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Ti Tree Basin
Water Resource Report

Department of Natural Resources, Environment, the Arts and Sport

Natural Resource Management Division

Water Management Branch

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The Ti Tree Region Water Resource Report is available at http://www.nt.gov.au/nreta/water/committees/titree/index.html.

Important Disclaimer

TABLE OF CONTENTS

1 INTRODUCTION

The *Ti Tree Basin Water Resource Report* is a supporting document to the *Ti Tree Water Allocation Plan* (NRETAS, 2009). This document builds on *the Ti-Tree Region Water Resource Strategy 2002* and describes the main regional water resource as best understood by scientific monitoring and modelling. Much of the information is derived from the map *The Ti-Tree Basin Aquifer* (Read and Tickle, 2007) or *Ti Tree Health of the Basin* reports (Knapton, 2005 & 2006).

2 KNOWN WATER RESOURCES

2.1 Overview

The aquifers of the Ti Tree Basin are the major water resource in the region (see Map 1). The Basin contains a large underground reservoir, recharged mainly by seepage from river channels and their floodout areas, and by occasional very heavy rainfall events. This main reservoir is referred to in this document as the Ti Tree Basin Aquifer or the Aquifer. The Aquifer is defined by a geology of mostly old river sand, but also silts, clay and brown coal.

There is an overall flow of groundwater towards the northern part of the Aquifer. Depth below ground level is sufficiently shallow in the northern part that groundwater is lost through transpiration and evaporation; this loss is the natural groundwater discharge from the Aquifer.

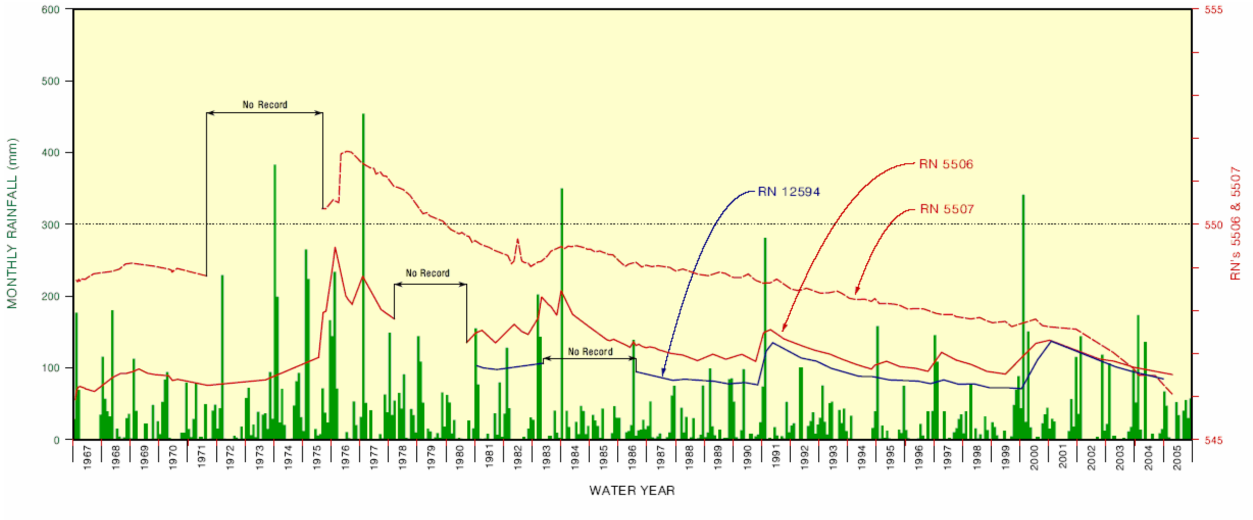
Over long periods of time, the natural groundwater discharge will be balanced by recharge from rainfall and streamflow. Sustainable use of the Ti Tree Basin Aquifer must be based on a sound understanding of this regional water balance.

2.2 Rainfall

A continuous record of daily rainfall is available for several locations across the Ti Tree Water Control District (Ti Tree WCD) including; Aileron between 1949 and 2002, Stirling Station between 1965 and 2002, and Woodgreen Station between 1946 and 1973, and 1998 and 2003. Average annual rainfall at Aileron was ~288 mm, ~335 mm at Stirling Station and ~246 mm at Woodgreen Station. Average rainfall across the Ti Tree WCD is about 300mm/yr. Monthly total rainfalls of more than 100 mm threshold are of specific interest; it is most likely that this threshold must be reached before regional rivers will flow, or rainfall seepage will reach regional aquifers.

Over the 57 years between 1946 and 2003, the records show that 33 years had at least one month in which the 100 mm threshold was reached or exceeded. This suggests that recharge to the main Aquifer can be expected once every two years, on average. Figure 1 shows a composite record of monthly rainfall (including rainfall at Ti Tree and Aileron) from 1967, together with bore traces; a correlation between rainfall and groundwater levels can be seen. Bores RN5506 and RN5507 are located in the western zone, and RN12594 in the eastern zone.

