NATURAL RESOURCES DIVISION

GROUNDWATER RESOURCES OF THE BERRY SPRINGS - NOONAMAH AREA

REPORT No 30/1994

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List of Abbreviations

°C	Degree Celsius
EC	Electric Conductivity
pH	Index of Acidity or Alkalinity
TDS	Total Dissolved Solids
µS/cm	Electric Conductivity
NTGS	Northern Territory Geological Survey
AGSO	Australian Geological Survey Organisation (ex BMR)
bgl	Below Ground Level
AHD	Australian Height Datum
SWL	Standing Water Level

SUMMARY

This study was carried out to investigate and establish boundaries of both the major and minor aquifers in the Berry Springs – Noonamah Area. Twenty-eight (28) bores were drilled of which ten (10) bores were constructed as monitoring bores. This study assisted in up dating the knowledge, which would assist in managing water resources of this region, where rapid horticultural and other industrial developments are taking place.

During this study, a major *dolomite aquifer* with an average depth 20 m below the ground level was established which covers approximately 20 x 20 km^2 area. This aquifer occurs at i) the unconformity of the *South Alligator Undefined dolomite layer (Psd)* and overlying *Cretaceous sediments (K)* and in the weathered/fractured *dolomite layer* and ii) in joints & fractures in dolomite, which has been found up to 199.0 m below ground level. Average sustainable yield in this aquifer is over 5.0 L/s. Though, it is found as high as 32.0 L/s, sometime the yield could be very low due to presence of clay and/or fine sand in the aquifer. This aquifer system sustains a number of local groundwater discharge features like - Lake Deane, Berry Springs, Parson Springs and Twin Farm Springs. A number of creeks and rivers are also sustained up to early dry season by the groundwater discharge. Sustainable yield of this *dolomite aquifer system* is estimated to be about 34,000 ML per year i.e. one 20 L/s bore per km^2 (24 hour continuous supply over 200 day period). This indicates that any extraction within 2 km radius of the Berry Springs has potential to adversely affect this spring. The water from this aquifer system is hard with a TDS around 200 mg/L and bi-carbonate (HCO_3) around 250 mg/L. Sodium and chloride contents are very low indicating that the water is recent.

Minor aquifers in the region occur in various formations of different ages. Groundwater availability in this area has been divided into three classes according to their type and yield range as follows:

a) *A major aquifer in fractured & karstic rock aquifer* with yield >5.0 in Dolomite Layer (*Psd*) of the South Alligator Group (*Ps*)

b) *Fractured rock* aquifer with yield 0.5 – 5.0 L/s in Koolpin Formation (*Psk*) of the South Alligator Group (*Ps*) and Whites Formation (*Ppi*) and Crater Formation (*Pp*r) of the Mt Partridge (*Pp*)

c) *Fractured & weathered rock* aquifer (minor aquifer) with yield range <0.5 L/s in the Mount Bonnie, (*Pso*) & Gerrowie Tuff (*Psg*) of the South Alligator Group (*Ps*) and in Wildman Siltstone (*Ppw*) & Acacia Gap Member (*Ppa*) of the Mt Partridge (*Pp),* *Burrell Creek Formation* (*Pfb) of the Finniss River Group (Pf)* & Rum Jungle Complex of *Archaean* (*Ar)*

