N.T. WATERWATCH
EDUCATION KIT

Part 7
Groundwater in the Northern Territory

NT WATERWATCH EDUCATION KIT

GROUNDWATER IN THE NORTHERN TERRITORY

WATERWATCH
Northern Territory

WATERWATCH
Australia
A program of the Natural Heritage Trust

Northern Territory Government
Department of Infrastructure, Planning and Environment

Natural Heritage Trust
Helping Communities Helping Australia
A Commonwealth Government Initiative

NT Waterwatch Education Kit. Part 7: Groundwater in the Northern Territory. Edited by Jennifer Harlock.

Published by Department of Infrastructure, Planning and Environment (DIPE)
PO Box 30
Palmerston NT 0831
Tel: 08 8999 4456
Fax: 08 8999 4445
Website: www.DLPE 2003.nt.gov.au/waterwatch

The information in this publication has been published by DIPE to assist public knowledge and discussion and to help improve the sustainable management of water.

Publication data

Harlock, J. (ed) 2003, NT Waterwatch Education Kit. Part 7 Groundwater in the Northern Territory, Department of Infrastructure, Planning and Environment, Darwin.

ISBN 1920 772 12X

Cover by Jennifer Harlock and Geraldine Lee

Funding provided by The Natural Heritage Trust and Department of Infrastructure, Planning and Environment.

TABLE OF CONTENTS

LIST OF PLATES

TABLE OF FIGURES

ACTIVITES

STUDENT SHEETS

Groundwater in the Northern Territory

Introduction

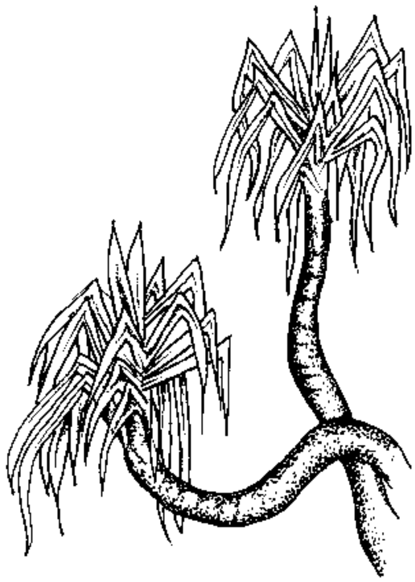
Groundwater is the largest accessible source of freshwater on Earth. Large quantities of groundwater are extracted each day from aquifers in the Territory to supply towns and communities, stock, domestic rural needs, mining and irrigation. In addition to meeting the need of people in the Territory, groundwater also plays a critical role in sustaining ecosystems, such as vegetation communities and wetlands.

With increased development in the Territory comes increase demand for groundwater and an increase in the risks to groundwater quantity and quality. Appropriate use of groundwater and limiting the potential impact of human activities on groundwater supplies will help ensure the availability of uncontaminated groundwater to meet the needs of the community and the environment.

Rationale

An understanding of groundwater formation, movement, storage and the needs of the community and environment are crucial when considering the management of groundwater resources.

Groundwater monitoring is an important aspect of groundwater management. Changes in groundwater levels and chemistry help to assess the impact of human activities on groundwater and subsequently the environment.



Groundwater

Groundwater is water that is stored below the Earth's surface in openings or voids in rocks and between grains of sand and soil.

It is part of the hydrological cycle, the continual movement of water from the atmosphere to the earth and back to the atmosphere via precipitation, evaporation, transpiration, run off and infiltration (DWR 2000). Precipitation that falls to the ground can either enter bodies of surface water, run off the land, be evaporated or soak into the ground.

Excess water not utilised by plants continues to move downwards through empty spaces or cracks in the soil, sand, or rocks until it reaches a layer of rock through which water cannot easily move. The water then fills the empty spaces and cracks above that layer. The top of the water in the soil, sand, or rocks is called the **water table** and the water that fills the empty spaces and cracks is called **groundwater** (Clark and Brair, 1993).

Water that reaches the groundwater is known as recharge. Recharge can occur from rain or from water seeping through the beds of rivers, lakes or swamps (DIPE, 2003).

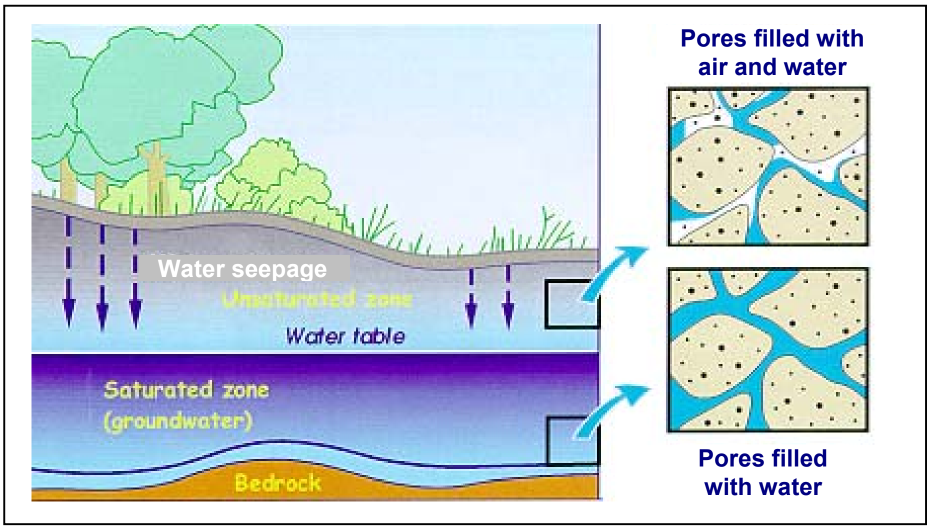


Figure 1 Recharge to groundwater (Source: DWR 2000)

See Activity 1 and 2 (p 25-26)

Aquifers

A common misconception is that groundwater occurs in underground rivers or lakes. In some areas underground streams are found in limestone caves, however, in most cases water is stored in empty spaces and cracks in soil, sand or rock (DIPE, 2002).

The term 'aquifer' describes porous rock or soil layers capable of storing and transmitting significant amounts of water. The geology of an aquifer controls the volume of water that can be stored, the rate of water extraction and the rate of water movement through the aquifer.

Characteristics of Geological Material

Porosity

The measure of geological material to hold water is known as its porosity. A geological material with high porosity (more pores), is able to hold more water than a geological material with low porosity (less pores).

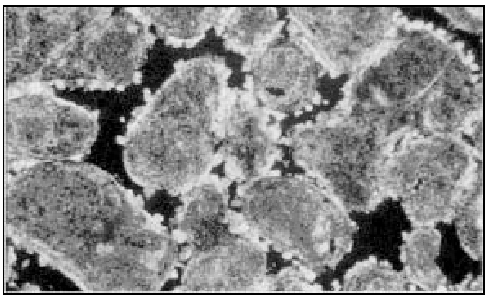


Figure 2 Microscopic section of sedimentary rock (Source DWR 2000)

Permeability

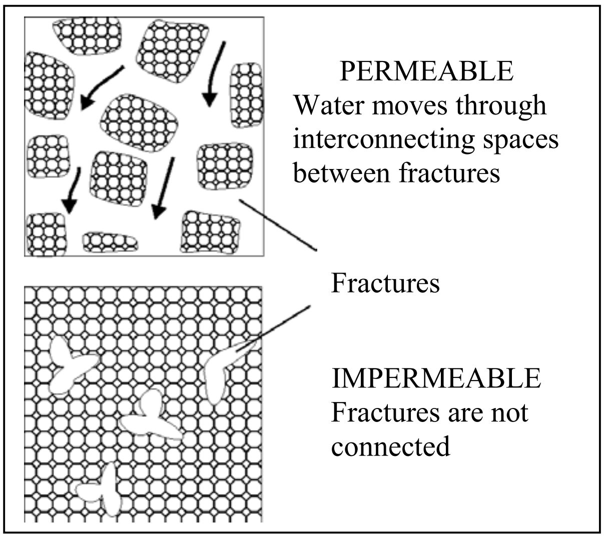


Figure 3 Permeability in rock

Permeability is a measure of the interconnecting spaces or cracks between pores that allow water to move from one pore to the next. In order to gain adequate yields the spaces and cracks must be abundant (DRW, 2000).

If the pores in a geological material are not connected, groundwater can not move from one space to another.

See Activity 3 (p 27)

Types of Aquifers

Confined Aquifer

Confined aquifers have a confining bed as their upper and lower boundary. A confining bed is a layer of geological material that is fully saturated, all spaces in the material are completely filled with water. However, poor porosity and/or permeability means that a confining bed can not provide a useable amount of water (DWR 2000).

Confining beds that are saturated and allow water to move vertically through them are known as **aquitards**, for example a silty clay or silt which have high porosity and some permeability. These layers are important sources of recharge to underlying aquifers. Confining beds that are saturated but do not allow water to pass through vertically are known as **aquicludes**, for example clay that had high porosity and low permeability. Confining beds that neither contain nor allow water to pass through them as known as **aquifuges**, for example solid granite that has no porosity and no permeability (DWR 2000).

Confined aquifers are recharged where they are exposed at the surface and from leaky confining beds (aquitards) (DWR 2000). Due to the confining beds, confined aquifers are under higher pressure than unconfined aquifers. When a bore is drilled in a confined aquifer the high pressure causes the water level in the bore to rise above the level of the confining layer. The level to which the water rises is known as the potentiometric surface (DWR 2000).

Confined aquifers are also known as artesian aquifers, where the water level in a bore that has been drilled into the confined aquifer rises above the surface of the ground (DWR 2000).

Unconfined Aquifers

Unconfined aquifers have an underlying confining bed and the water table as an upper layer. The water table in an unconfined aquifer is able to rise and fall. If a bore is drilled within an unconfined aquifer, then the water level in the bore will rise to the same water level as the water table (DWR 2000).

The capillary zone is located above the saturated zone. The spaces in the rock, sediment or soil in this zone contain air and water. The water is drawn upwards from the water table by the action of capilliarity. Capillary action is important for moving water and all that is dissolved in water. Capillary action in the sub surface works in much the same way as if we were to dip a paper towel into a container of water, the water will creep up the paper towel until it is overcome by the force of gravity (DWR 2000).

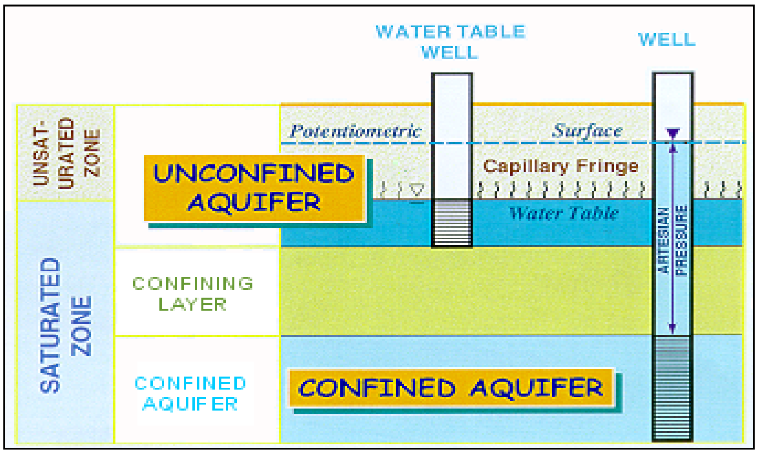


Figure 4 Unconfined and confined aquifers (Source: DWR 2000)

Perched Aquifers

A perched aquifer occurs where there is a confining layer with low permeability and of limited size. It is located above the water table within the unsaturated zone. This layer will trap water as it percolates downward and forms a /limited layer of water, also called a lense. It may only be ten centimetres thick or it may hold a useable amount of water (DWR 2000).

