DEPARTMENT OF INFRASTUCTURE, PLANNING AND ENVIRONMENT

CONSERVATION AND NATURAL RESOURCES GROUP

WATER RESOURCES

OF

WEST ARNHEM LAND

East Alligator River

REPORT NUMBER 34/2003D

ISBN: 1 9207 7218 9

U. ZAAR

DARWIN NT

CONTENTS

FIGURES

PLATES

ABBREVIATIONS

ADWG	Australian Drinking Water Guidelines
AHD	Australian Height Datum
ATSIC	Aboriginal and Torres Strait Islander Commission
$CaCO_3$	Calcium Carbonate
CNRG	Conservation and Natural Resources Group
DIPE	Department of Infrastructure, Planning and Environment
EC	Electrical Conductivity
GIS	Geographical Information System
km	kilometres
L/s	litres per second
m	metres
m^3, cumecs	cubic metres (1 m^3 = 1000 litres)
mg/l	milligrams per litre
mm	millimetres
NLC	Northern Land Council
NLP	National Landcare Program
NSD	Natural Systems Division (formerly Water Resources)
NT	Northern Territory
RN	Registered Number (referring to bore)
TDS	Total dissolved solids (in mg/l)
µS/cm	microSeimens per centimetre (units of EC)

NOTE:

Words in *italics* are defined in the GLOSSARY OF TERMS at the end of the report.

The Water Resource Maps described in this report are:

- Water Resources of North Western Arnhem Land
- Water Resources of West Central Arnhem Land

1.0 SUMMARY

The aim of this study is to provide an information resource that will help landowners and land managers incorporate water resources aspects in their planning processes. This report provides an explanation of the groundwater and surface water resources in the West Arnhem Land region, as depicted on the accompanying Water Resource Maps.

The partners in this study were DIPE, NLP, ATSIC and the NLC. The primary clients, who also assisted with the work, were the Homeland Resource Centres in West Arnhem Land.

A Water Resource Map was produced at a scale of 1:250 000. The *groundwater* resource has been classified according to the supply potential into the following categories:

- Lots of water
- Homeland supply
- Small Homeland supply
- Little chance of water

Most *groundwater* in the study area is fit for human consumption. The major aquifers occur in dolomite and poorly *consolidated* or fractured sandstones.

All Dry season flows in the river systems are maintained through *groundwater discharge*. The major *aquifers* maintain the flow in the major rivers such as the Blyth River. River flow has been classified according to the minimum flow recorded or estimated at the end of the Dry season. There are four categories that describe river flow; from rivers which are *ephemeral*, to rivers with a flow of more than 100 l/s at the end of the Dry Season.

Knowing how the *groundwater* and river systems respond to rainfall allows predictions to be made of their future behaviour. A study was made of the low flow characteristics of a number of *perennial* rivers allowing dry season flows to be predicted using daily rainfall information. Correlations between annual rainfall and minimum dry season flow in a number of the rivers were also ascertained. This work outlined the variability in dry season flow in the rivers of the region.

Other products produced from the study include a *GIS*, a photographic and video collection available on CD, posters, satellite imagery maps, Technical Data report and Aboriginal Knowledge report. The entire information resource aims to provide regional planners and land owners with a good starting point in the development of water resource management plans for the region.

2.0 INTRODUCTION

The products of this study have been produced to improve traditional owners' and land managers' access to water information by providing the information in a readily accessible form. Previously existing information sources were insufficient in content and form to enable water resources issues to be adequately included in land management planning. This project has produced an information set, which includes maps, reports, posters, *GIS* and photographic and video collection. This forms a set of decision making tools which will allow homeland organisations, community councils and government departments to readily include water resource considerations in their decision processes regarding future land management and development.

The partners in this three-year project were:

- Water Resources Section, Natural Systems Division, Conservation and Natural Resources Group of the Northern Territory Department of Infrastructure, Planning & Environment
- National Landcare Program – NLP
- Aboriginal and Torres Strait Islander Commission – ATSIC
- Northern Land Council - NLC

The major clients who also provided assistance in many ways were:

Bawinanga Aboriginal Corporation
Cobourg Board of Management
Djelk Rangers

Demed Association
Garngi Community Rangers

Gulin Gulin Resource Centre
Jibuwanagu Oustation Resource Centre

Warruwi Community Incorporated

The study area includes all of West Arnhem Land to as far east as the ATSIC Nhulunbuy Region boundary. It covers approximately 50000 km^2. For the project, this area has been divided into two sectors (Figure 1) resulting in two maps:

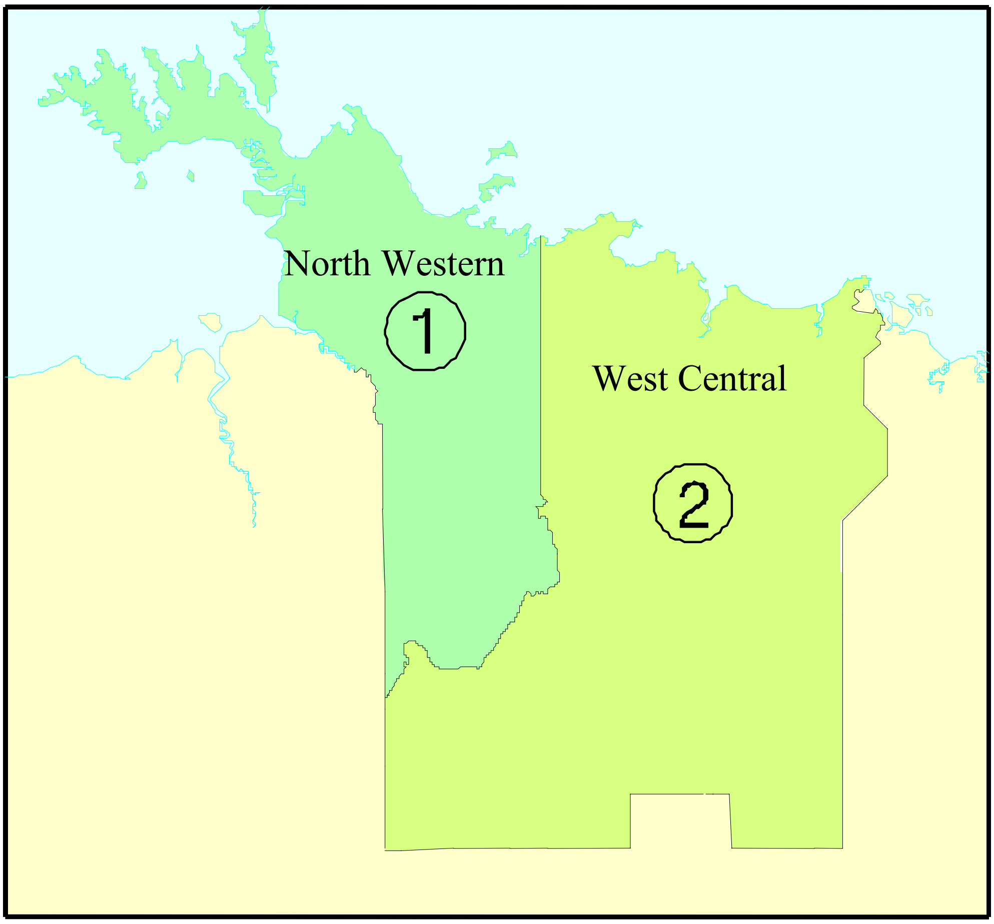
North Western
West Central

The study area is shown in Figure 1. The major communities in the region include Kunbarllanjnja (Oenpelli), Warruwi, Minjilang, Maningrida, Bulman and Weemol . In addition to these there are many smaller communities or outstations.

The Water Resources Map is an interpretation of the region's *geology*, *topography,* bore data, stream flows and vegetation patterns. To produce the map, satellite images and aerial photographs were studied, and field programs including investigation drilling, *geophysical* surveys, test pumping, water sampling and stream gauging were undertaken. The contribution from Traditional Owners, in particular their knowledge of the waterways, has been vital to this mapping exercise, particularly in areas where access was difficult. The maps show the generalised *groundwater* and surface water characteristics of the region, and present other information pertaining to water resources such as bore location and stream gauging and rainfall stations. In order to make the map products more accessible to the Aboriginal landowners and managers, Aboriginal placenames have been included where possible.

All data referred to in this report is held by DIPE at their offices in Darwin. Most is on public record and is easily accessible. (Refer to Section 7.0 for details regarding data format, location and availability)

Plate 1 Locals Using Maps to Discuss Water Resources at Warruwi



Division of the study area into two sectors

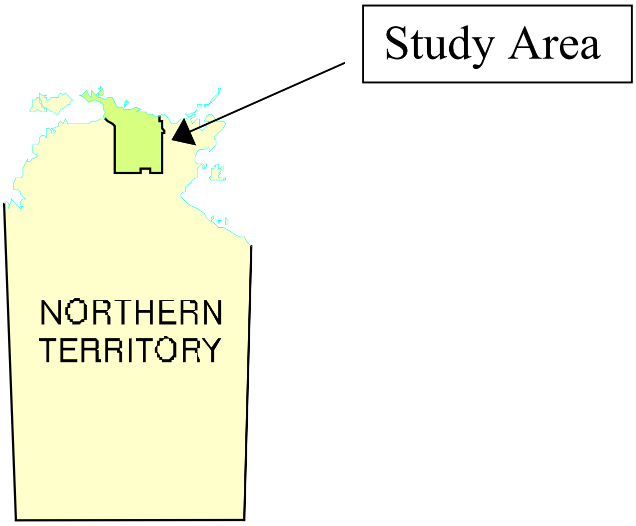


Figure 1 **Location Maps for West Arnhem Land Study Area**

2.1 Climate

The region lies in the "wet/dry" monsoonal tropics, with a long dry season between April and October, and a wet season from November to March. The mean annual rainfall for Kunbarllanjnja is 1375 mm, with the majority of rain falling between December and March. Average monthly rainfall and annual rainfall is shown in Figures 2 and 3. Temperatures range from a mean annual maximum of 34°C to a mean annual minimum of 20°C. Highest temperatures are recorded in October and November, when the mean daily maximum approaches 38°C. Evaporation is high, over 2200 mm per year, with monthly evaporation exceeding monthly rainfall throughout the dry season. There is high variability in annual rainfall, with a documented range from 730 mm in 1941/42 to over 2000 mm in 1975/76. The influence of the variable climate on the regions water resources is discussed in later chapters.

2.2 Geology

Rock type and geological structure are some of the main factors influencing *groundwater* occurrence and the location of *springs*. The study area is covered by the 1:250,000 geological map sheets COBOURG PENINSULA, JUNCTION BAY, ALLIGATOR RIVER, MILINGIMBI, MOUNT EVELYN and MOUNT MARUMBA.

The area contains rocks from two major units which are known as the McArthur Basin and the Arafura Basin. The oldest rocks are granites which underlie most of the region. Kombolgie Sandstone was deposited on top of these old rocks, and today forms the Arnhem Land Plateau that dominates the landscape of the region. The sandstone cliffs of the Arnhem Land escarpment were formed by the undermining effect of wave erosion at their base during a period of high ocean levels.

Much younger sandstones overlie all of these units. These sediments were deposited when much of the area was drowned by rising sea levels, leaving only the higher parts of the Arnhem Land Plateau above sea level. The sea level has since fallen, and intense weathering has stripped these sediments, and led to the development of iron-rich cappings on many surfaces, known as *laterite* or ironstone. The formation of the *laterite* has slowed down or prevented further erosion.

