NORTHERN TERRITORY OF AUSTRALIA
DEPARTMENT OF TRANSPORT & WORKS
WATER DIVISION

AYERS ROCK
WATER SUPPLY

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PROJECT 45
REPORT 9/1979

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1. SYNOPIS

During 1977 a Groundwater Investigation was undertaken in the Uluru National Park. This investigation was confined to the area to the south and south-west of Ayers Rock and within 3 kilometres of Ayers Rock. The results indicate that there are two major aquifers in the Southern Aquifer System and both are capable of supplying potable water. The combined safe annual yield of potable water from the system is in the order of $2 \times 10^5$ m$^3$.

A brief reassessment of the prospects of obtaining supplies of potable water in the Olgas - Ayers Rock area was carried out based on: (1) information gathered during this investigation; and (2) a reappraisal of the geological structure of the region. This reassessment indicates that future work is warranted in the region.
2. INTRODUCTION

The new investigation resulted from a reassessment of the work that had been carried out immediately to the south of the arkosic outcrop - Ayers Rock. The southern aquifer system previously referred to as the south-east aquifer has supplied all the groundwater used at Ayers Rock. The quality of this water varied depending on the depth and position of the production bore.

The reasons behind this reassessment are outlined below:

(1) The differentiation of at least two aquifers in each bore that has been drilled to a depth of 80 metres or more;

(2) The marked degradation in water quality with time on the commencement of pumping from bore RN 6273 (AR 29);

(3) The lack of knowledge of the aquifer system to the west and south of bores RN 6129 and RN 6133; and

(4) The problems encountered in the construction of production bores in the area.

As a result of this reassessment it was decided to comply in principle with recommendations 8.1 and 8.2 of the report "Water Availability and Demand 1976 - Ayers Rock" by B. Lally and R. Read - these recommendations being:

(i) "Drill investigation bores to define potentiometric and quality information west of bore RN 6129 (AR 3); and

(ii) using data as obtained, construct a well to test aquifer characteristics and bore construction methods in the area."

Between the 24th March, 1977 and the 19th May, 1977, nineteen bores were drilled in the southern aquifer area. Two more bores, RN 11605 and RN 11778, were drilled at a later date. A comment on each bore is contained in Appendix 1. This report will explain how the results obtained from this investigation have affected understanding of the southern aquifer system, and also discuss how this understanding may have relevance to a better understanding of the regional groundwater phenomena.
3. HYDROGEOLOGY

A summary of the interpreted results obtained from drilling and field work in and around the borefield follows. Bores will be referred to by their Registered Numbers (RN...) - other names for each are given in Table 1. Bores with registered numbers less than 11500 were drilled prior to the present investigation.

3.1 Geology:

The only outcrops known to exist within a three kilometre radius of Ayers Rock are Ayers Rock itself, and a smaller outcrop towards the south-west. Both consist of arkose and arkosic sandstone. It seems likely that the small outcrop to the south-west is a continuation of Ayers Rock displaced by faulting (see Section 3.5).

An appraisal of bore cuttings derived from the area south of Ayers Rock lends support to this concept of faulting. Dolomites and argillaceous rocks, believed to belong to the Pinyinna beds, abut the arkose parallel to the south face of and approximately 600 metres from Ayers Rock. The weathering of the softer dolomitic and argillaceous rocks has resulted in the formation of a deep Cainozoic Basin (Read 1974).

It appears that the depth of this Cainozoic Basin has been overestimated in some areas in past work. This was indicated from analyses of gamma ray logs run for bores drilled in this investigation. These logs were run to accurately locate aquifers and were also used to locate the interface between the Pinyinna Beds and the Cainozoic Sediments. With the aid of these logs it has been found that in this area at least the top twenty metres of the Pinyinna Beds consists of a siltstone. In past work this has often been thought to have been part of the Cainozoic Sediments.

It appears from the investigation that potable water can be obtained from the Pinyinna Beds and the overlying Cainozoic Sediments when they occur in close proximity to a recharge source. Geological and drilling logs indicated two major aquifers in the Southern Aquifer System, these being: (a) the permeable formations (e.g. chert, sandstones and dolomites) of the Pinyinna Beds and the permeable Cainozoic Sediments in hydraulic connection with them; and (b) the permeable Cainozoic Sediments (as intersected by RN 11605) not in hydraulic connection with the Pinyinna Beds (or at least in poor connection). The relationship of these aquifers and probable recharge sources is diagrammatically illustrated on Figure 2.

In the area investigated, the two major aquifers are bounded to the west by the Inindia Beds to the north by the Arkose and are open to the east and south as shown on Figure 1. The runoff from Ayers Rock and the subcropping Arkose to the west and immediate south of Ayers Rock recharges these aquifers probably through the fault zone to the south of Ayers Rock. Further details of the geology of the area are given in Section 3.5.