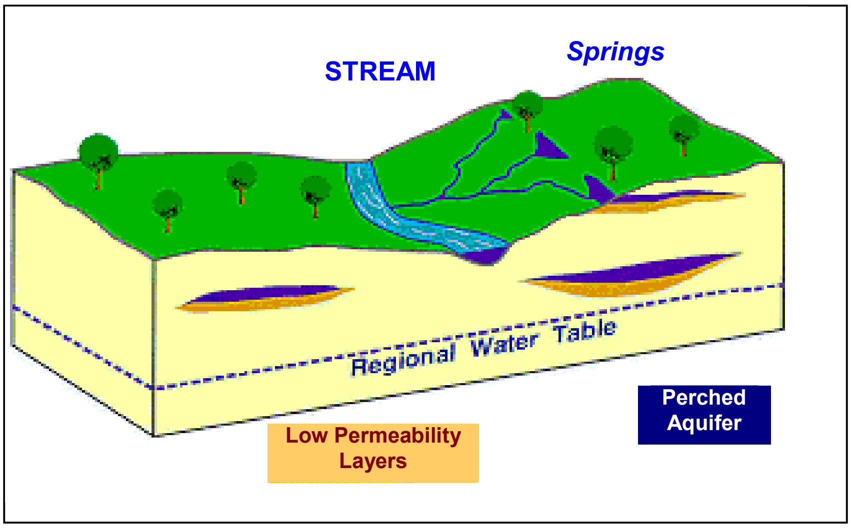


Figure 5 Perched Aquifer (Source: DWR 2000)

See Activity 4 and 5 (p 29-30)

Aquifers in the Territory

The majority of aquifers in the Northern Territory are fractured rock aquifers, which feature hard rocks, such as granites, basalts, shale and quartzites. These aquifers store water within fractures that have formed in the rock by tectonic movement (DIPE 2002). In contrast, softer rocks, such as limestone and dolomites, may develop cavities within them because water can dissolve the rock (DIPE 2002).

Sedimentary aquifers consist of loosely cemented grains of sand and the water is held in the voids between the sand grains. This is the case for the Mereenie Sandstone from which water is pumped to meet Alice Springs water supply needs (DIPE 2002).

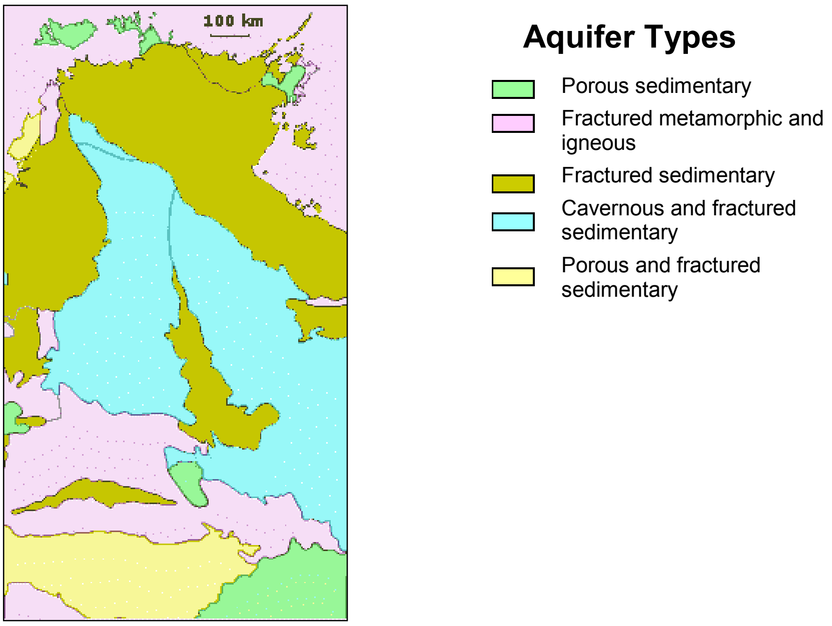


Figure 6 Aquifers in the NT

See Activity 6 (p 31)

Groundwater – a Natural Resource

Of the freshwater found on Earth, the majority is frozen in ice-caps and glaciers, while approximately 25% is stored as groundwater. Surface water represents less than 1% of the world's fresh water (DWR 2000).

Groundwater is used throughout Australia and overseas as a source of domestic, rural and industrial water. Groundwater is also part of the hydrological cycle and interacts with streams, lakes and wetlands.

Groundwater Resources in the Territory

Groundwater supplies 90% of the Territory's water supply. Some 30 000 bores have been drilled for pastoral/stock bores (40%), rural domestic (20%), water resource investigation (20%), town and community supplies (10%), mining (5%) and construction/roads/irrigation (5%) (DIPE 2002).

Darwin and surrounding areas

The Darwin water supply utilises a mixture of surface water obtained from Darwin River Dam and groundwater from the McMinns Borefield. Located 25km southeast of Darwin the McMinns borefield supplies up to 10% of Darwin's water. Some 15 million litres of groundwater are extracted per day from the aquifer situated in Proterozoic (1800 million years) aged dolomite (DLPE 2003).

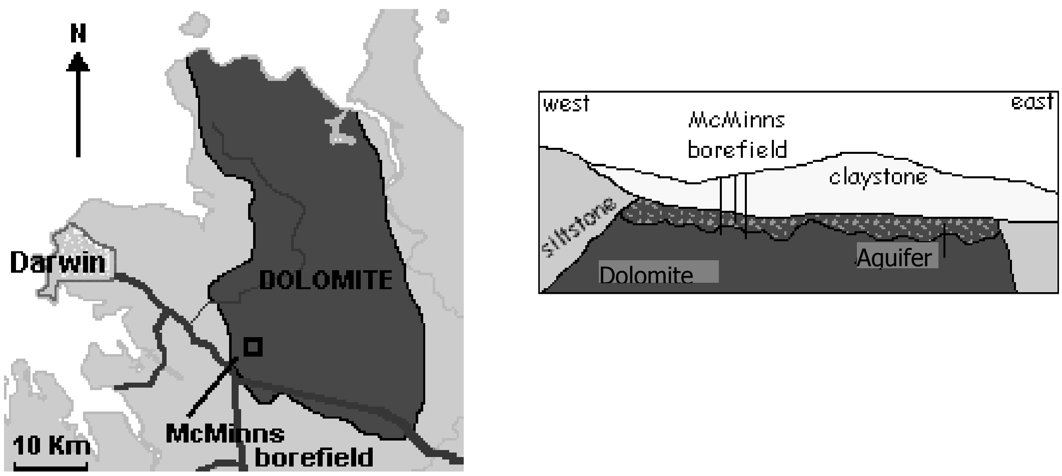


Figure 7 The McMinns Borefield

Palmerston

Palmerston receives the same water supply as Darwin. A groundwater resource exists in an aquifer located below the western and southern suburbs of Palmerston. This groundwater resource is tapped by a number of production bores and is used for irrigating parks and ovals and for occasionally topping up Marlows Lagoon in the dry season.

Katherine

In Katherine, 40% of water consumed annually is sourced from groundwater. Groundwater is extracted from a borefield located 3km east of the town and used to supplement the water supply from the Katherine River. Blending the surface water with groundwater increases the groundwater's pH, making the water less corrosive to pipes, the hardness of the groundwater (measurement of calcium and magnesium) limits the proportion of groundwater that can be used (DLPE 2003).

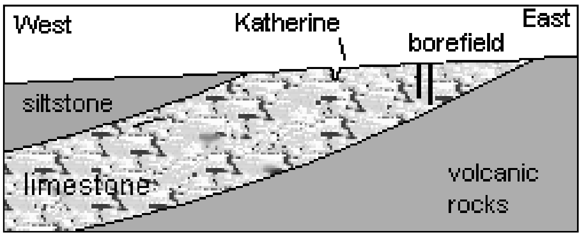


Figure 8 Geology of the Katherine Borefield

The aquifer tapped by the bores is a limestone formation at the base of the Daly Basin, an extensive sedimentary basin formed some 500 million years ago. It is cavernous and is connected to the Katherine River, which cuts into it. Springs in the riverbank at Katherine, discharge groundwater when the river level is low but during floods the river water flows back into the aquifer (DLPE 2003).

Tennant Creek

Surface water is scarce so the town's water supply is drawn from a borefield at Kelly Well 20km south. The bores tap an aquifer consisting of a hard rock composed of silica. The aquifer was developed by soil formation probably under wetter conditions than those of the present day. The rock is both riddled with cavities and is fractured, making it a productive aquifer. The borefield consists of some 10 bores, averaging 40 metres deep and each capable of pumping 6 litres per second (DLPE 2003).

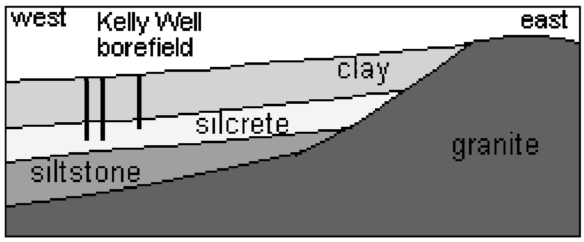


Figure 9 Geology of the Kelly Borefield

Alice Springs

All of the town's water is supplied from groundwater. In the past groundwater has been accessed through waterholes and shallow wells. Currently, Alice Spring obtains its water supply from the Roe Creek Borefield situated in the Mereenie Sandstone, which is part of the Palaeozoic (350-500 million years) aged Amadeus Basin. The town's production bores are typically 200 metres deep and pump 80 litres per second (DLPE 2003).

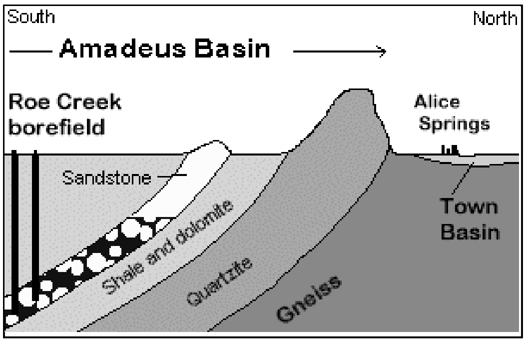


Figure 10 Geology of Roe Creek Borefield

See Activity 7 and 8 (p 32-35)

Groundwater Movement

The permeability and porosity of an aquifer influence groundwater movement from areas of high elevation to areas of low elevation in response to gravity. Groundwater movement is slow, ranging from a metre a day to a metre a decade.

Groundwater and surface water are fundamentally interconnected. In fact, it is often difficult to separate the two because they “feed” each other. This is why one can contaminate the other (Simmons 1998). As part of the hydrological cycle groundwater moves from areas of recharge to areas of discharge, such as lakes, rivers, streams, springs, wetlands or the ocean.

Groundwater – Surface Water Interactions

Seepage is generally defined as the movement of water between the groundwater aquifers and the surface water bodies. There can be two such movements. The water may move from a stream into the ground or it may move into a stream from the ground. Depending upon whether the water is entering the stream or going out of the stream, it is either called an *effluent (gaining)* stream or *influent (losing)* stream respectively. The same stream may behave as an effluent stream as well as an influent stream with changing seasons (Simmons 1998).

In dry conditions when the water level of a river is lower than the level of the water table, a flow will start from the water table into the stream (effluent) due to the difference in hydrostatic pressure between the water table and the stream. This groundwater inflow continues until the two water levels reach equilibrium (Simmons 1998).

During rainy seasons, when surface runoff occurs, the water table as well as the river will rise. However, the rise in the river water level will be much more than the corresponding rise in the watertable. When this occurs there is greater hydrostatic pressure in the stream than in the water table, groundwater inflow into the stream stops and water now moves from the stream (influent) into the ground. The flow continues until the water in the river is lower than the watertable. As soon as this happens, flow reverses again and the groundwater inflow starts (Simmons 1998).

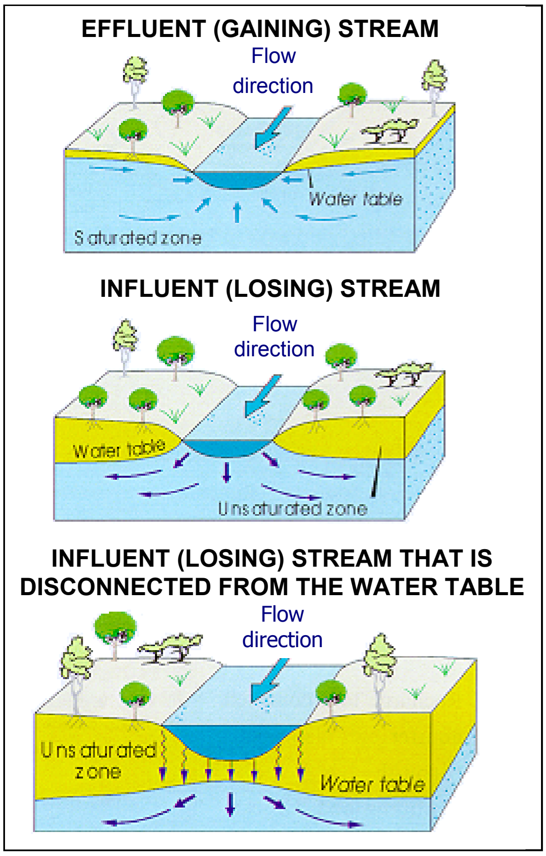


Figure 11 Groundwater-surface water interactions (modified from DWR 2000)

Groundwater and the Environment

Rivers, Streams and Springs

Groundwater plays a significant role in supporting a range of ecosystems but this link is poorly understood (DWR 2000). As previously discussed, groundwater and surface water are interconnected, making groundwater an important factor in supporting ecosystems in rivers and streams. Groundwater also provides springs in the Territory, such as Berry Springs and Mataranka Springs, with a continuous supply of freshwater.