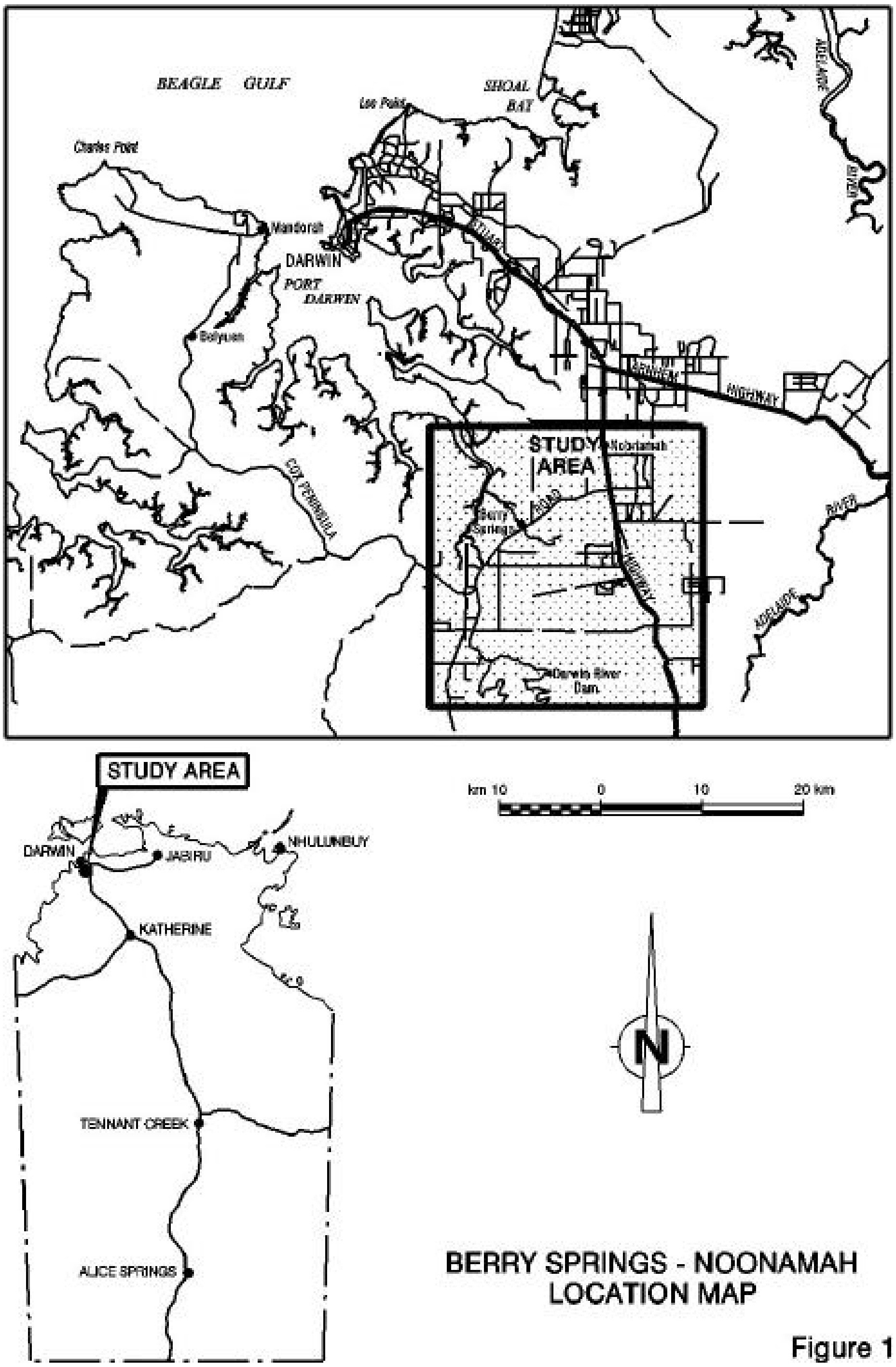
Water quality indicates that the recharge of the aquifer system is mostly by the local rainfall and the amount of recharge is considered to be about 30 to 40% of the rainfall (Pidsley et al 1994).

Water from the dolomite aquifer is very hard. However, water from one bore (9485) is being bottled as *mineral water* for its commercial quality.

The seasonal water level variation during the dry season ranges from 5.23 to 9.37 m (AHD) and from 9.50 to 18.07 m (AHD) in the wet season, which is quite significant. Aquifers in this area are recharged annually by the monsoonal rain.

INTRODUCTION

AMG co-ordinates of the study area is from 708000 to 735000 Eastings and from 8576550 to 8604150 Northings covering about 1,134 km^2 (Figure 1) and it is accessible around the year by the sealed and graded gravel roads. Most of the area lies within the Water Management District. There are various tourist places in this region such as N.T. Wildlife Park, Berry Springs Nature Park, Deer Park, Deer Farm, Recreational Lake Resort, Orchid Farm, etc. Also, the horticultural industry in this region is developing very fast. Mainly groundwater is used for both the domestic and industrial purposes though the water main from the Darwin River Dam to Darwin passes through this area. The northern boundary of the study area is about 45 km from Darwin.



BERRY SPRINGS - NOONAMAH LOCATION MAP

Figure 1

The area lies in the tropics having two distinct seasons - *wet* and *dry* with temperatures ranging from an average minimum of 22.8^0 C to a maximum of 31^0 C. The mean rainfall in this area is about 1636 mm per annum. However, during the 1994-5 wet season, the rainfall was over 2000 mm, the highest recorded in the history. The area is drained to the northwest by rivers, creeks, lagoons and springs (both perennial and intermittent). There are two major rivers (*Darwin* & *Blackmore*), two major creeks (*Berry* & *Ella*), two lagoons (*Lake Deane* & *Woodfords Lagoon*) and three perennial springs (*Berry, Parson & Twin Farm*). There are few more intermittent springs off the Darwin and Blackmore Rivers as well as Berry Creek. Berry Springs are located on a fault at the geological contact (between the Dolomite and Burrell Creek Formation). There are man-made features like lake & dam - Barden's Recreational Lake in the north and Darwin River Dam in the south, which supplies most of the domestic water to the Darwin urban and rural areas.

