Therefore:



The formula used in Excel at Cell E9 was (the letters referred to columns and the numbers to rows):

IF

(IF(E8>F2,(D9+10^(E3*(B9-B8)+LOG10(F2))),

(D9+10^(E3*(B9-B8)+LOG10(E8))))>F2,

F2,

(D9+10^(E3*(B9-B8)+LOG10(E8))))

where

E8 = Q_d

F2 = Q_0

D9 = ΔQ

E3 = k'

B9-B8 = t

4 Results and discussion

4.1 Annual rainfall and potential annual recharge in Tiwi Islands

The mean annual rainfall was 1603 mm and the mean potential annual recharge was 500 mm (Table 3.1; Figure 3.1). The potential annual recharge was in good agreement with annual rainfall with r = 0.9227 (Figure 3.2).

Table 4.1. Annual rainfall and annual potential recharge in Tiwi Islands (1913-2000).

	Annual rainfall (mm)			**Potential annual recharge (mm)**		
Station	DR014001	DR014142	both	DR014001	DR014142	both
mean	1447	1989	**1603**	421	695	**500**
max	2294	2997	**2997**	1130	1620	**1620**
min	694	1316	**694**	0	102	**0**

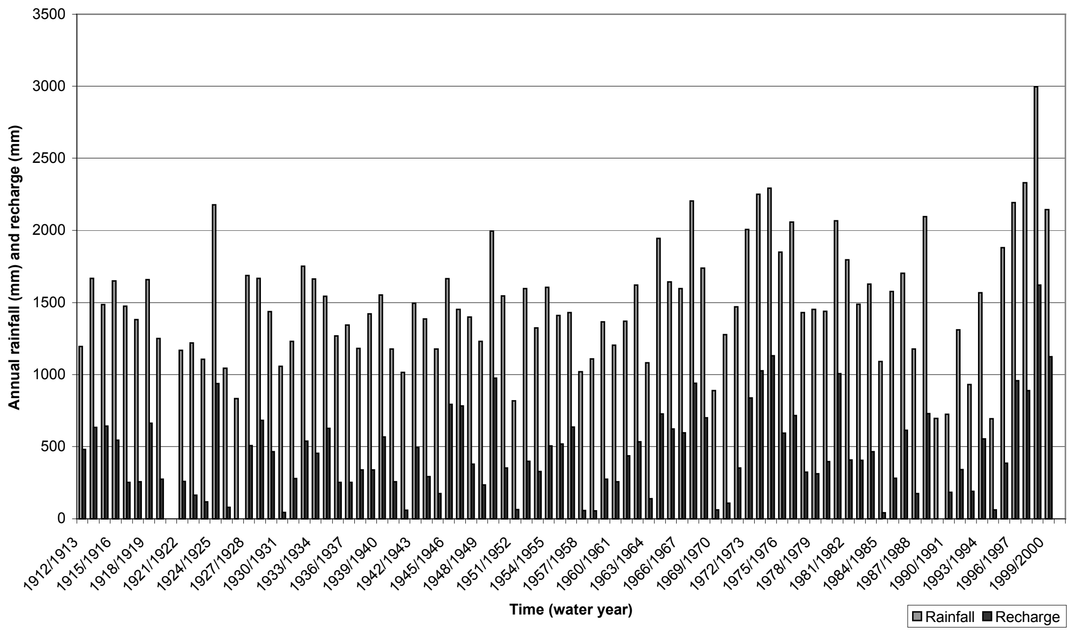


Figure 4.1. Annual rainfall and annual potential recharge in Tiwi Islands, 1913–2000.

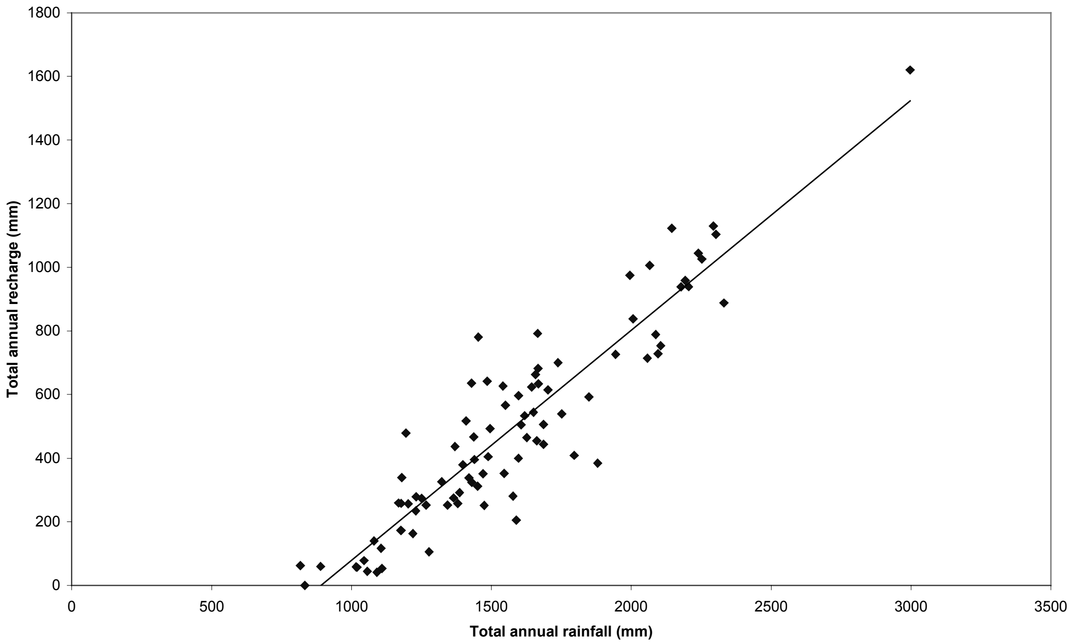


Figure 4.2. Relationship between rainfall and recharge in Tiwi Islands, 1913 – 2000.

4.2 Synthesis of spring flow at Bluewater Creek

The dry season flow in Bluewater Creek, after the aquifer feeding it had been fully recharged in the previous wet season, was represented by the following equation (Appendix A):

$$\log Q_t = \log Q_0 - k't$$

$$\equiv \quad \log Q_t = \log \mathbf{0.20} - 0.0013\ t$$

$$\equiv \quad \mathbf{\log Q_t = -0.6990 - 0.0013\ t}$$

The change in G8160001 flow relating to recharge events coefficient was a = **0.0011**.

The Bluewater spring flow for the period from 1913 to 2000 was synthesised using the relationships developed in Section 2.5 (Figures 3.3).

