This report reviews water supply development and management in the vicinity of Tea Tree township, Northern Territory. It examines available information and the methods of data collection and analysis. Several previous reports have examined the availability of groundwater in the Ti Tree Basin, though at present it is still impossible to determine the alternate course for water resources management in the Ti Tree Basin.

The report suggests that the area previously called the Ti Tree Basin should be enlarged and a full program developed to quantify and qualify groundwater availability in this region.
1. HISTORY OF WATER SUPPLY DEVELOPMENT

1.1 Previous Investigation

Jones and Quinlan (1) and Perry et al (2) were amongst the first to report the possibility of irrigation farming near Ti Tree. They stated the area was one of the six most promising new farm areas near Alice Springs. A report on the suitability of groundwater for irrigation in the Alice Springs area was produced by Perry et al (2) in 1963.

During 1966/67 Ride (3) conducted an extensive investigation of groundwater quality and availability in the area recommended by Jones and Quinlan, as part of a multi-disciplinary examination of probable new farm areas. Although some of Ride's conclusions have been disproved, he appears to have partially identified the nature of groundwater flow, the major aquifer distribution and also the areal extent of groundwaters containing excessive concentrations of nitrates and total dissolved solids.

In 1975 Macqueen (4) reported further drilling had only partially agreed with Ride's conclusions and stated that because of the complexity of the recharge and flow patterns and of the factors affecting fluoride and nitrate concentrations the distribution of these ions was also complex. Baker (5) has also compiled a brief report on the provision of groundwater supply for Jutunta.

1.2 Major Centres of Water Use

1.2.1. Tea Tree town is located one hundred and ninety road kilometres north of Alice Springs on the Stuart Highway. The present population is nearly fifty. The as yet unused new school, located adjacent to the Police Block was designed for up to three hundred pupils, though in the 1977 school year probably only sixty to ninety pupils are expected to attend. Some of these pupils will commute daily from Jutunta and Ti Tree Station.

It is envisaged that the population of Tea Tree Township may be up to four hundred persons by 2000 AD if new initiative in the area result in a growth rate of eight per cent per annum.

1.2.2. Jutunta community is located two hundred metres east of the Stuart Highway 840-mile peg (about seven kilometres south of Tea Tree township). This Gibb Community was started in the second half of 1975 by Aboriginaes previously camped near Aileron Dam. The present population is estimated at one hundred and twenty persons and it is expected to reach three hundred by 2000 AD if a growth rate of four per cent per annum is achieved.

1.2.3. Ti Tree Station has been bought for the Ti Tree Aboriginaes. About 100 people are presently camped near the homestead without an adequate water supply.

A one-square-mile section of Ti Tree Station, west of Goreys Bore (RN 2444) and south of the disused Primary Industry Branch experimental farm, has been sublet to Ian Dahlenburg since mid-1975. Dahlenburg plans to grow grapes commercially. At present he is market gardening until the vines mature. This area is referred to as Ti Tree Farm.
2. WATER CONSUMPTION

2.1 Tea Tree Town

No historical water consumption data exists for Tea Tree as none of the production bores within the Town Area have ever been equipped with water meters.

Presently the water supply may be divided into two sections: Police Bore (RN 1856) which supplies government water needs, and the private bores and wells located on private blocks throughout the town area. During a recent inspection the Police Bore was estimated to supply sixty five kilolitres per week to the Caravan School, Health Clinic and Police Block. Water consumption remains constant all year, as during the hotter summer months the school uses very little water, while during the winter months it uses up to half the bore discharge. It is thought the privately owned water supplies may produce an additional sixty five kilolitres per week.

The average rate of groundwater extraction in the Tea Tree Town area is one hundred and thirty kilolitres per week. The present weekly consumption is about fifty percent above the long-term groundwater yield for the town area, as estimated by Macqueen (4). It is probable the recent above average rainfalls in the region is all that prevents the town bores running dry.

The present per capita water consumption of nearly 0.3 kilolitres per day is expected to approach 1.0 kilolitres per day as more water becomes available. As mentioned in section 1.2.4 the population may be approaching four hundred people by 2000 AD. This may require a water supply source capable of supplying three thousand kilolitres per week during periods of peak summer demand.

2.2 Jutunta

During the nine months that the production bores at Jutunta have been operational the average water consumption has been fifty kilolitres per week, with peak summer consumption of nearly ninety kilolitres per week. These values represent per capita consumption of 0.07 and 0.10 kilolitres per day respectively. The average per capita consumption is extremely small and it is expected to increase rapidly once the community adjusts to the new found availability of water and commences a planned market garden.

If Jutunta develops a market garden and population increases to three hundred by 2000 AD then peak summer consumption may be four thousand kilolitres per week at the turn of the century.

2.3 Ti Tree Station

Very little is known about water consumption on Ti Tree Station, Dahlenburg's irrigation project may require four to five hundred kilolitres per week during the next twenty years, with the demand gradually increasing to four thousand kilolitres per week over the next ten years as more land is brought under cultivation. The stations has two stock bores, Carey's (RN 2444) and Annullica (RN 2445), within the region investigated by Ride and on average each bore would produce two hundred kilolitres per week. Water consumption on Ti Tree Station will increase over the next twenty five years, though the degree of increase will depend on the adopted patterns of landuse.