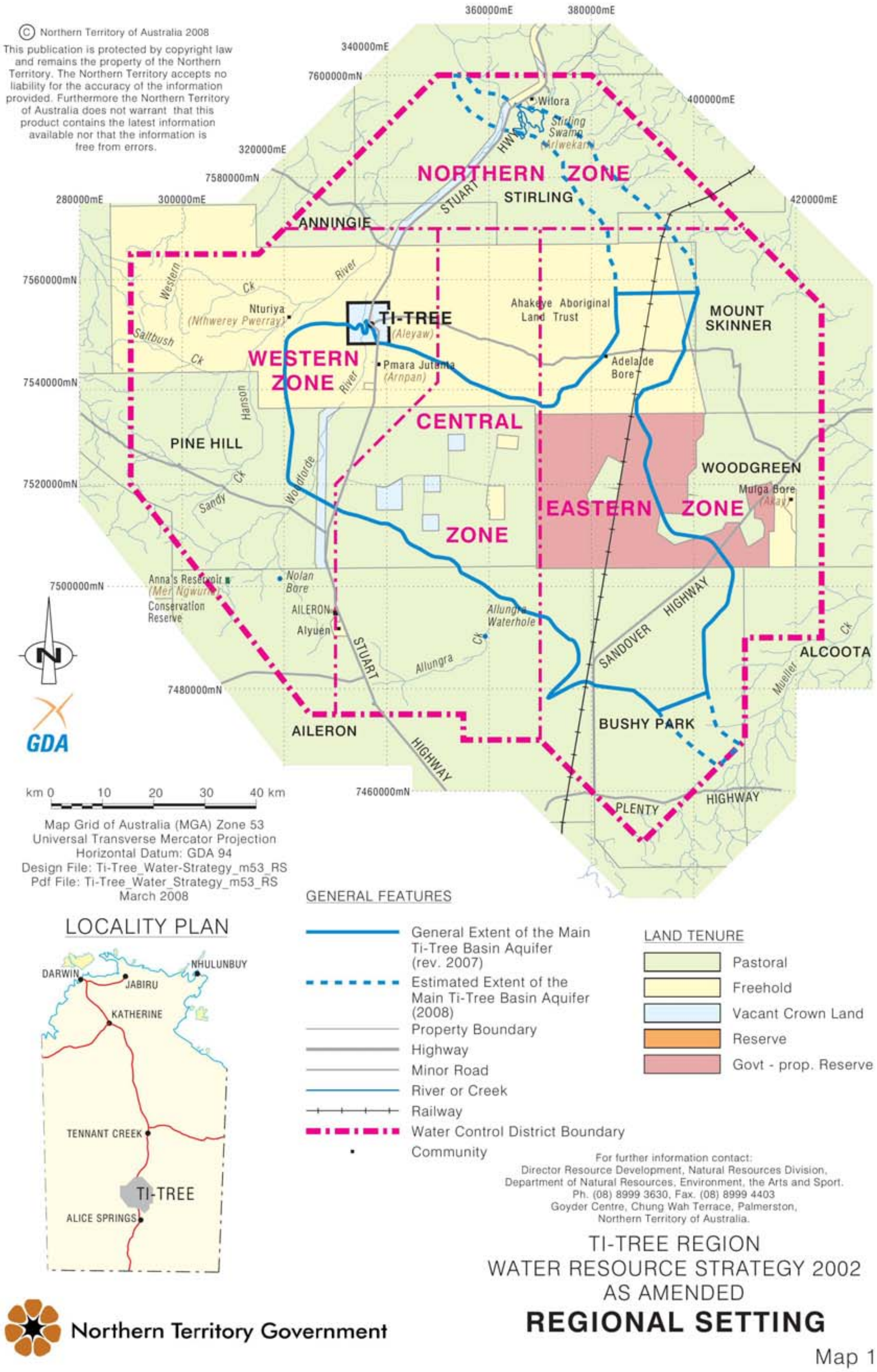
Figure 1. Composite monthly rainfall for the Ti Tree Basin (1967-2005) with three bore traces



Source: Read and Tickell (2007)

The longest period without meeting the threshold was five years. While monthly rainfall of less than 100 mm occurs quite regularly and reliably over the Aquifer, it is assumed that this water is transpired by vegetation. Chemical and isotopic analysis of the Aquifer waters indicates that long-term average recharge from direct rainfall is about 2 mm/year, equivalent to 2 ML/year per square kilometer of the Ti Tree Basin Aquifer; however it is assumed that this direct recharge to the Aquifer occurs only where threshold rainfall is reached.

Map 1. Groundwater features of the Ti Tree (Anmatyerr) Region



2.3 Surface Water

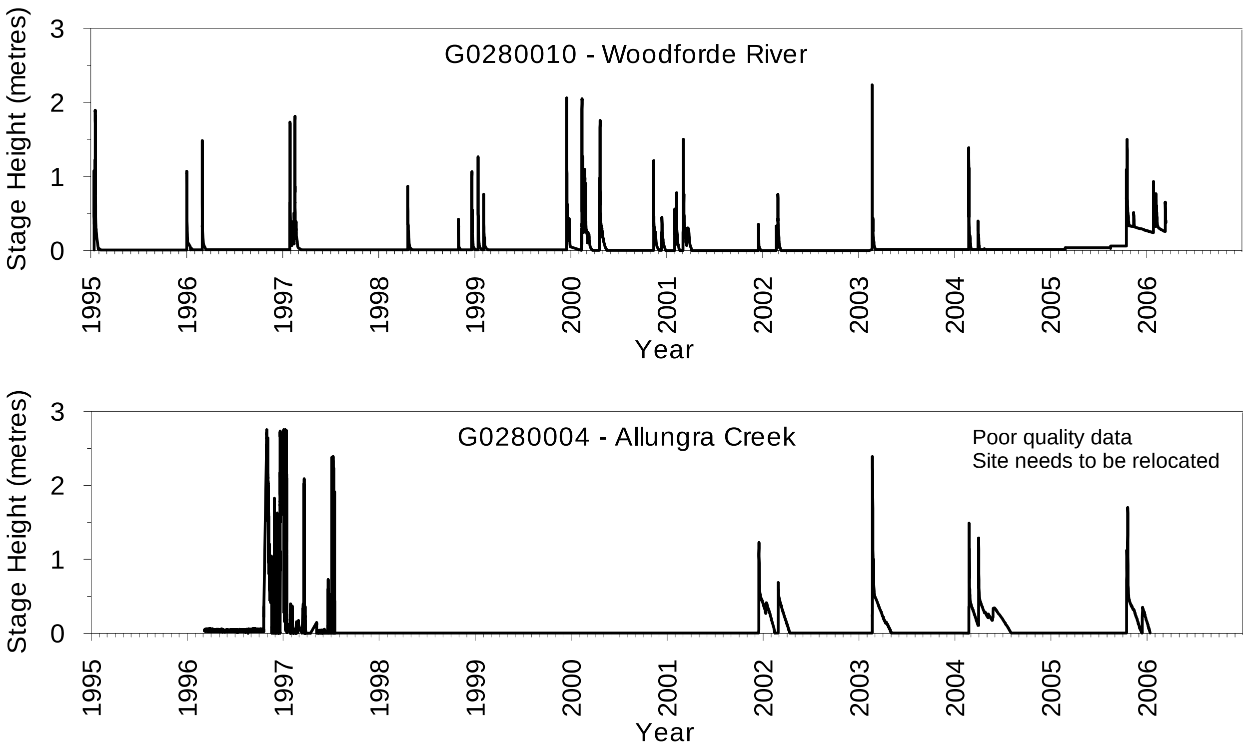
The Ti Tree WCD contains several creeks with associated flood outs that are an important source of recharge to the Ti Tree Basin Aquifer. Map 2 shows the surface water features of the region.