3.2 Aquifer Parameters:

Most of the pump tests in previous investigations failed to take into account the presence of more than one aquifer. For instance bores penetrating one aquifer were being used to monitor water level fluctuations in another aquifer that was being tested (e.g. test on RN 6134). In other cases water was being produced from more than one aquifer (e.g. RN 6273). In this report analyses are restricted to cases where the above did not occur. A summary of the results obtained from these tests is contained in Table 2.
The Tests which were carried out on aquifers in the Cainozoic Sediments were those on RN 6380, RN 10495 and RN 11605. It is considered that the aquifer cut by RN 6380 and RN 10495 is in connection with the aquifer in the Pinyinna Beds. The aquifer cut by RN 11605 has no connection with the aquifer in the Pinyinna Beds in the vicinity of RN 11605. The aquifer cut by RN 6380 and RN 10495 has a transmissivity (T) of 30 m²/day and a storage coefficient (S) of $3 \times 10^{-4}$. The aquifer cut by RN 11605 has a T of 90 m³/day and a S of $3 \times 10^{-5}$.

The aquifer in the Pinyinna Beds was tested by bores RN 11545, RN 11551 and RN 11605. While the composition of the aquifer in each bore differs (i.e. RN 11545 sandstone, RN 11551 dolomite, RN 11605 chert) it is considered that the bores cut different beds which are interconnected to form the one aquifer. Values of T varied from 20 m³/day to 70 m³/day, and values of S from $6 \times 10^{-5}$ to $4 \times 10^{-4}$.

An analysis of the test on bore RN 11545 was carried out using Boulton's delayed yield type curves (Boulton 1963). The resulting drawdown versus time curve for observation bore RN 11579 yielded the following information when "fitted" to these type curves. For the early part of the test values for T and S of 45 m²/day and $4 \times 10^{-4}$ and for the later part values for T and the Specific Yield of 30 m²/day and $1.3 \times 10^{-2}$. This indicates that the aquifer in this area is acting as a semi-unconfined aquifer with delayed yield and that the available storage is greater than that indicated by the storage coefficients shown in Table 2 and obtained from relatively short tests (one day).

3.3 Groundwater Movement and Recharge:

The correct interpretation of the potentiometric levels in the southern aquifer system is dependent on the recognition of three main points:

(1) The present of a number of aquifers:
(2) The structure of the Pinyinna Beds as explained in Section 3:1; and
(3) The cone of depression resulting from the pumping of RN 6273 between 1969 and August, 1977, and the pumping of RN 11605 since.

Following the observation of fluctuations in potentiometric levels for more than nine years, it was possible to decide which bores were monitoring which aquifers. The following bores monitor the aquifer in the Cainozoic Sediments cut by bore RN 11605 and not in connection with the Pinyinna Beds - RN 6129, RN 6133, RN 6264 RN 6268, RN 6271, RN 6135, RN 6284, RN 11539 and RN 11576. The bores that monitor the aquifers in the Pinyinna Bed plus the aquifers in the Cainozoic Sediments that are in hydraulic connection with the Pinyinna Beds are - RN 2006, RN 2007, RN 4848, RN 6130, RN 6262, RN 6131, RN 6134 RN 6380, RN 10495, RN 11541, RN 11542, RN 11545, RN 11551, RN 11574, RN 11577, RN 11578, RN 11579, and RN 11778. The bores that monitor the water level in the shallow Cainozoic Sediments to the west of Ayers Rock are RN 11540, RN 11547 and RN 11550.

The potentiometric contours thus constructed for 9/5/77 and 16/2/78 and shown on figures 4 and 5 respectively, indicate that:

(a) Recharge is occurring across the fault south of Ayers Rock. There is a possibility that the higher potentiometric levels to the south-west of Ayers Rock are due to the position of the production bores which have supplied water from the Pinyinna Beds for at least fifteen years. However, it is also possible that it is due to groundwater flowing from the shallow Cainozoic Sediments to the west of Ayers Rock across the fault into the Pinyinna Beds.
(b) Recharge to the aquifer in the Cainzoic Sediments (the aquifer cut by RN 11605) occurs mainly in the vicinity of RN 6129. Some recharge is also likely to occur from direct infiltration over most of the area covered by the aquifer.

(c) Groundwater flow is mainly to the south south-east for all aquifers. The contours for the 9/5/77 show increased drawdowns in the vicinity of RN 6273 which was the sole production bore at the time. The contours from the 16/2/78 indicate increased drawdowns in bores RN 6133, RN 6271 and RN 7056 in the vicinity of RN 11605 which was the only producing bore for the previous six months.

In the period since pumping from bores in the Pinyinna Beds or in connection with the Pinyinna Beds has ceased (i.e. from August 1977 to February 1978) recoveries of up to 1.29 metres (RN 4848) have been recorded in bores that monitor these aquifers (compared with greatest 6-monthly fluctuation in previous 34 months for RN 4848 which was 0.35 metres). The recoveries have been greater in bores in the Pinyinna Beds to the North North-West of RN 6273. This indicates that water flows in south south-easterly direction in the Pinyinna Beds.

Using this information on water movement and recharge, an estimate of the safe annual yield of the system was made and is presented in Appendix II. Two methods were used to evaluate the safe yield, one using the available recharge and the other, the groundwater flow through the system. Both methods pointed to a safe annual yield in the order of $2 \times 10^7$ m$^3$. The accuracy of this estimate will improve with time as more is learnt about the effects of long term pumping on the aquifer system.