Previous work carried out in this area included the water supply developments for the domestic, tourism, Parks, Berry Springs School, Majestic Orchid Farm, Barden's Recreational Lake and numerous horticultural farms. However, no major hydrogeological investigation had been undertaken in this area before.

A significant increase in the groundwater demand in recent years, in rural areas within the Darwin region, prompted the Water Resources Division to update its approach to the groundwater management The existing level of resource knowledge of this region was not sufficient to manage resource development. Therefore, several groundwater investigations were carried out to comprehend and establish both the hydrogeology and hydrology of the groundwater resources in order to formulate an appropriate long-term management framework. This project "*the groundwater investigation in the Berry Springs - Noonamah region*" is one of the several projects as a part of the proposed "*Hydrogeological Mapping of the Darwin sheet 1:250 000 scale*" which is a component of the "*Darwin Region Groundwater Evaluation*" project suite.

Objectives of this study included determining and establishing both the major and minor aquifers estimate hydrological behavior of the aquifers and produce a hydrogeological map at a scale of 1:50 000 scale of the *Berry Springs - Noonamah region*.

The scope of this project involved a search of all available relevant geological data, reports and maps produced by AGSO (ex BMR), NTGS and Water Resources Division, collect and collate all existing hydrogeological data. Fieldwork included geophysical survey and drilling for strata and water samples to fill the significant gaps in data.

Initially the literature and data search was carried out. The mainframe VAX computer system was used to enter all the available data on existing bores, which would be attached to the HYDSYS program, and this would be the medium to extract data in different formats. A base map was then produced to draft a hydrogeological map. This followed planning for an investigation drilling to fill in gaps in information. Investigation drilling was carried out in two stages - a) first stage to establish various aquifers and b) second stage to locate the boundary of the major aquifer accurately and establish its hydrological behavior.

The first stage drilling was carried out during the August - September 1993 period and a total of seventeen (17) investigation bores were drilled. This was followed by a geophysical survey during September-October 1993 to locate accurately the boundary of the major aquifer, which was subsequently established during the first stage of investigatory drilling, and also the local geology was modified. Geophysical survey provided some drilling targets for the second stage.

The second stage drilling was carried out during the June - July 1994 period based on the results of the first stage drilling and the geophysical survey. During this period, a total of eleven (11) bores were drilled of which ten (10) bores were constructed to monitor water level and water quality. They are monitored quarterly. Additional geophysical survey was carried out during and after the second stage of drilling until October 1994 to confirm the structure of the major aquifer and its areal extent and to locate further drilling sites to confirm the same. Down the hole geophysical logging was also carried out during and after the drilling.

A deep bore (199 m) was drilled during April 2001 to get information on depth of dolomite and coring of dolomite to determine its age, which is still in progress by the NTGS.

HYDROGEOLOGY

A. Geology

i) Regional & Local

Geologically, the area lies on the Batchelor Shelf on the western part of the Pine Creek Geosyncline. The early Proterozoic sediments were deposited on the slopes of the dome of the *Rum Jungle Complex* (*Ar*) of the Archaean age, situated in the extreme south of the study area. Two possible theories have been put forward in order to explain the geology of the study area.

A theory was proposed in the interim report (Verma, 1994) that the geology was strongly controlled by the geological structures like the *Giant Reef Fault*, which caused the displacement of both the Archaean and the Proterozoic rocks. Tight folding created a small basin in the study area in which the carbonate sediments (referred as Middle Proterozoic age in the Interim Report) are considered to be deposited over the Burrell Creek Formation (Pfb). It meant that these carbonate rocks are younger than the Burrell Creek Formation.