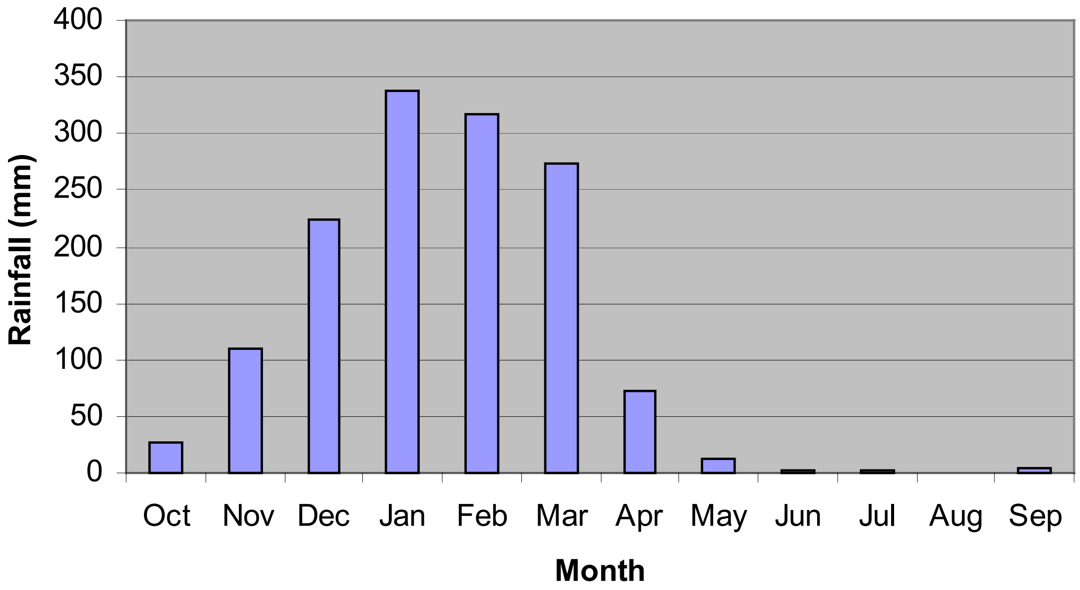


Figure 2 Average Monthly Rainfall – Kunbarllanjnja (Oenpelli)

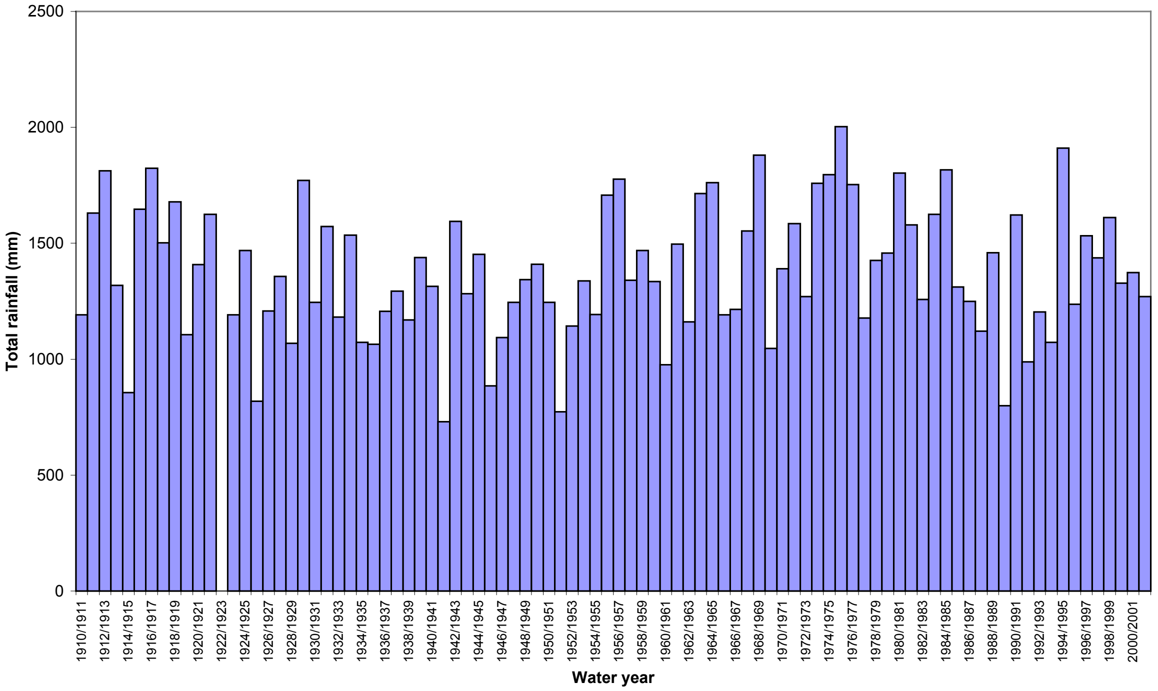


Figure 3 Annual Rainfall for Kunbarllanjnja (Oenpelli) (Water Years)

2.3 Current water usage

Traditionally, communities and outstations all obtained their water supply from surface water, such as billabongs or creeks, from *springs* or from shallow wells. Bore water is now used throughout, with the exception of a few locations such as Mount Catt, Malgawa, Malnjangarnak and Mamadawerre where water is abstracted from creeks sourced from *springs*. Bores drilled at these locations have been unsuccessful, inadequate or no drilling has yet been undertaken.

Plate 2 Hitler at the Mount Catt Water Supply. The Pump is Run by Solar Energy.

3.0 GROUNDWATER

3.1 The Groundwater System

To understand the *groundwater* system, it helps to have an understanding of the water cycle (see Figure 4). When rainfall hits the ground, some of it runs off into streams and creeks (surface *runoff*), some of it evaporates and some of it 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. As the water infiltrates it wets up the soil and moves down. Some of this water may be evaporated or used by plants, and the rest will move downwards until it reaches the watertable 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*.

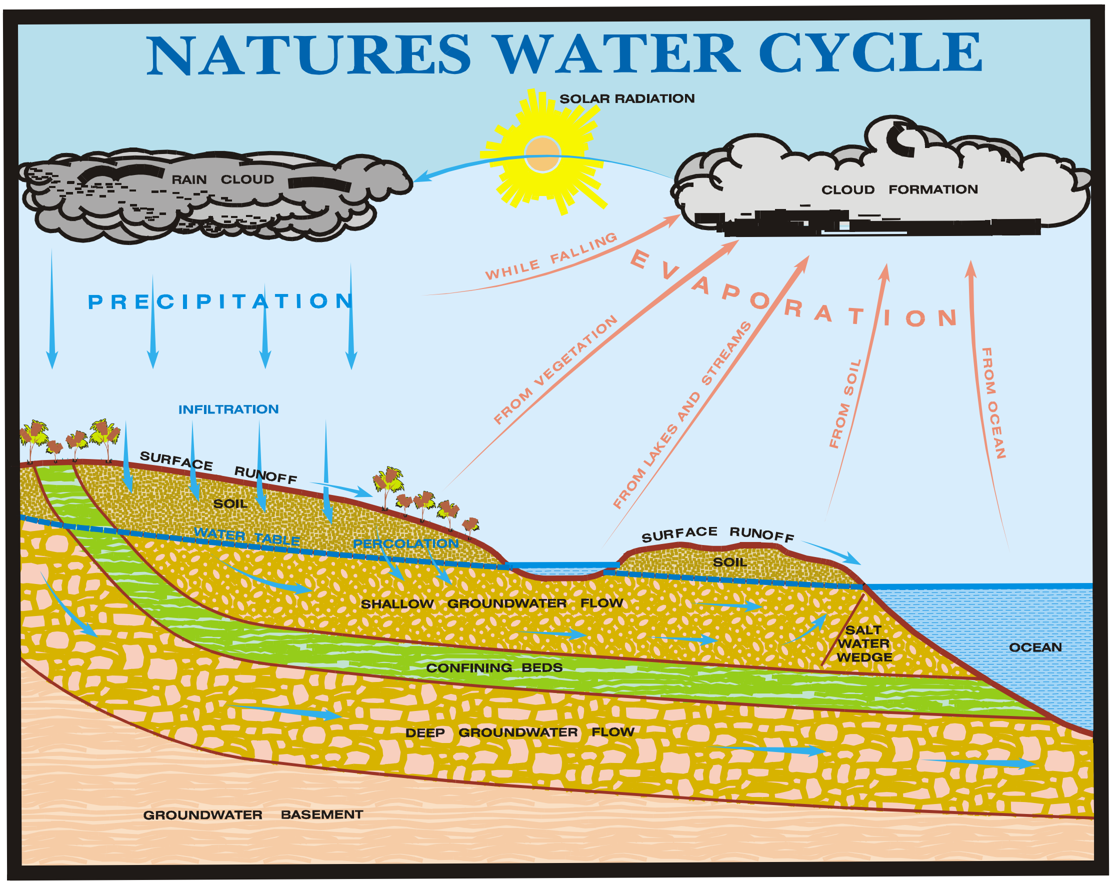


Figure 4 **The Water Cycle**

Recharge occurs only in the Wet season when rainfall intensity and duration is sufficient. *Groundwater* levels rise, while in the Dry season the levels fall (Figure 5). 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*. NSD monitors the change in *groundwater* levels in many *aquifers* throughout the Northern Territory, and has many years of record. This is done by measuring the depth of the *water table* in *observation bores*, which are generally bores that were primarily drilled for this purpose.

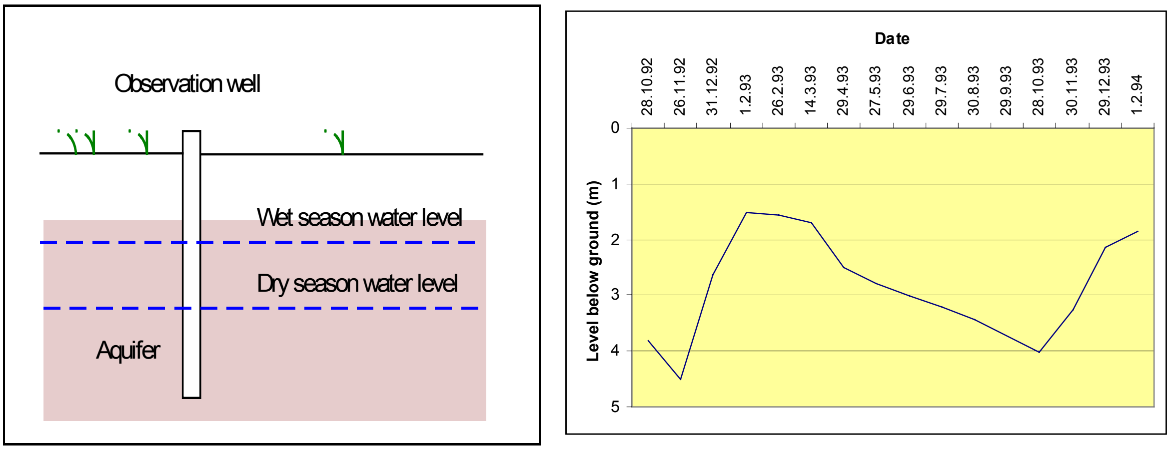


Figure 5 **Variation in Groundwater Levels in Observation Bore RN 8023 at Oenpelli**

Knowing how an *aquifer* responds to *recharge* and Dry season water level changes can help us determine how much *groundwater* is available for abstraction from a bore, and how the water levels will change in response to pumping.

When *groundwater* levels are high, the amount of water discharging from *springs* also increases.

3.2 Aquifer type

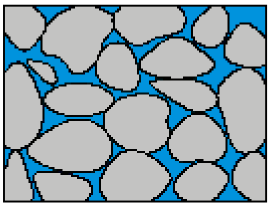
The different *aquifers* found in West Arnhem Land have been grouped according to the expected bore *yield*. Each of the *groundwater* groupings is discussed below, and their Sustainability is discussed in Section 5. Geological units have been grouped together based on their relevant properties.

The bore *yields* stated represent typical *yields* that could be expected from bores sited using geological and local knowledge. Natural variation in the properties of the *aquifers* means that variation in bore *yield* within a *groundwater* grouping will occur. As such, a percentage of bores within a particular grouping may have a lower or higher *yield* than described, but most will fall within the nominated limits. The amount of water that can be safely pumped from a bore over a long period is less than that which can be pumped over a short period. Therefore it is recommended that bores are pumped at a lower rate than the *yield* produced by *airlifting* whilst drilling is taking place.

3.2.1 Explanation of Aquifer Type as Shown on the Water Resource Map

🟦 LOTS OF WATER / LARGE SUPPLY

These regions marked blue on the map contain *aquifers* which can *yield* lots of water. Bore *yields* are typically above 5 l/s. These *aquifers* provide the most substantial and reliable *groundwater* resources in the region. The *aquifer* type has high *porosity* and *permeability* and can supply large volumes of water. These *aquifers* naturally discharge large volumes of water throughout the year and are responsible for the *baseflow* of many of the large rivers.



In the Murgenella region the *aquifer* consists of poorly *consolidated* sandstone allowing much water to be stored between the grains. The sandstone is overlain by another unit which largely consists of mudstone. The mudstone is non water bearing. It is therefore necessary to drill through the mudstone into the sandstone to obtain a good water supply.