3.4 Water Quality

Water analyses for all aquifers in the Southern Aquifer System indicate that a general deterioration in water quality does occur from the fault south of Ayers Rock to the south south-east. This deterioration is presumably related to the age of the groundwater and is more evident in the Pinyinna Beds than in the Cainzoic Sediments. The analyses of water quality data is difficult for the following reasons:

(a) Mixing of waters from aquifers (up to three mixed in any one sample e.g. RN 6273);
(b) Lack of knowledge as to which aquifer the sample has come from; and
(c) Comparison of water samples taken over a period of eighteen years from bores close to a recharge source.

Taking into consideration these difficulties, the contours for the ratio of the bicarbonate ion to the chloride ion (the higher the ratio the closer to the source of recharge) in the water of each aquifer were constructed as shown on Figure 6. These contours suggest a south south-easterly flow of groundwater in the Southern Aquifer System. In the Pinyinna Beds, or in the Cainzoic Sediments in connection with the Pinyinna Beds, the better quality water (Total Dissolved Solids concentration of 600 milligrams per litre to 800 milligrams per litre) can be found within 600 metres of the fault to the south of Ayers Rock.

The quality of water in the Cainzoic Sediments in the main aquifer which is not in connection with the Pinyinna Beds is generally less than 700 milligrams per litre (mg/l). The contours of RN 11539 and RN 6129 (possible through the fault zone in this area). The contours also indicate that some recharge is occurring from direct infiltration especially in the vicinity of RN 6134, RN 6135, RN 6131 and RN 6132. There is evidence of one more aquifer in the Cainzoic Sediments. This was intersected at 70 metres in RN 11778. The yield was small, about 0.2 litres per second, and it is thought that it may be recharges from leakage from the aquifer above it.
The aquifer in the weathered arkose to the west and south of Ayers Rock is important as a recharge source for the other aquifers. The TDS content of this water is generally around 700 mg/l.

The water analyses indicate that the better quality water has a nitrate and fluoride level higher than permissible by World Health organisation (W.H.O.) standards. This is unlikely to be a problem at Ayers Rock as the majority of users are tourists and most of the permanent residents have rainwater tanks that can be used to supply drinking water. Nevertheless, permanent residents should be educated to the hazards this water may represent to infants.

3.5 Regional Hydrogeology

A review of the geological structure of this area was carried out by Mr. D. Clarke (Geologist with the Mines Branch, Dept. of the Northern Territory, Alice Springs) using:

(1) data from drilling,
(2) the stratigraphy of the area (Forman, 1965),
(3) information on outcropping formations, and
(4) work previously done by Mr. R. Read (Read, 1974).

A brief resume of the postulated faulting is given below and shown diagrammatically on Figures 8 and 9. The events outlined occurred chronologically in the order given.

(1) A major normal fault (E-E on Figure 8) striking as shown and probably dipping to the south south-west. This faulted the Dean Quartzite and older Precambrian formations against the younger rocks.

(2) Three faults striking south-west north-east (B-B, C-C and D-D on Figure 8). These faults were largely vertical with only a minor lateral component. The sense of vertical displacement of each of these faults is as shown on Figure 8.

Hydrogeologically, the most significant result of this postulated faulting may be that in areas the Pinyinna Beds abuts the Mount Currie Conglomerate. Drilling in the 1977 Investigation and a reappraisal of prior investigations indicate that the formation which has the most aquifer potential in the Olgas - Ayers Rock area is the Pinyinna Beds. In addition, drilling in areas in which the Cainozoic Sediments are underlain by the Pinyinna Beds has resulted in the only high yielding bores (more that 4 l/s). Quality, however, is usually marginal when the Pinyinna Beds abut an outcropping formation with high runoff potential. Bores RN 10490, RN 10695, RN 11545, RN 11551 and RN 11605 (for location of these bores see Figure 11) all obtained supplies of 4 l/s or greater with a TDS content less than 1000 mg/l (except for RN 10490 where the water had a TDS content of 1460 mg/l) and all were within one kilometre of a high runoff area (e.g. arkose at Ayers Rock and Mount Currie Conglomerate at a shallow depth to the North West of RN 10490).

If, as drilling in the Southern Aquifer System indicated, recharge to the high yielding aquifers occurs mainly via fault zones, future investigations should take place in areas 1 to 3, as shown on Figure 10. Furthermore, insufficient drilling has been done to show that where outcropping formations unconformably overlie the Pinyinna Beds, good supplies of potable water could not be found in or above the Pinyinna Beds. It is therefore suggested that areas 4 and 5, as shown on Figure 10, could also be investigated.
4. WATER CONSUMPTION

The annual demand for Ayers Rock for the 1976/77 and the 1977/78 periods as derived from figures obtained for the periods November 1976 to May 1977 and October 1977 to April 1978 respectively, are given in Table 4. In addition, the predicted annual demands for the period 1975 to 1987 are given in Table 5 (Lally 1976). The figures in Table 4 and 5 compare favourably for the 1976/77 and 1977/78 periods. Using these figures as a guide, a safe annual yield of $2 \times 10^5 \text{ m}^3$ (as estimated in Appendix II) would supply the predicted requirements up until the end of 1984.