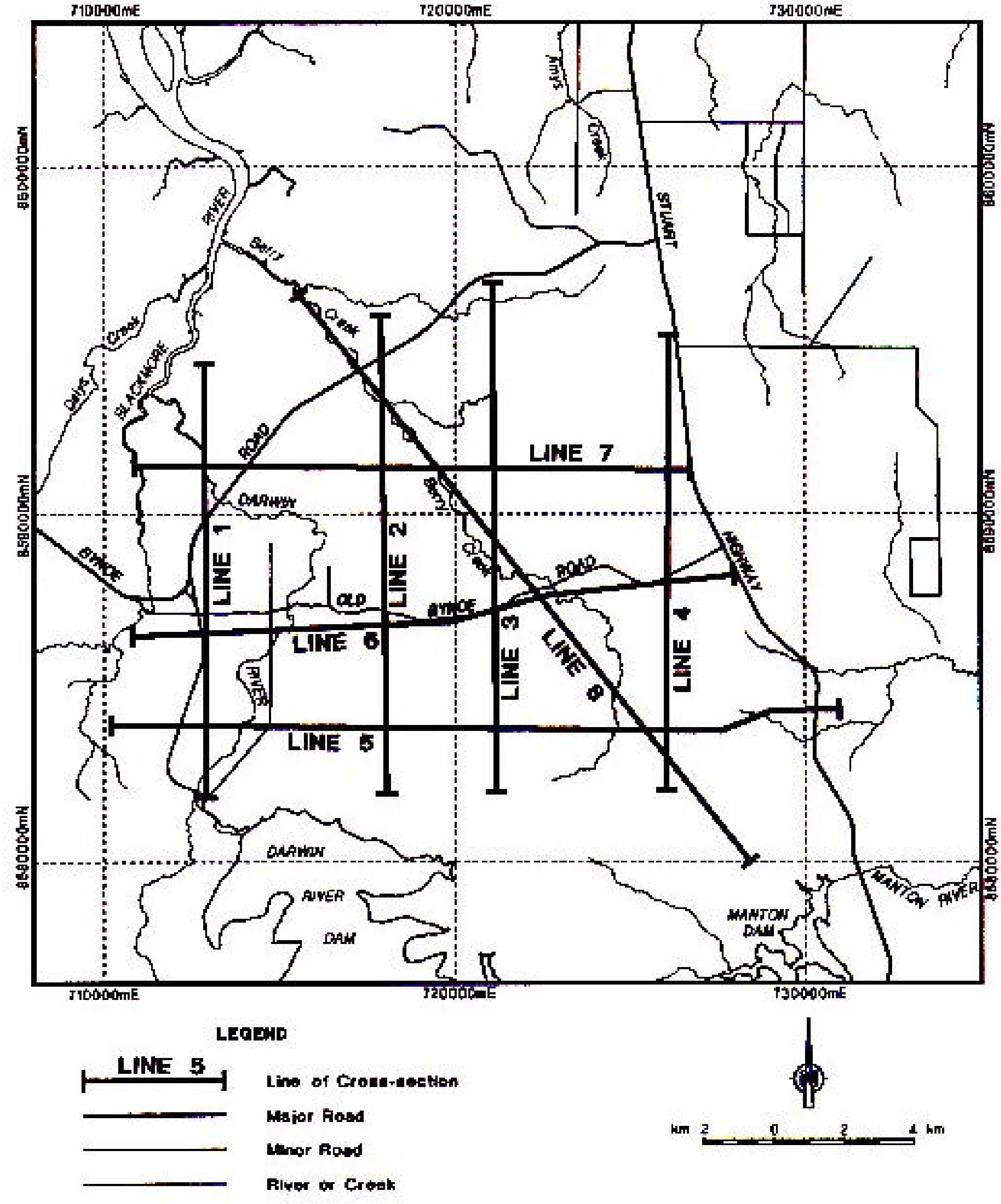
However, due to lack of age determination of these dolomite they were placed a part of the South Alligator Group because this carbonate aquifer appeared to be similar to the carbonate found in the Palmerston area.

If the first theory is accepted that this carbonate is younger than the Burrell Creek Formation then this carbonate may be established this carbonate (of Berry Springs area) continues to Palmerston in the northern region through Knuckey Lagoon to the Shoal Bay area.

On the other hand, this dolomite has been assumed as the *Undefined Layer* of the South Alligator Group of the Lower Proterozoic age for the moment due to inconclusiveness of the carbonate age in the first theory mentioned above. Therefore, please note that the second theory has been adopted for this report. This *Undefined Layer* has been described in the NTGS 1:50 000 scale geology map and explanatory notes.

The NTGS geological (compilation) maps in 1:25 000 scale (Pietsch, 1983) were digitized on the Intergraph using Geographic Information System (GIS). Some necessary modifications in geology were made on the basis of this study to produce a hydrogeological map in 1:50 000 scale (Figure 2). The stratigraphy of this region is provided in the Table 1.