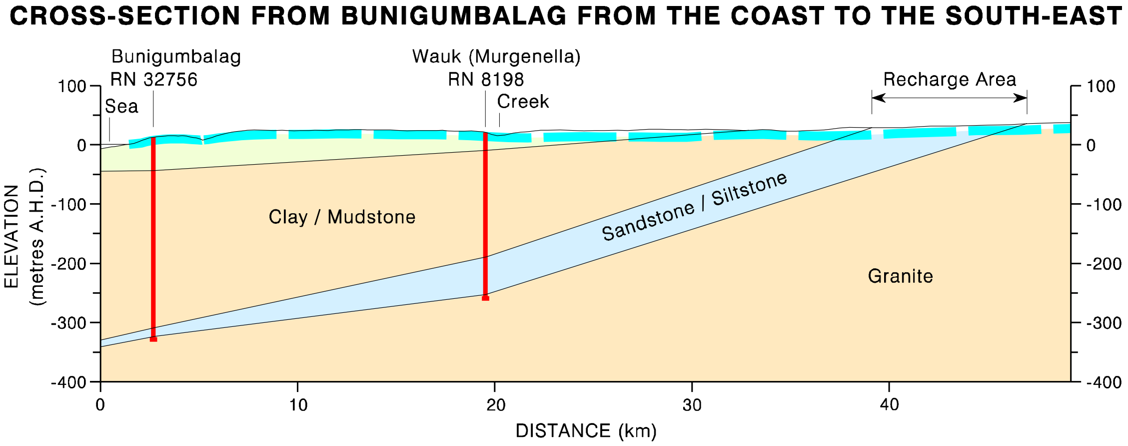


Figure 6 **Cross Section Showing Location of High Yielding Aquifer**

The sandstone unit outcrops south-east of Murgenella and dips towards the north west (Figure 6). Hence at Waidabonoor (in the south) the depth to the *aquifer* is approximately 40 m, whereas the depth to this *aquifer* at Bunigumbalag (in the north east) is approximately 330m. The area in which the sandstone unit outcrops is the *recharge* area for the *aquifer*. When bores are drilled through the mudstone into this *aquifer* at a location where ground level is below the *water table* of the *recharge* area, artesian conditions occur and the bore will flow. This is the case for the bore at Murgenella Plains.

The sandstone *aquifer* extends along the north coast from Aurari Bay to Arrla Bay. Bores drilled at the headwaters of Jungle Creek confirmed the presence of a high yielding sandy *aquifer* in this region as well. *Groundwater discharge* from these *aquifers* maintain the flow in Angularli, Marligur and Jungle Creeks.

The *aquifer* which underlies Maningrida also consists of a sandstone unit but is older than the one discussed above. This sandstone forms part of the Arafura Basin which is made up of a series of sandstone and mudstone units (Figure 7). The units dip to the north-east in the area around Maningrida. Good supplies have been attained where the sandstone has been fractured.

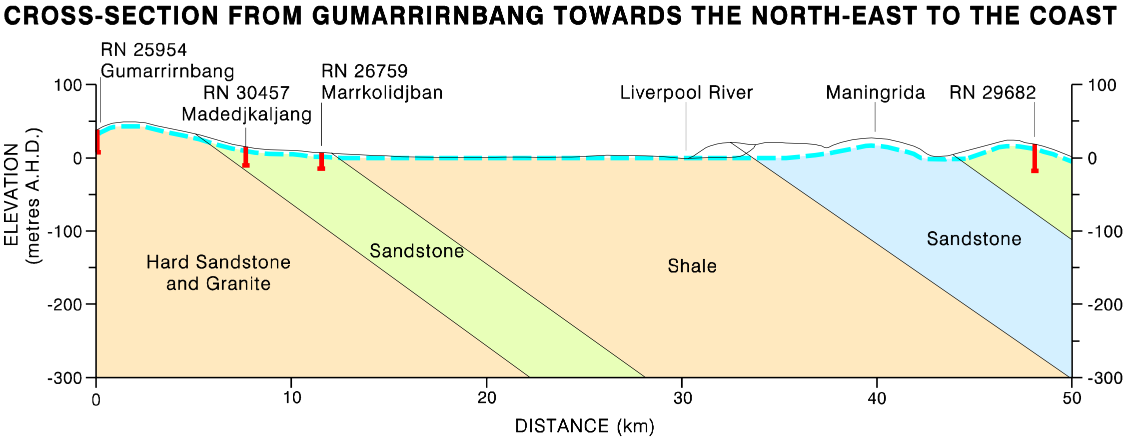
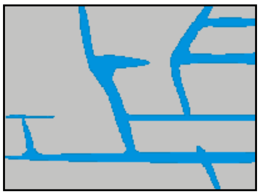


Figure 7 Cross Section Showing Location of Arafura Basin Rock Units



A large *karstic aquifer* extends in the region just north of Bulman. In this type of *aquifer groundwater* is stored in networks of cavities or fractures in the rock. Cavities are caused by water slowly dissolving the rock over many years. Sinkholes are a common feature of this *aquifer*. The rock type is dolomite.

Groundwater discharge from this extensive *aquifer* provides Dry season flows to Guyuyu Creek, the Blyth River, the Wilton River and Mainoru River. The water supply for Bulman is sourced from bores drilled into this *aquifer* in fractured zones. There are a number of large point sourced *springs* which emanate from this *aquifer*. These include Top Spring, Lindsay Spring and the spring at Weemol and Mt Catt. The large extent of this *aquifer* is shown in the diagram below. As can be seen, the outline of the *aquifer* is not dissimilar in shape to that of the Rainbow Serpent; a coincidence which has gained much interest from local people.

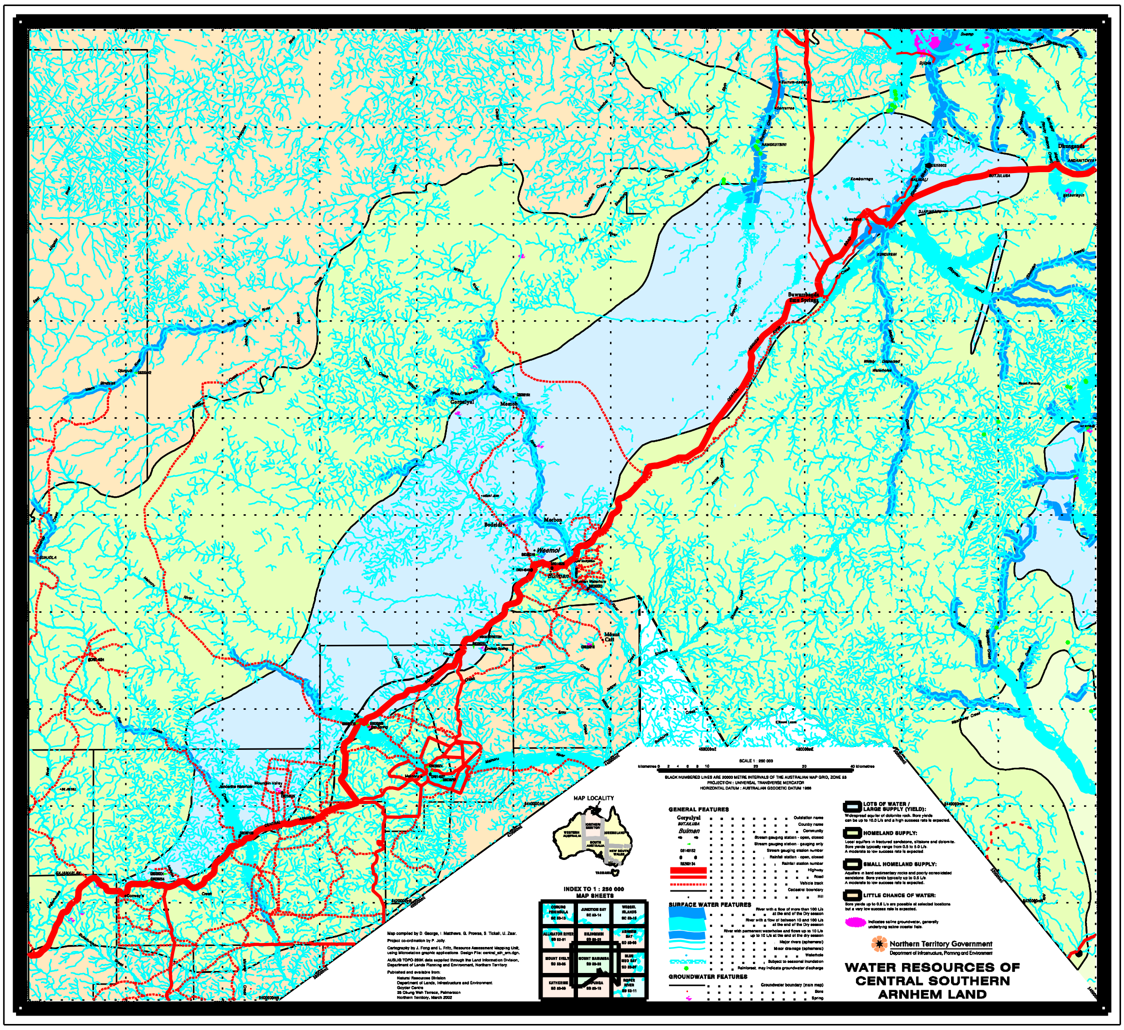


Figure 8 **Extent of High Yielding Dolomite Aquifer**

🟩 HOMELAND SUPPLY

These regions are marked green on the map and contain *aquifers* which can yield a typical homeland supply of 0.5 to 5 l/s. In the north the *aquifer* occurs in poorly *consolidated* or fractured sandstone. In the south the *aquifers* are locally developed in fractured sandstone, siltstone and dolomite. Higher *yields* can be obtained from these *aquifers* where fracturing is more intense, such as fault zones, but can also occur where there has been a significant weathering of the surface rock. Faults and fractures are shown on *geology* maps and can also be identified on aerial photographs or satellite imagery. Geophysical surveys can also be used to identify potential bore sites.

The effects of fracturing and weathering generally decreases with depth, and therefore drilling depths are seldom more than 60 metres. Bore *yields* from these *aquifers* tend to be low, generally up to 5 l/s with correct siting and careful construction. The nature of these *aquifers* makes it very difficult to predict the quantity of water available, as even bores drilled close together can have very different *yields*.

🟩 SMALL HOMELAND SUPPLY

These regions are marked in light green on the map and may contain shallow *aquifers* which typically yield up to 0.5 l/s. Sites need to be carefully selected and a low success rate is expected.

North of Murgenella Plains the *aquifers* occur in sandstone and sandy horizons. In the Oenpelli region *groundwater* can be found in alluvial deposits and fracture zones. In the region near Maningrida the *aquifer* lies in sandstone deposits situated above impervious shale. Elsewhere *aquifers* are found in sands, sandstone and fracture zones. In some of these areas there has been no drilling investigation undertaken, however the *geology* and presence of *springs* is a strong indicator that a small *groundwater* supply is feasible.

Small homeland supplies may also be obtained from *aquifers* in sand dunes. This is the case at Smith Point on Cobourg Peninsula where water is drawn from a fresh water lens in sand dunes.

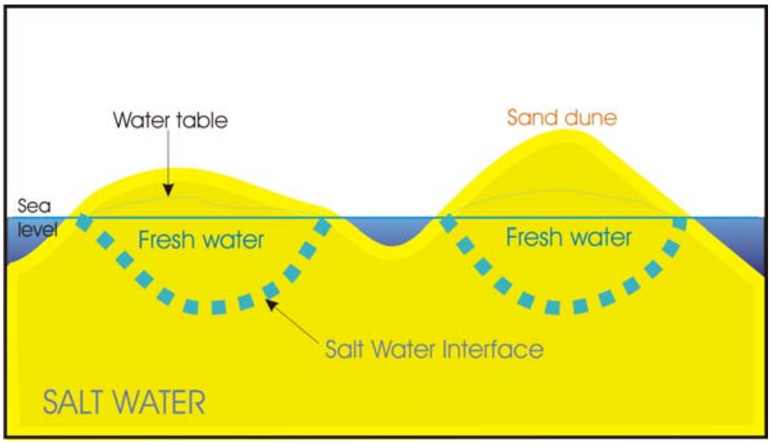


Figure 9 **Location of Fresh Water Lens in Sand Dunes**

🟧 LITTLE CHANCE OF WATER

This group is coloured pink on the maps. These areas are mostly underlain by hard rocks such as granite, hard sandstones and schist. The area north-east of Mumeka is underlain by shale. These rocks are poor *aquifers*, with only small, isolated supplies available. Most bores drilled in these areas are dry.