The Ti Tree WCD contains all of the Hanson River catchment south of Mount Stirling (located northwest of Wilora). Its largest tributary is the Woodforde River, which flows across the western part of the Ti Tree Basin Aquifer. The Allungra Creek flood out crosses the central part of the Aquifer. Mueller Creek crosses close to the south east corner of the Basin and its flood out areas lead to the eastern zone of the Aquifer. Stream records have been collected on Allungra Creek and on the Woodforde River (Figure 2).

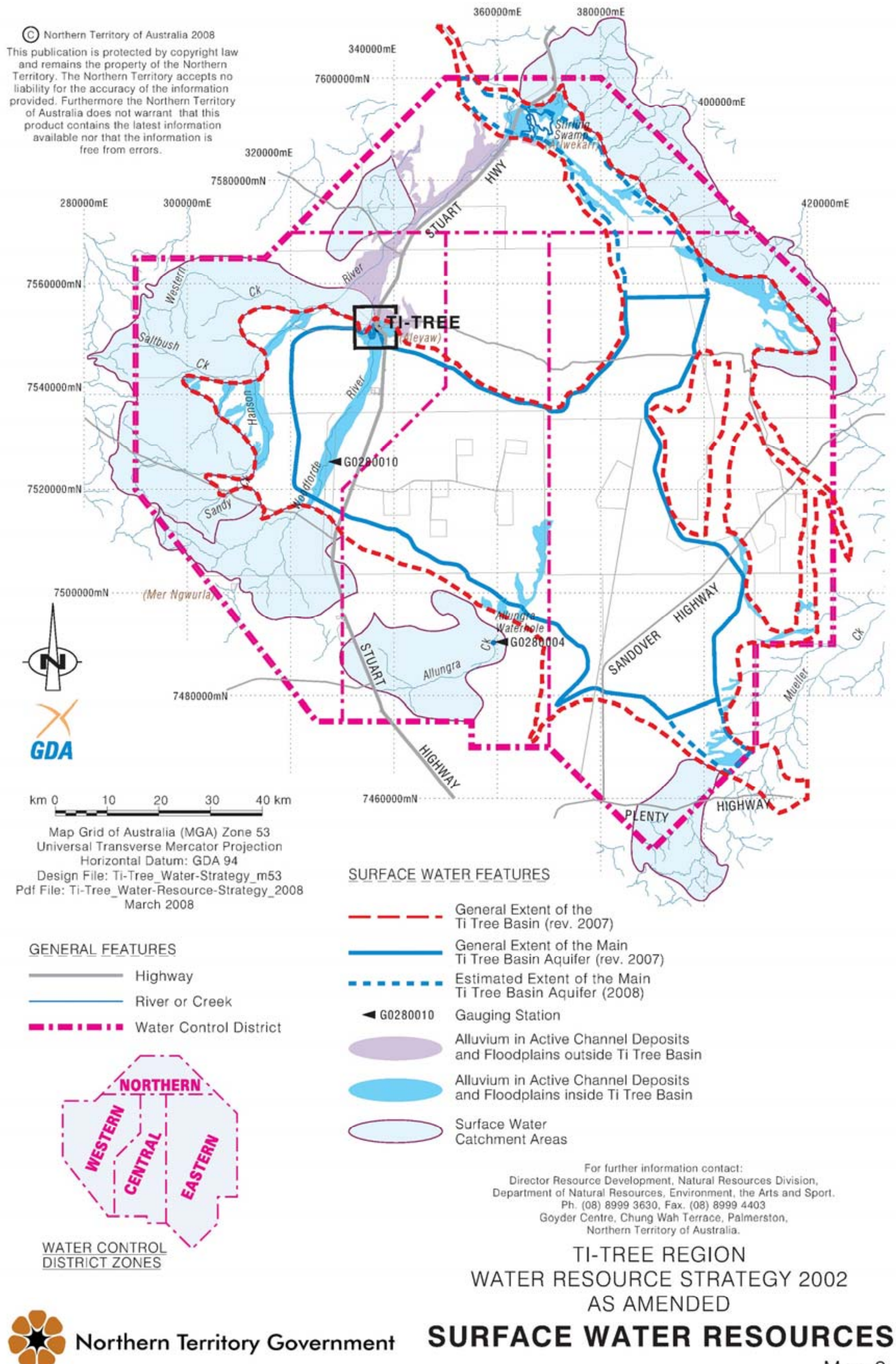
Water levels have been monitored continuously on the Woodforde River since 1975. Discharges have been measured only a few times, however, and the height data cannot be reliably translated into volumetric flow rates. The water level data show that the Woodforde River probably flowed in 18 out of the 21 years up to 1996. This frequency is similar to the frequency of groundwater recharge in the region indicated by Figure 1.

The gauging station for Allungra Creek, situated at Allungra Waterhole (G0280004), has been recording river levels intermittently since 1996. Flows in Allungra Creek can only be safely assessed from 2002 as earlier data is of poor quality or missing. Still, since 2002 flows occurred in at least four out of the six years.