Mataranka Springs

Located east of the town of Mataranka, about 100km south east of Katherine, the area features a series of springs along a 3km stretch of the Roper and Waterhouse Rivers. Rainbow and Bitter Springs are the most accessible in the series. Locally referred to as "thermal springs" the water emerges at 32 degrees Celsius, an average temperature for groundwaters in the northern part of the Northern Territory.

The springs are supplied by the Tindal Limestone aquifer of the Daly Basin. The aquifer is unconfined, groundwater moves from the fractures and cavities in the aquifer to the rivers. Rainbow Spring emerges from a small cave in the limestone and then flows into the thermal pool. Bitter Springs does not have a localised discharge point but it consists of several hundred metres of swampy palm forest with diffuse seepage to the river (DIPE 2003).

Plate 1 Rainbow Spring

See Activity 9 and 10 (p 36-37)

Terrestrial Vegetation

Terrestrial vegetation may depend to varying degrees on the diffuse discharge (root uptake) of shallow groundwater, either to sustain transpiration and growth during dry seasons or for the maintenance of perennially lush ecosystems in otherwise arid environments (Barber, 2001).

Palm Valley

Palm Valley is an oasis in an arid area with a rainfall of only 200mm per year. Located in the Finke Gorge National Park, the valley is a low gorge with a series of springs along its floor. The spring water supports a diverse range of plant species, many of which are rare and unique to the area, including the Red Cabbage Palm (*Livistonia mariae*). Some tens of millions of years ago when the climate was wetter than it is today, such vegetation were widespread. The preservation of these remnants is due to the existence of these springs over a vast time span (DLPE 2003).

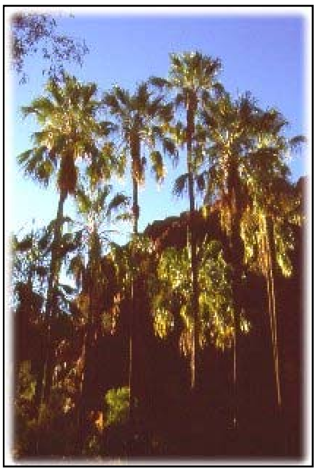


Plate 2 Palm Valley

The springs are a discharge point for groundwater in a fractured sandstone aquifer. The rocks are part of the Palaeozoic aged Amadeus Basin and are folded into broad arches and basins. The folding created fractures that form the aquifer and the valley itself. Water can be seen seeping from small fractures on the valley floor. Patches of lush vegetation consume most of the spring water, only a small proportion reaches the surface where it collects in small pools (DLPE 2003).

Aquifer Ecosystems

The hypogean (subterranean/underground) habitat represents the most extensive ecosystem on the planet (Humphreys 2000). Stygofauna is an all encompassing term for animals that occur in groundwater. Stygofauna can be classified into three groups; stygoxenes, stygophils and stygobites.

Stygoxenes are epigean (surface) animals that enter subterranean waters accidentally and can include insects and crustacea. Stygophils have clear affinities for the subterranean realm and actively enter ground waters spending part or all of their life in groundwater environments. Stygobites are specialised for and restricted to subterranean waters (Ward *et al* 2000).

Obligate inhabitants of groundwaters are characterised by a series of convergent morphological features termed troglomorphies (cave form) including loss of eyes, pigmentation and elongation of appendages and thus they appear white, fragile and translucent (Barber 2001). As these species have such specialised habitats they are susceptible to changes in the groundwater environment.

Groundwater dependant ecosystems are under pressure from human activity. Bores used for domestic and commercial purposes can potentially significantly lower the amount of water available and pressure in an aquifer. Groundwater resources that become depleted, polluted or saline will have adverse effects on all groundwater dependant ecosystems. Unsustainable depletion can cause natural springs to dry up. Over the last 100 years many springs within Australia have dried up, destroying various species even before they could be discovered. (DWR 2000).

See Activity 11 (p 38)

Accessing Groundwater

Groundwater is accessed by drilling a well or bore into an aquifer. Water bore drilling must be undertaken by a driller licensed under the *Water Act*. A licensed driller must meet qualification requirements set by the Australian Drilling Industry Association. A permit is required for any bore construction in a Water Control District (discussed later) (DIPE 2002).

Position of bores

It is not possible to simply look at a map and determine where a successful bore could be drilled. On some properties a successful bore is established on the first drilling attempt, and on others a number of drilling attempts may be required.

Before drilling begins landowners and licensed drillers are advised to examine the local area. Geological information can indicate the presence of an aquifer, while the extraction rates and depths of bores on neighbouring properties indicate at what depth groundwater may be reached and potential yields. Most aquifers in the Territory are fractured rock aquifers and to access stored groundwater the drilled bore will need to intercept rock fractures capable of storing and transporting groundwater.

Another aspect to be considered when positioning a bore is separation distances. There should be a separation distance of 70 metres between bores, including your neighbours. A full septic tank or poorly operating drain field allows bacteria and toxic levels of nutrients to contaminate groundwater. Absorption trenches from septic tanks should be located at least 100 metres from a bore to prevent the bore water becoming polluted by any leaks from a septic tank (DIPE 2002).

Bores

The size and type of bore sunk will depend on the material being drilled to gain access to the groundwater and how much water is to be extracted.

All bores have similar construction features. They require casing to help prevent the bore collapsing and to prevent surface water entering the bore and possibly contaminating the groundwater supply.

A bore screen is a filtering device that allows water to enter a bore via openings that have been cut in the material. A screen also prevents unwanted particles entering and clogging the pipe.

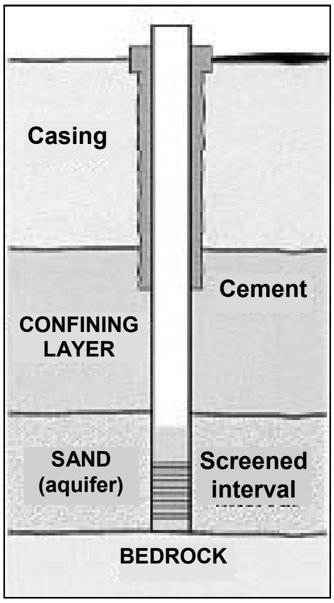


Figure 12 Diagram of a constructed bore (source DWR 2000)

Plate 3 Completed bore

A concrete block at least one metre wide and sealed to the casing should be provided around a bore. The top casing should be sealed to prevent the access of dirt, small animals and birds. If stock or poultry are kept on the property, a five metre perimeter fence should be erected around the bore.

Cone of Depression

Pumping a bore alters the direction of groundwater flow in an aquifer. When a single bore is pumped groundwater flows towards the bore forming a depression in the water table in the shape of an inverted cone. The area of land above the cone of depression is called the area of influence (DWR 2000).

The cone of depression is determined by the amount of time the bore is pumped, the aquifer material and the rate at which the bore is pumped.

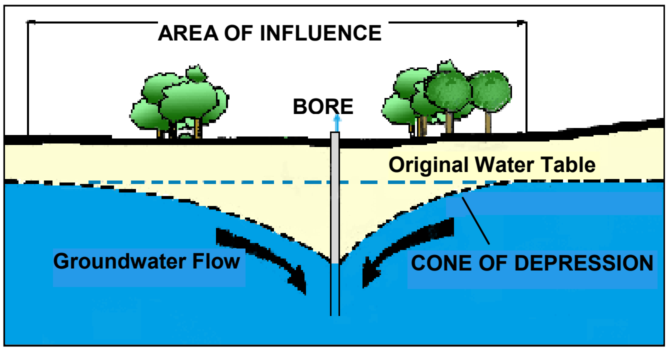


Figure 13 Cone of depression (adapted from DWR 2000)

Interference

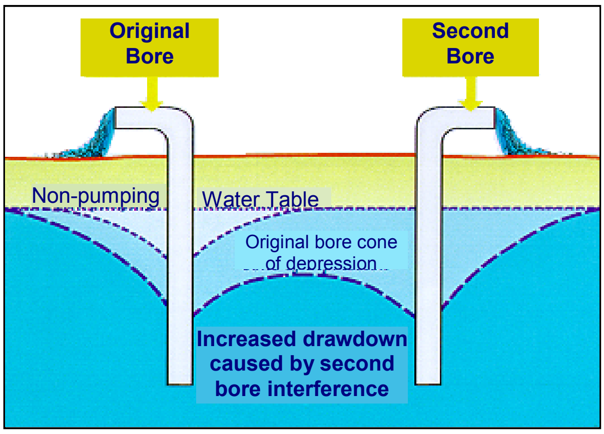


Figure 14 Interference (source DWR 2000)

A cone of depression can extend over a large area near the pumping bore. When the cone of depression from two or more bores overlap, interference occurs. Interference reduces the amount of water that is available to each bore (DWR 2000).

Water requirements for crops in the NT

The majority of crops in the Northern Territory are irrigated by groundwater. The amount of water needed to produce healthy crops will depend on a number of factors that will vary between properties, such as the species planted, number of plants, soil type and irrigation system.

Table 1 indicates the water requirements of crops grown in the Darwin and Katherine regions per year and therefore how much groundwater is extracted to irrigate crops. The figures provided however, do not take into account the above mentioned variables.

Table 2 Water requirements for major crops (DPIF 2001, pers comms)

Crop	Megalitres per hectare per annum (mL/ha/pa)	litres per hectare per annum (L/ha/pa)
DARWIN REGION		
Mango	4.5	4500000
Banana	15	15000000
Citrus	6.8	6800000
Rambutan	11.4	11400000
Carambola	8.8	8800000
Pumpkin	3.5	3500000
Asian Vegetables (general)	3.5	3500000
Rockmelon	3	3000000
KATHERINE REGION		
Mango	5.2	5200000
Banana	16.3	16300000
Citrus	7.7	7700000
Rockmelon	3	3000000

See Activity 12 (p 40)

Groundwater Management

Groundwater is a natural resource utilised by humans and the environment. Problems that arise with groundwater systems are often attributed to human activities. To ensure the continued use of groundwater with minimal impact on the environment and the availability of the resource for future generations groundwater resources need to be managed appropriately.

The use of this resource is dependent on the quantity and quality of groundwater. This section discusses major issues that relate to groundwater quality and management of groundwater quality in the Northern Territory.

Groundwater Issues

Groundwater Pollution

Despite not being immediately visible to the community, groundwater is still susceptible to pollution. Groundwater pollution is not readily detectable and problems may not become evident for many years after the pollution has occurred. Contaminated groundwater is difficult and expensive to clean up.

Groundwater pollution occurs when waste products or other substances change the chemical or biological characteristics of the water and degrade water quality so that animals, plants or humans uses of the water are affected (WRC 2003). On a smaller scale, septic tanks, stables and general household chemicals can also negatively affect groundwater quality (DIPE 2002).

Possible pollutants include heavy metals, nutrients, viruses, faecal bacteria, fertilisers, fungicides, pesticides, herbicides, hydrocarbons and other toxic chemicals.

Localised pollutant spills are known as **point sources** of contamination. In these cases the source of the pollutants can generally be identified and the pollution monitored and regulated.