Within the shales prospects are very low to nil. Further drilling is not recommended. Within the hard rock areas, drilling should be targeted at the fractured and weathered portions. *Hydrogeologists* should be consulted prior to drilling as careful site selection will increase the likelihood of obtaining a useable supply. In rugged terrain such as the Arnhem Land plateau prospects are particularly limited because of the poor access. The small islands have limited prospects for *groundwater* because there is little storage space for fresh *groundwater*.

3.3 Water quality

The quality of *groundwater* depends upon factors such as the type of rock that makes up the *aquifer*, and the amount of time that the water has been moving through the *aquifer*. This is because, as water moves through the *aquifer*, it picks up (dissolves) salts along the way from the surrounding rock. Salts are minerals such as table salt (sodium choride, NaCl) or limestone (calcium carbonate, $CaCO_3$). Rocks are made up of minerals. In order to describe the quality of water and its suitability for drinking or other use, a number of parameters can be measured in the field and in the laboratory. One of these parameters is *Total Dissolved Solids* (TDS) which is a measure of the saltiness of the water.

TDS is a measure of the amount of salt in milligrams (mg) in one litre (l) of water. The Australian Drinking Water Guidelines (ADWG, 1996) define good quality drinking water from the perspective of health and aesthetics. The ADWG states that good drinking water has a TDS of less than 500 mg/l, and that a TDS of 500 – 1000 mg/l is acceptable according to taste. Greater than 1000 mg/l may be associated with excessive scaling, corrosion and unsatisfactory taste. Water can also be described as being ‘hard’ or ‘soft’, a measure of the amount of calcium and magnesium present. ‘Hard’ water requires more soap to produce suds than ‘soft’ water, and is generally associated with *groundwater*s occurring in limestone and dolomite *aquifers*. These *aquifers* contain calcium or magnesium. Water having more than 150 mg/l *hardness* can deposit scale in pipes and water heaters.

A simple way of estimating TDS in the field is by measuring the water’s electrical conductivity, EC. Salt present in the water will make it more conductive for an electrical current, which can be easily measured with a small field probe. EC is measured in microSeimens per centimetre, µS/cm. At a temperature of 30 degrees Celsius, water with a TDS of 1000 mg/l will have an EC of approximately 1600 µS/cm. Figure 8 below shows the approximate relationship between TDS and the EC as measured in the field.

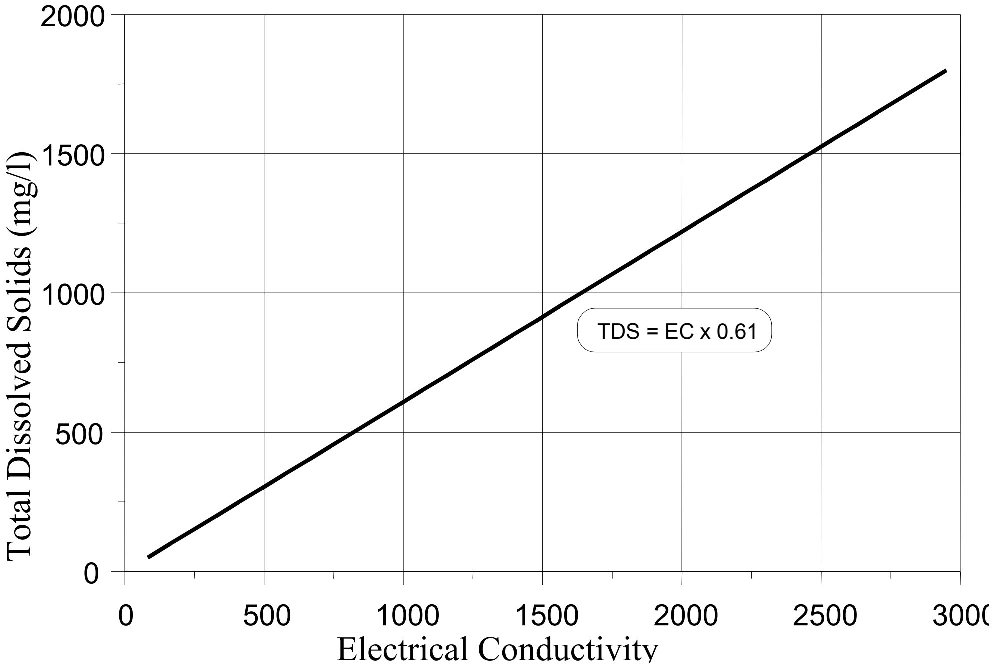


Figure 10 **Approximate Comparison Between Electrical Conductivity and Total Dissolved Solids**

Another parameter which can be easily measured in the field, and give an immediate indication of *water quality* and suitability is *pH*. *pH* is a measure of the hydrogen ion concentration. Water is said to be either acidic or alkaline, depending on the relative concentration of hydrogen ions. A *pH* of 7 indicates neutrality, a *pH* of less than 7 indicates an acidic water and a *pH* of greater than 7 indicates an alkaline water (although temperature does have a small effect). The *pH* of most *groundwater*s results from the balance between dissolved carbon dioxide derived from the atmosphere, and the dissolved carbonates from the *aquifer* material. A low *pH* can be caused by high levels of dissolved carbon dioxide. An acidic water generally indicates that *recharge* is recent and has occurred rapidly. Acidic water is corrosive to metal bore casing and pipes, but is still suitable for consumption if plastic or PVC bore casing and pipes are used to distribute the water. Alternatively, the water can be treated by aeration, which allows the dissolved carbon dioxide to be released to the atmosphere, causing the *pH* to increase. Alkaline water is generally associated with limestone or dolomite aquifers, and is a good indicator of the *aquifer* rock type. High alkaline waters can also be treated to lower *pH*.

It should be noted that *pH* measurements taken from airlifted water during the drilling process may not give a true indication of the *pH*.

Measurement of *pH* in the field is important, as during sampling, storage and transportation to a laboratory, there may be changes in *pH* due to chemical reactions. Field measurement is easy, and generally done by using a small probe which can give excellent results if regularly calibrated.

Plate 3 Taking Water Chemistry Measurements in the Field

Besides undertaking field measurements of *water quality* parameters, water samples were also taken from a number of *springs*, creeks and bores prior to and during this project. Physical and chemical parameter analyses of the samples were undertaken in a laboratory. The *water quality* could then be characterised for the region. The accompanying technical report contains detailed analyses of the water samples. Specialised water sampling has also been undertaken in several areas: the Environmental Research Institute of the Supervising Scientist (*ERISS*) conducted macroinvertebrate and full trace element sampling in the upper reaches of the Mann and Katherine Rivers. This was to provide baseline chemistry data of this near pristine environment before any changes in land use (such as mining) have any impact. Trace element sampling has also been undertaken for a number of bores in the region.

The great majority of *groundwater* in West Arnhem Land has a low TDS and is fit for human consumption. Most of the bores which have supplied salty water have been drilled close to the sea or salty mangrove and swamp areas. Near the coastline or tidal streams, fresh water in *aquifers* can become mixed with sea water. This can happen naturally on a seasonal basis, or when water is pumped from an *aquifer* close to the ocean. These waters can be distinguished by high sodium and chloride concentrations.

3.3.1 Relationship Between Water Quality and Aquifer Type

Each *groundwater* grouping as shown on the water resource maps is discussed.

🟦 LOTS OF WATER / LARGE SUPPLY

There are two distinctly different *aquifers* in this group. One aquifer type consists of sandstone and the other of dolomite.

The dolomite *aquifer* is located in the south-eastern part of the region close to Bulman. Bore and *spring* water sourced from this *aquifer* generally has a TDS ranging from 200 to 500 mg/l, and is slightly alkaline with a *pH* of 7 to 8. The water can be described as 'hard', with $CaCO_3$ concentrations of up to 350 mg/l. Hard water requires more soap to produce suds. This water may be associated with excessive scaling of water heaters, jugs and pipework. Otherwise, this water is suitable for all uses.

The sandstone *aquifer* located around Maningrida generally has a low TDS, typically less than 100 mg/l, a *pH* of less than 7, generally around 5, and can be classed as very soft (ie generally less than 10 mg/l of calcium carbonate, $CaCO_3$). This water is corrosive to metal bore casing and pumps, but is still suitable for consumption if PVC casing and pipes are used, or if treated by aeration. Aeration can also be used to treat for the high iron content that, although not a constraint on *potability*, can be high enough to discolour the water.

The sandstone *aquifer* located around Murgenella has a variable *pH* from 6 to 8 and TDS from 40 to 270. The variation is due to the *aquifer*'s interaction with its surrounds and the variability in its mineral content.

🟩 HOMELAND SUPPLY

🟩 SMALL HOMELAND SUPPLY

🟧 LITTLE CHANCE OF WATER

These *aquifers* are in many different types of rocks, which can often have a direct effect on *groundwater* quality. In general however, *groundwater* will be of good quality, with low to moderate TDS and a low *pH*.

4.0 SURFACE WATER

Surface water occurs as billabongs, river pools, rivers and *springs*, and can be characterised into two main sources: directly from rainfall and rainfall *runoff*; or from *groundwater discharge* or *baseflow*.

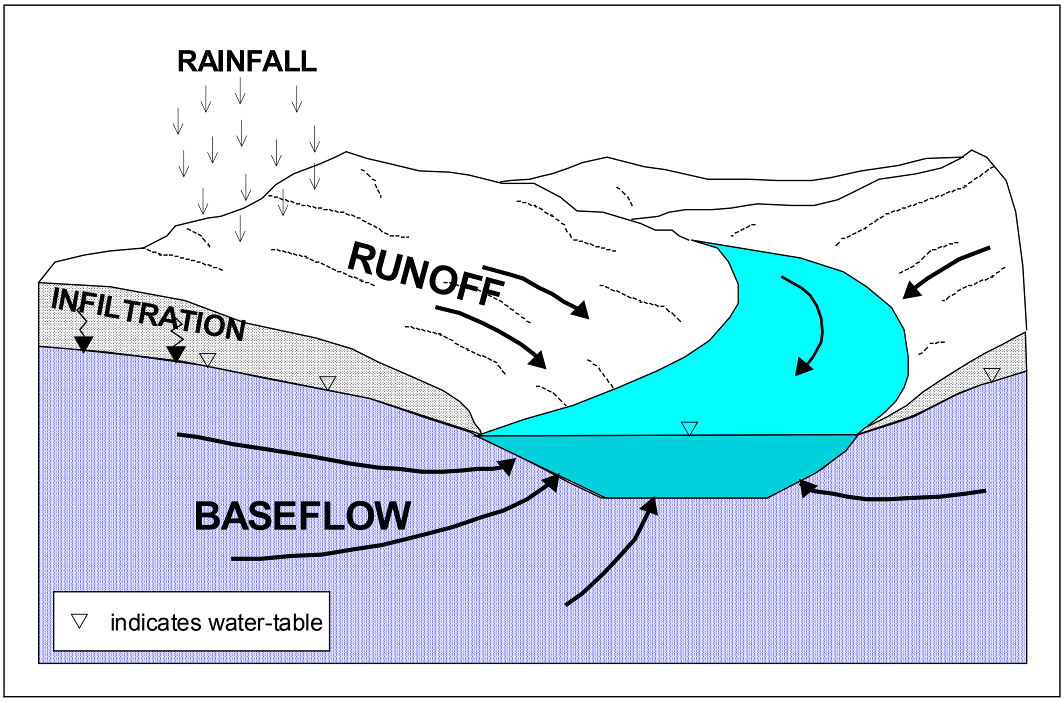


Figure 11 Runoff and Baseflow Components of Surface Water

When examining surface water occurrence it is important to distinguish between these two sources. Surface water derived from wet season rainfall and *runoff* will only persist if storage is high enough to last through the Dry season. It is the *baseflow* component that keeps rivers and creeks flowing through the long Dry season.

Flow in a river is often presented as a *hydrograph*, which usually shows daily or monthly variations in water flow or height. Figure 12 depicts the variation in flow for Blyth River between December 1982 and February 1984. The two components of *baseflow* and *runoff* are easily distinguished.

NSD records the variation in river height and flow at a number of sites (*gauging stations*) in the region. Currently monitored sites (open) and previously monitored sites (closed) are shown on the Water Resources Map and listed in Tables 4 and 5 of the Technical Data report.