Figure 2. Woodforde River (G0280010) and Allungra Creek (G0280004) Hydrographs



Map 2. Surface water features of the Ti Tree (Anmatjere) Region



There are several ephemeral surface water bodies in the region. Stirling Swamp, located north of the Ti Tree Basin, is a large complex of ephemeral wetlands with areas of bare claypan, lignum swamp, semi-saline samphire and temporary open water. Stirling Swamp collects flood runoff from the Hanson River and the ridges to the east of Wilora. Anna’s Reservoir (Mer Ngwurla) is a semi-permanent waterhole on the Wickstead Creek in the southern part of the western management zone. Allungra Waterhole is a semi-permanent waterhole on the Allungra Creek just south of the central zone.

2.4 Water Dependent Ecosystems

Water dependent ecosystems described in this section are those supported by groundwater or surface water. Surface water may be an expression of groundwater or a collection of rainfall or runoff, and may be permanent or ephemeral. Water found underground can be groundwater that is held in saturated sediments (an aquifer) or soil water that is held in unsaturated sediments.

Surface water ecosystems

Several ephemeral surface water bodies within the Ti Tree WCD support vegetation or other ecosystems that may be surface or groundwater dependent. Table 1 lists the surface water bodies and outlines whether these are dependent on groundwater and management status.

Table 1: Surface water in the Ti Tree WCD; source water and management status

Water body	Source of water	Management status
Stirling Swamp (Arlwekarr)	- Recharged by a combination of surface water (flood outs, streams and runoff near Wilora and Mt Skinner) and discharge from the Ti Tree Basin Aquifer - Possible groundwater dependence	- Located on Stirling Station pastoral property - More research needed to determine importance of different source waters
Anna’s Reservoir (Mer Ngwurla)	- Perched surface water with possible connection to local aquifers; no connection to the main Ti Tree Basin Aquifer	- Conservation reserve with management plan - Fenced to exclude cattle and horses
Allungra Waterhole	- Waterhole connected to local aquifers; no connection to the main Ti Tree Basin Aquifer	- Located on Aileron pastoral property - Riparian degradation caused by cattle and feral animals
Rockholes (various)	- Surface water collected from rainfall stored in solid rock cavities for varying lengths of time - Possible connection to local aquifers; no connection to the main Ti Tree Basin Aquifer	- Some rockholes located on Ahakeye Aboriginal Land Trust - Unmanaged or managed by local Anmatyerr people

Most surface water features within the Ti Tree WCD are not dependent on the main Ti Tree Basin Aquifer (Table 1). Well known surface water features include Anna's Reservoir, Allungra waterhole and rockholes (solid rock cavities). These features either collect rainfall and runoff and exist temporarily, or may be supported by local aquifers that are not connected to the Ti Tree

Basin Aquifer and therefore not affected by extraction for irrigation.

Groundwater dependent ecosystems

A groundwater dependent ecosystem requires access to groundwater (as opposed to soil water) to meet all or some of its water requirements. Groundwater dependent ecosystems within the Ti Tree WCD are thought to include Stirling Swamp, River Red Gums (Eucalyptus camaldulensis var. obtuse) and several terrestrial (phreatophytic) tree species.

Stirling Swamp

Stirling Swamp is located in the most northern part of the Ti Tree WCD where the water table nears the ground surface and water is naturally discharged by evaporation. Within the Swamp are areas of Samphire *(Halosarcia sp.)*, Inland TeaTree (*Melalueca glomerata*) and small areas of Lignum (*Muehlenbeckia florulenta*). The Swamp is fed by the Hanson River in flood, streams or runoff near Wilora and Mt Skinner to the north, and discharge from the Ti Tree Basin Aquifer.

Stirling Swamp exhibits complex interactions between fresh (low salinity) recharged surface water and high salinity groundwater. The relative importance of these different water sources in maintaining the health of the ecosystem is not clear and more research is needed to ascertain groundwater dependence. However, there is evidence to suggest that some groundwater dependence is likely in the northern part of the Ti Tree WCD.

River Red Gums

The River Red Gum (*E. camaldulensis var. obtuse*) is a riparian tree species that lines river banks within the Ti Tree WCD. This species is groundwater dependent; Cook *et. al.* (2008) found trees along the Woodforde River accessing a shallow perched aquifer that had formed from river flow recharge. This shallow aquifer is not connected to the main Ti Tree Basin Aquifer and is therefore not affected by current pumping for irrigation.

Terrestrial tree water dependence

Several studies (Howe, 2007; Cook et. al., 2008) show that use of groundwater by arid zone plants is widespread. Use of groundwater by trees is investigated through;

- chloride profiles in the soil that provide a record of water movement over time, for instance demonstrating where a tree has drawn up water through the soil profile,
- leaf water potential that indicates whether a plant is attempting to extract soil water or groundwater, and
- stable isotopes of water that indicate whether water in a wetland is similar to that of the surrounding groundwater and therefore derived from that groundwater (Howe, 2007).

Studies in the Ti Tree region (Howe, 2007; Cook *et. al.*, 2008) confirm that some terrestrial tree species use and transpire groundwater, including Bloodwood *(Corymbia opaca)* and Smooth-barked Coolibah *(Eucalyptus victrix*). The two species use groundwater from a range of depths and vary highly in daily water use. *C. opaca* was found to draw groundwater from 20m below ground level. Mulga (*Acacia aneura*) is a common arid zone species that relies on soil water, appearing not to draw on underlying groundwater.

Use of groundwater does not necessarily imply groundwater dependence. Determining groundwater dependence with certainty is a difficult task and requires more research into ecosystem processes in regions like Ti Tree (Howe, 2007; Cook *et. al.*, 2008). The Department recognises the complexities in defining groundwater dependent ecosystems and takes a precautionary approach by assuming that Stirling Swamp, Bloodwood and Smooth-barked Coolibah's are all groundwater dependent.