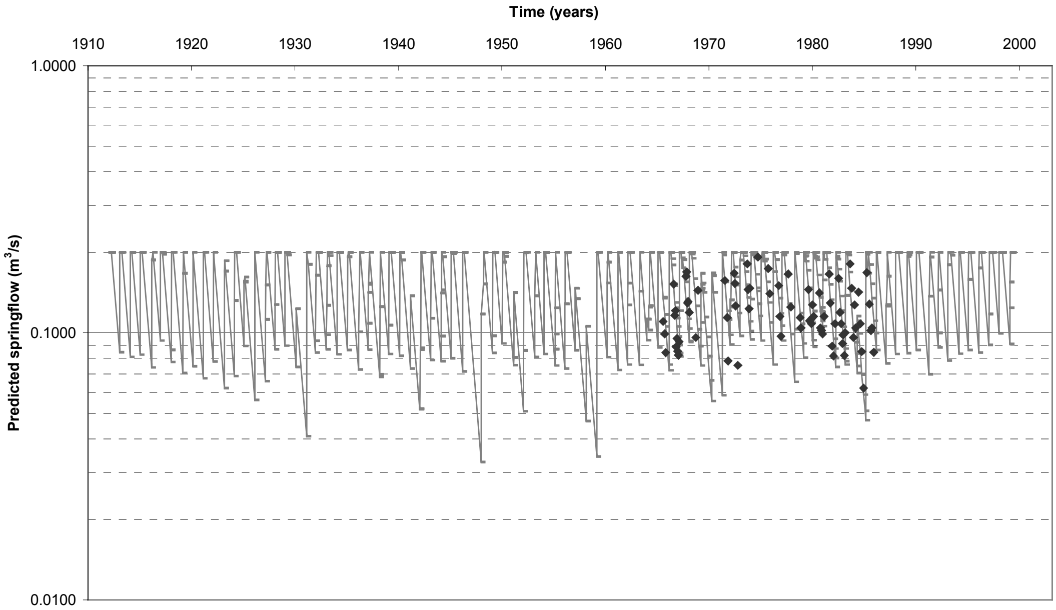


Figure 4.3. a). Predicted spring flows (1913 – 2000) and actual gauged flows (1966 – 1986) at Bluewater Creek.

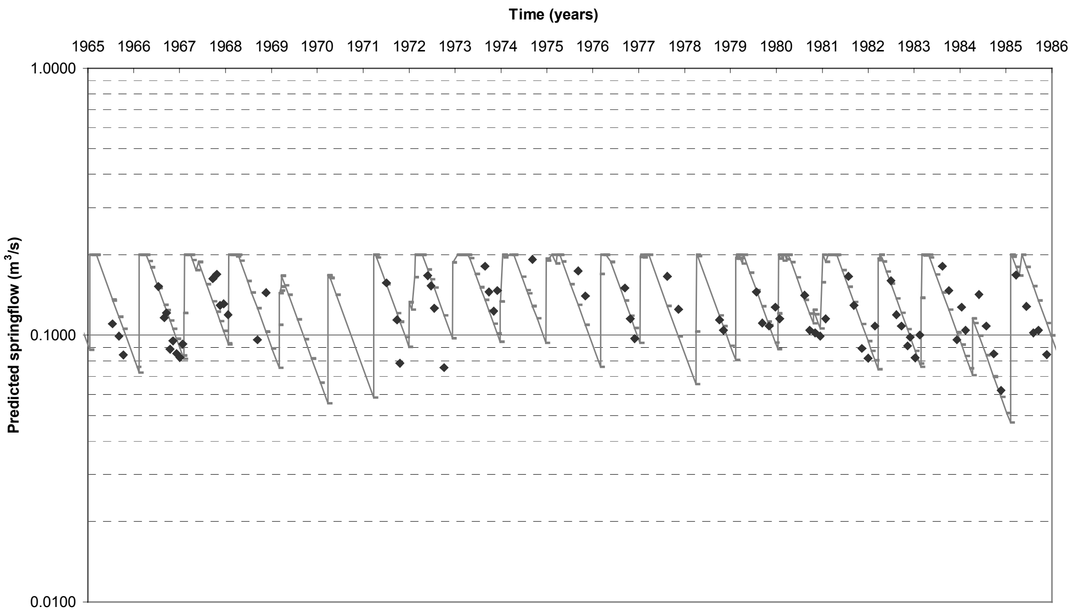


Figure 3.3. b). Predicted and actual gauged flows at Bluewater Creek (1966 – 1986).

The actual gauged flows at G8160001 (Bluewater Creek at Garden Point) were compared to the predicted spring flows deduced from the formulae developed in this study for the same days (Table 3.2). Predicted and actual gauged flows were in good agreement (Figure 3.4).

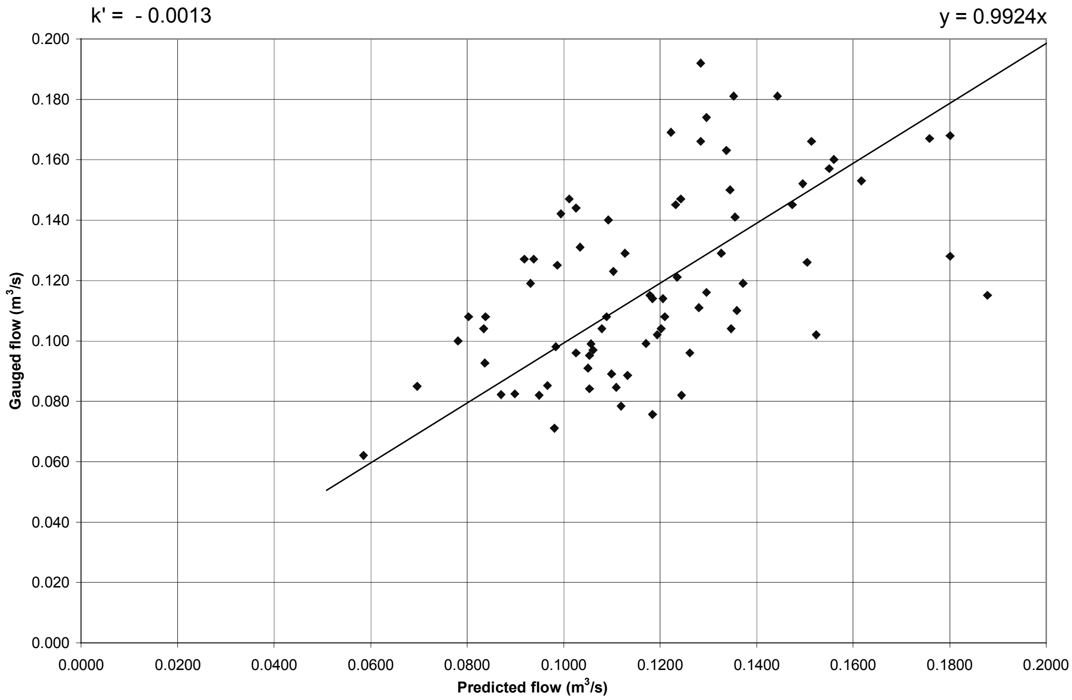


Figure 4.4. Relationship between predicted and actual gauged spring flows at G8160001, Bluewater Creek at Garden Point, 1966 – 1986.