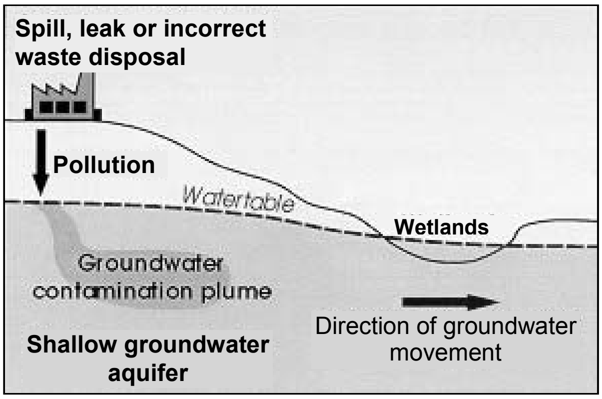


Figure 15 Point source pollution (source DWR 2000)

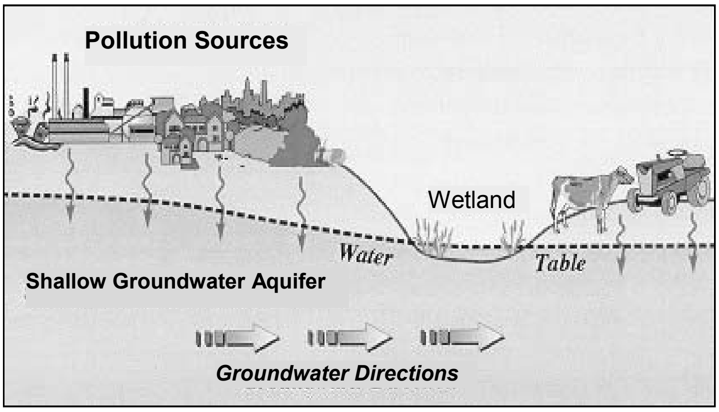


Figure 16 Non-point source pollution (Source DWR 2000)

Diffuse or **non-point sources** can also contaminate groundwater. Non-point contamination occurs over a wide area, an example is the contamination of groundwater from agricultural activities.

Salinisation

Extensive clearing and the subsequent planting of pastures and crops in parts of Australia since European settlement has altered the natural water balance. Crops and pastures use less water than the cleared native vegetation, which results in more water passing though the soil causing the watertable to rise. As the watertable rises, salts are mobilised to the surface. Through the process of evaporation salts are left behind in the soils resulting in dryland salinity.

Clearing that has taken place in the Northern Territory is considered to be minor in comparison to other areas of Australia and no occurrences of dryland salinity have yet been recorded (Tickell 1994).

See Activity 13 (p 41)

Managing Groundwater in the NT

Bores have been drilled within the NT to gain access to groundwater used to:

- meet town and community water supplies;
- meet rural domestic needs;
- water stock;
- irrigate crops; and
- in the mining industry.

Recognised as a valuable resource, groundwater management is a high priority in the NT. The Department of Infrastructure, Planning and Environment (DIPE) is involved in groundwater management and monitoring in the Territory. Groundwater management is needed to estimate how much water can be sustainably pumped from aquifers without depleting the resource.

Groundwater Investigations and Modelling

An important part of groundwater management is determining the needs of the environment and community that utilise groundwater. Information collected on rainfall, groundwater levels, recharge, pumping rates and, where known, the water needs of groundwater dependent ecosystems help to construct groundwater models.

Hydrologists use models to predict the behaviour of groundwater systems and to make management decisions for the future use of an area or catchment (DWR 2000). Using field data hydrologists can predict the impact of additional pumping on groundwater resources and any impact on the environment.

Water Control Districts and Water Allocation Plans

Water Control Districts can be declared under the Northern Territory *Water Act* in areas where there is a need for closer management to avoid stressing groundwater reserves, river flows or wetlands. Districts have been declared in the Darwin Rural Area, Gove Peninsula, and the Katherine, Tennant Creek, Ti Tree and Alice Springs regions (DIPE 2002).

Water Allocation Plans will be declared for Water Control Districts to manage water extraction to sustainable levels. The plans will allocate water resources to the types of Beneficial Uses occurring in the district. Beneficial Uses are community derived water management objectives declared under the *Water Act*. These beneficial Uses are the basis for waste discharge licences, water allocation planning and water quality planning, and include (DIPE 2002):

- Agriculture;
- Aquaculture;
- Public water supply;
- Environment;
- Cultural;
- Manufacturing industry; and
- Riparian (stock and domestic).

Monitoring Groundwater

Groundwater quality changes over times. Prolonged contact with soils, sands and rocks alters the chemistry of groundwater as minerals in these materials are gradually dissolved. Changes in groundwater quality can also be due to land use changes and excessive extraction from human activities.

Groundwater monitoring is an integral aspect of groundwater management, providing data on groundwater quantity and quality. Continual monitoring of groundwater assesses the impact of human activities on groundwater systems.

Groundwater Level monitoring in the Territory

Currently over 1 000 bores are monitored in the NT. The bores have been established to monitor groundwater quality and quantity within the Territory, tapping into the same aquifers that supply residential and production bores.

Measurements are usually taken quarterly or at least twice a year to record groundwater level before (November- December) and after (April-May) recharge has occurred. Staff from the Department of Infrastructure, Planning and Environment (DIPE) carry out groundwater monitoring. In some remote communities, (such as in Oenpelli), residents have become involved in monitoring local bores. Groundwater quality is also examined where a change in quality is suspected, however monitoring currently focuses on groundwater levels.

How are Groundwater Levels measured?

Groundwater levels are usually measured before a bore is pumped to obtain groundwater samples as pumping can temporarily alter water levels in the bore.

Groundwater levels are usually measured using a **plopper**. A plopper is a device that is essentially a tape measure with a weight attached. Measurements are taken from the same reference point on the bore each time, usually from the highest point of the bore casing.

When lowered into the bore the plopper will make a ‘plop’ sound when it comes into contact with the water. The tape is moved up and down a number of times to determine the exact level the ‘plop’ sound is heard (DA 2001).

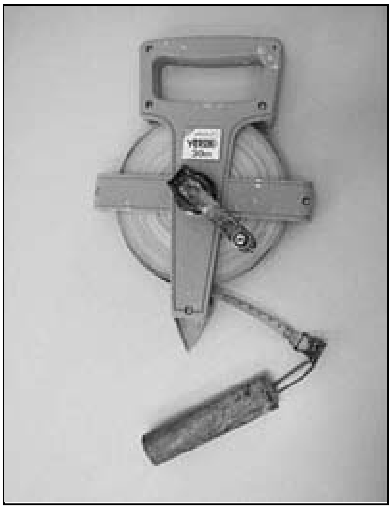


Plate 4 Plopper (Source DA 2001)

Some monitoring bores in the Territory have been fitted with automatic loggers that record groundwater levels over time. Recorded groundwater levels are entered into a database held by DIPE. The information obtained helps hydrologists determine the impact of human activities and seasons on groundwater levels.

Interpretation - Hydrograph

Groundwater level monitoring examines how local groundwater levels responds to different recharge and extraction rates during the year as demand for groundwater changes. Groundwater levels can be represented in a hydrograph. Hydrographs represent a combination of natural and human factors that influence groundwater levels.

The hydrograph in Figure 17 illustrates the level of extraction and water level recharge that occurred between 1983 and 2003. At the end of the dry season (September – October) the groundwater level is at its lowest, 12 metres below ground level. Most years the bore water level recovers to in the vicinity of 2.5 metres below ground level at the end of the wet season (April – May).

Groundwater levels from bores situated in developed and undeveloped areas can be used to compare the impact of development over time on the local groundwater levels. Bores in areas that have been developed may experience a larger drop in groundwater levels due increased extraction in the area.

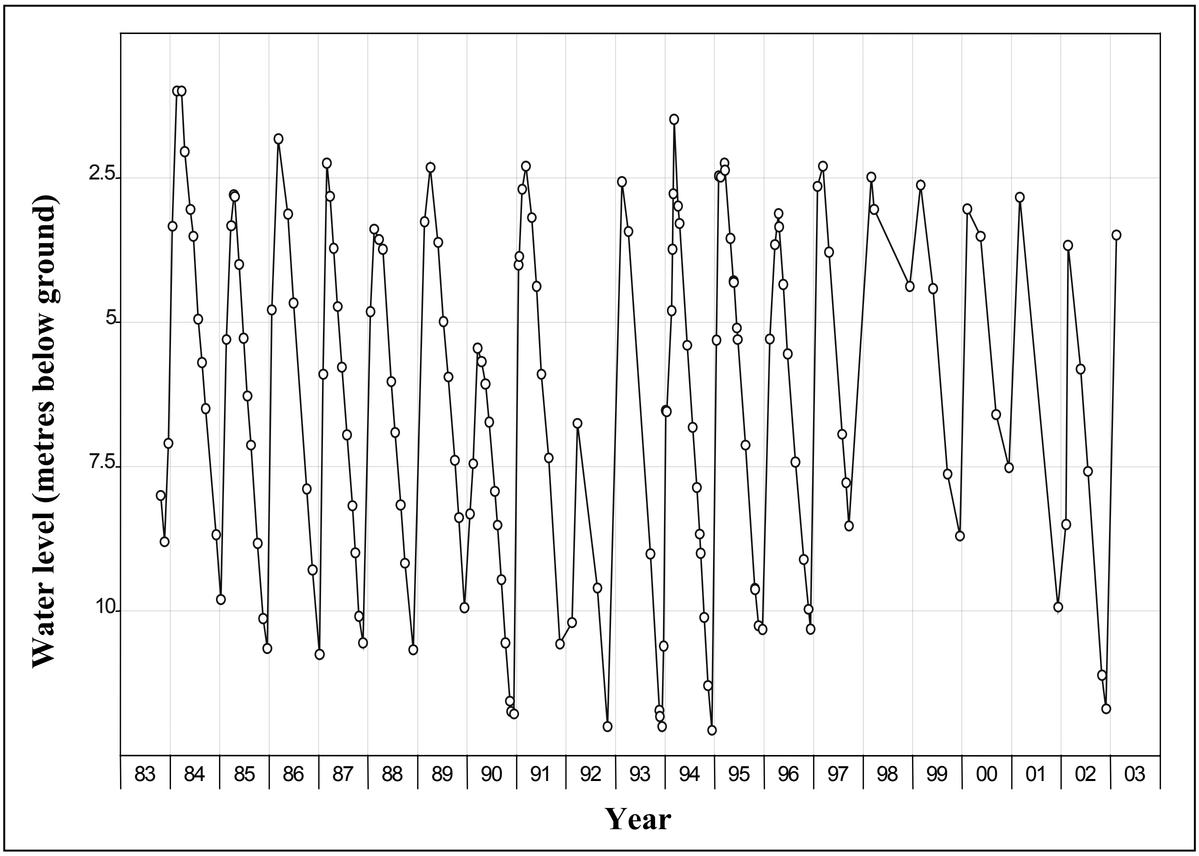


Figure 17 Hydrograph of a monitoring bore located in McMinns Lagoon area

Water Quality

pH

What is pH?

The acidity or alkalinity of water can be determined from pH readings that measure the relative concentration of hydrogen ions in the water. The pH scale ranges from 1-14, the lower the reading the more acidic the substance. A pH test can be conducted using a pH probe, paper tests or colour comparator tests.

Interpretation of groundwater pH

Determining the pH of groundwater is important in the management of bores and groundwater resources. Low pH values may indicate that the groundwater is likely to be corrosive to metals used in bore construction. Alkaline groundwater can be used to 'soften' other water supplies increase water's pH readings, as seen in Darwin and Katherine, making the water available to a wide range of uses.

Salinity

What is salinity?

Salinity is a measure of the amount of different inorganic compounds (salts) dissolved in water. Salts have various origins. Some come from dissolving minerals as groundwater travels through aquifers. Other saline groundwaters are actually seawater trapped when the aquifers were deposited in marine environments. Some salt is transported from the sea to the land in rainfall and although it is at a very diluted concentration, it is possible for these salts to build up over time (Waterwatch Queensland 1994).

Salinity can be measured two ways: using total dissolved solids (TDS) or electrical conductivity (EC). In the total dissolved solids method salinity is measured directly by filtering the sample to remove suspended solids and then evaporating the water, leaving behind the salt with small amounts of other dissolved substances. This can then be weighed. The value obtained from this test is termed total dissolved solids (TDS). It is measured as milligrams per litre (mg/L) (Waterwater Queensland 1994).

Conductivity or electrical conductivity (EC) is a measure of salinity, specifically the ability of water to conduct electricity, which is proportional to the total concentration of ions in the solution (Stanger 1998). A conductivity meter is usually used in this method and measurements are taken microsiemens per centimetre (µS/cm).