2.5 Groundwater

2.5.1 General Extent and Variability

Refer to Read and Tickle (2007) for a summary of groundwater characteristics.

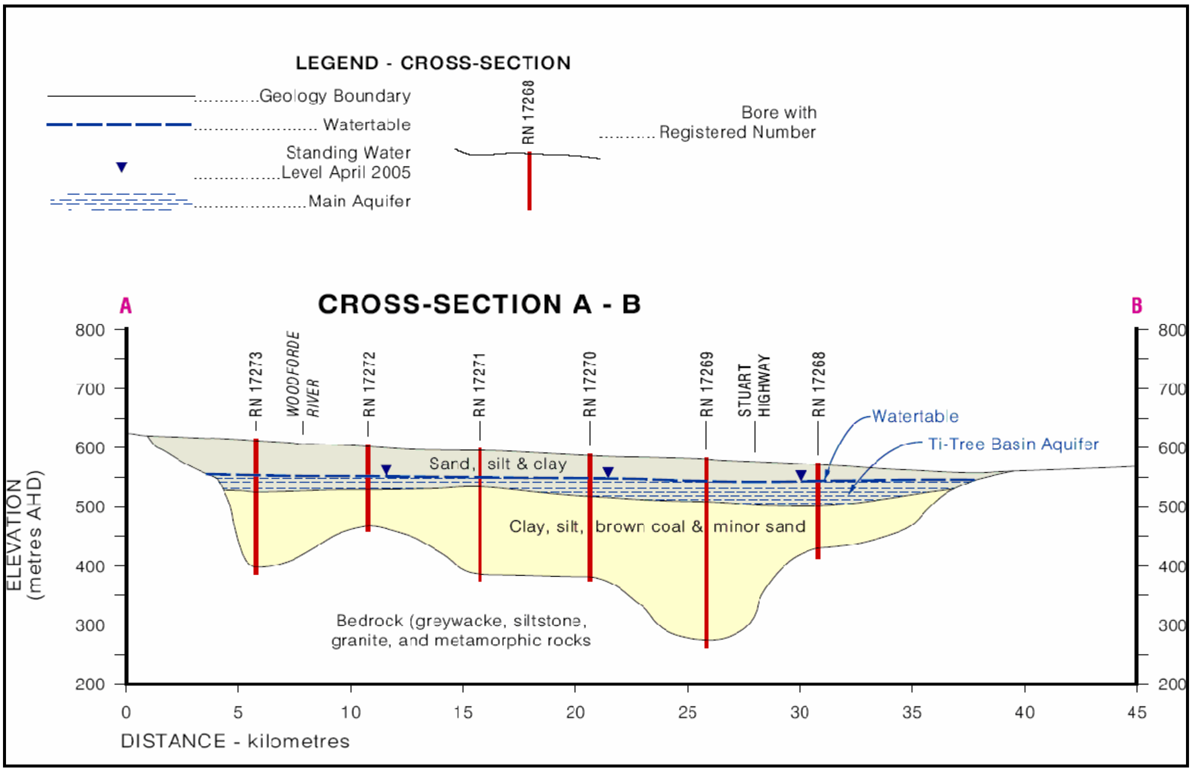
Mapping of the Ti Tree Basin (2002) has been revised leading to a minor change in the original Basin boundary and the addition of an Aquifer boundary, representing saturated sediments. The original 2002 Ti Tree Basin map was produced using remote sensing techniques. Subsequent work involved detailed investigation of bore drilling logs and modelling to produce an outline of the main underground reservoir (Aquifer).

The Basin boundary outlines the extent of potential water-bearing geological formations in the region, mainly sand but also silts, clay and brown coal. The Basin contains the saturated sediments of the main Ti Tree Basin Aquifer, which is developed in old river sands. Smaller, isolated areas of groundwater may exist between the Aquifer and Basin boundaries, but not of sufficient yield for irrigation or public water supply. Outside of the Basin boundary and also outcropping within the boundary (particularly in the east), is bedrock comprised of greywacke, siltstone, granite and metamorphic rocks.

Minor aquifers occur beneath the main Aquifer but they are of limited extent and thickness. The rate at which the Aquifer can deliver water to bores varies across the Ti Tree Basin Aquifer with some areas experiencing moderately high yields of 5 L/sec to 15 L/sec. Yield varies according to the amount of clay and silt mixed in with the sand, and thickness of the Aquifer. Figure 3 shows a geological cross-section of the Basin including the location of the main Aquifer in relation to the two main sedimentary layers.

Groundwater in the Aquifer varies in height relative to sea level; water levels are higher in the southern parts of the Basin and lower in the northern parts, causing water to generally flow from south to north. Depth below ground level to the water table also varies; the water table lies less than 10m below ground level in the northern zone and northern parts of the western and eastern zones, and up to 60m below ground level in southern parts of the western and eastern zones.