3. WATER SUPPLY SYSTEM 5

3.1 Tea Tree Town

For some time the present water supply has been labelled "inadequate" Macqueen argued ... "The use of privately controlled bores in small blocks in a town should be avoided for reasons of noise, aesthetics, human interference and management problems".
As part of a programme to provide a better water supply at Tea Tree, two production bores were drilled about three kilometres south of the town in 1973. These bores were not equipped because of financial constraints but it was expected they would be equipped by 1977. Early in 1976 routine chemical analysis of water from these bores revealed that the nitrate ion concentration had increased to twice the maximum permissible level for human consumption as prescribed by the World Health Organization International Standards for Drinking Water (WHO ISNW). See Appendix for chemical analysis. It is now no longer proposed to equip these two bores. Geochemistry of groundwater near these bores is covered in section 7.1.2.

It is now planned to supply water for Tea Tree Township from the bores at the Jutunta Community.

3.2 Jutunta

Water is supplied by three recently equipped production bores located between the Stuart Highway and the community. The water supply network was designed and installed by Habaco Engineering Pty Ltd and is fully documented in the operations manual (6). The equipment is in good order and each bore is presently equipped with a pump capable of supplying two litres per second. If the maximum continuous water supply is evaluated using the critical pumping capacity (in which at least twenty five percent of the productive bores are considered to be inoperative) the present maximum continuous pumping capacity is four litres per second, which is more than adequate for the Jutunta Community.

The water supply system has extensive scope for enlargement, the production bores are each capable of six litres per second (see the completion reports in Appendix B). Larger pumps will have to be placed in the bores now that water for Tea Tree Township is to be pumped from Jutunta. Using the concept of critical pumping capacity, allowing a maximum of five hundred kilolitres per day for market gardening, and adopting one kilolitre per person per day as the maximum summer water demand these three bores can supply a combined population at Jutunta and Tea Tree of five hundred and fifty persons. By 2000 AD the combined population is expected to be seven hundred persons, so a new bore capable of six litres per second may need to be drilled near Jutunta in the early 1990's. The recommended location of any new bore near the Jutunta borefield is covered in Section 7.2.2.

3.3 Other Major Users of Water

Presently only Ti Tree Farm (run by Ian Dahlenburg) has the potential to be another major user of water in the Ti Tree area. As mentioned previously this irrigation scheme may use four to five hundred kilolitres per week during next summer. Water for irrigation is presently being pumped at a rate of four litres per second from one of the production bores at the FIB experimental farm (RN 5542). This bore was test pumped at 15.6 litres per second in June 1969 and a maximum pumping rate of 12.5 litres per second was recommended on the bore completion report. As the area under irrigation and the water consumption increase it is expected the pumping capacity will be increased. Sometime in the future it may prove advantageous for the owners to construct and equip a second production bore as an emergency standby. No other significant water consumption in the Ti Tree Area can be foreseen, though it is possible other market garden enterprises may be established near Ti Tree if Ian Dahlenburg's scheme proves successful.
4. DRAINAGE AND SEWAGE

4.1 Tea Tree Town -
Waste water is disposed via several small septic tank systems. There is little available data on their performance, however it is known the present water supply source suffers from bacteriological contamination of a human origin. Once the new water reticulation system from Jutunta is operational the present disposal practices may be adequate because the new source of groundwater is well isolated from the contaminated groundwater near the township.

If either the town population or water consumption increase greatly it may prove necessary to install a town sewage disposal system, with the sewage works located to the north of Tea Tree Township.

4.2 Jutunta -
No formal waste disposal techniques have evolved at Jutunta. It is proposed to install pit latrine disposal system at Jutunta. This should not cause contamination of groundwater near Jutunta, so no danger to the new Jutunta - Tea Tree Township water supply is foreseen.

4.3 Tea Tree Station -
Both the Station II.7ld De.1henburg have adequate waste disposal practices at present. The Aboriginals camped near the homestead may have to develop better waste disposal techniques if contamination of the aquifer is to be avoided, especially if a new (bore) water supply is developed. Pit latrines could be an adequate disposal system.

5. WATER SUPPLY QUALITY

5.1 Tea Tree Town -

5.1.1. Chemical analysis of groundwater close to Tea Tree Town has disclosed the presence of a large volume of groundwater, flowing to the north through the town containing higher than permissible by WHO ISNW, concentrations of nitrate and fluoride ions. The results of a recent chemical analysis of water from the Police Bore (RN 1856) are included in Appendix 6.

In recent years the chemical quality of groundwater near the Tea Tree town has altered considerably, though at no time has water from the Police Bore (RN 1856) been classified as suitable for human consumption by WHO ISNW. Reasons for fluctuations in groundwater chemical quality are dealt with in Section 7.

5.1.2. Bacteriological quality of the water supplies have always been suspect because the bores are all located very close to the septic tank effluent flows around town. In recent years Water Resources Branch bacteriologists have recorded high counts of human faecal organisms in groundwater pumped from Tea Tree Bore (RN 448) and the Police Bore (RN 1856). Based on results from these two bores all groundwater in the town area may suffer from bacteriological contamination and should be disinfected prior to consumption by humans.