Table 4.2. Predicted and actual gauged springflow at G8160001, Bluewater Creek at Garden Point, 1966 – 1986.

Gauging dates	Predicted springflow (m^3/s)	Gauged springflow (m^3/s)
29/06/1966	0.1359	0.110
18/08/1966	0.1170	0.099
22/09/1966	0.1054	0.084
28/06/1967	0.1496	0.152
15/08/1967	0.1296	0.116
31/08/1967	0.1235	0.121
29/09/1967	0.1132	0.089
23/10/1967	0.1054	0.095
21/11/1967	0.0966	0.085
15/12/1967	0.0899	0.082
08/01/1968	0.0837	0.093
04/09/1968	0.1337	0.163
04/10/1968	0.1222	0.169
31/10/1968	0.1128	0.129
29/11/1968	0.1034	0.131
03/01/1969	0.0931	0.119
23/08/1969	0.1261	0.096
31/10/1969	0.1026	0.144
13/06/1972	0.1551	0.157
05/09/1972	0.1206	0.114
30/09/1972	0.1119	0.078
13/11/1972	0.0981	0.071
03/01/1973	0.1244	0.082
08/05/1973	0.1758	0.167
05/06/1973	0.1617	0.153
29/06/1973	0.1505	0.126
17/09/1973	0.1184	0.076
07/08/1974	0.1352	0.181
07/09/1974	0.1232	0.145
14/10/1974	0.1103	0.123
12/11/1974	0.1011	0.147
20/08/1975	0.1284	0.192
16/08/1976	0.1296	0.174
12/10/1976	0.1093	0.140
23/08/1977	0.1345	0.150
06/10/1977	0.1179	0.115
10/11/1977	0.1061	0.097
27/07/1978	0.1284	0.166
23/10/1978	0.0987	0.125
14/09/1979	0.1184	0.114
15/10/1979	0.1079	0.104
04/07/1980	0.1474	0.145
20/08/1980	0.1280	0.111
13/10/1980	0.1089	0.108
02/12/1980	0.0938	0.127
23/07/1981	0.1355	0.141
01/09/1981	0.1202	0.104
14/10/1981	0.1194	0.102
24/11/1981	0.1056	0.099
05/01/1982	0.1878	0.115
05/07/1982	0.1514	0.166
18/08/1982	0.1327	0.129
20/10/1982	0.1099	0.089
08/12/1982	0.0949	0.082
02/02/1983	0.0803	0.108
08/06/1983	0.1560	0.160
21/07/1983	0.1372	0.119
01/09/1983	0.1210	0.108
18/10/1983	0.1051	0.091
09/11/1983	0.0984	0.098
20/12/1983	0.0870	0.082
25/01/1984	0.0781	0.100
23/07/1984	0.1443	0.181
11/09/1984	0.1243	0.147
14/11/1984	0.1026	0.096
21/12/1984	0.0918	0.127
22/01/1985	0.0835	0.104
08/05/1985	0.0994	0.142
04/07/1985	0.0838	0.108
04/09/1985	0.0696	0.085
01/11/1985	0.0585	0.062
28/02/1986	0.1801	0.168
20/05/1986	0.1801	0.128
15/07/1986	0.1523	0.102
25/08/1986	0.1347	0.104
29/10/1986	0.1109	0.085

4.3 Synthesis of spring flow at Tarakumby Creek

The dry season flow in Tarakumby Creek, after the aquifer feeding it had been fully recharged in the previous wet season, was represented by the following equation (Appendix B):

$$\log Q_t = \log Q_0 - k't$$

$$\equiv \quad \log Q_t = \log \mathbf{0.20} - 0.0023\ t$$

$$\equiv \quad \mathbf{\log Q_t = -0.6990 - 0.0023\ t}$$

The change in G8160003 flow relating to recharge events coefficient was a = **0.0011**.

The Tarakumby spring flow for the period from 1913 to 2000 was synthesised using the relationships developed in Section 2.4 (Figures 3.5).

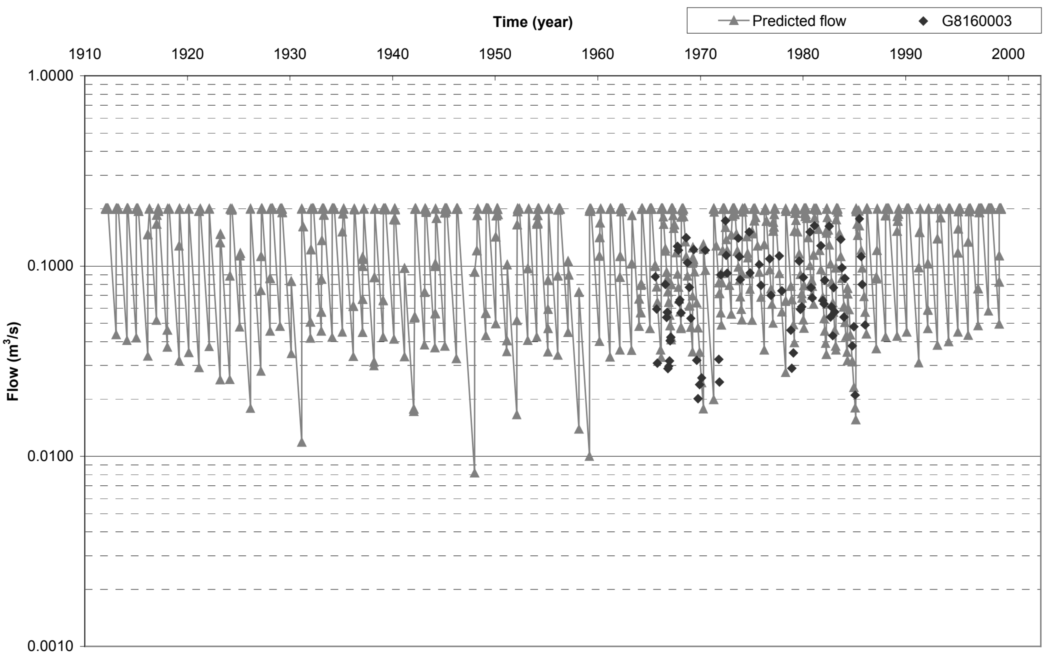


Figure 4.5. a). Predicted spring flows (1913 – 2000) and actual gauged flows (1966 – 1986) at Tarakumby Creek.