Figure 3. South to north cross section in the western management zone



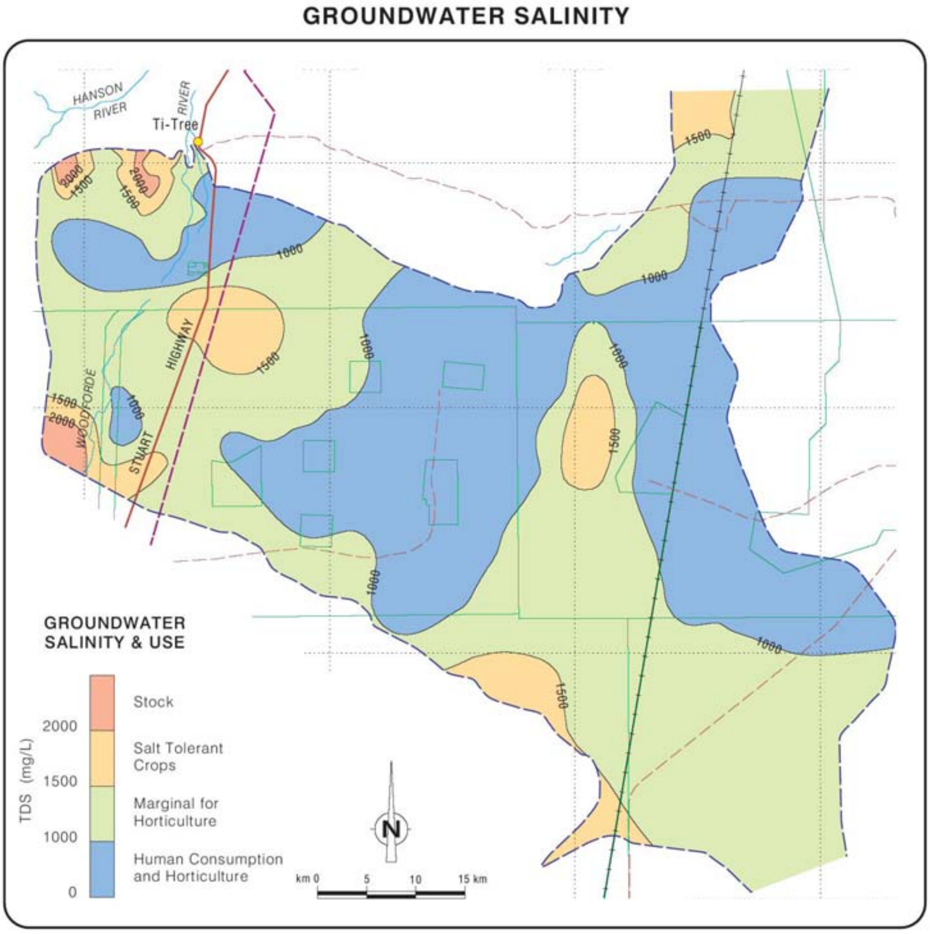
Source: Read and Tickell (2007)

Map 3 outlines the distribution of salinity across the Aquifer, represented as Total Dissolved Solids (TDS). This map was prepared using all available monitoring data and should not be compared to the 2002 map of salinity due to differences in mapping methods. Generally, salinity is lower where recharge occurs and higher where evapotranspiration concentrates salts in the soil. Total Dissolved Solids, referred to as salinity (predominantly common salt, sodium chloride), broadly indicates the potential uses of groundwater.

Drinking water and irrigation supplies are generally preferred to have a salinity of less than 1 000 mg/L (or 1 000 parts per million). Some irrigated crops tolerate salinity up to 1 500 mg/L. There is little or no economic use, at this time, for water with salinity over 1 500 mg/L, other than as stock water. All of the horticultural activity takes place in areas of good quality water, however, in the Ti Tree Farms area the potential exists to draw in adjacent water of a higher salinity over time.

Changes in salinity are best observed over long periods of time, for instance 5 yearly intervals. In areas where water quality changes may affect drinking water or economic activities (horticulture), the Department recognises the need to assess water quality changes over shorter periods. This need is identified in the Ti Tree Water Allocation Plan, Implementation Plan (NRETAS, 2009).

Map 3. Ti Tree Basin Aquifer – Salinity



Source: Read and Tickell (2007)

Aquifer thickness varies from zero to 80m. The highest yielding areas are found in Aquifer layers that are generally more than 40 metres thick and it is in these areas that the potential for new horticultural activity exists. It is most likely however, that groundwater may only be economically extracted over 20 to 30 metres of the total Aquifer thickness in these locations.

In some parts of the Aquifer naturally occurring nitrate, uranium and fluoride concentrations are higher than the Australian Drinking Water Guidelines recommend and limit groundwater use, particularly for public water supply.

2.5.2 Water Level Changes

Over the past few years water levels have been static or slightly declining across the Ti Tree Basin Aquifer at rates of about 1 to 5 cm per year (Knapton, 2005). This is due to the natural recession of groundwater levels as water flows to the north discharging at Stirling Swamp or via evapotranspiration.

Greater groundwater declines are associated with localised borefield extraction. For example, since 2002 groundwater levels have declined at Ti Tree Farms (RN5724) in the western zone by about six metres and at Table Grape Growers of Australia (TGGA) (RN12156) in the central zone by less than one metre. Declines are roughly as predicted by groundwater models, with the exception of Ti Tree Farms where the effects of pumping have been greater than anticipated. The difference in response of groundwater levels to extraction is probably influenced by the proximity of bores; at TGGA bores are located a greater distance apart.

Different bores can be used to investigate the effects of recharge events on regional water levels. Bores that respond readily to flood events in the region indicate that there has been no significant recharge since the 2000/01 high rainfall events (Knapton, 2006).

In 2005/06 total extraction was approximately 3 670 ML, while discharge from the western, central and eastern zones to the northern zone was estimated at 8 000 to 9 000 ML. Total groundwater volume in the Ti Tree Basin Aquifer is estimated at 4 850 GL, greatly exceeding combined extraction and discharge. A comparison of extraction with changes in total Aquifer volume or water depth over time is an important future task identified in the Ti Tree Water Allocation Plan, Implementation Plan (NRETAS, 2009).

2.5.3 Groundwater Modelling

Groundwater modelling allows annual recharge, hydraulic conductivity and specific yield to be quantified, leading to an estimation of groundwater volume in storage. Modelling of the Ti Tree Basin Aquifer is based on the conceptual model developed by Water Studies (2001). The modelled was recalibrated in 2007 due to differences between observed groundwater levels and predicted changes in some areas. Recalibration sought closer agreement between predicted and actual groundwater level declines at Ti Tree Farms, and between recharge and groundwater levels in the TGGA area adjacent to the Allungra Creek floodout.