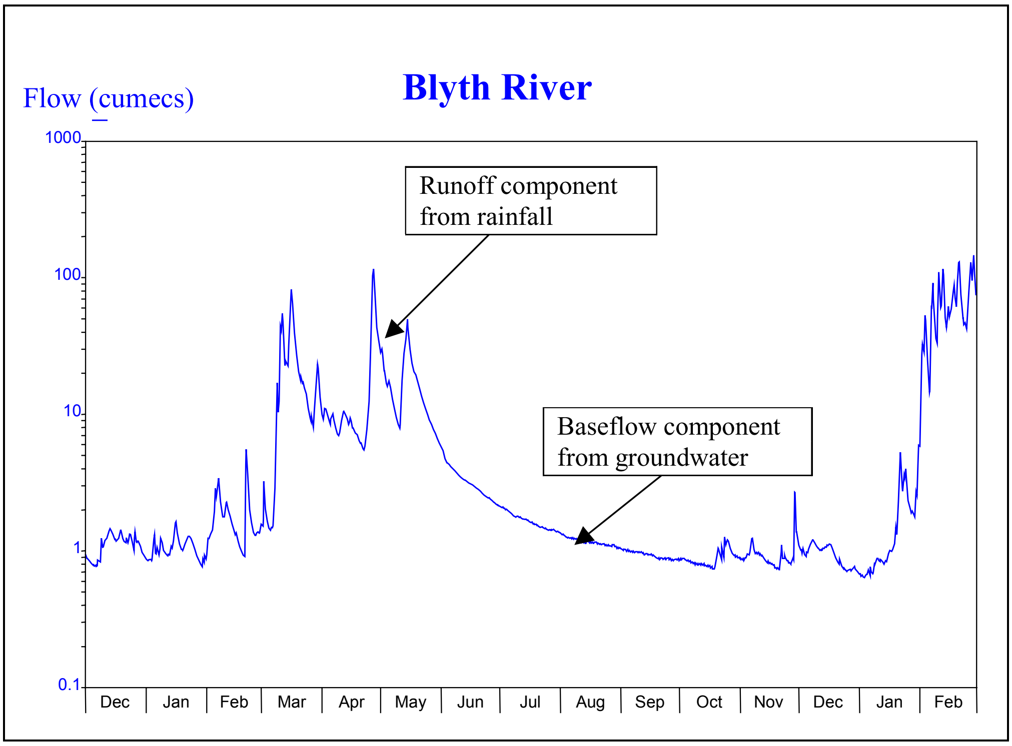


Figure 12 **Flow in Blyth River from December 1982 to February 1984. Flow Record from NSD's Gauging Station G8140159**

At a *gauging station* river height is continuously recorded. Many *gauging stations* have wells which have a pipe connection to the river. A float in the well moves up and down with the water level. The height variation is recorded using a device such as a data logger. Manual flow measurements (gaugings) of the stream are made at different river heights. Hence the relationship between river height and flow can be determined. The records from these *gauging stations* have also been used to correlate river flows with variation in *groundwater* levels and rainfall.

Plate 4 **Gauging Station at Liverpool River GS 8230237**

Plate 5 **Students Measuring the Flow in Gudjarama Creek**

4.1 Minimum Flows

In order to know what quantity of water can be sustainably pumped out from a river, it is necessary to know what the minimum flow is, and how much variability there is. Figure 13 shows the flow at Blyth River since 1969. It can be seen that the minimum dry season flow in 1972 was under 0.2 cumecs (200 l/s), whereas the minimum flow in 1976 was over 1 cumec. This variation is due to variations in annual rainfall. Analysis of the rainfall records for the region shows that the combined impact of several years of rainfall influences the minimum annual flow.

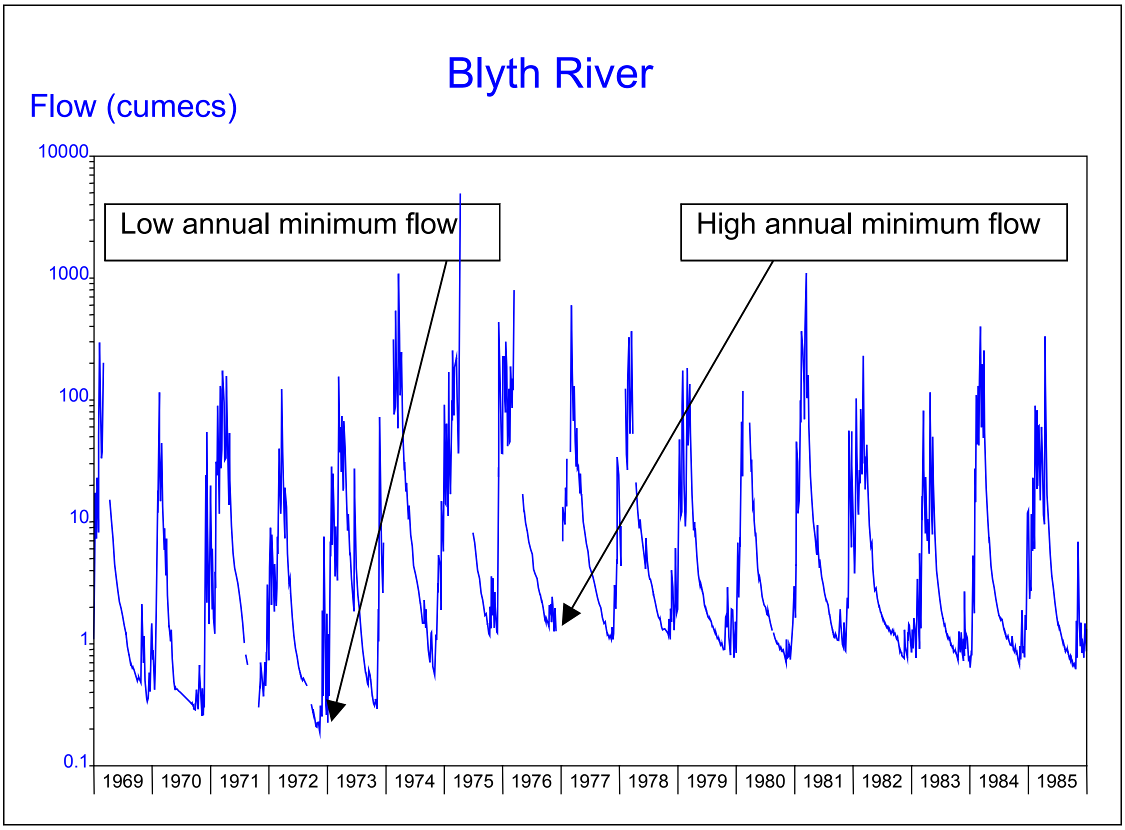
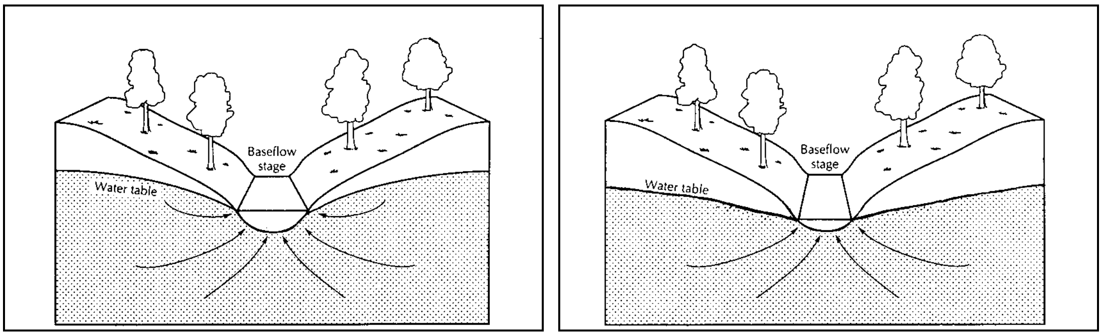


Figure 13 **Flow at Blyth River from 1969 to 1985 Recorded at NSD's Gauging Station G8240002**

For example, the annual minimum flow in the East Alligator river was found to correlate well with the two year moving average rainfall at Oenpelli. This suggests that the last two years rainfall has influence on the minimum annual flow in the East Alligator river in that year. The correlation can be seen in Figure 15. Different rivers show different annual minimum flow/rainfall correlations. Differences are a reflection of different *aquifer* characteristics.

A relationship between rainfall and river *baseflow* has also been established for some of the rivers using computer modelling. This method of analysis allows the production of a *baseflow hydrograph*, which depicts the *groundwater baseflow* contribution to river flow for the period of rainfall record. Details are given in the technical report.

Developing such relationships allows predictions to be made on minimum river flow based on rainfall. The relationships are a reflection of how rainfall influences *groundwater* level which in turn effects river flow. In general a period of high rainfall years will enable the *water table* to rise higher causing higher flows in rivers (Figure 14).



High *water table* = large flow in river **Low *water table* = low flow in river**

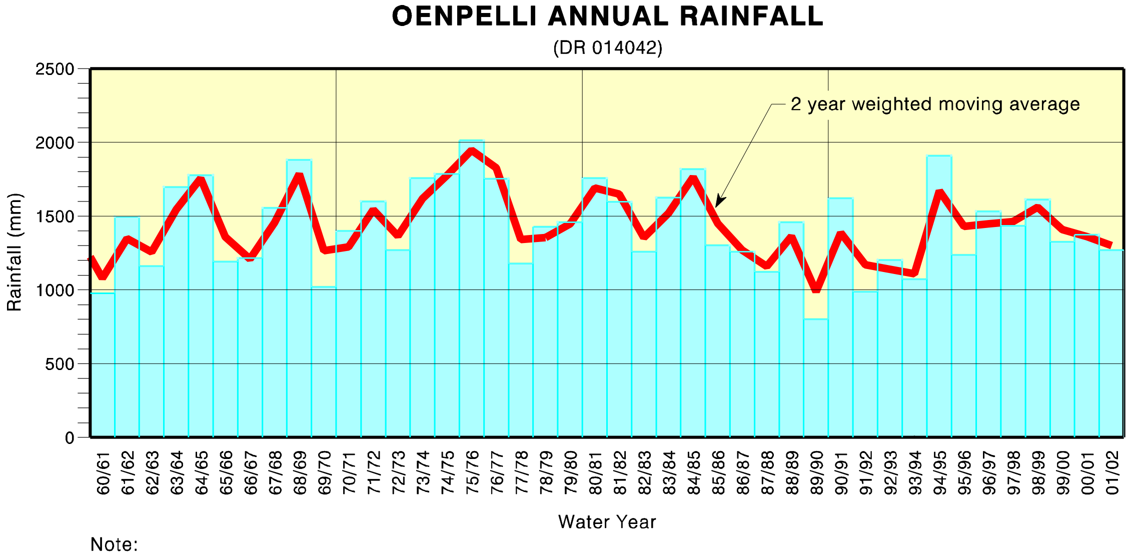
Figure 14 Effect of Water Table Level on River Flow (Adapted from Fetter, 1994)

Correlations between rainfall and minimum water level have been depicted on each of the water resource maps for rivers with a continuous flow record. General trends of high and low periods of both rainfall and flow are easily distinguished.

4.2 Mapping minimum flows

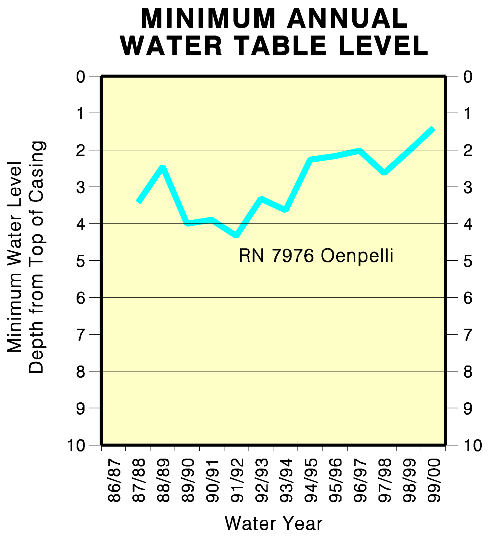
River and creek flow on the Water Resource Map was plotted according to its minimum expected flow. Some of the river systems have been gauged and monitored for many years, and the long term variation in flow was taken into account when establishing minimum flows. In cases where no long term record exists, site visits, gaugings and local knowledge were used to determine flows. This project was conducted during a time of above average rainfall and consequently higher than minimum flows were observed in most river systems. This has been taken into account, and minimum expected flows have been estimated using Traditional Knowledge and scientific analysis.