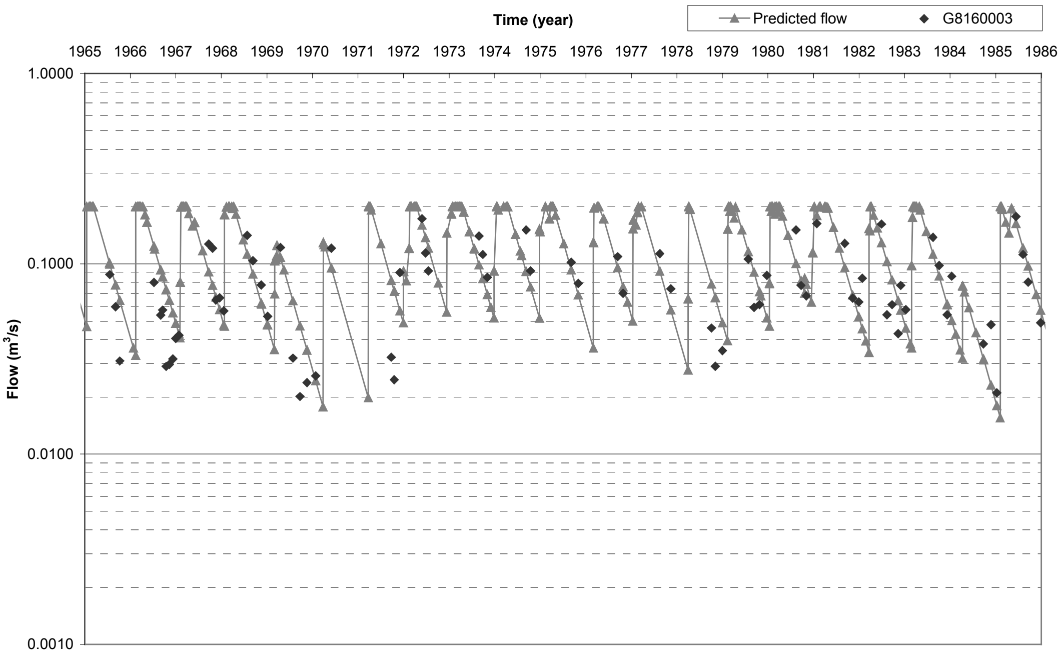


Figure 3.5. b). Predicted and actual gauged flows at Tarakumby Creek (1966 – 1986).

The actual gauged flows at G8160003 (Tarakumby Creek at Pine Plantation) were compared to the predicted spring flows for the same days (Table 3.3). Predicted and actual gauged flows were in good agreement (Figure 3.6).

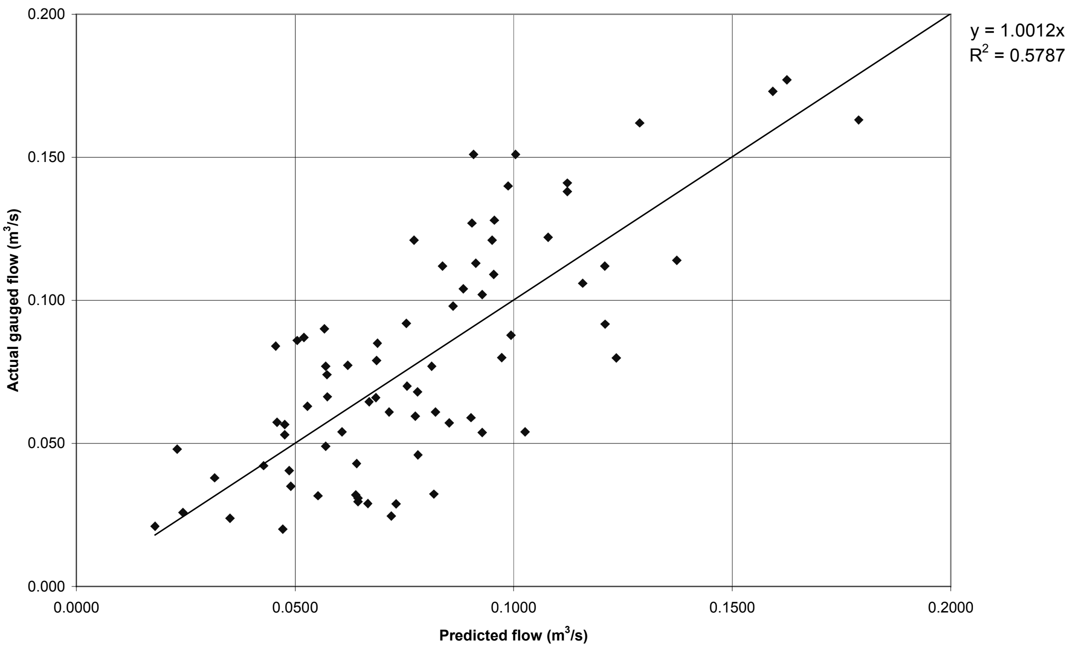


Figure 4.6. Relationship between predicted and actual gauged spring flow at G8160003, Tarakumby Creek at Pine Plantation, 1966 – 1986.

Table 4.3. Predicted and actual gauged springflow at G8160003, Tarakumby Creek at Pine Plantation, 1966 – 1986.