Conversions can be made between the two methods as follows (Waterwatch Queensland 1994):

$$TDS\ mg/L = 0.64 \times EC\ \mu S/cm$$

$$EC\ \mu S/cm = 1.6 \times TDS\ mg/L$$

Interpretation of salinity data

The salinity level of the groundwater will determine its possible uses. Different animals and crops have different levels of tolerance to salty waters. Some water may be unsuitable for human consumption but tolerable to cattle, without impacting on the health of the animal. The sensitivity of plants to saline water also varies between crops and species.

In the Territory, saline waters are mainly found in the southern part of the NT due to a combination of low rainfall and high evaporation. In the northern areas groundwaters are mainly fresh because the high rainfall tends to flush away salt before it has a chance to be concentrated by evaporation (DLPE 2003).

Saline waters found along the coastline occur beneath low lying coastal plains. Aquifers beneath the plains are either recharged by tidal rivers or contain fossil seawater that remained in the sediment since it was laid down in an estuarine environment, thousands of years ago (DLPE 2003).

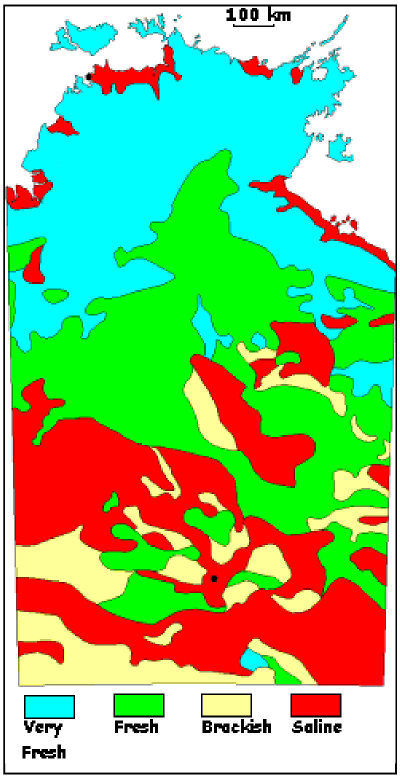


Figure 18 Zones of groundwater salinity in the NT

Water Quality Guidelines

All groundwater contains various kinds of dissolved salts (minerals) originating from rainwater and the chemical breakdown of rocks. The concentration of minerals in groundwater determines its use. Excessive concentrations of some minerals can limit the uses of the groundwater, making it suitable for livestock or industry but not human consumption.

At high concentrations some of these dissolved salts will alter the taste (eg chloride and sulphate) and or appearance of water (eg iron and magnesium), but will not cause adverse health problems. The limits for other minerals, such as nitrate, have been established in regard to health concerns.

The maximum recommended values for each salt listed in Table 2 are guidelines rather than strict limits. The reason for this is because there are often many factors governing how a particular salt affects the user. These can include a person's age and the total volume of water consumed. The guidelines given below are conservatively chosen in order to cover most situations (DLPE 2003).

Large quantities of sodium and chloride cause groundwater to become corrosive, which can damage infrastructure, such as pipe. High levels of magnesium and calcium cause hardness and groundwater, which makes it difficult to lather soap and leave scaly deposits in water heaters and pipes (DWR 2000).

Table 2 Guideline values for selected minerals in water pertaining to use

DISSOLVED SALTS (mg/litre)	DOMESTIC USE	CATTLE
Calcium	-	1000
Fluoride	1.5	2
Hardness	200	-
Iron	0.3	-
Nitrate	50	400
pH	6.5-8.5 pH	5.5-9.0 pH
Sulfate	250	2000
Total dissolved solids	500	10000

.

DEMONSTRATING GROUNDWATER B1- B3

Activity 1

> ***Curriculum Links:***
>
> **Science** Concepts and Context / Natural and Processed Materials CC 1.1, CC 2.1, CC 3.1
>
> **SOSE** Environments / Place, Landforms and Features Env 1.1, Env 2.1, Env 3.1

Focus Questions:

- **What is groundwater?**

Aim:

To use a groundwater model to investigate how water is held in the soil.

Main Ideas:

- Groundwater is water that has infiltrated into the spaces within the soil and rock.
- Groundwater is an important source of water for humans, especially in regions where surface water is not readily accessible.

Need:

A clear plastic container, a measuring jug, rocks, stones, sand and water.

Consider:

Place rocks in plastic container, then add smaller stones, then add sand until the container is 'full'.

Analysis:

Ask the students: If the container is full yes/no?

Gradually add water to the container, carefully measuring the quantity added.

Ask the students: If the container was full then how can it take the water as well? Explain that water is held in similar tiny spaces between soil particles underground.

The experiment may be taken a step further by asking the children to change the ratio of large and small rocks used and to remeasure the water held in the container as it is consumed.

Reflection:

What would happen to the water if the spaces between the soil particles were to become waterlogged?

What might happen to rainfall if the landscape where uniformly impervious?

> **Note**: The Department of Infrastructure, Planning and Environment (DIPE) have more complex models that may be requested by your school with DIPE staff to assist in its demonstration.

CREATE A GROUNDWATER MODEL B3-B5

(Source: Dept of Water Resources SA 2000)

Activity 2

Curriculum Links:
Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1
SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1

Focus Question:

- **What is groundwater?**

Aim:

Students use a groundwater model to investigate how water is held in the soil

Main Ideas:

- Groundwater is water that has infiltrated into the spaces within the soil and rock.
- Groundwater is an important source of water for humans, especially in regions where surface water is not readily accessible.

Need:

Clear container, clay, gravel, plastic zip lock bag filled with water, a layer of soil, a small plastic colander sealed with plastic on its inside, model trees, straw.

Consider:

Using a clear container, create 'the ground' area. From the bottom up, place the following materials in layers.

1) clay
2) gravel
3) the plastic zip lock bag with water in it
4) a layer of soil
5) the colander lined with plastic in its inside, filled with water to be sunk into the soil so that the top is at surface level to simulate a lake.
6) models of grass and trees.
7) add the straw sinking it almost into the bottom of the gravel layer to represent a bore hole.

Pour a small amount of water onto the soil part of the model.

Analysis:

Ask the students where they think the water might have gone?

Name four different forms of water storage in the model.

Reflection:

Why does the model have trees to simulate vegetation?

SOIL AS A FILTER

B3

Activity 3

Curriculum Links:

Science Concepts and Context / Natural and Processed Materials CC 3.1

SOSE Environments / Place, Landforms and Features Env 3.1

Focus Questions:

- **How does soil affect water quality?**

Aim:

To review the concept of groundwater and relate it to human use and consumption of groundwater.

Main Ideas:

- Groundwater is water that has infiltrated the Earth's surface into the, often tiny, spaces which exist between soil and rock particles.
- Groundwater is frequently accessed by people for domestic and commercial purposes
- Soil particles can act as a filter to improve groundwater quality.

Need:

Three 2 litre soft drink bottles, some gravel, some clay and some sand, stocking and water.

Consider 1:

Look at the groundwater map on the web site: http://www.DLPE 2003.nt.gov.au/advis/WATER/ground/resources.htm

What do the different colours on the map mean? Why do the colours start and stop where they do?

Consider 2:

(Department of Water Resources SA 2000).

Cut the soft drink bottles in half and discard the bottom part.

Secure the stocking material over the top of the bottle (lids off).

Place the bottle halves upside down, so that the stocking capped end is facing downwards.

Fill one half bottle with the gravel, the next with the sand and the next with the clay (leave some space at the top of each).

Place under each of these a clear container to catch water.

A sample of water is then added to each of the half bottles (ask students to predict what might happen before pouring the water in).

Time how long the same amount of water takes to permeate through the containers.

Does each sample of 'filtered' water have the same clarity?

Analysis:

Describe what happened. Were the predictions correct? Which sample was the most / least permeable? How might this experiment relate to the groundwater maps on the web site?

Use Student Sheet 7.1 (below).

Student Sheet 7.1
Soil as a filter

Determine:

(1) The length of time it takes for the water to pass through each material.

(2) The volume of water that can be collected after the water has passed through.

Did the water flow through all the materials at the same rate?

Did similar amounts of water pass through all the materials? If not, what happened to it?

Make bar graphs using the information gained from the tests. (use graph paper/computer)

Discuss the results.

If an accidental oil spill occurred in an area of sandy soil, would there be a potential for groundwater contamination?

If the same spill occurred in an area of clay soils would you expect to see any difference?

If groundwater is moving at a rate of 15cm per year, how many years might it be until it reaches a location of 1.5km away?

GROUNDWATER TERMINOLOGY B3-B5

Activity 4

Curriculum Links:

Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1

SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1

Indigenous Languages and Culture Natural Environment

Focus Question:

- **What is groundwater?**

Aim:

To introduce students to groundwater terminology

Main Idea:

- Groundwater is water that has infiltrated into the spaces within the soil and rock.

Need:

Access to Internet.

Consider:

Go to the web sites:

- **http://www.DLPE 2003.nt.gov.au/advis/WATER/ground/basics.htm; and**
- **http://www.cwmb.sa.gov.au/kwc/interactive/groundwater/index.htm**

Analysis:

As a class create a groundwater dictionary as a poster on the wall. (This can be added to over a number of weeks.)

Reflection:

Why is it important that everyone has the same understanding of a technical term? When might this be important?

Investigate:

Advanced groundwater terminology: aquifuge, aquitard, artesion, discharge, recharge, porosity, saturation or other terms you come across.

Work together as a class to make a crossword using these terms and to develop questions/clues.

FACTORS INFLUENCING GROUNDWATER

B3-B5

Activity 5

Curriculum Links:
Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1
SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1

Focus Question:

- **What factors influence groundwater?**

Aim:

To make links between environmental conditions and groundwater.

Main Idea:

- Soil type, geological layers, rainfall regimes and discharge rates all affect groundwater flow.

Need:

Clear plastic disposable containers, eg: soft drink bottles, various soil types and rocks of various sizes, water, measure jug, scissors and a straw.

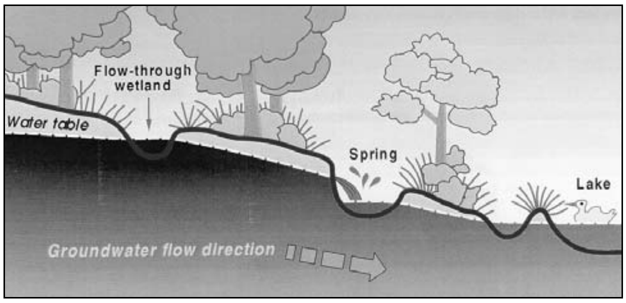
Consider:

To compare the water holding capacity of various soils, fill four containers with different soil types. Compare volumes of water which can be added.

Observe the time it takes for the water to infiltrate the different substrates.

Place a straw into the container after having added the water, to represent a plant sucking up the water into its roots. What happens, does the water start to come up the straw?

Cut a hole in the side of the container and place a small tube/straw into the hole to represent tapping into and pumping the groundwater, by being at the side not the top it will receive faster flow as it would if it was being pumped or if there was a natural reason for its discharge such as a spring.



(Source: Dept of Water Resources 2000)

Analysis:

Explain how groundwater may be influenced by the variables below:

1. Soil type – eg: variations in the size of spaces between particles. Consider clay in relation to gritty sand?
2. Geological layers – confined or unconfined storage.
3. Rainfall for recharge – seasonality and rainfall intensity.
4. Human extraction (pumping) of water for human/stock use.

Reflection:

How well does the model help to explain groundwater and factors influencing it? What type of aquifer is represented by the models?

GROUNDWATER SOURCES

B3-B5

(Source: "Plugged In and Turned On", PAWA 1996)

Activity 6

Curriculum Links:
Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1
SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1
Indigenous Languages and Culture Natural Environment

Focus Question:

- **What are the different groundwater sources?**

Aim:

Students will be able to distinguish between the different types of groundwater sources.

Main Ideas:

Three different aquifer types exist:

- **Confined** aquifers usually have a confining bed as their upper and lower boundary.
- **Unconfined** aquifers have a confined lower boundary but the upper boundary is the water table being recharged from surface water infiltration.
- **Perched** aquifers are those that have a confining bed as the lower boundary and it is limited in size.

Need:

Access to Internet.

Consider:

Go to the web sites:

- **http://www.DLPE 2003.nt.gov.au/advis/WATER/ground/basics.htm; and**
- **http://www.cwmb.sa.gov.au/kwc/interactive/groundwater/index.htm**

Analysis:

Ask students:

Draw diagrams, posters or design models to demonstrate the types of groundwater.

Using the web site, investigate which type of groundwater is the most common in the NT.

Investigate:

Do local indigenous people use groundwater?