Assuming that the per capita peak daily demand (plus standby capacity) is 100 percent greater than the average daily per capita requirement, a supply of $1100\text{m}^3$/day would be required when annual extraction attains the safe annual yield figure. This would require a supply capable of producing 13 litres per second. The developments recommended in Section 6 will provide this.
CONCLUSIONS

The results obtained indicate that the bores in the Southern Aquifer System have intersected two major aquifers and at least two minor aquifers. The two major aquifers are:

(a) The permeable formations (e.g. cherts, sandstones, dolomites) of the Pinyinna Beds and the Cainozoic Sediments in connection with these formations; and

(b) The permeable Cainozoic Sediments (as intersected by RN 11605) not in connection with the Pinyinna Beds

Recharge to both aquifers appears to occur primarily through the fault zone to the south and south west of Ayers Rock. The quality of water deteriorates in both these aquifers in a south-easterly direction from this fault - more markedly so in the Pinyinna Beds than in the Cainozoic Sediments.

The system has a safe annual yield in the order of $2 \times 10^5$ m$^3$ if exploitation is carried out as specified in Section 6. The accuracy of this estimate will improve with time as more is learnt about the effects of long term pumping on the aquifer system.

In the light of the findings of this investigation, other areas in the Olgas - Ayers Rock region may warrant further attention in respect of their groundwater potential.
The results from drilling investigations carried out indicate that development of the Southern Aquifer System could take place in the sectors shown on Figure 7 as 1, 2, 3, 4 and 5. These sectors should be developed as follows:

Sector 1: The area around RN 11605. There are two major aquifers in this area suitable for development. RN 11605 intersected the upper aquifer in the Cainozoic Sediments and is capable of producing 4 l/s of water with a TDS content of 700 mg/l. RN 11778 was completed in the Pinyinna Beds (upper aquifer was cemented off) and is capable of producing at least 5 l/s of water with a TDS content of 3400 mg/l.

Sector 2: The area around RN 10495. A bore, correctly constructed, in this area should be capable of producing 4 l/s of water with a TDS content of 900 mg/l.

Sector 3: The area around RN 11551. This bore is capable of producing 4 l/s of water with a TDS content of 700 mg/l.

Sector 4: The area around RN 11545. A correctly constructed bore (see Appendix III) should be capable of producing 4 l/s of water with a TDS content of 800 mg/l.

Sector 5: The area around RN 11541. A bore capable of producing 4 l/s of water with a TDS content of 1500 mg/l could be constructed in this area.

Due to the variability in the nature of both the Cainozoic Sediments and the Pinyinna Beds, alternate locations for production bores can not be accurately predicted without further investigation drilling being done. It is possible however, that one bore in Sector 6 could be as effective as the bores in Sectors 3 and 4.

The developments proposed will result in an available peak yield in excess of 20 l/s. It is recommended, however, that the System is managed as outlined below:

(1) The field is pumped at 11 l/s using a combination of 3 bores as indicated below:-

(a) RN 11778 or a bore in Sector 3 producing at 3 l/s.
(b) RN 11605 or RN 11551 producing at 4 l/s.
(c) A bore in Sector 4 or a bore in Sector 2, producing at 4 l/s.
(d) instead of (b) and (c), two of the following bores - RN 11605 a bore in Sector 2 and a bore in Sector 6 - each producing at 4 l/s.

This will result in a supply of water with a TDS ranging from 1000 mg/l to 1500 mg/l depending on which combination is used. The aim of spreading the production bores as recommended is to "harvest" as much of the available safe yield as possible while keeping the TDS of the water supplied within WHO limits (1500 mg/l).
(2) Annual production should be limited to the safe annual yield of $2 \times 10^5$ m$^3$.

(3) The discharge from each production bore should be metered.

(4) All substantial users should be metered.

(5) Production bores in each sector should be constructed as indicated in Appendix III.

(6) Water from each production bore should be sampled every six weeks and tested for conductivity and nitrate content.

(7) Water levels in the following bores should be monitored at six weekly intervals - RN's 2006, 2007, 4848, 6129, 6130, 6133, 6135, 6262, 6264, 6268, 6271, 6273, 7056, 10495, 11539, 11540, 11541, 11542, 11547, 11550, 11573, 11574, 11576, 11577, 11578, 11579.