5.1.3. No 'town water' treatment plant has been installed at Tea Tree, because most of the supplies are connected directly to individual houses. Most people in the town have been advised by Water Resources Branch personnel to add calcium hypochlorite to their storage tanks at least weekly; there is little evidence this advice is being followed.
5.1.4. As the present groundwater source suffers from bacteriological pollution and is chemically unsuitable for human consumption it was decided to develop a new water supply as soon as possible. Water from the Jutunta borefield will be available in the town early in 1977.

5.2 Jutunta

5.2.1 Chemical quality of groundwater close to the Jutunta production bores is very complex. With the exception of marginal fluoride ion concentrations (by the WHO ISW), the groundwaters may be classified chemically suitable for human consumption. Copies of the most recent chemical analyses of water pumped from Jutunta are included in Appendix B.

The geohydrology and geochemistry of the Tea Tree – Jutunta area is discussed in Section 7.

5.2.2. Bacteriological pollution of groundwater has not occurred near the Jutunta production bores, and is not expected to occur if suitable disposal techniques are developed at Jutunta. See section 4.2.

5.2.3. Treatment Plant has yet to be installed at Jutunta. It would be advisable for a chlorination unit to be installed before Tea Tree Town draws its town water supply from Jutunta. This is not because the groundwater suffers, or may suffer, from bacteriological pollution but rather it is a precaution against contamination introduced into the reticulation network.

5.2.4. There is little scope for improvement of the water supply. The present production bores are capable of supplying all Tea Tree Town and Jutunta's water requirements until the 1990's when it may be necessary to install a fourth production bore. The only desirable addition to the reticulation system would be the aforementioned installation of a chlorinator.

5.3 Other

There are no other major users of water for domestic purposes in the area of study. The groundwater at the farm has been classified as suitable for human consumption by WHO ISW, though the fluoride ion concentration is slightly above that recommended. Using a copy of Richards Classification system, groundwater near Ti Tree Town may be called C2-S1. It is claimed such water may be used to irrigate all but the most sensitive crops. A copy of the last groundwater chemical quality analysis is included in Appendix G.

6. WATER SUPPLY SOURCES - HANSON RIVER CATCHMENT

6.1 General

When evaluating the geohydrology of an area it is constructive to examine how the area is affected by and effects a much larger region.

Prior to Ride's investigation of groundwater near Tea Tree several reports had been written by Jones, Quinlan and other (1,2) about the suitability of groundwaters of the Alice Springs Area for irrigation. The area was divided up into about a dozen "Groundwater Provinces" and groundwater potentiometric formlines were drawn over the Alice Springs area. Ride's investigation only examined the Ti Tree Groundwater Province as formulated by Jones and Quinlan.

In this section the geohydrology and surface hydrology of a larger area than was included in Ride's Ti Tree Investigation will be examined. On the basis of this information a groundwater management program for Jutunta and the Ti Tree Basin will be evolved in a later section of this report.

The larger area being examined will be known as the "catchment" and has been defined as the total catchment area of the Hanson River at Mount Stirling; the catchment is shown in Figure 1. It should be noted that approximately half of the watershed is poorly defined on the 1 : 250,000 map.
6.2 Physiography -

The major physical features of the catchment have been summarised by Perry et al (2).

A. Mountains and Hills - These are the highest points of the catchment and consist of steep rocky slopes and little soil or vegetation, and have a high rate of rainfall runoff. These areas are shown in Figure 1 as area 3.

B. Undulating Plains - These form a belt adjacent to and regionally sloping away from the mountains and hills. They are mainly found in the west of the catchment and are characterised by mulga vegetation or residual red earth soils over rock or laterite.

Run-off occurs as sheet flow, but is at a lower rate than that from the rocky hills. Infiltration losses are much higher on the undulating plains than on the mountains and hills.

C. Sand Plains - These occur downslope from the undulating plains, especially in the western section of the catchment. The soils are very permeable and runoff is low or nil and therefore little accumulation of rainfall occurs. This unit is characterised by a lack of any developed drainage pattern. Physiographic units B and C have been combined as area 2 in Figure 1.

D. Alluvial Fans and Flood Plains - Small areas of alluvial fans fringe the mountain and hills and many of the small drainage channels from the uplands end within them. Flood-plain areas are shown as area 1 in Figure 1 and occur along the Hanson River and Woodforde River and several residual streams in the south and east of Figure 1. Runoff from the dams and flood plains is low, but these areas are the major areas of concentration of runoff and of recharge to groundwater storage.

E. Salt Lakes - A salt lake and swamp called Stirling Swamp exists in an isolated drainage depression in the north of the catchment. An additional drainage depression known as Wood Duck Swamp is located east of Tea Tree Town, though it is not thought to be a salt lake.

6.3 Geology -

The surface geology closely corresponds to the physical surface relief. According to Perry et al the catchment geology may be divided into two broad groups, the basement rocks and the basin sediments.

6.3.1. The basement rocks belong to the Precambrian Arunta Complex and the Proterozoic Georgina Basin Sequence. Within the catchment any aquifers in these rocks are mainly restricted to fractured and weathered zones and are of low permeability and storage capacity.