Reflection:

Why do you think it might be important to know what type of aquifer is providing your water supply?

GROUNDWATER SOURCES IN OUR ENVIRONMENT

B3-B5

Activity 7

Curriculum Links:

Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1

SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1

Focus Question:

- **How do humans source their water?**

Aims:

1. To gain an understanding of groundwater as a major component of the water cycle.
2. To demonstrate the importance of groundwater as a water source for human use and consumption.

Main Ideas:

- There are two types of stored water which people successfully extract potable (drinkable) water for domestic, industrial, irrigation and other uses.
    1. Groundwater: People use wells and bores to extract the water that flows underground known as groundwater.
    2. Surface Water: People pump water from dams, creeks, rivers and reservoirs which are all surface water collections.

Need:

2 litre soft drink bottle, sand, film canister with some holes made around its bottom edges like a plant pot, bendy straw, cup, coffee, foam or block of wood to tilt the bottle on an angle and stop it sliding flat again, access to water.

Resources:

Department of Infrastructure, Planning and Environment groundwater models
Telephone: (08) 8999 3678.

Consider:

Use/create a model to examine groundwater and bores:

In this model the bottle represents an unconfined aquifer, the canister film tube a well, the straw is a pump for groundwater extraction/bore, the coffee is pollution and the notch is a spring. The cup of water is the rainfall and run off acting to recharge the groundwater.

Cut the drink bottle in half longitudinally with a small V notch just before the neck.

Fill the half bottle with sand and tilt it neck down on the foam or wood block on an angle.

Add some water at the bottom end of the bottle with a cup of water.

Dig into the sand to see if water fills the void.

Add some more water as before, this time place the camera film tube without its lid and with some holes in its base into the sand watch as the water fills into this 'well'.

As more water is added it travels and starts to poor out of the neck end of the bottle where the V notch is – this represents a spring.

Use a bendy straw to siphon water from the 'well' by placing the short end in and bending it downwards out of the bottle, watch as the water travels like a pump out of the 'well'.

Continue to add water to the model, then dig a hole in the sand ‘up stream’ of the ‘well’.

Add a spoonful of coffee into the hole just dug. As the water is added, watch how the coffee enters the well, this represents a source of groundwater pollution, eg: from a dump that travels through the groundwater and enters the well.

Analysis:

Ask students to draw the model they have created, labelling appropriate features. The relevance of these features should then be written on a separate piece of paper.

Investigate:

What local knowledge is passed down from generation to generation in Indigenous communities about sources of groundwater and their protection – invite a guest to discuss.

Reflection:

Why does society need to be careful about how we store and dispose of wastes?

Estimate what percentage of the NT population depends on groundwater for their or their businesses survival.

Extension:

How it is possible for pollution from the surface to affect groundwater quality?

Groundwater in the NT B3-B5

Activity 8

Curriculum Links:

Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1

SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1

Science Working Scientifically / Investigating WS 3.2, WS 4.2, WS 5.2 / Evaluating WS 3.3, WS 4.3, WS 5.3

Focus Question:

- **How do we use water in the catchment?**

Aim:

To investigate water availability in the NT and locally.

Main Ideas:

- The low and sporadic rainfall in NT can result in unreliable and poor quality surface water. Most developments and population centres in the NT are dependent on groundwater resources.
- Groundwater is stored in aquifers. Aquifers form when the pores or joints in the under ground rock beds are large enough to allow the continued flow of water under the pressure of gravity.
- Watertable aquifers found in the Top End are readily rechargeable each wet season. Confined aquifers, such as those which supply Tennant Creek and Alice Springs, are very slowly recharged from distant places and are considered to be 'fossil' waters, originating from recharge that occurred thousands of years ago when the climate was wetter than today.

Need:

Water Consumption Water Wise Education Kit. Water Notes: The Alice Springs Town Basin Area.

Internet access:

http://www.DLPE 2003.nt.gov.au/advis/water/facts/alice.htm

Consider 1:

Look at the groundwater web site – map of the NT groundwater resources.

Analysis 1:

Examine the key on the map and identify the quality of groundwater available to each population centre.
Record information on individual student maps.
Jointly construct a statement that describes and explains the nature and quality of groundwater found in the humid and arid zones.

Consider 2:

Using local services such as a bore driller gain access to a source of groundwater. The bore driller may be willing to discuss the process of drilling for groundwater and operation of equipment.

Analysis 2:

Students write a report about the trip which includes the following information:

town water supply;

amount of water used - compare wet/dry season usage - why are they different?

current or potential problems of your local water supply and quality.

EXCURSION

Encourage use of diagrams, maps, flow charts and other relevant visual representations.

Students to:

1. Look at town bores, private bores etc and what they are used for and what changes to water quality is made before human consumption.
2. Undertake a water use survey: how much water does your family use? Combine survey results, and estimate total residential use. Compare this to similar information from PAWA.
3. Write an argumentative essay showing reasons for and against current water usage levels by the community.

Reflection:

Participate in a class discussion about the possible limitations imposed by water resources on the growth of population and industries in the Top End and Central Australia. How might these limitations be overcome?

Extension: (Central Australia)

Undertake a study of Alice Springs water use – Roe Creek bore field.

LOCAL GROUNDWATER INVESTIGATION

B3-B5

Activity 9

Curriculum Links:

Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1

SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1

Indigenous Languages and Culture Natural Environment

Focus Questions:

- **What happens to groundwater,**
- **Where does groundwater travel?**

Aim:

To encourage students to consider where groundwater exists in their local environment and where it goes.

Main Idea:

- Groundwater is water that has infiltrated into the spaces within the soil and rock.

Need:

WATERWATCH Northern Territory A Federal - Territory Partnership

The Internet. The assistance of a Waterwatch Coordinator.

Consider:

Go to the web sites: **http://www.DLPE 2003.nt.gov.au/advis/WATER/ground/basics.htm; and**

- **http://www.cwmb.sa.gov.au/kwc/interactive/groundwater/index.htm**

Investigate:

As a class or individually, investigate your local area for the presence of groundwater.

Ask the Waterwatch Regional Coordinator if they are monitoring any groundwater sources? They may advise on a location to visit.

Ask your local Indigenous community to identify local sources of groundwater and any dreamings associated with these sources.

Analysis:

Record your findings and discuss direction of flow, where does the ground water end up?

Discuss the findings as a class.

Resources:

DIPE staff telephone: (08) 8999 3678.

Reflection:

What is the relationship between surface, groundwater and the ocean?

DIGGING FOR GROUNDWATER B1-B3

Activity 10

Curriculum Links:

Science Concepts and Context / Natural and Processed Materials CC1.1, CC 2.1, CC 3.1

SOSE Environments / Place, Landforms and Features Env 1.1, Env 2.1, Env 3.1

Indigenous Languages and Culture Natural Environment

Focus Questions:

- **What is groundwater?**
- **What happens to groundwater?**

Aim:

To investigate how water can be sourced from the ground.

Main Ideas:

- Gravity acts on groundwater in a similar way to surface water. The water underground flows from high points to low points depending on the nature of the substrate and points of extraction.
- Indigenous cultures learnt about groundwater and access points through the generations of information exchange.

Need:

Sandpit and bucket of water.

Consider:

In a sand pit of dry sand, poor in a bucket of water and watch the water sink in to the sand.

Where does it go?

Dig into the sand where the water was poured into the sand and watch the water flow into the hole just dug.

Analysis:

Why does the water come back into the space of the hole? (The release of resistance which the sand was placing on the water has been removed allowing the water to flow to the areas of least resistance. The base of the sand pit acts as an impervious layer stopping the water from disappearing completely into the Earth's subsoil.)

Try doing this in other locations, eg: at the beach in the wet sand or along the banks of the Todd River where groundwater feeds the River Todd. Ask your local indigenous community for ideal locations to demonstrate this.

Encourage students to record their actions and findings and discuss as a class. How is gravity related to sourcing groundwater?

Reflection:

Could we successfully dig for water without the benefit of gravity?

Note: Areas in the Top End are potential hazards for leptospirosis, please take precautions when digging in soil. Contact Territory Health Services for further advice.

GROUNDWATER DEPENDANT AQUATIC ECOSYSTEMS

B3-B5

Activity 11

Curriculum Links:
Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1
Science Working Scientifically / Investigating WS 3.2, WS 4.2, WS 5.2 / Evaluating WS 3.3, WS 4.3, WS 5.3
SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1

Focus Question:

- **What are some types of aquatic habitats within the NT?**

Aim:

To investigate local aquatic environments for interactions with groundwater.

Main Idea:

- Groundwater is water that has infiltrated the Earth's surface into the, often tiny, spaces which exist between soil and rock particles.
- Some plants are directly dependent on sourcing groundwater for their survival.

Need/Consider:

Student Sheet 7.2 (overleaf).

Analysis:

Students investigate their region for natural springs and other aquatic habitats that are fed by groundwater. Investigate seasonal fluctuations in recharge.

Investigate the uniqueness, distribution and land use of these habitats in the NT. Ask the students to make judgements about the degree of risk that these are under and what protection may be required. Is the recharge to the groundwater sufficient to maintain the ecosystem while water extraction/diversion continues at the current rate?

Reflection:

How important do you think it is to ensure there is a balance between human use of groundwater and conservation of ground water for the survival of other groundwater dependant species.

Student Sheet 7.2
Groundwater Ecosystems

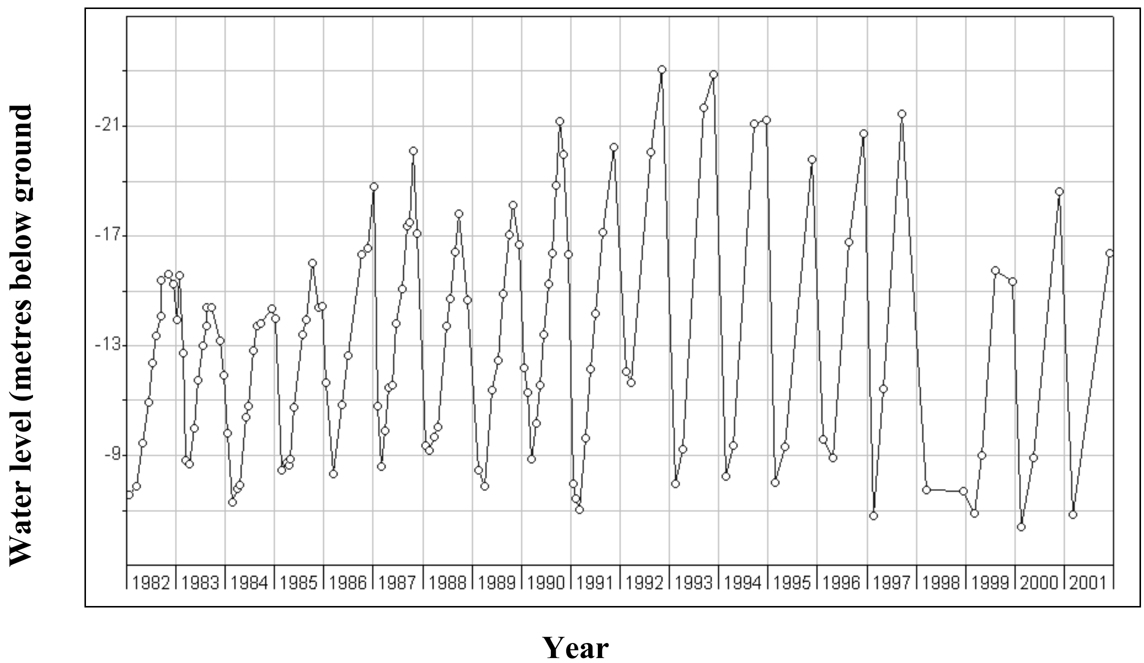
Groundwater dependent ecosystems are under increasing pressure from human activity. Bores used for domestic and commercial purposes can potentially significantly lower the amount of water available and pressure in an aquifer. Unsustainable depletion can cause natural springs to dry up. Over the last 100 years many springs within Australia have dried up, destroying various species even before they could be discovered (DWR 2000).

Many native vegetation, animal and bird species are totally or partially dependent on groundwater for their survival. This is particularly true in arid regions of Australia where surface water can be hard to come by. If the groundwater becomes depleted, polluted or saline then vegetation will die, adversely affecting other flora and fauna species (DWR 2000).