The categories of some rivers have been estimated from anecdotal evidence or scientific interpretation, as some areas were inaccessible during the project duration.



Note:
- Water flows recorded from gauging stations.
- 65/66 means the water year October 1965 to September 1966.
- Predicted values based on correlation with 5 year moving average rainfall.

Note:
Water level data was not taken from continious data but spot readings. As such the records only give an indication of minimum annual water level, but at least they appear to show the trend.



East Alligator River at G8210010 ━━━
- recorded minimum river flow

East Alligator River at G8210010 ━━━
- predicted minimum river flow based on correlation with 2 year moving average rainfall

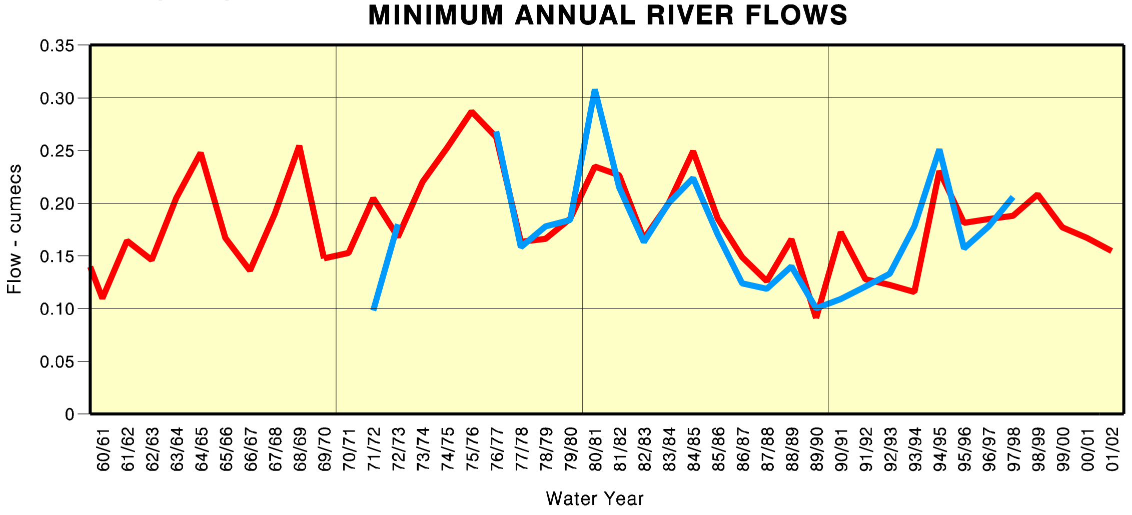


Figure 15 **Correlation Between Rainfall, Water Table Level and River Flow**

There are four categories of minimum flow shown on the Water Resource Map as follows:

▬ River with a flow of more than 100 l/s at the end of the Dry season.

These rivers can provide a large water supply. The Blyth River, Guyuyu Creek, Jungle Creek and the very downstream end of Alaru Creek are the only rivers in this region that will always flow in excess of 100 l/s along any significant length.

Plate 6 Jungle Creek

▬ River with a flow of between 10 l/s and 100 l/s at the end of the Dry season.

These rivers could provide a supply for an outstation or community depending on the amount of minimum flow. The creeks at Mammadawerre, Malwon and Malgawa are examples of this category and currently supply these communities.

Plate 7 Creek at Mammadawerre

▬ River with permanent waterholes or flows up to 10 l/s at the end of the Dry season.

This category indicates a potential water supply for outstations. It includes rivers which cease to flow on the surface, but maintain permanent waterholes which could supply an outstation through the Dry season. The Liverpool River is an example of this category.

Plate 8 Liverpool River

——— River which is dry at the end of the Dry season.

These rivers are not suited to supply water throughout the year. Many rivers and creeks will continue to flow throughout the Dry season after average and above average wet periods, but will cease to flow during drier times.

Plate 9 Goomadeer River

4.3 Wet Season Flows

In the Wet season, river flows increase due to rainfall *runoff*. The increase in flow at a point along the river is dependent upon the rain that has fallen in the *catchment* upstream from that point. The larger the *catchment*, the bigger the increase in flow due to rainfall. Major *catchment* boundaries are shown on the Water Resource Maps. The variation in river flow over the year is graphed for a number of rivers on the Water Resource Maps.

A good example of the relationship of *runoff* to *catchment* size is shown in Figures 16 and 17. The *catchment* area above the *gauging stations* G8210011 (Tin Camp Creek) and G8210010 (East Alligator River) are shown, and it can be seen that the East Alligator River *catchment* is about five times the size of Tin Camp Creek's *catchment*. Figure 16 shows the Average Monthly Flow for these two *gauging stations*. During the wet season, average flow in the East Alligator River is almost ten times that of Tin Camp Creek. During the Dry season, flows in Tin Camp Creek and the East Alligator River are maintained by *groundwater,* and aquifer parameters rather than catchment size determine flow quantities.

Catchment boundaries are useful for relating Wet season flows and *water quality* at different points within a *catchment*. For example, an increase in *turbidity* in a stream could be due to eroding soils from a rough track in its vicinity, or perhaps due to feral animals damaging the river banks and allowing the soil to wash into the creek with the rain. *Turbidity* can destroy otherwise healthy habitats. Plate 10 shows the impact that feral buffalo and pigs have had on *water quality* in the most upstream parts of the Mann River.

Plate 10 Feral Buffalo Damage – Upper Mann River

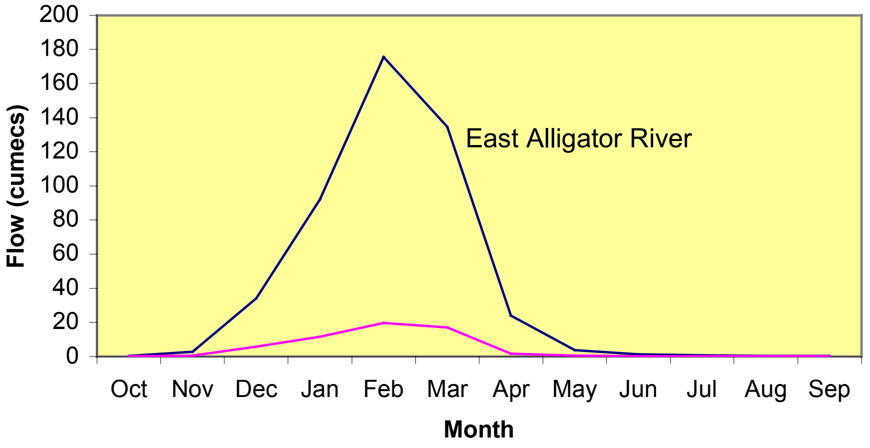


Figure 16 Comparison of Mean Monthly Flows for Tin Camp Creek and East Alligator River

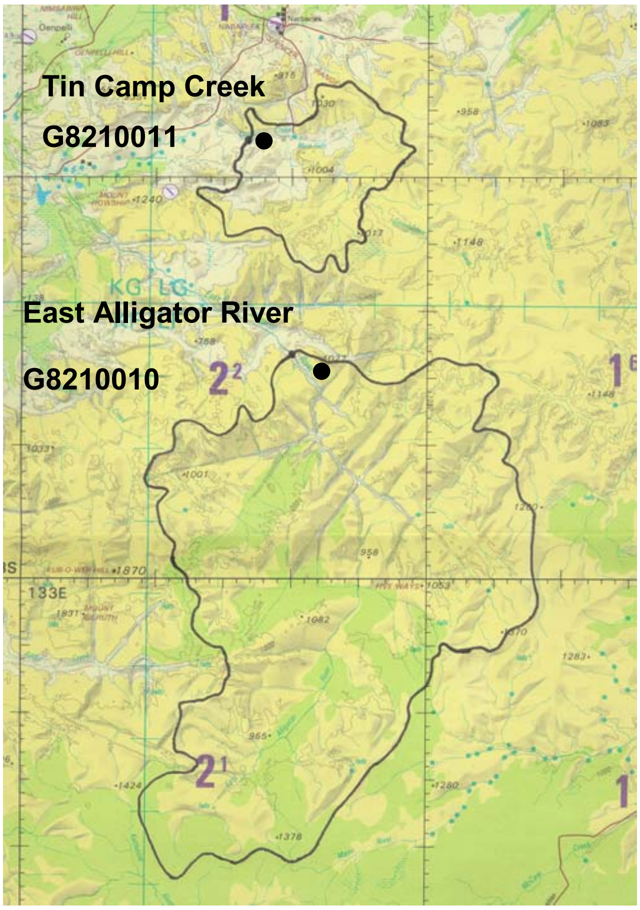


Figure 17 Comparison of Surface Water Catchment Area. Tin Camp Creek Compared with East Alligator River

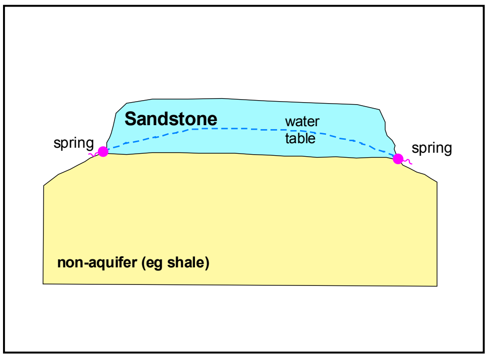
5.0 INTERACTION OF SURFACE WATER AND GROUNDWATER

Interaction between *groundwater* and surface water takes place in the form of *groundwater discharges*, either as discrete individual *springs* or as a diffuse flow into creeks and rivers. It can also take place in reverse, as surface water from rainfall *runoff* can *recharge aquifers* through streambeds and sinkholes.

Springs are natural outflow points for *groundwater*. They occur where the watertable is at or above the ground surface, and can be permanent (*perennial*) or seasonal (*ephemeral*), depending on the fluctuations in the local watertable.

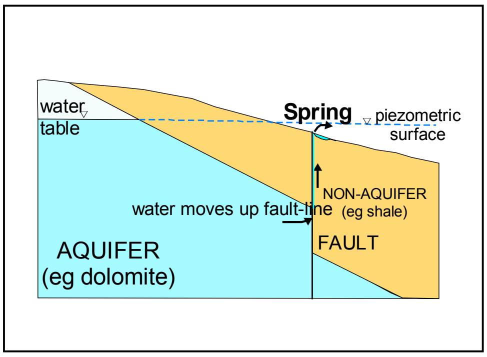
5.1 Spring types

The location of *springs* is determined by a combination of rock type, *aquifer* location and *topography*. There are many different occurrences of *springs* in this region, a few of these are described below.



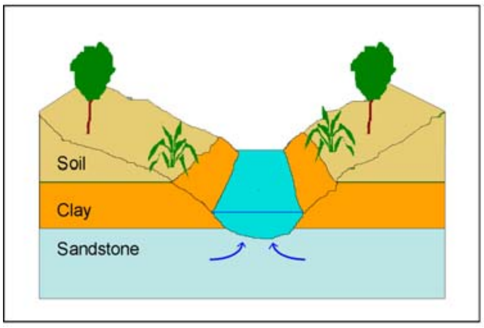
SPRING TYPE 1

This *spring* type occurs where a layer of *porous* and *permeable* sandstone overlies a low *permeability* rock such as shale or granite. This occurs south of Maningrida along the escarpment by the Tomkinson River. Water stored in the upper layer seeps out at the contact between the two rock types. This is generally in the form of a seepage zone or swampy area at the contact. Seepage over an area will eventually coalesce to form a creek. Occasionally there will be a discrete *spring* or permanent waterhole.



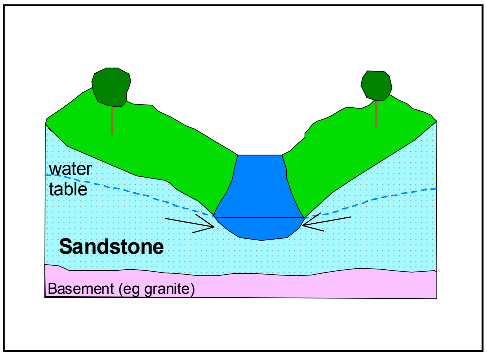
SPRING TYPE 2

This type of *spring* occurs when a geological fracture or fault provides a pathway to allow *groundwater* to rise to the surface, in areas where it is normally confined beneath a low *permeability* rock. A good example of this is at Mount Catt, where a large *spring* provides the community water supply. Smaller *springs* and seeps of this type may occur in fractured rock areas.