Gauging dates	Predicted springflow (m^3/s)	Gauged springflow (m^3/s)
02/07/1966	0.0994	0.088
18/08/1966	0.0775	0.060
22/09/1966	0.0644	0.031
22/06/1967	0.1235	0.080
15/08/1967	0.0928	0.054
31/08/1967	0.0853	0.057
29/09/1967	0.0731	0.029
23/10/1967	0.0644	0.030
21/11/1967	0.0552	0.032
15/12/1967	0.0486	0.041
08/01/1968	0.0428	0.042
04/09/1968	0.0905	0.127
04/10/1968	0.0772	0.121
31/10/1968	0.0669	0.065
29/11/1968	0.0574	0.066
03/01/1969	0.0477	0.057
09/07/1969	0.1123	0.141
23/08/1969	0.0885	0.104
29/10/1969	0.0620	0.077
18/12/1969	0.0476	0.053
01/04/1970	0.1079	0.122
09/07/1970	0.0639	0.032
04/09/1970	0.0472	0.020
30/10/1970	0.0351	0.024
07/01/1971	0.0244	0.026
14/05/1971	0.0950	0.121
05/09/1972	0.0817	0.032
29/09/1972	0.0720	0.025
13/11/1972	0.0567	0.090
08/05/1973	0.1593	0.173
05/06/1973	0.1373	0.114
29/06/1973	0.1209	0.092
07/08/1974	0.0987	0.140
07/09/1974	0.0838	0.112
14/10/1974	0.0689	0.085
21/08/1975	0.0909	0.151
25/09/1975	0.0755	0.092
16/08/1976	0.0928	0.102
12/10/1976	0.0686	0.079
23/08/1977	0.0955	0.109
06/10/1977	0.0756	0.070
27/07/1978	0.0913	0.113
23/10/1978	0.0573	0.074
14/09/1979	0.0781	0.046
14/10/1979	0.0666	0.029
11/12/1979	0.0490	0.035
04/07/1980	0.1158	0.106
20/08/1980	0.0903	0.059
03/10/1980	0.0715	0.061
02/12/1980	0.0520	0.087
23/07/1981	0.1005	0.151
01/09/1981	0.0813	0.077
14/10/1981	0.0780	0.068
05/01/1982	0.1789	0.163
18/08/1982	0.0956	0.128
20/10/1982	0.0685	0.066
08/12/1982	0.0528	0.063
05/01/1983	0.0455	0.084
08/06/1983	0.1289	0.162
21/07/1983	0.1026	0.054
01/09/1983	0.0822	0.061
18/10/1983	0.0641	0.043
09/11/1983	0.0570	0.077
20/12/1983	0.0459	0.057
23/07/1984	0.1123	0.138
11/09/1984	0.0862	0.098
16/11/1984	0.0607	0.054
21/12/1984	0.0505	0.086
02/09/1985	0.0316	0.038
01/11/1985	0.0230	0.048
18/12/1985	0.0179	0.021
20/05/1986	0.1626	0.177
15/07/1986	0.1208	0.112
25/08/1986	0.0973	0.080
04/12/1986	0.0570	0.049

4.4 Synthesis of spring flow at Takamprimili River

The dry season flow in Takamprimili River, after the aquifer feeding it had been fully recharged in the previous wet season, was represented by the following equation (Appendix C):

$$\log Q_t = \log Q_0 - k't$$

$$\equiv \quad \log Q_t = \log \mathbf{2.10} - 0.0059\ t$$

$$\equiv \quad \mathbf{\log Q_t = 0.3222 - 0.0059\ t}$$

The change in G8160235 flow relating to recharge events coefficient was a = **0.004**.

The Takamprimili spring flow for the period from 1913 to 2000 was synthesised using the relationships developed in Section 2.5 (Figures 3.7).

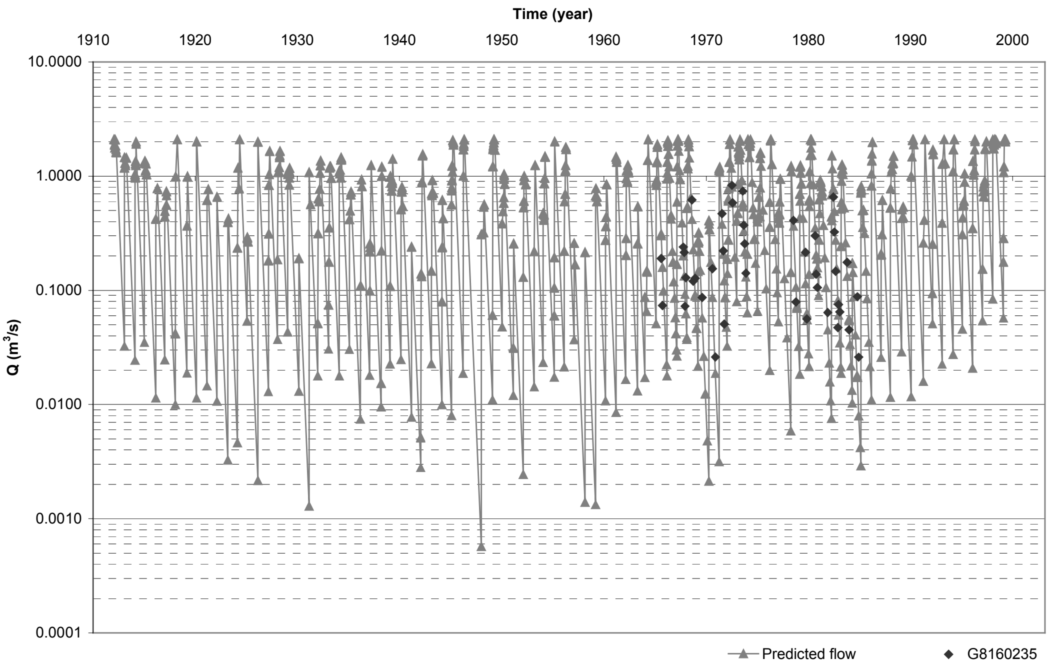


Figure 4.7. a). Predicted spring flows (1913 – 2000) and actual gauged flows (1966 – 1985) at Takamprimili River.