Groundwater and surface water catchments are strongly interconnected, making groundwater an important factor in supporting aquatic ecosystems associated with surface water. Recent scientific research has shown that aquifers themselves contain many forms of life and biological processes, some of which are new to scientists (DWR 2000).

Watertable aquifers found in the Top End are readily rechargeable each wet season. Confined aquifers, such as those which supply Tennant Creek and Alice Springs, are very slowly recharged from distant places and are considered to be 'fossil' waters.

The graph below demonstrates the recharge rate of a bore in the McMinns Lagoon area near Darwin between 1982 and 2001. Even in dry years when the bore was significantly depleted (eg: in both 1992 and 1993 water levels dropped to approximately 21 m below ground level) the bore water levels annually recover to in the vicinity of 9 m below ground level.



Clearly groundwater is a very important component in the environment and any plans to extract groundwater should take into account any detrimental effects on dependent ecosystems.

ACCESSING GROUNDWATER B3-B5

Activity 12

Curriculum Links:

SOSE Environments / Place, Landforms and Features
Env 3.1, Env 4.1, Env 5.1

Focus Question:

- **How do we use water in the catchment?**

Aim:

To gain an insight into the factors involved in accessing and maintaining groundwater suitable for human use.

Main Ideas:

- Unless the groundwater has the opportunity to come to the surface, groundwater must be accessed by the establishment of a bore.
- Legislation exists that requires a permit to establish a bore, and a licence to pump groundwater.
- The chemical nature of groundwater and its flow potential will determine the capacity for use.

Need:

Consult your local water resources person from DIPE or Power Water and gain permission to visit a local bore, to inspect, see how it operates and discuss how it is maintained and for what it is used.

Consider:

As a class, determine what knowledge students have already about groundwater. Does anyone use groundwater directly in their community or on their property?

Analysis:

Students determine:

What is another name for a 'bore'?

How can bores be of use when monitoring groundwater?

What are some factors to be considered when locating a bore?

How is the bore's column maintained and how does the well stop leakage to/from its column?

Why are 'headworks' important?

Why might a mild chloride solution be required to maintain the well?

What are some of the mineral salts found naturally in groundwater?

Investigate legislation associated with the establishment of a new bore.

Reflection:

How might the NT's population have been distributed if bore technology was *not* available? This could be represented on a map of the NT.

GROUNDWATER WARNING B3-B5

Activity 13

Curriculum Links:

Science Concepts and Context / Natural and Processed Materials CC 3.1, CC 4.1, CC 5.1

SOSE Environments / Place, Landforms and Features Env 3.1, Env 4.1, Env 5.1 / Environmental Awareness and Care Env 3.2, Env 4.2, Env 5.2

Focus Question:

- **How has human use of catchment's affected on catchment health?**

Aims:

1. To review the potential for exploitation of groundwater supplies in the NT.
2. To gain an understanding about water as a finite resource.

Main Ideas:

- Groundwater resources are an important water resource for communities in the NT.
- Careful management and planning is required to conserve and protect these resources from pollution or overuse.

Need:

Case study: Doctors Gully (overleaf).

Consider:

Read the case study by Erin White: Doctors Gully.

Analysis:

Students create three main messages from the Doctors Gully Case Study.

Students list some factors involved in aquifer recharge.

Students list some factors involved in pollution or overexploitation of groundwater.

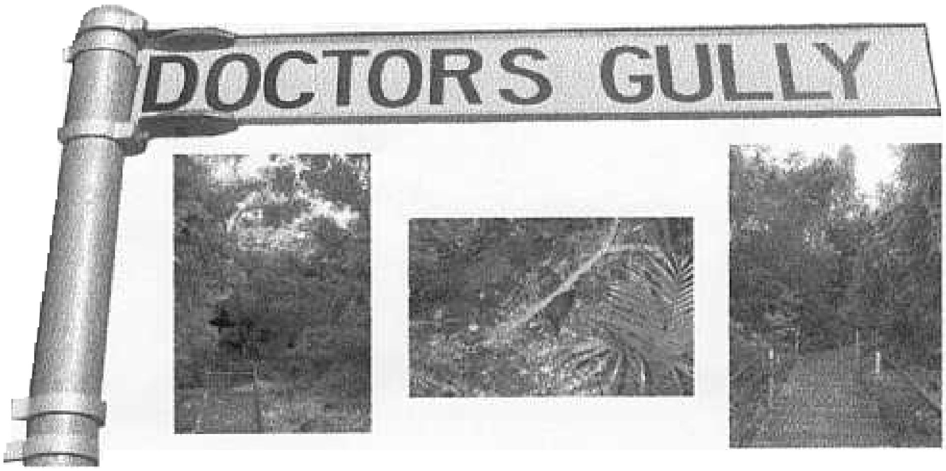
Consider:

Students research NT legislation which has been put into place to prevent the over exploitation and pollution of groundwater resources (See Part 6).

What is happening nationally to assess human impacts on (surface and groundwater)?

Reflection:

Create an awareness program about the need to protect groundwater supplies, as a finite resource, and what society can do to prevent pollution or overuse of groundwater resources.



Location

Doctors Gully is located in the heart of Darwin. The groundwater that discharges in this gully flows directly into Darwin Harbour (See Figure 1).

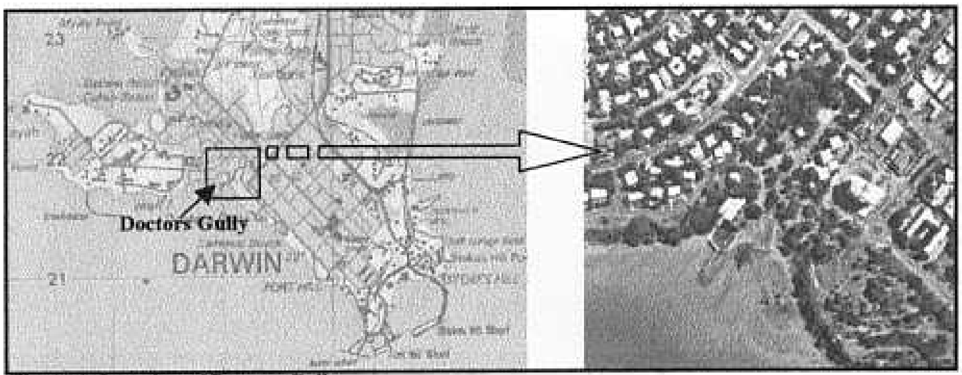


Figure 1: Location of Doctors Gully

History

In February 1869 Dr Robert Peel (See Figure 2) and a team of well diggers went ashore at Doctors Gully in search of a good supply of potable water. Runoff water would have been reasonably abundant at this time of year however there was a need to find a suitable supply of water that would not run dry during the dry season months. Peels successful well digging coupled with a good wet season runoff suggested that the gully be made the major watering point for the camp and stock. Peels Well was an important source of water for visiting shops for many years. Initially water was carried by the ships' boat to the camp below Fort Hill but eventually was hauled by wagon.


Figure 2: Doctor Robert Peel

Market Garden

Apart from finding a good supply of freshwater the next necessity was a garden to supply fresh vegetables and fruit for the camp. Seeds and plants were quickly planted in the rich floodplain of Doctors Gully and watered from its abundant well and adjacent creek. Many vegetables flourished including cress, radishes, melons potatoes and also sugarcane and bananas. A vegetable Garden reserve and adjacent water reserve was then established in 1872 (See figure 3). For many years the Gully provided ample fresh water for a very successful Market Garden.

In 1873, the water was highly regarded for its quality and became the base ingredient used by a softdrink factory and brewery. However in 1874 due to illness upon the proprietor the operations ceased.

Hospital

Figure 3 features a hospital reserve just above the gully. In 1874 the hospital was opened due to the increasing number of outbreaks of malaria within the settlement. The hospital was built on top of the north western cliff enclosing the gully. In 1913 A. Holmes describes the hospital in 1911 "... The drains were incomplete and ineffective, often offensive... urinal and earth closets situated on verandahs... a Chinese gardener used the night soil as fertiliser in the adjacent gully and sold the vegetables back to the hospital...(Dermoudy,1995)".

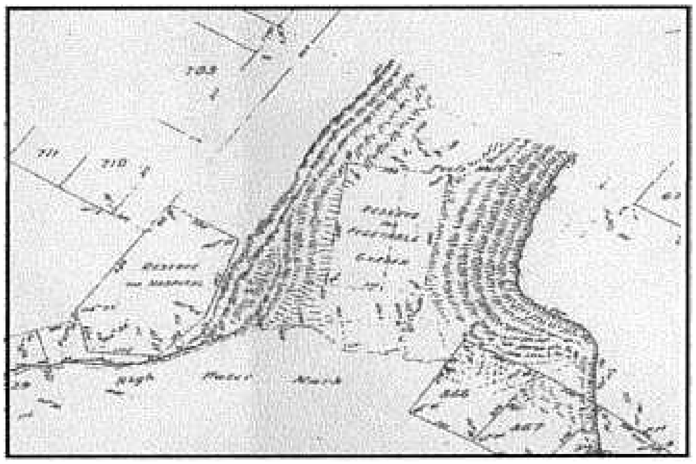


Figure 3: Market Garden and Hospital Reserve

Chinese

During the early 1900's there was a strong Chinese presence in Darwin and there was construction of a number of Chinese temples. Figure 2 is a photograph of a Haka Temple built on the foreshore of Doctors Gully. The gully was handed over to the control of the Town Council for public purposes on 31/1/1921, as was the whole of the Esplanade. This marks the end of the Market Garden era.

Figure 4: The Haka Temple

RAAF

In the 1930's Doctors Gully was used by fishermen and small trading vessels, which were able to enter the small creek that led to the well. The next phase in history came about with the threat of war with Japan. In 1939 the RAAF formed a flying Boat Squadron and based it out of Doctors Gully. There was a construction of a ramp and some buildings in 1941 as well as jetties and slipways for workboats and a refuelling tripod. Aircraft and personnel did not however become permanent residents of Doctors gully until 1944. The bombing of Darwin illustrated the vulnerability to aerial attacks of the fuel tanks at Stokes Hill. The government then decided to build underground oil tanks in the escarpment surrounding the city. They also constructed 5 aboveground oil tanks at the edges of town, two of which were located in Doctors Gully.

Fish Feeding

Figure 5: Fish Feeding at Doctors Gully

After the war the government decided to hire a caretaker of Gully in order to prevent vandalism within the area. Carl Atkinson took over the caretaker's position in 1946. In 1962 Atkinson started to attract mullet to the surface on high tides by feeding them bread. He also experimented with meet and found that Carnivores could be attracted as well. He soon had Batfish, Bream, Milkfish and catfish feeding every high tide. In 1964 he convinced the government to declare a suitable area as a Fish Reserve. In 1979 he decided to retire to New South Wales and left the venture to Marshall and Cherry perron to take over. The Perrons have developed the area and employ 10 staff and have over 500 visitors a day (statistics from 1995).

Changes

Below is an Aerial photo of Doctors Gully taken in 1945. The different land uses over 50 years has had an effect on not only the water quality but also the vegetation density.

1945

1999

Peel's Well

Figure 6 is a photo of the relic of Peels Well. Just a small cement structure today it provided many people with vital freshwater. . In October 1969 the groundwater level was recorded at 2.1m. And even after the removal of 2000-2500 Litres the level only fell to 1.5m.

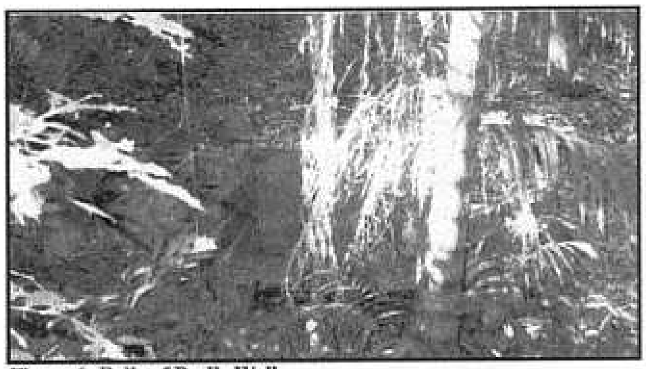


Figure 6: Relic of Peel's Well

Aquifer

Doctors Gully is part of a perched aquifer. There is an impermeable layer of siltstone that acts as a confining layer for the groundwater. This formation has been geologically "squashed" and the layers are now vertical, which makes water penetration near impossible. The escarpment is made up of a claystone which has reasonably high porosity and permeability. Precipitation therefore infiltrates the claystone until it hits the siltstone. On top of this layer of siltstone there is a small band of gravel that allows free movement, under gravity, of water to flow towards the gully's creek. Figure 7 depicts the geology of Doctors Gully.