Further work in the Olgas - Ayers Rock area is also warranted. It is suggested that future investigations could take the format outlined below:

(1) Geophysics - mainly magnetometer traverses to locate faults,
(2) drilling in areas 1 to 5 and shown on Figure 10,
(3) two bores in each area to delineate which areas require further testing and
(4) further testing of promising areas, once these stages have been completed.
7. BIBLIOGRAPHY


TABLE 1 -

Bores Drilled in 1977 Investigation

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TABLE 2 - Pump Test Results

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<td>RN 4851</td>
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<td>Constant Rate</td>
<td>S v t 1.75</td>
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### TABLE 3 - WATER ANALYSES

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<th>Date</th>
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<th>Cl</th>
<th>SO₄</th>
<th>NO₃</th>
<th>HCO₃</th>
<th>Fl</th>
<th>Total Alkalinity (as CaCO₃)</th>
<th>Total Hardness (as CaCO₃)</th>
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<th>Mg</th>
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### TABLE 4 - Annual Water Consumption for 1976/77 and 1977/78

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<th>DERIVED CONSUMPTION (kl)</th>
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<td>13/10/77 to 7/4/78</td>
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### TABLE 5 - Predicted Annual Demand for Period 1975/76 to 1986/87

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<th>Motels (kl)</th>
<th>Locals (kl)</th>
<th>Total (kl)</th>
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<td>15000</td>
<td>40000</td>
<td>67000</td>
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<td>17100</td>
<td>45600</td>
<td>76380</td>
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<td>50710</td>
<td>63390</td>
<td>169050</td>
<td>283150</td>
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APPENDIX 1


1. Drilling:

Twenty-one bores were drilled during the investigation. A brief comment on each bore follows:

RN's 11539, 11540, 11541 and 11542 were drilled to define the potentiometric surface and gather further information on the quality of water to the west of bores RN 6129, 6130 and 6133. RN 11539 was drilled to 117 metres (m). A small supply of 0.6 litres per second (l/s) with a Total Dissolved Solids (TDS) content of 440 milligrams per litre (mg/l) was cut at 55m. The bore penetrated the Pinyinna Beds at 75m.

RN 11540 was drilled to 77m. Water was cut at 21m and the supply slowly increased with depth to 2 l/s. The water had a T.D.S. of 600 mg/l and a potentiometric level (SWL) of 11.20 metres. Arkose and siltstone equivalent to Cambrian Mount Currie Conglomerate was cut at 23m.

RN 11541 was drilled to 118m. A supply of 3 l/s was cut at 66m. This supply had a TDS of 1200 mg/l. The Pinyinna Beds were intersected at 87m.

RN 11542 was drilled to 82m. Seepage occurred at 65m and the water had a TDS of 1120 mg/l. The Pinyinna Beds were cut at 69m.

RN's 11543, 11544 and 11545 were drilled to the west of RN 11542 in an attempt to define the western boundary of the Pinyinna Beds.

RN 11543 encountered siltstone at 3m. This siltstone may belong to the Inindia Beds. Drilling became harder with depth and ceased at 35m.

RN 11544 encountered a similar material at 3m, at which depth drilling ceased.

RN 11545 intersected the Pinyinna Beds at 17m. A supply of 6 l/s was cut at 47m. This water had a TDS of 700 mg/l and a SWL of 23.5m.

RN 11546, 11547, 11548, 11549 and 11550 were drilled to determine the depth of Cainozoic Sediments and weathered rock in an area into which considerable runoff from Ayers Rock flows. They were also to provide information on the Potentiometric Surface and water quality in the area.

RN 11546 encountered 17m of Cainozoic and 12m of weathered arkose. The hole was completed at 34m in arkose and filled in. The SWL was 22.5m.

RN 11547 was completed at 19m in arkose after passing through 6m of Cainozoic and 3m of weathered arkose. The TDS of the seepage water was 710 mg/l and the SWL was 9.9m.

RN's 11548 and 11549 were both completed in Cainozoic Sediments - at 4m and 5.3m respectively.

RN 11550 was completed at 8m after passing through 6m of Cainozoic and 2m of Arkose. The TDS of the seepage water was 670 mg/l and the SWL was 5.4m.
RN 11551 was sighted in an attempt to accurately locate the NE-SW fault between the Arkose of Ayers Rock and the Pinyinna Beds. This it achieved when it intersected the Pinyinna Beds at 22m. Water was cut at 38m and the supply increased slowly to 3 l/s at total depth which was 60 metres. The supply was cut mainly in dolomite and had a TDS of 600 mg/l and a SWL of 25m.

RN 11573 was to be a test production bore. However, less than 1 l/s was airlifted from a depth of 72m at which drilling ceased. The bore unexpectedly intersected a hard fine grained feldspathic greywacke at 42m. This greywacke is similar to but much finer grained than the arkose outcropping at Ayers Rock.

RN's 11574 and 11579 were drilled as observation bores from RN 11545 which was screened as a test production bore.

RN 11574 was drilled to 77m. A supply of 2 l/s was cut at 53m. This water had a TDS of 650 mg/l. The Pinyinna Beds were intersected at 29m.

RN 11579 was drilled to 61m and cut the Pinyinna Beds at 28m.

RN 11576 was sited to gain further water quality information. The bore was completed in Cainozoic Sediments at 83m, and cut a small supply of 53m. This water had a TDS of 730 mg/l.

RN 11577 was drilled as a control for past drilling in the area. Information gathered from this bore was to enhance understanding of drillers logs of old bores - especially the deeper bores drilled using "mud". The Pinyinna Beds were cut at 90m and the hole completed at 148m. Since a useful supply of 4 l/s (TDS 1490 mg/l) was airlifted from 83 metres an attempt was made to screen the aquifer. This was unsuccessful.