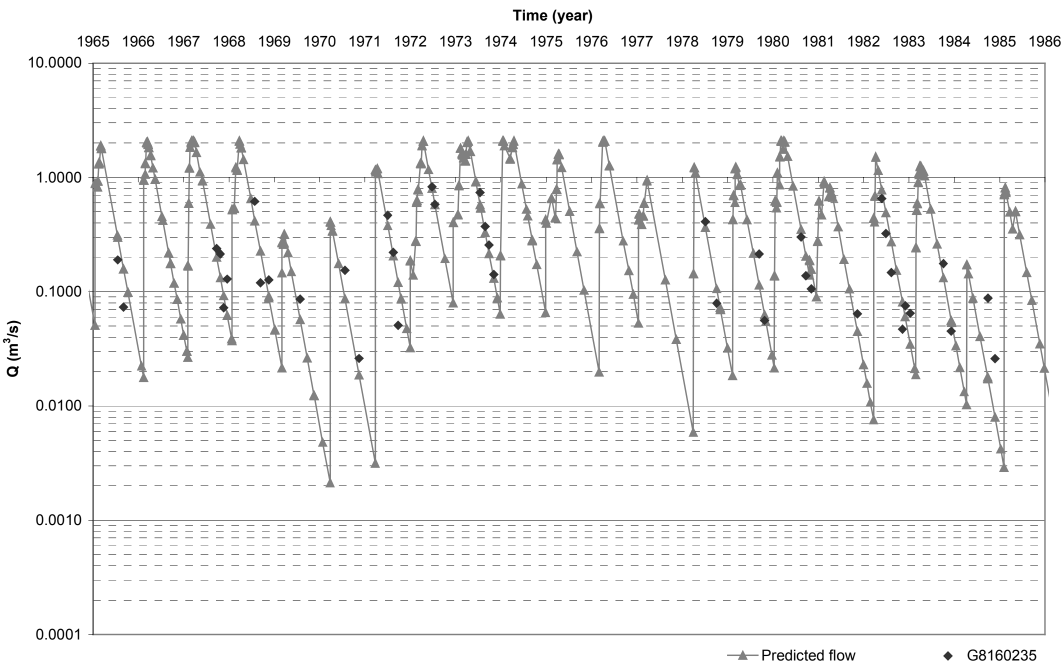


Figure 3.7. b). Predicted and actual gauged flows at Takamprimili River (1966 – 1985).

The actual gauged flows at G8160235 (Takamprimili River at Dam Site) were compared to the predicted spring flows for the same days (Table 3.4). Predicted and actual gauged flows were in good agreement (Figure 3.8).

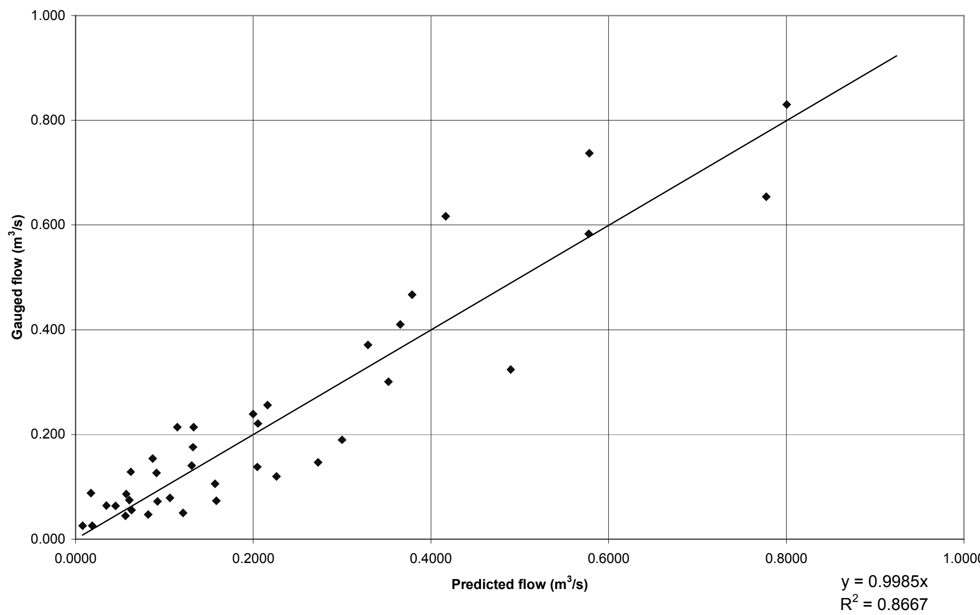


Figure 4.8. Relationship between predicted and actual gauged spring flow at G8160235, Takamprimili River at Dam Site, 1966 – 1985.

Table 4.4. Predicted and actual gauged springflow at G8160235, Takamprimili River at Dam Site, 1966 – 1985.

Gauging dates	**Predicted springflow (m^3/s)**	**Gauged springflow (m^3/s)**
02/07/1966	0.2999	0.190
18/08/1966	0.1584	0.074
04/09/1968	0.1999	0.239
04/10/1968	0.1330	0.214
31/10/1968	0.0921	0.073
29/11/1968	0.0621	0.129
09/07/1969	0.4166	0.617
23/08/1969	0.2261	0.120
29/10/1969	0.0910	0.127
10/07/1970	0.0571	0.086
05/07/1971	0.0868	0.154
26/10/1971	0.0187	0.026
13/06/1972	0.3786	0.467
28/07/1972	0.2054	0.221
05/09/1972	0.1209	0.051
05/06/1973	0.8004	0.830
29/06/1973	0.5777	0.583
27/06/1974	0.5783	0.737
07/08/1974	0.3290	0.371
07/09/1974	0.2160	0.256
14/10/1974	0.1306	0.141
15/06/1979	0.3655	0.410
14/09/1979	0.1062	0.079
20/08/1980	0.1143	0.214
03/10/1980	0.0629	0.056
23/07/1981	0.3520	0.301
01/09/1981	0.2044	0.138
14/10/1981	0.1570	0.106
21/10/1982	0.0448	0.064
05/05/1983	0.7775	0.654
08/06/1983	0.4899	0.324
21/07/1983	0.2731	0.147
18/10/1983	0.0815	0.047
10/11/1983	0.0605	0.075
20/12/1983	0.0346	0.065
11/09/1984	0.1322	0.176
13/11/1984	0.0562	0.045
05/09/1985	0.0172	0.088
01/11/1985	0.0079	0.026

5 Conclusion and recommendation

The equation representing the dry season flow in Bluewater Creek, after the aquifer feeding it had been fully recharged in the previous wet season, was:

≡ $\log Q_t = \log \mathbf{0.20} - 0.0013\ t$

≡ $\mathbf{\log Q_t = -0.6990 - 0.0013\ t}$

The equation representing the dry season flow in Tarakumby Creek, after the aquifer feeding it had been fully recharged in the previous wet season, was:

≡ $\log Q_t = \log \mathbf{0.20} - 0.0023\ t$

≡ $\mathbf{\log Q_t = -0.6990 - 0.0023\ t}$

The equation representing the dry season flow in Takamprimili River, after the aquifer feeding it had been fully recharged in the previous wet season, was:

≡ $\log Q_t = \log \mathbf{2.10} - 0.0059\ t$

≡ $\mathbf{\log Q_t = 3.222 - 0.0059\ t}$

These equations were determined using the following parameters: maximum springflow Q_0, baseflow recession coefficient *k'* and the increase in baseflow *versus* recharge event coefficient *a*. The maximum springflow Q_0 and the recession coefficient *k'* were derived from hydrographs of respective gauging stations and were independent of the type of aquifer. The recharge events were computed from the soil moisture deficit of 150 mm and evapotranspiration of 7 mm day^{-1}. These parameters were derived from studies on dolomite aquifer. The Tiwi Islands aquifer was more permeable sandstone and siltstone.