SPRING TYPE 3

Streams such as the one at Mandillbareng obtain their flow in areas where the river bed has cut down through a clay confining layer. This allows water from the underlying poorly cemented sandstone *aquifer* to discharge.



SPRING TYPE 4

Seeps and *springs* occur in areas where the local *groundwater* table is high enough to be intersected by the drainage lines and creek beds. Besides drainage from an un*consolidated* sandstone environment or alluvial deposits, this can also occur in fracture zones in hard sandstone which may contain sand infill providing storage. This can be a temporary feature after periods of above rainfall. Many creeks in the region are sourced from this *spring* type such as the Mann and Goomadeer Rivers.

The locations of discrete *springs* are indicated on the Water Resource Map. Many of the *perennial* rivers in the region are sourced from diffuse flow and hence are marked in according to their minimum flow category. A classic example is Jungle Creek where it can be seen that discharge increases gradually as one travels downstream. The *springs* shown on the maps are a combination of those visited during fieldwork, identified on satellite imagery and aerial photographs, and several located remotely using local Traditional Knowledge and maps. All of these *springs* are thought to be permanent features, providing some *groundwater discharge* even during periods of below average rainfall. During the period of fieldwork for this study there were many additional *springs* and seeps located, but remote sensing, *geology*, *topography* and local knowledge has helped to identify many of these as *ephemeral*. Some of the *springs*, particularly those occurring in the dolomitic *aquifers*, have a discrete source with considerable flows, and are important local water supply sources, such as the *spring* at Mount Catt.

All *springs* are important for maintaining dry season flow in creeks and rivers, and most of them sustain small rainforest or pandanus/paperbark swamp pockets. This is covered in more detail in Section 5.0. Many of the *springs* indicated on the Water Resource Maps appear in areas of apparently low *groundwater* availability. Such *springs* are sourced from relatively small areas of sandstone or *unconsolidated* sand, which do store a certain volume of *groundwater*, but are unsuitable for *groundwater* abstraction. With specialist scientific advice, a successful bore could be located in some areas.

5.2 Water quality

The *water quality* of *groundwater discharges* are directly related to the *geology* of the *aquifer* supplying that particular *spring*. Most *springs* are sourced from sandstone or *unconsolidated* sand, and consequently have a TDS of less than 50 mg/l, and are acidic with a *pH* of less than 7. *Springs* sourced from other *aquifer* types are easily identified by their chemistry.

Most *springs* in the south-eastern region are sourced from the Dook Creek *Aquifer*, a dolomitic *aquifer* with *water quality* TDS values in excess of 200 mg/l. Consequently, the *water quality* of the creeks and rivers in the eastern region, for example Mainoru River, Guyuyu Creek and the Wilton River, changes through the year. *Runoff* water (basically rainwater) has very low TDS and is slightly acidic. As the wet season *runoff* component of flow into the rivers decreases, the relative proportion of *groundwater discharge* into the rivers increases, reaching 100% by the mid to late dry season. The water chemistry therefore becomes higher in TDS and *pH* as the dry season progresses.

Plate 11 Clear spring water in a creek in Cobourg Peninsula

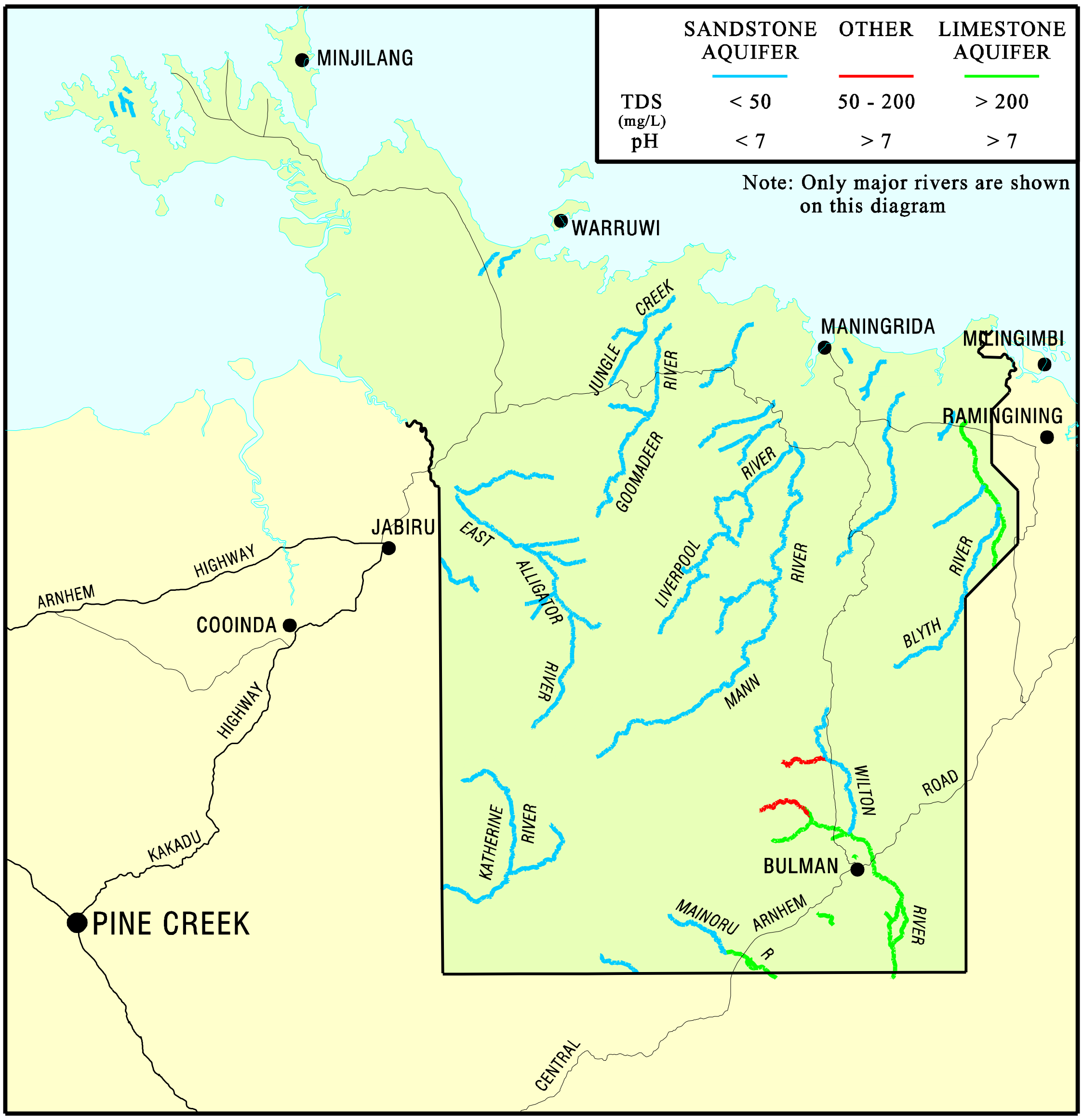


Figure 18 Chemistry of Dry Season River Flows

5.3 Sinkholes

Plate 12 **Ann at sinkhole**

Sinkholes are a common surface feature of limestone or karstic aquifer systems. They are widespread in the Dook Creek Formation *aquifer*. A sinkhole is a localised sinking of the land surface caused by the dissolution of the underlying rocks. They can form as depressions or more dramatically as cavern systems. Sinkholes are a natural feature, but many collapses can be induced by changes of land use causing changes in the water table or drainage system. Sinkholes can act as a pathway for rapid *recharge* to the underlying *aquifer*.

6.0 SUSTAINABILITY OF WATER SYSTEMS

Water levels in bores, springflows and *baseflow*s in rivers are all directly related to the *recharge* of the *groundwater* system. In this region, rainfall is quite variable, with a pattern of wet and dry periods being normal. *Recharge* amounts vary with rainfall, hence a knowledge of past climatic variations is essential in determining the variability in water levels and *baseflow*s, and therefore determining if usage from bores and river *baseflow*s can be maintained.

The term *Sustainable* Yield is used to describe the amount of water which can be extracted from a resource without a long term adverse effect on the environment or the resource.

6.1 Sustainability of aquifer systems

🟦 LOTS OF WATER / LARGE SUPPLY

This *groundwater* resource category contains two different types of *aquifers*, one sandstone and one dolomitic type *aquifer*.

The dolomitic *aquifer* lies in the south east of the mapped area and consists of the Dook Creek Formation. In this region the *aquifer* is largely undeveloped, and from a water resources aspect, appears to have great potential for *groundwater* abstraction and development. There is no long term water level record from bores drilled into this *aquifer*. However, several rivers and *springs* receive continuous *baseflow* from this *aquifer*, which is sustained during dry periods, suggesting a large volume of *groundwater* in storage in the *aquifer*. Some of these *springs* and rivers include Mt Catt Spring, Lindsay Spring, Weemol Spring, the creek near Galparran and Guyuyu Creek. Water supplies at Bulman and the surrounding outstations are sourced from this *aquifer*, and there is no evidence of any local impact on *water table* levels due to abstraction.

Plate 13 Lindsay Spring

Sandstone type *aquifers* lie in the north. In the Maningrida area the high yielding *aquifer* consists of the Marchinbar Sandstone. *Groundwater* investigations around Maningrida have identified two *aquifers* in the Marchinbar Sandstone: an upper unconfined *aquifer* and a lower *aquifer* locally confined by a clay band. The lower *aquifer* is the high yielding *aquifer* and its *sustainable* yield has been assessed in the order of 1.5 million cubic metres/year (equivalent to 47 l/s) for an area of 10 sq km. Around Maningrida the depth to this *aquifer* is around 100 m. Bores typically yield around 10 l/s. This gives and indication of what this *aquifer* can yield across its wider region. In the upper *aquifer* typical *yields* are in the order of 5 l/s which is suitable for a homeland supply.

In the Murgenella region the *aquifer* consists of poorly *consolidated* sandstone namely the Marligur Member of the Bathurst Island Formation. For a number of the bores drilled in this *aquifer* artesian conditions were encountered ie the water flowed freely from the bore without the aid of a pump. Flow rates varied from 19 l/s at Murgenella Plains Outstation to a few litres per second at Wauk. As shown in Figure 6 the *aquifer* decreases in its thickness and increases in its depth from South to North. At Bunigumbalag, on the north coast, artesian conditions were not encountered but the *standing water level* came close to the surface (0.1 m below surface). Here the *aquifer* was only 8 m thick and pumping was *sustainable* at 0.7 l/s. Hence the *aquifer* has great variation in its bore yield depending on where a bore is sited. Certainly the *aquifer* shows it may have a vast supply and good *sustainable* yield.

There has been little investigation drilling undertaken in the sandstone *aquifer* around Jungle Creek however one bore drilled yielded a significant supply of 10 l/s. It is anticipated that the *baseflow* in Jungle Creek is maintained by this *aquifer*. As flow in Jungle Creek has been measured at its downstream end in excess of 600 l/s in the late Dry Season, this *aquifer* shows great potential as a major resource in the region. Similarly, although no drilling has occurred in the Malgawa area south of Maningrida, the good discharges from *springs* in the area indicate that a high yielding *aquifer* exists in *Cretaceous* sandstone sediments. *Springs* in this area are generally aligned with fractures.

Plate 14 Airlifting 10 l/s at the bore near Jungle Creek

🟩 HOMELAND SUPPLY

🟩 SMALL HOMELAND SUPPLY

🟧 MINOR GROUNDWATER RESOURCES

All other areas outside of the main ‘large supply’ *aquifer* types have limited resources available. Some of the *aquifers* may have large amounts of *groundwater* in storage, but the low *permeability* of the *aquifer* means that bore abstraction rates are low, and pumping *drawdown*s may be large. Overpumping may lead to bore failure and even damage the *aquifer*. In some areas yield is substantially increased by the presence of fractures. Locating fractures can require specialist advice and equipment and even then success is variable.

Other *aquifers* may have higher *permeability*, but their limited extent means that there is little water in storage, and bores tend to fail by the end of each Dry season. If the *aquifer* is able to *recharge* during the subsequent Wet season, then bore performance should return to normal.