Outcrops of the basement rocks form the mountains and hills, discussed in Section 6.2. Runoff from these areas is fed into the flood-plain unit.
As well as forming much of the basin boundary these rocks also form the floor of the basin and their relatively low permeability, when compared with basin sediments, precludes the possibility of vast groundwater flow across the catchment boundaries and except where younger sedimentary deposits are continuous across the boundary.

6.3.2. Basin sediments south of Ti Tree Town are known to extend to depths of over 300 metres. Perry et al claimed the topography of the basin floor suggested it may be a Mesozoic erosional valley that has been later modified by warping and erosion. It is now believed that the basin is a Cainozoic feature that probably started to develop during the lower Tertiary. Shaw (7) states "the Hanson Plain formed at the same time as the Waite 'Surface', but continued to develop in the Pleistocene and possibly early Holocene. A complex drainage system outlined by calcrete deposits originated in the Tertiary Ti Tree Basin in the Napperby Sheet area and continued across the Hanson Plain to flow northwards into the Barrow Creek Sheet area. The Hanson Plain persisted into the Pleistocene, when it was covered by aeolian sand and red earth soil. Wet interludes in an otherwise arid period produced northward-flowing drainage channels that laid down alluvium locally. These drainage channels have been largely abandoned".

Ancient'seif-like' dunes and residual sand fields form the surface cover over a major portion of the catchment. Both the dunes and sand fields are fixed by vegetation. The aeolian sands post-date all alluvium except that related to present stream channels. The larger streams are still depositing sand, silt and clay in and near their channels and floodouts. Deposition has been continuous since the Tertiary, although deposition at one site may have been intermittent. These permeable gravels and sands adjacent to all major streams are the principle sites within the catchment where water is recharged to the aquifers. Most of the area covered by sand and soil is probably underlain by Pleistocene wash and alluvium. Ride and others have claimed the only significant aquifers near Ti Tree are those found in Cainozoic deposits near the ground surface.

6.4 Surface Water Hydrology

As with most streams in arid Australia even the major streams only flow after moderate to heavy rainfall events and it is unusual for the stream to flow over its full length for more than a few days following the event. A large proportion of the stream flows is recharged to the aquifers via the permeable stream channels and flood plains of the lower catchment area.

If surface waters are to be used for any purpose, other than to recharge aquifers within the catchment, it will be necessary to construct reservoirs to store surface water between rainfall events. It is probable only small surface water reservoirs would be developed on the catchment because:

A. The best dam sites, based on engineering geology and physiography occur near the catchment boundaries in areas where the basement rocks outcrop. The most favourable of these sites are found south and west of Ti Tree where any reservoir catchment area would be small.

B. The present climate patterns near Tea Tree may result in up to 3000 millimetres potential evaporation per year, while annual rainfall is about 275 millimetres. If the coefficient of annual runoff from basement rock outcrops is 0.20, then any reservoirs with a catchment mainly composed of basement rock outcrops, should not have a surface area greater than 2 percent of the reservoir catchment area, if water is to remain in storage between rainfall events. A usable storage reservoir, would need to have a smaller surface area if all the stored water is not to evaporate before it is needed, and should have a large average depth.
The maximum surface area of a usable storage reservoir on either the Hanson or Woodforde Rivers is about 0.1 square kilometres and the reservoir storage would be about 10$^7$ cubic metres. The average depth would be very low (1.0 metres). During a drought such a reservoir would rapidly run dry though in normal or wetter than normal years it could supply water to irrigate approximately one hundred farms similar to the Ti Tree Farm. The costs of construction and maintaining such a reservoir would be prohibitive for irrigation farmers especially as silting could be a major problem and the storage would be unusable during successive dry years. (This is predicted by the low average depth and the high evaporation rate). At present the only feasible use of surface water in the Hanson and Woodforde Rivers may be for artificial recharge to the aquifers. This could be achieved by constructing a series of low barrages across the flood-plain and stream channel and may eventually form a part of an intergral system of water resource management near Tea Tree.

6.5 Geohydrology and Geochemistry -

Any assessment of the groundwater reservoirs of the catchment must be based on the interpretation of sketchy geological and hydrological data available from a small number of bores located on and around the catchment. The geohydrology and geochemistry is covered in section 7.

6.5.1 The groundwater equipotentiometric contours drawn in figure 1 were derived from known standing water level data for the bores shown and ground-surface elevations interpreted from the relevant 1:250,000 series planimetric maps. The maximum expected error in the potentiometric surface elevation is twenty metres though on average the error should be less than ten metres. In his paper Shaw (7) drew equipotential contours over the western portion of the 1:250,000 series Alcotta map, and although these two equipotential plots were obtained independently they are in substantial agreement.

The equipotential contours show that, groundwater flow is generally from south to north and, groundwater only discharges from the catchment aquifers via the Hanson River's alluvium near Mount Stirling. At first inspection the Total Dissolved Solids (TDS) expressed on Figure 1 as milligrams per litre (mg/l) do not appear significant. However, when examined in association with the geology of the catchment they reveal that the poorest quality water is generally found in bores located in or near the ancient basement rocks which form the catchment boundaries.

Along the Hanson River north of Tea Tree Town there is an apparent gradual improvement in groundwater quality but this is because the water samples are from bores associated with different aquifer systems (Cainozoic Sediments or basement geology) and not dependent upon recharge from the Hanson River.