It was then recommended to have soil moisture measurements undertaken to determine a more accurate soil moisture deficit.

It was also recommended to measure the tree water use, understorey evaporation and ecosystem flux to determine the vegetation water use and calculate the evapotranspiration and interception.

6 References

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Appendix A Bluewater Creek

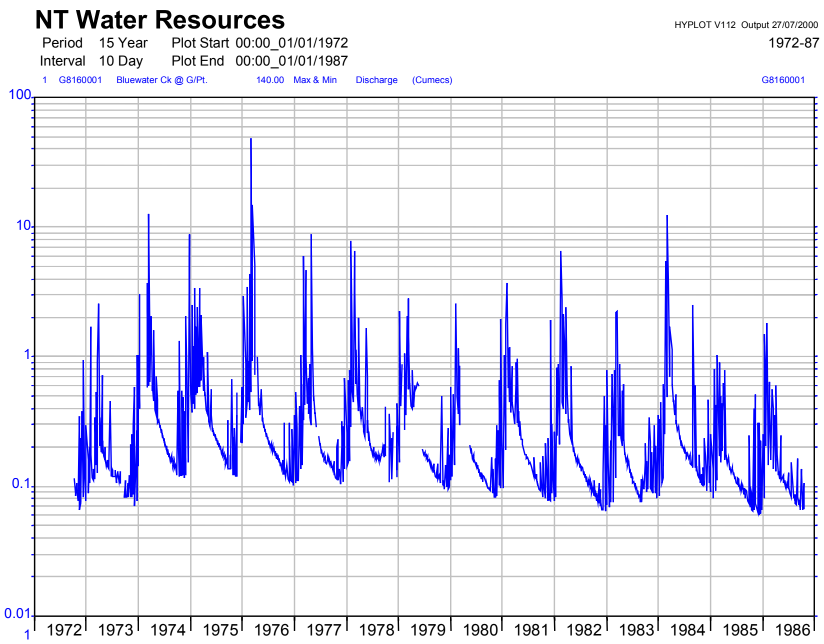

Figure A1. Flow record for GS8160001 on Bluewater Creek (HYDSYS, DIPE).

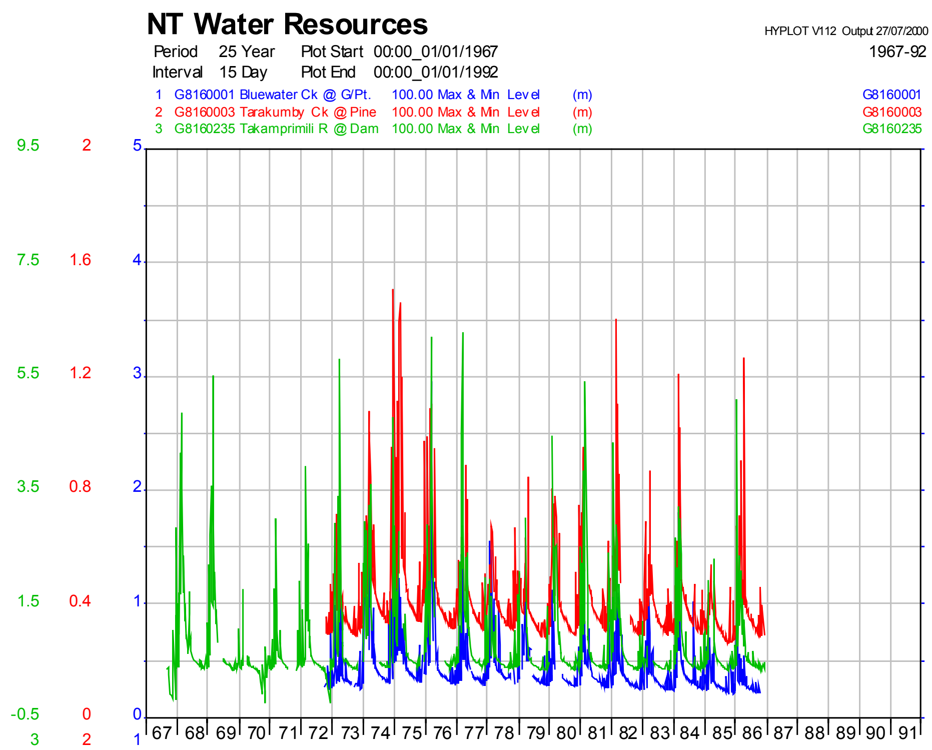

Figure A2. Creek height records for Tiwi Islands (HYDSYS, DIPE).

Appendix B Tarakumby Creek

The G8160003 hydrograph could not be printed out of the HYDSYS database:

Separate gauging data from 1966 to 1986 were plotted in EXCEL to derive the coefficient *a* and the recession coefficient *k'*.