The original hydrologic conceptual model for the Ti Tree Basin is outlined in Water Studies (2001) and included these main aspects;

- the Aquifer is comprised of two layers, an upper layer with low permeability and a lower (basal) layer with higher permeability (higher yield),
- the average elevation of the contact between the two layers is approximately 520 metres above the Australian Height Datum,
- the average elevation of the base of the lower layer is approximately 480 metres above the Australian Height Datum,
- transmissivity or the ability of the Aquifer to transmit water, derived from test pumping vary from between 180 to 500 m^2/day and are generally estimated at approximately 270 m^2/day (Water Studies, 2001),
- specific yield or the Aquifer’s ability to store water is estimated at between 0.03 and 0.1 with a most probable value of 0.07. That is, 1 m^3 (1 000 litres) of aquifer yields 0.07 m^3 (70 litres) of water,
- the Aquifer covers an area of approximately 4 700 km^2 with an average available

drawdown of 26.3 metres and a specific yield of 0.07 giving a volume of water 8 647.3 GL (8 647 300 ML),

- recharge can occur in three ways (see Section 2.5.4), and
- surface discharge is over a large area and is due to water use by phreatophytes (vegetation which uses shallow groundwater) and diffuse or regional discharge at the ground surface. The main areas of discharge occur in the northern zone and the northern portions of the eastern and western zones.

Recalibration of the 2001 Ti Tree Basin modelling required a decrease in hydraulic conductivity and specific yield to provide closer agreement between predicted and observed groundwater levels (Knapton, 2007). The following are current estimates for the Ti Tree Basin;

- annual recharge is approximately 4 400ML/year (previously 10 000ML/year),
- hydraulic conductivity (ability of the Aquifer to transmit water) is 5m/day (previously 7m/day),
- specific yield (ability of the Aquifer to store water) is 0.04 (previously 0.07), and
- groundwater volume in storage is approximately 4 850 GL (previously ~8 650 GL) including all water quality. See Table 1 for a summary of groundwater storage estimates for the Ti Tree Basin Aquifer.

Table 1. Storage estimates for the Ti Tree Basin Aquifer

Western Zone	**Total**	**<1000 mg/L**	**1000 to 1500 mg/L**	**1500 to 2000 mg/L**	**2000 to 4000 mg/L**
Area (km^2)	614	175	252	149	38
Volume, 4% (ML)	808 000	214 000	402 000	161 000	31 000
Central Zone	**Total**	**<1000 mg/L**	**1000 to 1500 mg/L**	**1500 to 2000 mg/L**	**2000 to 4000 mg/L**
Area (km^2)	1 167	627	445	95	0
Volume, 4% (ML)	1 853 000	1 153 000	600 000	100 000	0
Eastern Zone	**Total**	**<1000 mg/L**	**1000 to 1500 mg/L**	**1500 to 2000 mg/L**	**2000 to 4000 mg/L**
Area (km^2)	1 799	613	911	275	0
Volume, 4% (ML)	2 180 000	720 000	1 130 000	330 000	0
All Zones	**Total**	**<1000 mg/L**	**1000 to 1500 mg/L**	**1500 to 2000 mg/L**	**2000 to 4000 mg/L**
Area (km^2)	3 580	1 415	1 608	519	38
Volume, 4% (ML)	4 843 000	2 088 000	2 133 000	591 000	31 000

2.5.4 Recharge

Groundwater recharge occurs where water seeps through the unsaturated zone into the main Aquifer (saturated zone). Groundwater modelling estimated recharge from rivers and creeks to the main Ti Tree Basin Aquifer to be 4 430 ML/yr (Table 2). The model excluded recharge from direct rainfall, thought to be mostly, if not all, directly evaporated or transpired by vegetation. This provides a conservative estimate of recharge that does not rely on rainfall averages, likely to vary with climate change.

Table 2. Current estimated Ti Tree Basin Aquifer recharge (2002 estimate in brackets)

Ti-Tree Basin Average Recharge	Western Zone (Woodforde River)	Central Zone (Allungra Creek)	Eastern Zone (other unspecified)
Flood recharge	450 ML/yr (2 980 ML/yr)	1 850 ML/yr (2 120 ML/yr)	2 130 ML/yr (1 320 ML/yr)
Direct rainfall recharge	0 ML/yr (690 ML/yr)	0 ML/yr (130 ML/yr)	0 ML/yr (1 580 ML/yr)
TOTAL	**450 ML/yr (3 670 ML/yr)**	**1 850 ML/yr (3 470 ML/yr)**	**2 130 ML/yr (2 900 ML/yr)**

Recharge to the Aquifer can occur in three ways;

- direct infiltration of rainfall through the soil when rainfall events overcome the soil/moisture deficit and "push" water below the root zones of the vegetation,
- infiltration from depressions that collect rainfall, and
- infiltration from creeks (Woodforde, Hanson and Allungra) during times where the floodouts are activated.

The latter is considered to be the most important recharge mechanism in the Ti-Tree Basin Aquifer.