RN 11578 was drilled to be a test production bore. It was completed at 60m and was similar to RN 11551. During development, however, problems were encountered with sand being pumped. This was thought to have come from the small supply cut in the siltstone above the dolomite. To overcome this RN 11551 was reamed out to take 200mm (8 inch) casing to 55m (using a percussion rig). This was expected to seal off the upper supply. The casing was then pulled from RN 11578 and run down RN 11551. RN 11551 then was developed successfully with no sand problems.

RN 11605 was drilled as a replacement bore for RN 6273 (AR 29). RN 11778 cut a supply of 4 l/s in Cainozoic Sediments at 49m. This water had a TDS of 670 mg/l.

RN 11778 was drilled as a standby bore for RN 11605. This bore was designed to pass through the aquifer cut in RN 11605 and penetrate the lower aquifer in the Pinyinna Beds. The quality of the water was expected to be about 2300 mg/l. The upper aquifer was cut at 59m and cemented off. A further supply of 0.5 l/s was cut at 72m. The lower aquifer was cut at 110m. A supply of 10 l/s was airlifted. The TDS of the water was worse than expected being 3400 mg/l. Recommendations regarding the use of this bore can be found in Section 6.
2. Geophysics:

The geophysical work was undertaken concurrently with the drilling program. The following geophysical techniques were used.

(a) Downhole logs were run in most of the 1977 investigation bores plus some of the existing bores using one or more of the following probes - gamma ray, single point resistance, self potential and caliper. All of these except the caliper probe were used to locate aquifer zones and the contact between the Cainozoic Sediments and the underlying formation. The caliper probe was used to evaluate the condition of a number of existing bores (usually to find out if screens were still in their correct position).

(b) A number of Potential Drop Ratio (PDR) probes were done in the investigation area. These were done to assist the location of the interface between the Cainozoic Sediments and the underlying formations.

(c) Four resistivity traverses were done. These were used to provide information on the profile of the contact between the Cainozoic Sediments and the underlying formations. They were also used to locate the fault to the south of Ayers Rock.

(d) Four magnetometer traverses were done to give more information on the contact between the Cainozoic Sediments and the underlying formations.

3. Pump Tests:

Testing of bores followed the general format outlined below:

(a) Development. This usually only required the cleaning out of small quantities of sand and silt from the bore. In two bores - RN 11545 and RN 11577 - it also required development of the sand aquifer adjacent to the screens.

(b) Step Tests. This test involved five steps (a step being an interval of time during which the discharge rate is held constant) each of 100 minutes duration with discharges usually ranging from 1 l/s to 5 l/s.

(c) Constant Rate Test. During this test each bore was pumped at a constant rate (usually 3 l/s to 4 l/s) for a period of 24 hours. Only one bore was tested for a longer period - RN 11545 at 2 l/s for 48 hours.

(d) Recovery. On completion of the constant rate test, measurements are taken as the water level begins to rise again. The period over which measurements are taken depends on the recovery rate of the bore.

The following bores were tested to the above format - RN 11545, RN 11551, RN 11778. The tests carried out on bores RN 11577, RN 11578 and RN 11605 were: RN 11577 - development plus short constant rate; RN 11605 - development plus step test. These were the only bores tested during this investigation.
Estimation of the Safe Yield of the Southern Aquifer System at Ayers Rock (incorporating the area formerly known as the South-East Aquifer)

1. Safe Yield (Calculated from Estimated Recharge)

The safe yield of the Southern Aquifer can be estimated by considering the availability of recharge to the aquifer system. To do this we have confined our interest to Areas A, B, C and D as indicated on Figure 7 for the following reasons:

(a) Area A is the portion of Ayers Rock that contributes runoff that recharges the Southern Aquifer System;

(b) Area B is that part of the Southern Aquifer System where basement rock is usually encountered at a depth of less than fifteen metres (basement rock is arkose in this area);

(c) Area C is also underlain by arkose - usually at a depth greater than fifteen metres; and

(d) Area D is the area in which Cainozoic Sediments (from 20m to 100m thick) overlay the Pinyinna Beds, and contains the most important aquifers so far investigated in the Southern Aquifer System.

Available information indicates that the water that infiltrates into the aquifers in Areas B, C and D recharges the aquifers in Area D. Thus, by making the following assumptions, we can estimate the safe yield of the Southern Aquifer System (i.e. the recharge to aquifers in Area D).

(1) Annual rainfall at Ayers Rock is 175 millimetres

(2) Seventy-five percent of rainfall that falls onto Area A will runoff into Areas B, C and D;

(3) One third of this runoff will contribute to recharge of the aquifer system;

(4) Ten percent of rainfall that falls on Areas B and C will contribute to recharge and;

(5) Two percent of rainfall that falls on Area D will contribute to recharge.