In the vicinity of Wood Duck Swamp several bores are known to produce reasonable quality water (TDS ranges from 700 to 1200 mg/l) though the quality deteriorates when the water mixes with other groundwaters while flowing toward Mount Stirling. Though the standing water level is less than 30 metres it is probable groundwaters in this area will only be used for stock watering because with the exception of a few bores near Wood Duck Swamp, the TDS's are above the levels normally recognised as the limits for domestic or agricultural usage. Near southern boundaries of the catchment the potentiometric contours are roughly parallel to the watershed. This may indicate some groundwater flows across the catchment boundary though it is more likely the result of local recharge from floodouts near outcrops of the Precambrian basement rocks. Figure 1 shows that groundwater from these areas generally flows toward the centre of the catchment and thence north toward Mount Stirling. Groundwaters near basements, is catchment boundaries generally have higher TDS than
the groundwater systems in the Ti Tree region. Additional recharge gradually reduces the TDS as the water moves away from the hilly areas.

The disturbances of the potentiometric surface which occurs between Ti Tree, Aileron and the eastern boundary of the catchment reflects the superposition of unrelated events. North of Tea Tree the basement rocks are known to either outcrop or occur close to the ground surface. The low permeability basement rocks act as a flow-regulating structure, similar to the spillway of a surface-water reservoir. The approximate position of the "spillway" is shown by the line A'-A' on Figure 2. The spillway is not a uniform depth below the surface, nor is it of uniform transmissivity. The spillway section is least permeable in the West and most permeable in the area of Wood Duck Swamp, though considerable throughflow is known to occur through a narrow section of 'weathered basement' aquifer near Tea Tree town (this is discussed further in Section 7).

The second major cause of the disturbances in the potentiometric surface is the large volume of water recharged to the aquifers from the Hanson and Woodforde Rivers. This recharge water is effectively dammed behind the impermeable basement spillway near Tea Tree Town so the general direction of groundwater flow changes from northerly to easterly. The nett result is that most water recharged near the Woodforde and Hanson Rivers is retained near the area of recharge for much longer than would otherwise be expected. There is additional recharge to the groundwater basin from the Sandover River System, on the Eastern extreme.

To the east of Tea Tree and Aileron the Cainozoic sediments are known to increase in depth, and this is responsible for the increased spacing of the equipotentiometric contours (and hence transmissivity is higher) to the south of Wood Duck Swamp. There are no major surface streams in this area and hence little concentration of rainfall, and it is unlikely significant recharge could regularly occur in this area unless as during recent years, storms in the Alice Springs area resulted in monthly rainfalls of up to five hundred millimetres and it is postulated that such heavy rainfall events in adjacent months may produce significant recharge event, the surface water being locally concentrated in small depressions prior to recharge. The TDS of groundwater sampled from this area suggests that significant recharge events do occur, however much more work is needed before any of the arid-zone recharge mechanisms are fully understood. It is suggested one percent of a rainfall event may be recharged directly to the aquifer if the rainfall is above two hundred millimetres in any month and there is no defined pattern of surface drainage.

Based on TDS and the potentiometric surface, an area of 2500 square kilometres centred halfway between Aileron and Wood Duck Swamp could be further investigated as a possible "New Farm Area" for Alice Springs. Such an investigation is outside the scope of this report. It is suggested that a series of twelve to fifteen bores be drilled in this central area to more accurately examine regional flow and groundwater quality phenomenon. Possible locations for these investigation bores are shown on Figure 2. The maximum permissible annual extraction rate has not been rigidly calculated, though it is probable up to 10° cubic metres could be annually extracted from the area between the 525 and 575 metre potentiometric formlines east of the Hanson River. This may be sufficient water for thirty square kilometres of market garden, which could adequately supply all the fruit and vegetables presently consumed in the Northern Territory.

7. WATER SUPPLY SOURCE - TI TREE AREA AS INVESTIGATED BY G. RIDER

This area is a subregion of the catchment discussed in section 6 and it is not proposed to re-examine the physiography, geology or surface water hydrology as these have been adequately covered.
7.1 Geohydrology and Geochemistry

Ride stated, "The major aquifers of the Ti Tree Basin are under confined conditions." Subsequent drilling and pumping tests near Tea Tree have neither proved nor disproved this conclusion. In the Ti Tree Basin the potentiometric surface ranges from one metre to thirty metres below the ground surface, being closest to the surface near Tea Tree Town.

7.1.1 Potentiometric surface formline plots have been drawn for approximately yearly intervals over the last ten years though only three have included in this report. The first plot (Figure 4) is for the period November 1966 to February 1967. This figure is intended to give an overall appreciation of the initial undisturbed patterns of groundwater flow. During Ride's investigation several of the 'back-filled' investigation bores had only one standing water level measurement recorded (between November 1966 and February 1967).

The formlines proposed in Figure 4 differ from those proposed by Ride, especially to the east of the highway. This variation is the result of Ride having plotted an incorrect value for the bore at grid point 155/80. The formlines indicate that groundwater generally enters the area being examined from the south-west and flows either to the north through a gap near Ti Tree, or to the east under the highway.