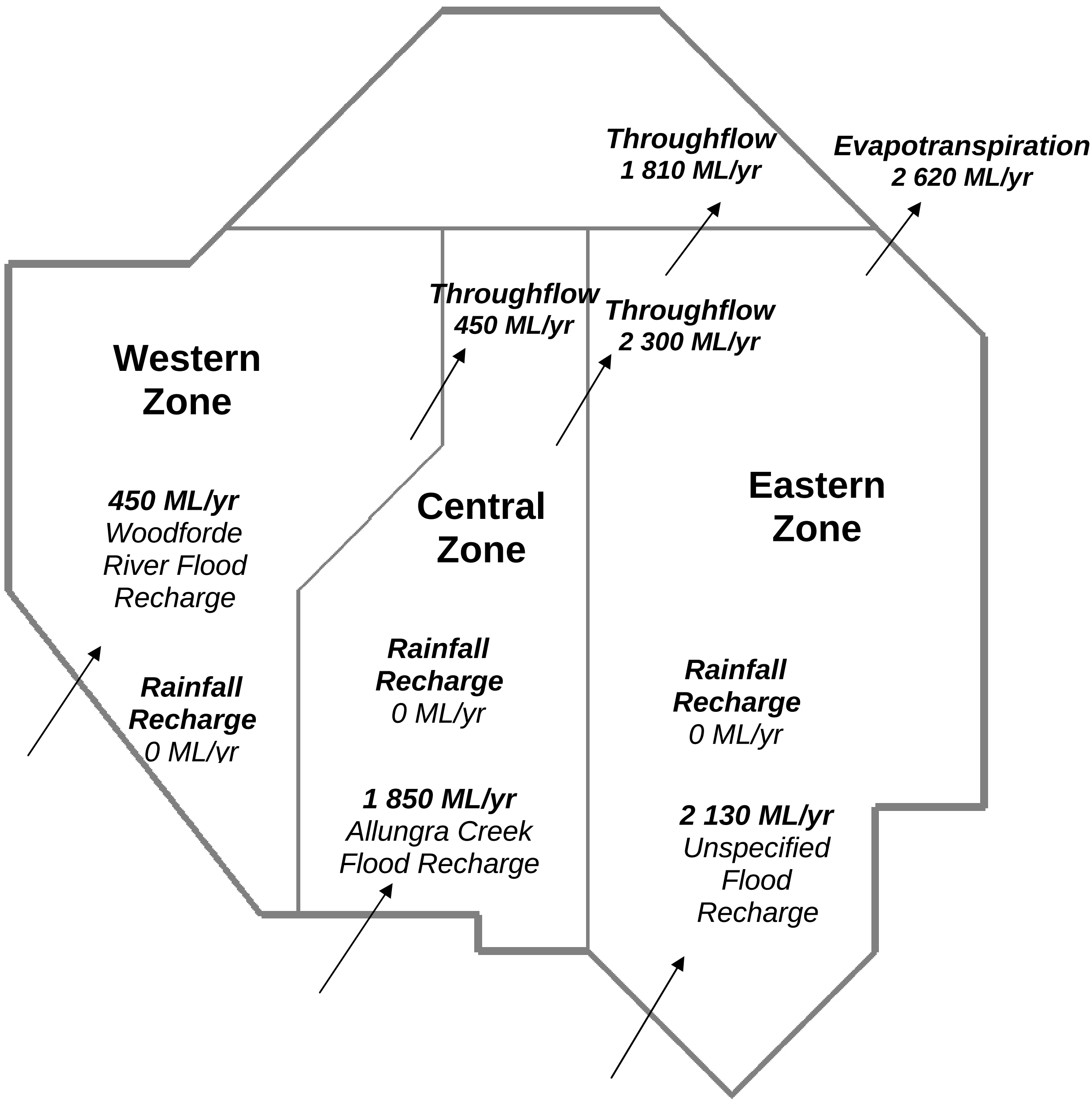
Due to the low average rainfall (approximately 300mm/year) and its sporadic nature, the Aquifer does not receive recharge every year. The abrupt rises in groundwater levels seen in Figure 1 record recharge events typically associated with heavy rainfall. Of note is an exceptionally large event occurred in the mid to late 1970's.

Recharge is not evenly distributed across the Basin but is concentrated in flood-outs. These are features in the landscape where rivers enter the Basin from adjoining hills and fan out across the plains. During the rare times that the rivers flood, most of the water soaks into the sandy soils of the flood-outs and the flood-waters only reach a limited distance from the hills. The Allungra Creek, Woodforde River and Mueller Creek flood-outs are the most important recharge areas in the Basin.

2.6 Regional Water Balance

Based on groundwater modelling (Knapton, 2007) Figure 4 represents the regional water balance for the Ti Tree Basin Aquifer. In the natural state, recharge is estimated to be 4 430 ML/yr from flood recharge including from the Woodforde River, Allungra Creek and Mueller Creek floodout or other, currently unspecified flood out areas. There is a general flow of groundwater from south to north where shallow groundwater is discharged via evaporation in the Stirling Swamp region. Throughflow to the northern zone is estimated to be 1 810 ML/yr and evapotranspiration from the eastern zone is estimated to be 2 620 ML/yr.

Figure 4. Long term, steady state water balance for the Ti Tree Basin Aquifer under natural conditions



3 REFERENCES

Cook, P.G., O'Grady, A.P., Wischusen, J.D.H., Duguid, A., Fass, T. and Eamus, D. (2008). *Ecohydrology of sand plain woodlands in central Australia*. Report to Natural Heritage Trust Project number 2005/147.

Howe, P. (Ed), O'Grady, A.P., Cook, P.G. and Fas, T. (2007). *Project REM1 – A Framework for Assessing Environmental Water Requirements for Groundwater Dependent Ecosystems Report 2 Field Studies*. Prepared for Land and Water Australia.

Knapton, A.K. (2005). *Ti Tree Health of the Basin 2004-05*. Technical Report No. 19/2005A. Produced by Land and Water Division, NT Department of Natural Resources, Environment and the Arts.

Knapton, A.K. (2006). *Ti Tree Health of the Basin 2005-06*. Technical Report No. 27/2006. Produced by Land and Water Division, NT Department of Natural Resources, Environment and the Arts.

Knapton, A. (2007). *Development of groundwater model for the Ti Tree Basin (Report 18)*. Department of Natural Resources, Environment and the Arts.

NRETAS (2009). *Ti Tree Region Water Allocation Plan*. Produced by the Department of Natural Resources, Environment, the Arts and Sport.

Read, R.E. and Tickell, S.J. (2007). *The Ti Tree Basin Aquifer*. Hydrogeological map produced by the NT Department of Natural Resources, Environment and the Arts.

Water Studies Pty Ltd (2001). *Development of a groundwater model for the Ti Tree Farms area*. Report No. WSDJ00205. Produced for the Department of Lands, Planning & Environment.