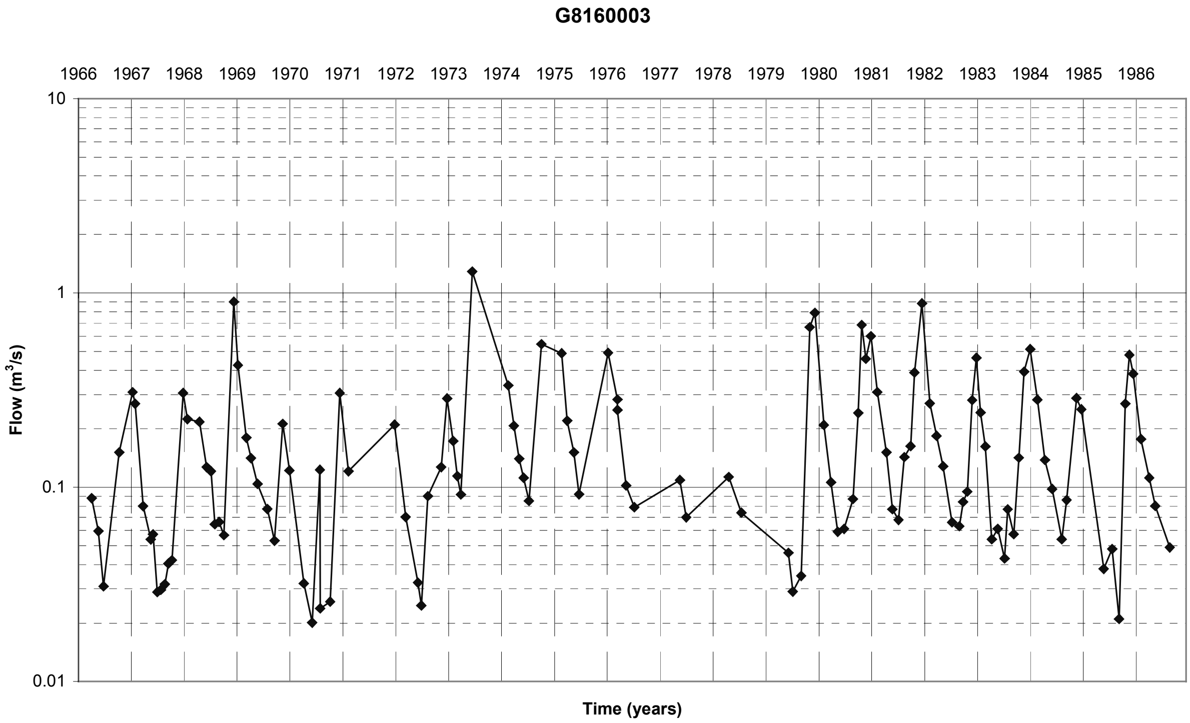

Figure B1. Hydrograph for GS8160003 on Tarakumby Creek.

Appendix C Takamprimili River

The G8160235 hydrographs could not be printed out of the HYDSYS database

Separate gauging data from 1966 to 1986 were plotted in EXCEL to derive the coefficient *a* and the recession coefficient *k'*.

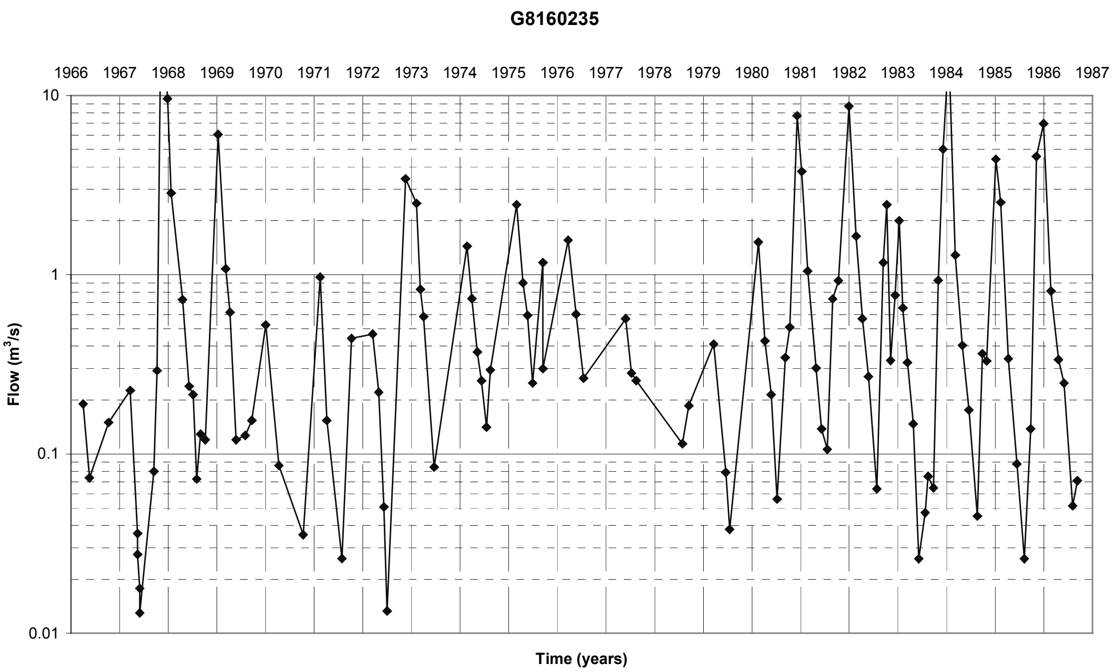

Figure C1. Hydrograph for GS8160235 on Takamprimili River.

Appendix D Tiwi Islands stations

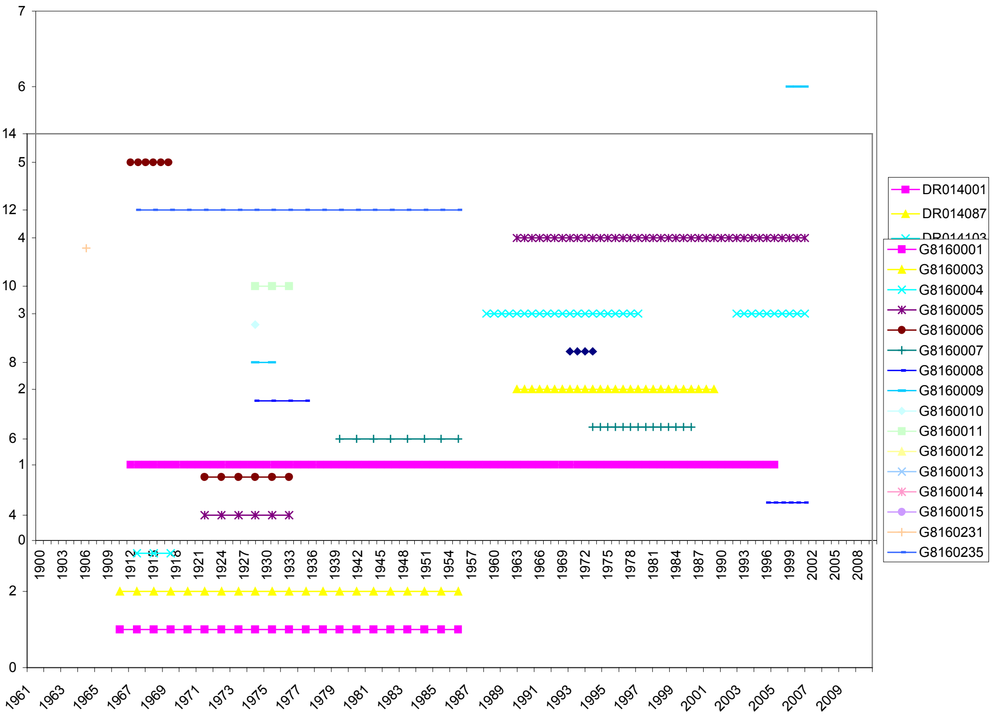

Figure D1. Rain stations on Tiwi Islands and their periods of record (HYDSYS, DIPE).

Figure D2. Gauging stations on Tiwi Islands and their periods of record (HYDSYS, DIPE).