All three plots of potentiometric surface formlines, (Figures 4, 5 & 6) show that pumping near Tea Tree has created a significant cone of depression south of Tea Tree. The shape of the cone of depression reflects the influence of both pumping rates and changes in the depth to basement rock. Figures 7 and 8 are cross sections along the 130 East and 95 North grid lines respectively, showing the basement level, ground level and two potentiometric surface profiles, February 1967 and September 1976. In both figures the groundwater flow is from left to right over a flow-regulating structure in the basement rock.

7.1.2 Groundwater quality varies greatly in the Ti Tree Basin. Some groundwater near Jutunata has less than 800 milligrams per litre (mg/l) Total Dissolved Solids (TDS), 10 mg/l nitrate and 1.0 mg/l fluoride while groundwater near grid point 145/130 contains TDS in excess of 4000 mg/l and nitrate in excess of 260 mg/l. More detailed information, including the results of water-quality testing conducted during the investigation, are given in the Geochemistry section of Ride's report.

In 1975 groundwater samples from about half of the permanent observation bores were chemically tested. The results are included in Appendix E. The only other chemical analysis of groundwater samples from Basin has been in conjunction with the development of new production bores for both Tea Tree Town and Jutunata. Both of these testing programs began in 1973. To date these sampling programmes have provided very little additional information. To unravel the complex geochemistry of the Ti Tree Basin! (Macqueen 4) several plots showing inferred isohalines of total dissolved solids and several other ion relationships were drawn from the 1966/67 and 1975 data. The 1966/67 water analysis results are for airlifted sample from the completed bore. In 1975 the groundwater samples were obtained by airlift with the airtube outlet close to the bottom of the bore. In both cases the samples are representative of the groundwater that could be pumped from the bore and in no way do they indicate the chemical quality of the groundwater at a particular depth near the bore. After examining the isohalines plots it was decided to only include in the report isohaline plots of chemical substances that may be found, in the Ti Tree Basin, at concentrations well above the recommended limits for potable water by WHO ISDW; total dissolved solids and nitrate.

Figure 9 shows that groundwater flowing into the Ti Tree Basin from the south-west contains in excess of 2000 mg/l TDS and 700 mg/l nitrate, resulting in groundwater being classified as unsuitable for human consumption by WHO ISDW. As the groundwater...
flows through the basin dilution by recharge may result in an improvement in chemical quality, especially to the west of the Woodforde River. To the west of the Woodforde River there are several minor areas where the groundwater quality improves. The most significant of these is centred near grid point 90/95.

The major significance of the 1975 isohalines (Figure 10) is the threefold increase in nitrate concentrations near grid point 150/90 since 1966/67. As yet the most significant mechanism of nitrate accumulation in groundwaters of Central Australia is not known, however, several mechanisms have been postulated; these include leaching of fixed nitrogen from the root zone of Acacia scrub, the concentrating and oxidising of nitrogen compounds normally present in inland precipitation, and a lack of a suitable denitrifying bacteria in the soils. Considering the relatively high incidence of groundwaters containing over 40 mg/l nitrate any examination of the occurrence and cause of nitrates in groundwaters should have a high priority with researchers during the next decade.

7.13. Groundwater flow in the Ti Tree Basin is very complex. Full investigation of the changes in water levels and water chemistry during the last ten years is beyond the scope of this report. This section attempts to define some of the probable recharge and flow phenomena of groundwater in the Ti Tree Basin.

Figure 11 shows changes in the potentiometric surface between February 1967 and October 1975. If the average value of storage coefficient in the upper sediments of the Ti Tree Basin is 0.001 then approximately $12 \times 10^6$ cubic metres was added to the groundwater store. Hidy examined the total volume of groundwater stored in the upper Ti Tree Basin to be $2 \times 10^9$ cubic metres, approximately 200 times the change in storage mentioned above.

A comparison of annual rainfall and annual change in volume of groundwater storage within the Ti Tree Basin for the years 1967 to 1970 resulted in relationship which is graphically represented as Figure 12. Using this relationship and the annual rainfalls from 1967 to 1975 the change in volume storage within the basin was calculated to within 1% of the previously mentioned estimation.

The large changes in potentiometric surface shown near grid point 110/95 on Fig 11 are caused by groundwater backing up on the upgrade side of a flow obstruction. This flow obstruction extends north-west from grid point 130/95, across the Hanson River and coupled with above average recharge for each year since 1973 has resulted in a change in the direction of groundwater flow near the 95 north grid line. Where previously most groundwater in this region was flowing northwards, it now appears a significant volume of water has been forced to the north-east, toward Tea Tree Town. This poorer quality groundwater has flowed more than two kilometres in the last four years, resulting in the deterioration of chemical quality of groundwater near the proposed Tea Tree Town Production Bores and subsequent decision not to equip these bores.

The later increase in potentiometric surface elevation near grid point 140/100 (Fig 11) is the result of increased outflow through this area of reasonably low transmissivity. The drilling log of the bore mentions a small groundwater supply from seepage through the weathered zone of the basement rocks. The basin sediments, especially the sandy aquifers, are not found near this bore.