Safe Annual Yield = Recharge (3) + Recharge (4) + Recharge (5) of Southern Aquifer.

\[
= (3.0 \times 10^6 \times 4.4 \times 10^{-3}) + (5.0 \times 10^6 \times 17.5 \times 10^{-3}) \\
+ (5.0 \times 10^6 \times 3.5 \times 10^{-3}) \\
= 2.4 \times 10^5 \text{ m}^3
\]

2. Safe Yield (Calculated from Groundwater throughflow)

The safe yield can also be estimated by calculating the throughflow in both the major aquifers.
2.1 Aquifer in, or in connection with, the Pinyinna Beds.

The calculation of throughflow is based on:

(a) Groundwater flow is entirely to the south-south east;

(b) An average value of $30 \text{ m}^3/\text{day/m}$ for the transmissivity ($T$) of the aquifer; and

(c) An exploited aquifer width ($w$) of 4000 metres.

Throughflow ($PB$) \[= \frac{T \times w \times \text{Potentiometric Level Gradient}}{2} \]
\[= \frac{30 \times 4000 \times 6000}{2} \]
\[= 400 \text{ m}^3/\text{day} \]

2.2 Aquifer in the Cainozoic Sediments.

The calculation of throughflow is based on:

(a) Groundwater flow is entirely to the south-south east;

(b) An average value of $90 \text{ m}^3/\text{day/m}$ for the Transmissivity ($T$) of the aquifer; and

(c) an assumed aquifer width ($W$) of 1000 metres.

Throughflow ($CS$) \[= \frac{T \times W \times \text{Potentiometric Level Gradient}}{2} \]
\[= 90 \times 1000 \times 1000 \]
\[= 180 \text{ cubic metres/day} \]

2.3 Safe Yield = Throughflow ($PB$) = Throughflow ($CS$)

\[= 580 \text{ cubic metres/day} \]

Safe Annual Yield \[= 2.1 \times 10^5 \text{ cubic metres} \]

3. Annual Safe Yield:

The annual safe yield as calculated by both methods is approximately $2 \times 10^7 \text{ m}^3$, which is equivalent to a continuous supply of 6.5 l/sec.
Bore Construction.

The bore construction techniques used at Ayers Rock have been varied due mainly to the differing composition of the aquifers intersected and to the different levels of bore construction technology applied over the years. The degree of success of these techniques can be gauged from the following resumes on each bore that has been equipped or has had a reliable test carried out on it.

RN 2006 (Pioneer Tuits Second Att): This bore obtained a supply of 1 l/s in sand and perforated casing was used. A pumpjack was used and problems resulted from sand entering into the bore.

RN 2007 (NT Reserves Board Number 2, Second Try): As for RN 2006.

RN 4851 (Ayers Rock Number 4): A supply of 2 l/s was obtained from sand. Casing with 6 millimetre (mm) perforations was used adjacent to the aquifer. As with RN 2006 and RN 2007 problems resulted from sand entering into the bore.

RN 10495 (Ayers Rock Number 4 Replacement): A supply of 4 l/s was airlifted from sand at 66m. The aquifer was screened off using 0.508 mm screens. This bore originally had development problems then at a later date sand began entering the bore. Later tests indicate that the screens had fallen out of the bottom of the casing.

RN 6385 (AR 64): A supply of 1 l/s was airlifted from sand at 63m. Casing with 3mm perforations was used. No problems encountered mainly because of low pumping rate - less than 0.4 l/s.

RN 6273 (AR 29): This bore produced 4.5 l/s of water between 1968 and 1978. At present it is unusable due to a section of pump shaft being stuck in the bore. This bore had quality problems - TDS content of 2300 mg/l. It also produced small quantities of sand which came from the upper aquifer which was composed of a poorly sorted sandstone. The water quality problems were due to poor quality water (3400 mg/l) coming from the lower aquifer (chert formation in the Pinyinna Beds). Casing with 6mm perforations was used.

RN 6380 (AR 56): A supply of 3 l/s was airlifted from sand at 82m. The aquifer was screened but the water produced continued to have a milky colour. When a sample of this water was filtered, a very small amount of dirty white clay was removed and the resulting filtrate was colourless. This dirty white clay could have been part of a band of white clay that was intersected in the interval 60m to 75m. Water from a small supply (0.1 l/s) cut at 60m moving down the outside of the casing could have eroded small amounts of white clay and the resulting solution could have imparted the milky colour to the water pumped from the bore. Recent tests also indicate that the screens have fallen out of the bottom of the casing.

RN 11577 (AR 77/17): This hole was originally drilled as an investigation hole. It was drilled using bentonite to 146m and an attempt was made to screen an aquifer in the interval 80m to 83m (sieve analysis of the sand of which the aquifer is composed is given in Figure 11). Poor development techniques resulted in this bore being abandoned.
Bore Construction - Cont'd.

RN 11605 (AR 77/20 - Production Bore Number 5): This bore currently produces 4.2 l/s. Slight sand problems are likely to occur (and have) as casing with 6mm perforations has been used adjacent to a loosely cemented, poorly-sorted silty sandstone aquifer.

RN 11778 (AR 78/1): This bore is capable of producing in excess of 5 l/s. The water produced, however, has a very high TDS content (3400 mg/l).