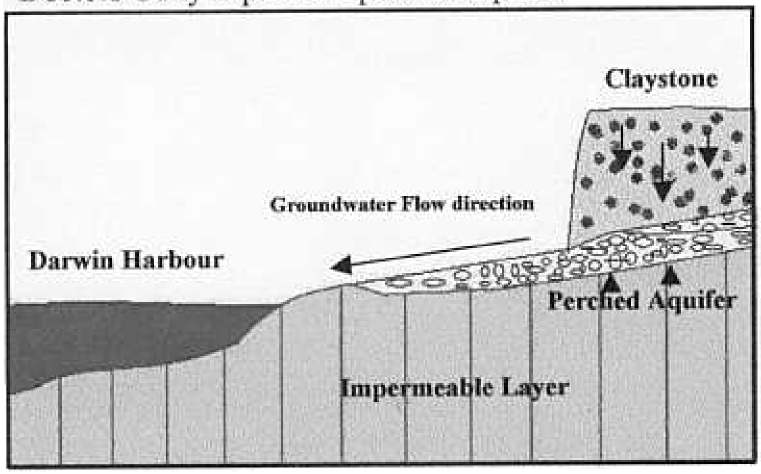


Figure 7: Geology of Doctors Gully

DOCTORS GULLY

Groundwater Flow


Figure 9: Photo of the creek in Doctors Gully

The water infiltrates the top layer through to the perched watertable. The water then, under the influence of gravity, flows towards the ocean. This water is discharged in the form of a spring at the base of the escarpment. Figure 8 is a photo of the historic walk with escarpment in the background. The constant flow of the spring has formed a small creek flowing through the gully. Figure 9 is a photo of this creek flowing through the gully.

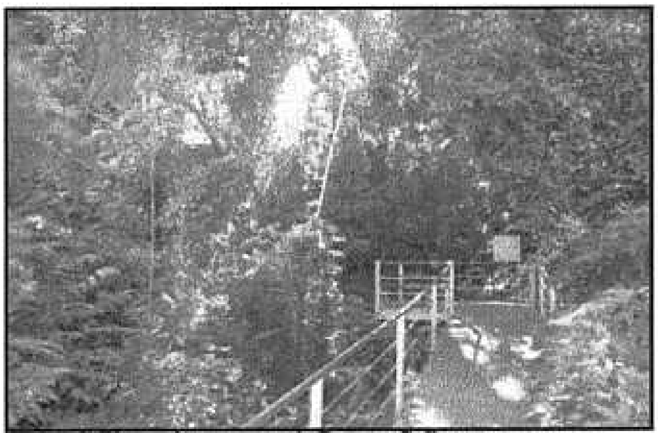


Figure 8: Photo of escarpment in Doctors Gully

DOCTORS GULLY

Today

Today pollution is a serious threat to Groundwater systems, and Doctors Gully is no exception. There are two types of pollution, Point Source Pollution and Dispersed Pollution. Point source pollution in Doctors Gully is evident through pipes and drains. Figure 10 displays the closest sources of pollution to Doctors Gully in the form of drains. The catchment area is quite large with the pipe disposing the waste water into the creek at Doctors Gully. Disposal of household pollutants (washing detergent etc) all can enter the drainpipes and effect the native plants and animals that survive there.

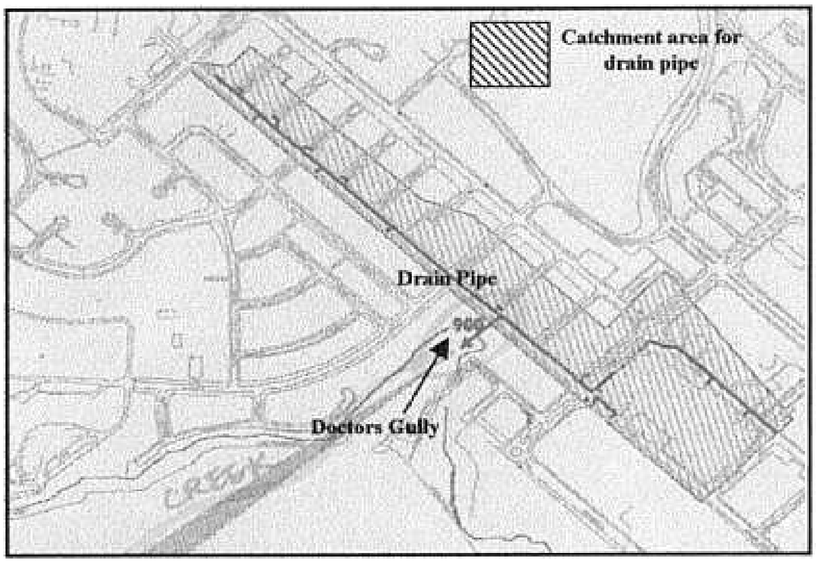


Figure 10: Catchment Area for the drainpipe located in the gully

The stream discharges straight into Darwin harbour very close to where they conduct a local Fish feeding venture. The pollutants contaminating the groundwater could have devastating effects on this tourism venture, let alone the natural aquatic life of Darwin Harbour. Because groundwater is part of the hydrological cycle pollutants can continue to travel through the cycle effecting anything or anyone in its way.

References and Bibliography

Barber, C. (2001) Surface water – groundwater interactions and Ecosystem dependence on groundwater. In C. Barber and D. Armstrong (eds) *Fundamentals of Groundwater Science Technology and Management Volume 1 Science*. Centre for Groundwater Studies, Adelaide, pp 43-90.

Clark, D.W. and Brair, D.W. (1993) *How does water get into the ground?* United States Geological Survey. Retrieved April 2003 from the United States Geological Survey web site: http://water.usgs.gov/pubs/FS/OFR93-643/

Department of Agriculture – Western Australia (2001) Monitoring Groundwater levels. Retrieved May 2003 from the Department of Agriculture web site: http://www.agric.wa.gov.au/environment/land/salinity/measurement/monitoring_groundwater.htm

Department of Infrastructure, Planning and Environment (2002) Series of fact-sheets. Retrieved April 2003 from the Department of Infrastructure, Planning and Environment web site: http://ipe.nt.gov.au/publications/factsheets/

Department of Infrastructure, Planning and Environment (2003) *Springs in the Northern Territory* – unpublished.

Department of Lands, Planning and Environment (2003) *Groundwater Northern Territory, Australia*. Retrieved 2 April 2003 from Department of Lands, Planning and Environment web site: http://www.DLPE 2003.nt.gov.au/advis/WATER/ground/DEFAULT.HTM

Department of Water Resources (2000) *ABC's of Groundwater*, Centre for Groundwater Studies, South Australian Government, Adelaide.

Humphreys, W. F. (2000) Background and Glossary. In H. Wilkins, D.C. Culver and W.F. Humphreys (eds) *Ecosystems of the World, vol. 30 Subterranean Ecosystems*. Elsevier, Amsterdam.

Simmons, C. T. (1998) Surface water –Groundwater Interaction. In Centre for Groundwater Studies *Fundamentals of Groundwater Science, Technology and Management Vol. 1*. South Australian Government, Adelaide.

Stanger, G. (1998) Groundwater Chemistry. In Centre for Groundwater Studies *Fundamentals of Groundwater Science, Technology and Management Vol. 1*. South Australian Government, Adelaide.

Tickell, S.J. (1994) *Dryland salinity hazard of the Northern Territory Report 54/94D*, Power and Water Authority. Retrieved April 2003 from the Department of Infrastructure, Planning and Environment web site: http://www.lpe.nt.gov.au/advis/land/dryland/default.htm

Water and Rivers Commission. *Groundwater Pollution*. Retrieved 7 April 2003 from Water and Rivers Commission web site: http://www.wrc.wa.gov.au/public/waterfacts/10_groundwater_pollution/pollution.html

Ward J.V., Malard, F., Standford, J.A. and Gonser, T. (2000) Interstitial aquifer fauna of shallow unconsolidated sediments, particularly hyporheic biotopes. In H. Wilkins, D.C. Culver and W.F. Humphreys (eds) *Ecosystems of the World, vol. 30 Subterranean Ecosystems*. Elsevier, Amsterdam.

Waterwatch Queensland (1994) *Waterwatch Technical Manual: Involve me and I'll understand*. Department of Primary Industries, Brisbane.

Glossary

Area of influence – the area of land above the cone of depression.

Aquifer – a porous rock or soil layer capable of storing and transmitting significant amounts of water.

Aquiclude – a saturated confining bed that does not allow water to pass through vertically.

Aquifuge – this is a confining bed that does not contain water and the confining bed does not allow groundwater to pass vertically through it.

Aquitard – a saturated confining bed that allows water to move vertically through the geological material.

Bore – a deep hole drilled through geological material that reaches an underground water source.

Capillary Zone – where water is drawn up above the water table by capillarity.

Capillarity – the affect of surface tension drawing water up into narrow pores against the force of gravity (DWR 2000).

Confined aquifer – an aquifer that has confining beds as upper and lower boundaries.

Confining bed – is a layer of geological material that is saturated, but can not produce a useable amount of water. There are three types of confining beds, aquitards, aquicludes and aquifuges.

Cone of depression – a depression in the water table in the shape of an inverted cone formed when a single bore is pumped and groundwater flows towards the bore. The cone of depression is determined by the amount of time and rate a bore is pumped and the aquifer material.

Effluent Stream – water from the water table enters a stream due to the difference in hydrostatic pressure between the water table and the stream. Also called a gaining stream.

Fractured rock aquifer – these aquifers store groundwater within fractures that have formed in hard rocks through tectonic movements. Groundwater moves through the aquifer via interconnecting fractures.

Groundwater – water that is stored below the Earth's surface in opening or voids in rocks and between grains of sand and soil.

Hydrogeologist – a scientist who works with groundwater.

Hydrograph – a graph of groundwater levels from one bore measured at regular intervals over a period of time.

Hydrological cycle – the continual movement of water from the atmosphere to the earth and back via precipitation, transpiration, run off and infiltration (DWR 2000).

Hydrologist – is a scientist that works with surface water.

Hypogean – subterranean.

Influent stream – when water moves from a stream into the water table due to the hydrostatic pressure being higher in the stream. Also called a losing stream.

Interference – when the cone of depression from two bores overlaps. Interference reduces the amount of water that is available to each bore.

Modelling – models are used to help predict the behaviour of groundwater systems and aid in making management decisions.

Non-point sources of contamination – contamination that occurs over a wide area.

Perched aquifer – is located in the unsaturated zone above the water table where confining layer of limited size occur. Water become trapped on these confining layers as it percolates downward forming a "lense" of water.

Permeability – is a measure of the interconnecting spaces or cracks between pores that allow water move through the pores towards a bore or area of discharge.

Point sources of contamination – localised pollution spills that can generally be identified and the pollution monitored.

Pores – the voids between grains of sand in sedimentary material in which water is stored.

Porosity – a measure of the number of pores in geological material and the amount of water that can be stored in the material.

Recharge – replenishment to an aquifer due the infiltration of rain. Recharge can also occur from water seeping through beds of river, lakes and swamps.

Saturated – all the voids or fractures in the geological material are filled with water.

Salinisation – a process in which the concentration of in the root zone of the soil increases.

Salinity – concentration of salts, measures in milligrams per litre (mg/L) or microsiemens per centimetre (µS/cm).

Sedimentary aquifer – consist of loosely cemented grains of sand, water is stored in the void between the sand grains.

Seepage – the movement of water between the groundwater aquifers and the surface water bodies.

Stygobites – stygofauna specialised for and restricted to subterranean waters.

Stygofauna - an all encompassing term for animals that occur in groundwater.

Stygophils – stygofauna that have clear affinities for the subterranean realm, spending part or all of their life in groundwater environments.

Stygoxenes - surface animals that enter subterranean waters accidentally, can include insects and crustacea.

Surface water – any body of water on the surface, such as lakes and rivers.

Unconfined aquifers – an aquifer that has the water table as its upper boundary and a confining bed as its lower boundary.

Water table – the surface of an unconfined aquifer where the groundwater is at atmospheric pressure.

Yield – the amount of water that is pumped from a bore, measured in litres per second.

INDEX