Based on an analysis of Figures 9, 10 and 11 most recharge to the groundwater aquifers, within the area of interest is related to the Woodforde River, especially between grid lines 60 north and 60 north. To the west of the Woodforde River the poorer quality groundwater flows predominantly to the north, whilst to the east of the river most groundwater flows in an easterly direction. Figures 9 and 10 show the groundwater in this region to have low concentrations of both TDS and nitrate ions. The only other area near Tea Tree where groundwaters of similar quality may be found includes Annulica Bore (RN 2445) and extends to the south west. Annulica Bore is located near grid co-ordinate 100/98.
East of the Woodford River between grid lines 60 north and 80 north, the poor quality groundwaters have been replaced by better chemical quality recharge water. The recharge waters have not moved far to the west of the Woodford River because groundwaters recharged from the Hansom River near grid co-ordinate 60/40, south east of Tea Tree, have forced the poorer quality groundwater to flow parallel to the Woodford River toward Tea Tree.

7.2 Areas where Development of Domestic or Irrigation Water supplies are possible.

7.2.1. Tea Tree will soon be receiving its domestic water supply from bores near the Jutunta Aboriginal communities, though it is necessary to discuss why the earlier proposed production bores are not recommended for use.

The bores were sited near grid co-ordinate 12/22, and originally produced groundwater that could be classified as suitable for domestic consumption, by the WHO ISW though the fluoride concentration is marginal. Had these bores been equipped they would have produced significant regional drawdowns and the pump rate may have had to be reduced because on three sides (north, east and west) at about one kilometre from the bores, the basement rocks restrict the aquifer to less than thirty five metres. The imposed hydraulic restrictions may have resulted in the bores being abandoned because of poor yield within ten years.

Before the doubts of the bores hydraulic suitability had been expressed abnormal recharge in the Ti Tree Basin had pushed a large volume of poor quality groundwater into and through the borefield area. At present it is not possible to predict for how long the water from these bores may be classified unsuitable for human consumption by WHO ISW though for the aforementioned reasons it is recommended that these bores never be equipped.

7.2.2. Jutunta presently receives a good chemical quality groundwater from production bores near grid co-ordination 136/74. It has been stated earlier in this report that most of the groundwater in this area has originated from recharge along the Woodford River between grid lines 60 north and 90 north. There appears to be more than adequate volume of suitable groundwater stored near Jutunta. It is expected that pumping at high rates (5 to 6 litres per second) will result in upconing of more saline groundwater, though at no time is water from the Jutunta bores expected to be classified as unsuitable for human consumption by the WHO ISW. The exact change in groundwater chemistry can not be predicted; the TDS may increase to 1200 or 1400 mg/l, and the nitrate may increase to 50 mg/l during heavy pumping in an extended dry period. If additional bores or better quality water are required for Jutunta the new bores should be drilled to the south within eight kilometres of Jutunta. It is doubtful a suitable quantity of good quality groundwater could be developed closer to Tea Tree than the present Jutunta Bores. Any attempt to develop a water supply in this region should be discouraged because such a development may cause degradation of chemical quality near Jutunta borefield.

7.2.3. Ti Tree Farm is ideally located to intercept a good quantity of the groundwater recharged from the Woodford River. The water quality near grid point 130/60 is not expected to alter radically in the future.

7.2.4. Other small water supplies could probably be developed adjacent to the Woodford River, especially between the Stuart Highway and the Woodford River. Any increase in the extraction of groundwater by additional users will need to be accurately monitored if groundwater in the Ti Tree Basin is not to be overcommitted. For the Ti Tree Basin the average groundwater through-flow has been estimated at 100 litres per second, most of which could be extracted from within five kilometres of the Woodford River.
8. WATER RESOURCES MANAGEMENT

8.1 Aims of Water Resources Management -

The major objective of any water management programme in the Ti Tree Basin is the provision of, and maintenance of, a suitable water supply for both the Tea Tree Town and Jutunta communities.

Several other minor aims of the management program are the supply and regulation of water to any irrigation farmers in the area, the quantification of changes that would result from an increased rate of groundwater extraction and hence the siting and maximum pumping rate of any new bores drilled in the Ti Tree Basin and the study of the potential of water resource development in a much larger area (i.e. the Hanson River Catchment).

At present the only management aims that can be fulfilled in the short term concern the further development, and management of existing facilities at Jutunta and Ti Tree Farm.

8.2 Monitoring Facilities -

The present monitoring of groundwater in the Ti Tree Basin consists of routine water level measurements in approximately thirty permanent observation bores, supplemented by occasional chemical analysis of groundwater samples airlifted from selected observation bores. The present basin management operations are not efficiently providing the data needed to monitor water supplies drawn from the Ti Tree Basin.

It is recommended water levels be measured annually in all observation bores. At the same time groundwater samples should be collected from the Ti Tree Farm (RN 6542), Goreys Bore (RN 2444), Tea Tree Well (RN 448) and Anniloca Bore (RN 2445) and airlifted from bores PIB 1 (RN 6543), 130/675 (RN 5507) and 130/75 (RN 5723). At a more frequent interval, every six weeks, water levels should be recorded in the following observation bores PIB 11 (RN 6544), PIB 1 (RN 6545), 130/675 (RN 5507), 130/60 (INV and A) - (RN 5724, 5726), 130/75 (RN 5723), 122.5/77.5 (RN 5503), 159.4/89 (RN 5626) and the Jutunta Observation Bore (RN 1067).