RN 11545 (AR 77/7): It appears that this bore would have been capable of producing 4 l/s if it had been correctly developed. Results of a sieve analysis of the sand aquifer intersected are plotted on Figure 12.

RN 11578 (AR 77/18): When development was carried out prior to testing a considerable quantity of sand was produced. As the main aquifer in this bore was in fractured dolomite, it was considered that the sand was coming from a small aquifer higher up the hole. When the sand problem persisted it was decided to develop RN 11551 as a test production hole. Bores RN 11551 and RN 11578 had the same characteristics when drilled.

RN 11551 (AR 77/13): The small upper aquifer was sealed off and the bore tested. The bore was tested for 24 hours at 4 l/s and pumped water with no trace of sand throughout the test.

Considering the success or lack of success of the techniques used for the construction and development of these bores, it is suggested that the following techniques be adopted for the areas mentioned in Section 6 and shown on Figure 8.

Sector 1 (Area around RN 11605): There are two main aquifers in this area.

(a) Upper Aquifer - if the amount of sand being produced by RN 11605 increases markedly, screening of this aquifer (preferably using a gravel pack) might be necessary.

(b) Lower aquifer - same as for bore RN 11778.

Sector 2 (Area Around RN 10495): A 'gravel pack' bore should be constructed in this area - the gravel pack' fulfilling the same specifications as those indicated on Figure 12 for RN 11545. A bore of at least 330mm diameter should be drilled, 150mm diameter casing and 0.889 mm screen used. Development should follow one of the recognised methods. Jetting of air through the screens, however, must not be used since the sand aquifers in this area are thin and are overlain with a soft clay. The action of air may result in sand cavities into which the overburden collapses behind the screen and can result in the complete loss of the bore. If any small aquifer (supply of less than 0.5 l/s) is intersected before the main aquifer, it should be cemented off.

Sector 3 (Area around RN 11551): Same as for bore RN 11551

Sector 4 (Area around RN 11545): The same as for Sector 2.

Sector 5 (Area around RN 11541): As for Sector 2 except that -

(a) 'gravel pack' should fulfill the same specifications as those indicated on Figure 11 for RN 11577 and

(b) 0.889mm screens should be used.
The three main points to be considered when constructing a production bore in the Southern Aquifer System are:

(1) The number and type of aquifers to be intersected;

(2) to cement off any aquifer (no matter how small the supply) above the aquifer that is to be exploited; and

(3) to use the correct development procedure.
AYERS ROCK SOUTHERN AQUIFER SYSTEM
FIG 1: GEOLOGY
FIG. 2  AYERS ROCK SOUTHERN AQUIFER SYSTEM – CROSS SECTIONS A–A AND B–B (as per Figure 1)
Match Points for drawdown (s) vs time (t) curve for observation bore RN.11579 (Using Boulton's Delayed Yield Type Curves)

Distance from pumped bore RN.11545 to observation bore RN.11579 = 21.7 metres

Date of test: 10-6-77
Pumping rate: 2.15

\[
\frac{4T_y^4}{r^2} (u_y + S_y) \text{ (Specific Yield)} = 1.4 \times 10^{-2}
\]

\[
\frac{4T_x^4}{r^2} (u_x + S_x) \text{ (Storage Coefficient)} = 4 \times 10^{-4}
\]

FIG. 3 DRAWDOWN Vs TIME FOR PUMP TEST ON BORE RN.11545 AT AYERS ROCK
AYERS ROCK SOUTHERN AQUIFER SYSTEM

FIG 6  CONTOURS OF RATIO OF DICARBONATE ION TO CHLORIDE ION (CO3/Cl)
CONTENTS

1. Introduction
2. Background
3. Methodology
4. Results
5. Discussion
6. Conclusion
7. References

FIG. 1: Diagram of the Ayers Rock Southern Aquifer System.
FIG. 8 THE OLGAS, AYERS ROCK AREA
GEOLOGICAL INTERPRETATION
NOTE: These sections are given to indicate the relationship of formations to each other. The dips of faults and thicknesses of formations are diagrammatical.

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FIG. 9 THE OLGAS, AYERS ROCK AREA
CROSS SECTIONS V-V, W-W, X-X, AND Y-Y
FIG. 10  THE OLGAS, AYERS ROCK AREA, AREAS PROPOSED FOR FURTHER INVESTIGATION
FIG. II  PLOT OF RESULTS FROM Sieve Analysis OF Sand FROM AQUIFER IN BORE RN. 11577

GRAVEL PACK
Sieve Opening  % Retained
4·0mm   12 - 28
2·8mm   16 - 34
2·0mm   26 - 42
1·4mm   42 - 60
1·0mm   76 - 94
0·5mm   90 - 100

Effective Size 0·9mm
Uniformity Coefficient 1·9
Screen Slot Opening 0·889

CUMULATIVE % Retained

SIEVE SIZE mm

Effective Size 0·170mm
Uniformity Coefficient 3·8
FIG. 12 PLOT OF RESULTS FROM SIEVE ANALYSIS OF SAND FROM AQUIFER IN BORE RN.11545