Conservation values must be carefully considered before planning any significant development based on *groundwater* availability. Inappropriate bore locations and pumping rates have the potential to seriously impact upon natural *groundwater discharges* such as *springs* and creek flows. There are many examples of *groundwater* dependant ecosystems in this region, such as rainforest pockets and *perennial* waterholes. Many of these could be impacted by inappropriate siting of bores, for example bores located too close to the margins of the *Cretaceous Aquifer*, or by overabstraction of *groundwater*.

Plate 15 Rainforest and creek at Cobourg Peninsula

7.0 ABORIGINAL KNOWLEDGE

The aims of this study were not only to provide a scientific assessment of *groundwater* and surface water in the region, but also to include traditional Aboriginal knowledge about water occurrence and significance. In undertaking a cross-cultural study, it is hoped that common understandings will develop between Aboriginal people and land managers about water in the region.

During the course of the study, many Aboriginal people from the communities and outstations provided extensive help with locating water sites such as *springs*, and also invaluable knowledge about their historical behaviour.

Plate 16 Eric and Neville talking with Ursula about water in their country

In order to make the map as accessible as possible to local people as well as land managers, many language placenames and country names were documented. Where appropriate, these have been included on the map and other products, in addition to language names previously documented by other researchers.

This information remains the intellectual property of the West Arnhem people, and has only been reproduced with their permission.

7.1 How information was gathered

On most field trips, CNRD officers were accompanied by Traditional Owners or their representatives, who imparted their knowledge on water resources and placenames, either during site visits, or during group discussions. Discussions and visits were aided by the use of reference material such as satellite imagery, aerial photographs and topographic maps. Information was recorded in written notes and occasional tape recordings and video. Placename locations were recorded onto working maps directly, or with the use of a GPS unit (Global Positioning System). At all times when collecting names and data, it was made clear that this information would be public, and so culturally sensitive information was never recorded.

Plate 17 **Djelk Rangers, Russell, Stuart and Winton in the Blyth River catchment.**

7.2 Where the information is recorded

A separate report has been written titled 'Water Resources of West Arnhem Land, Aboriginal Knowledge'. This report contains Aboriginal knowledge collected during field trips as well as information that has been recorded by various community organisations. The data consists largely of placenames and their location. Some of these placenames, where appropriate, have been recorded on the Water Resource Map and are also included in the *GIS* version of the map.

Cultural and historical knowledge recorded on video tape has been transformed into digital format and is included in the photograph collection available on CD.

Posters have also been produced for the islands, which explore Aboriginal as well as scientific knowledge.

8.0 WATER RESOURCE DATA – FORMAT, LOCATION AND AVAILABILITY

The Water Resource Maps that accompany this report were produced by the NSD, and is stored in digital form as a MicroStation "Design File". This can be reprinted at any time, and is available to interested parties. The data is also available on a CD-ROM as ESRI shape files and can be viewed using the program ArcExplorer which is also included on the CD. This effectively forms a *GIS* in which individual components of the map can be viewed and manipulated.

A report has also been compiled titled 'Water Resources of West Arnhem Land – Technical Data'. This provides a bibliography of all NSD reports relevant to this area, a summary of all bores, *water quality* data, and information on surface water sites such as *gauging stations* and rainfall stations. This data is also available in digital format on CD-ROM.

As mentioned earlier, a report titled 'Water Resources of West Arnhem Land – Aboriginal Knowledge' has been written. This is also available on CD.

A photographic collection and some video footage was built up during this project. All photographs have been scanned and available in digital format. A selection of photos and some digitised videos are on the CD-ROM.

All reports and maps are also available digitally in ***.pdf*** format, to be read by Adobe Acrobat Reader.

Copies of bore reports are held by NSD in Darwin in both digital and paper form, and are available on request by quoting the RN (registration number). This data, along with digital versions of many of the NSD's reports are available via the Internet.

Detailed information on NSD gauging and rainfall stations is kept on the 'HYDSYS' database. This includes river height, flow data and *water quality* data, and is available on request.

9.0 ACKNOWLEDGEMENTS

This project was funded jointly by DIPE and NHT. ATSIC provided funds towards drilling investigations and the NLC contributed with liaison.

The author would like to thank her fellow staff who provided help on this project: Peter Jolly, who instigated this project; Linton Fritz and Jeff Fong for the cartography and to the following people for their assistance and/or field support : Anthony Knapton; David Williams; Aya Matsuyama; Tho Tien; Steve Tickell; Jennifer Harlock; John Scott; Trevor Haig; Des YinFoo; Peter Waugh; Gary Humphries; Roger Farrow; Bill Panton; Erin White; Dave George; Kate Richardson; Ross Sinordin and to Peter Garone and the Technical Services Section who undertook the drilling operations.

The author would also like to thank the Homeland resource centres, Community ranger groups and Parks and Wildlife rangers for their assistance with this project.

This work would not have been possible without the assistance and knowledge of the many Traditional Owners and their families who were involved throughout the project. I thank them with respects.

Plate 18 NSD staff and locals undertaking a flow gauging together

10.0 FURTHER WORK

This project has compiled existing data and new data to give an overview of the water resources of the West Arnhem Land Region. It is not to be used as a final detailed water resources study for potential developments, but as an information source to allow land managers to take water resources into consideration during initial land management planning.

Water resources availability estimates are being constantly updated by the NRD as more data is collected each year. The following further work is recommended in order to refine these calculations and more comprehensively understand the resource and its dynamics.

Improved low flow ratings for the major river *gauging stations*

Further late Dry season flow gaugings to better define minimum flow

Total water balances for *aquifer* systems

Further develop models relating rainfall with river flow

Establishing *Environmental Flows* for all rivers and *springs*, incorporating conservation values

In the course of gathering data for this project a determined effort was made to use the wealth of local knowledge from the traditional owners. However there is still more work to be done in this area, especially in documenting place names correctly and describing water resources in terms of Aboriginal culture and their links to the land.

Plate 19 Freshwater wetland near Angularli Creek

11.0 REFERENCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, 1975. *1:250 000 Geological Series Cobourg Peninsula – Melville Island.* Bureau of Mineral Resources, Geology and Geophysics, Department of Minerals and Energy.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, 1983. *1:250 000 Geological Series. Alligator River.* Bureau of Mineral Resources, Geology and Geophysics, Department of Minerals and Energy.

GEORGE, D., 2001. *Water Resources of the Katherine Region and South West Arnhem Land.* Department of Lands, Planning and Environment, Natural Resources Division, Report No 28/20001D.

JOLLY, P. D. GEORGE et al 2000. *Analysis of Groundwater Fed Flows for the Flora, Katherine, Douglas and Daly Rivers.* Department of Lands Planning and Environment, Natural Resources Division, Report 36/2000D.

NORTHERN TERRITORY GEOLOGICAL SURVEY, 1997. *1:250 000 Geological Series, Milingimbi.* Northern Territory Geological Survey, Department of Mines and Energy, Darwin, Australia.

SWEET . I.P., et al, 1999. *1:250 000 Geological Series. Mount Marumba*. Australian Geological Survey Organisation, Canberra.

TYSON, P. et al. 1991. *Maningrida Groundwater Resource Evaluation.* Power and Water Authority, Report 39/1991.

VERMA, M. N. 1992. *Bulman Groundwater Resource Evaluation*. Department of Lands Planning and Environment, Natural Resources Division, Report 57/91.

ZAAR, U. , G. PROWSE & I. MATHEWS 1999. *Water Resources of East Arnhem Land.* Department of Lands Planning and Environment, Natural Resources Division, Report 02/1999D.

12.0 GLOSSARY OF TERMS

Airlift Yield: The rate at which water is extracted from a bore with compressed air as drilling takes place.

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 a stream. Baseflow often maintains the flow in a stream over the Dry season.

Catchment: Area in which rainfall collects to form the supply of a river.

Chert: Very hard and brittle rock that is often fractured. Associated with quartz.

Confined aquifer: An aquifer that occurs beneath an impermeable layer. The amount of water available for abstraction from this type of aquifer is lower than an unconfined aquifer.

Consolidated: Any process whereby soft or loose earth materials become firm, for example the cementation of sand or the compaction of mud.

Cretaceous: A geological time period from 65 to 144 million years ago. This is the age of the rocks that form one of the major sandstone aquifers in the study area.

Current meter: A device for measuring water velocity, consisting of a propeller that turns at a rate dependent on the water's velocity.

Drawdown: The lowering of the water level of a well as a result of the withdrawal of water.

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 microseimens 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.

Gauging station: Site on a stream where direct observation of water velocities, heights and volumes are made and recorded. *Pictured – gauging station recording river height.*

Geology: science of earth's crust, rocks, strata etc

Geographical Information System (GIS): A computer system that allows the storage of data so that it can be viewed and accessed using a computerised map.

Geophysics: The use of specialised surveys to give an indication of underlying rock type. Techniques such as *magnetics, gravity, elctro-magnetics*, and *seismics* can be used on the earth's surface in order to indicate geology.

Groundwater: Subsurface water contained in aquifers.

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. Results in increased quantities of soaps necessary to lather.

Hydrogeologist: A geologist who studies the relationship between geology, groundwater and surface water.

Hydrograph: A graph that shows water levels or flow in a stream, or the watertable level in a bore.

Impermeable: An impermeable soil, rock or sediment is that in which fluid (water) is unable to pass through.

Karst: A network of caves and fissures that form in a limestone or dolomite rock.

Laterite: A residual rocky material formed through prolonged weathering, probably under warm, wet conditions.

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

Perennial: A stream, lake or waterhole which retains water throughout the year.

Permeability/Permeable: The ability of water to move through soil or rock.

pdf: A file format that allows reports and maps to be viewed using the software package Adobe Acrobat

pH: A measure of acidity (low pH) or alkalinity (high pH). A pH of 7 indicates neutrality - non corrosive to metal.

Potable: Water that is fit for human consumption

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

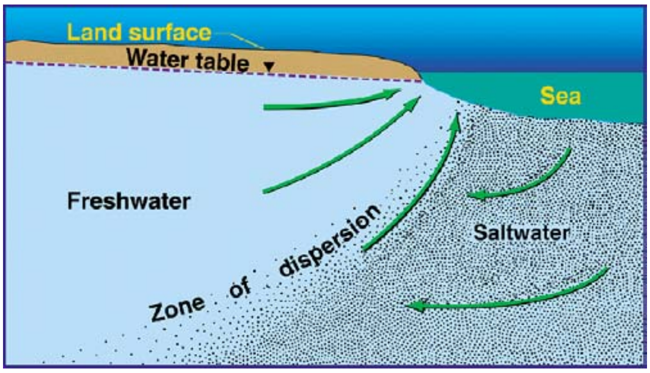
Porous: Containing pores and able to absorb water, air or other fluids.

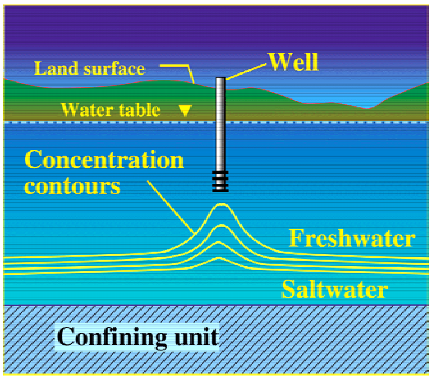
Recharge: Addition of surface water to an aquifer to become groundwater.

Runoff: Rainwater that leaves an area as surface flow.

Salinity: The degree to which water contains dissolved salts.

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





Diagrams from: http://water.usgs.gov/ogw/gwrp/saltwater/salt.html http://water.usgs.gov/ogw/gwrp/saltwater/fig4.html

Satellite Imagery: Digital ‘photographs’ taken from satellites orbiting the Earth in space.

Spring: Outflow points for groundwater where the watertable is near or above the ground surface.

Standing Water Level: The level below ground surface, to which groundwater rises in a bore.

Sustainable: maintain (without adverse effect)

Topography: The shape and height of the land surface.

Turbidity: Relative measure of the clarity of the water. The greater the turbidity, the murkier (muddier) the water.

Total Dissolved Solids (TDS): A measure of the salinity of water, the amount of salt dissolved in the water, usually expressed as milligrams per litre.

Water table: Level of the surface of the groundwater. It is often measured in observation bores.

Water quality: Physical, chemical biological characteristics of water and how they relate to it for a particular use.

Water Year: In the NT, the water year splits the year from October of one year to September of the next year. This is so that the total Wet season rainfall is accounted for.

Wetland: Land which remains wet for a large part of the year.

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