Prior to the operation of the new reticulation system a water sample should be collected from the Police Bore (RN 1856) at three-monthly intervals. Additional samples, also at a three-monthly interval, should be collected from each of the Jutunta Production Bores and the Ti Tree Farm Bore (RN 6542).

The airline and watermeters installed on the Jutunta Production Bores should be read every six weeks. It will be beneficial if all recorded information is plotted on an updated graph immediately following the visit. This system allows trends to be discerned early and possible measurements are obvious and may be immediately remeasured.

9. SUMMARY AND CONCLUSIONS

9.1 There are three major centres of water consumption in the Ti Tree area, with a combined population of two hundred people. An additional fifty Aboriginals are camped near Ti Tree Homestead without access to an adequate water supply.

9.2 The present water supply at Jutunta is more than adequate. The only possible improvement to the water supply would be the installation of a chlorination unit.
9.3 The present water supply at Tea Tree is classified chemically unsuitable for human consumption by WHO ISDW. It also suffers from bacteriological contamination of human faecal origin. The Water Resources Branch have recommended that water for Tea Tree be reticulated from the Jutumba borefield. This work should be completed within eighteen months.

9.4 The peak weekly water consumption at Tea Tree and Jutumba is 200 kilolitres. Ti Tree Farm may presently be using up to 500 kilolitres per week.

9.5 By 2000 AD the peak weekly water consumption at Tea Tree and Jutumba may approach 8000 kilolitres with Ti Tree Farm consuming an additional 5000 kilolitres per week.

9.6 To cater for the increase in water demand it will be necessary to drill and equip a new production bore south of the present Jutumba borefield. This new bore won't be required until the 1990's.

9.7 There is little scope for development of surface water other than for artificial recharge along the major streams of the Tea Tree Region.

9.8 The potentiometric surface and geochemistry of the Tea Tree Basin are too complex to be accurately monitored by the present observation bore network. Present knowledge of groundwater flow in the Tea Tree Basin may be summarized as:

a) throughflow through the Tea Tree Basin is approximately 100 litres per second,

b) the better quality groundwater is predominantly related to the Woodforde River south of Tea Tree,

c) above average annual rainfalls in the last ten years have produced large variation in the potentiometric surface and also in geochemical quality,

d) a groundwater flow regulatory structure running east-west through Tea Tree has a large effect on regional and local groundwater phenomenon in the Tea Tree Region.

9.9 The present groundwater monitoring program is not providing adequate information so a new monitory program has been developed. See Section 8.2.

10. RECOMMENDATIONS

10.1 The monitoring program mentioned in Section 8.2 should be reviewed after twelve months operation and if necessary modify the monitoring program.

10.2 The two production bores drilled 5 kilometres south of Tea Tree Township should not be equipped because of their proximity to a groundwater flow regulating structure which may cause the bores to suffer from excess long term drawdowns and poor chemical quality water.

10.3 The groundwater potential of the much larger Hanson River catchment should be investigated as time permits during the next few years.
REFERENCES

   Part VI of Lands of the Alice Springs Area 1956-57
   Land Research Series No. 6 CSIRO 1962.

2. Perry, R.A., Quinlan, T., Jones, N.O., Basinski, J.J.
   "Preliminary Assessment of Ground Water Suitable for Irrigation in the Alice Springs Area, and its Agricultural Significance"
   Division of Land Research and Regional Survey Technical Paper No. 21
   CSIRO - Melbourne 1963.

3. Ride, G. "Ti Tree Groundwater Investigation 1968"

4. Macqueen, A.D., "Tea Tree Water Supply"

   for Fmara Jutunta Era Inc"


   Bureau of Min. Resources Aust explan. notes SF 53-10.
APPENDIX E5

A. Bore Data for Proposed Tea Tree Town Bores i.e. Bore Yield Curves, Chem. Analysis, Completion Report.


C. Bore Data for Ti Tree Farm Bore i.e. Bore Completion Report - Chem. Analysis.

D. Bore Data for Tea Tree Police Bore i.e. Chemical Analysis.

E. Results of 1975 Groundwater Sampling Program.
Graphical solution to find relationship between annual rainfall and change in volume of groundwater stored in aquifers of the Ti Tree basin.

Data derived from records for period 1966/67 to 1970.

From assumption that there will be no change in the volume of groundwater in the aquifer in an average year.

Solutions:
1. \[ \Delta V = 58(P - 225) \]
   - where \( \Delta V \) in \( 10^6 \text{m}^3 \) and \( P \) in mm
2. Average inflow/buffer of groundwater is approximately \( 2.9 \times 10^6 \text{m}^3 \)
FIG. 5

LEGEND

River

Potential Surface

Trends

POTENTIOMETRIC SURFACE

WATER RESOURCES BRANCH

1:20,000

1370 6 86
FIG. 7
SECTION ALONG 95N GRID LINE

FIG. 8
SECTION ALONG 130E GRID LINE

WATER RESOURCES BRANCH
TRE TREE

DEPARTMENT OF THE NORTHERN TERRITORY

DRAWING NO 1501-6-94