Regionally, the sediments of the Finniss River, the South Alligator and the Mount Partridge Groups underlie the area. The *Cretaceous* sediments overly mostly the *South Alligator Group* rocks and occasionally the *Finniss River Group* and the *Mount Partridge Group* rock. The *Cainozoic* sediments cover most of the areas except hills and steep slopes. All the formations are shown in geological cross-sections except Ella Creek Formation (*Pse*) due to its very small areal coverage of the area. Locations of all the cross sections are shown in Figure 3. All the formations are briefly described below.

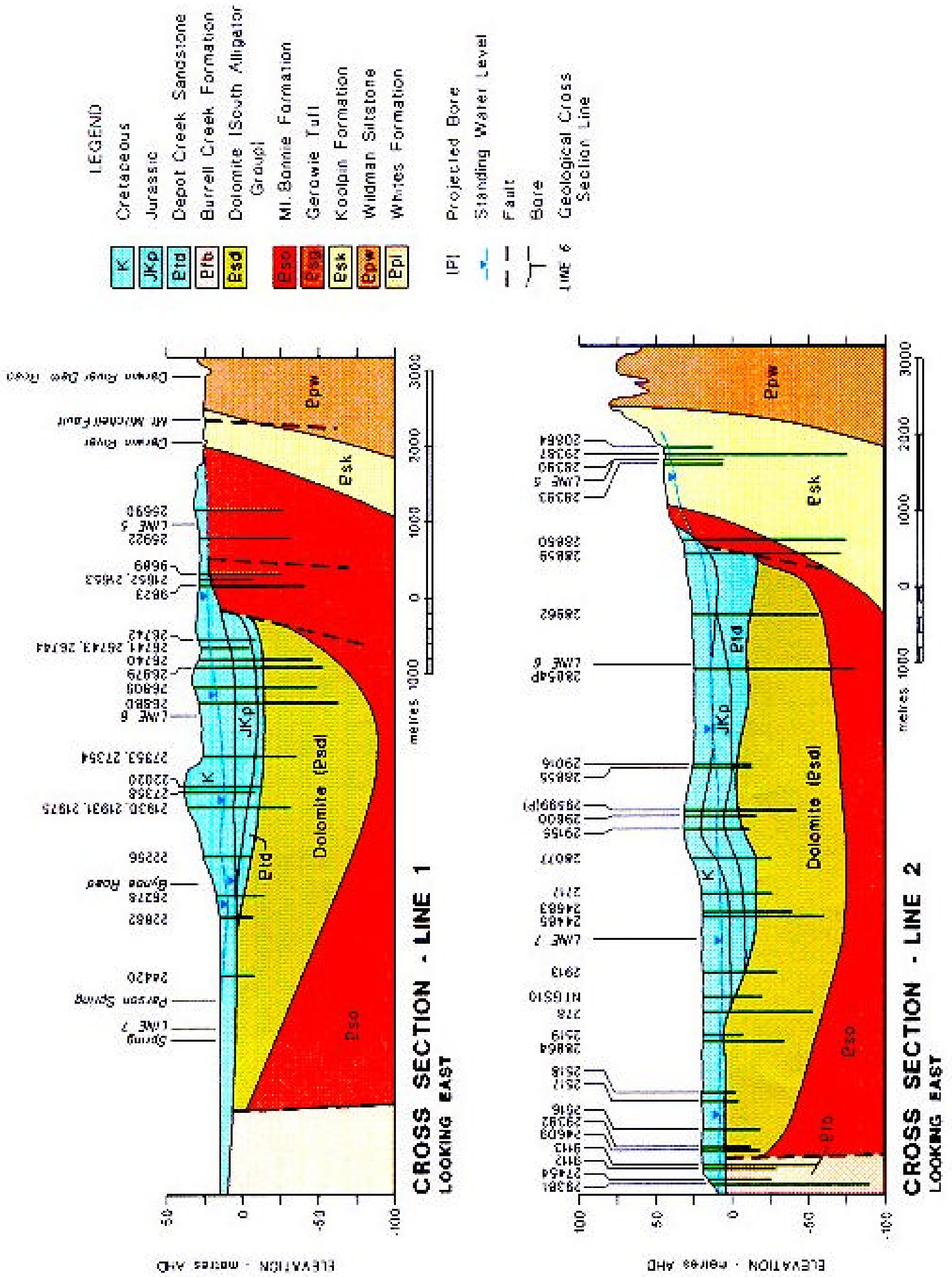


GEOLOGICAL CROSS SECTIONS
LOCATION MAP

Figure 3

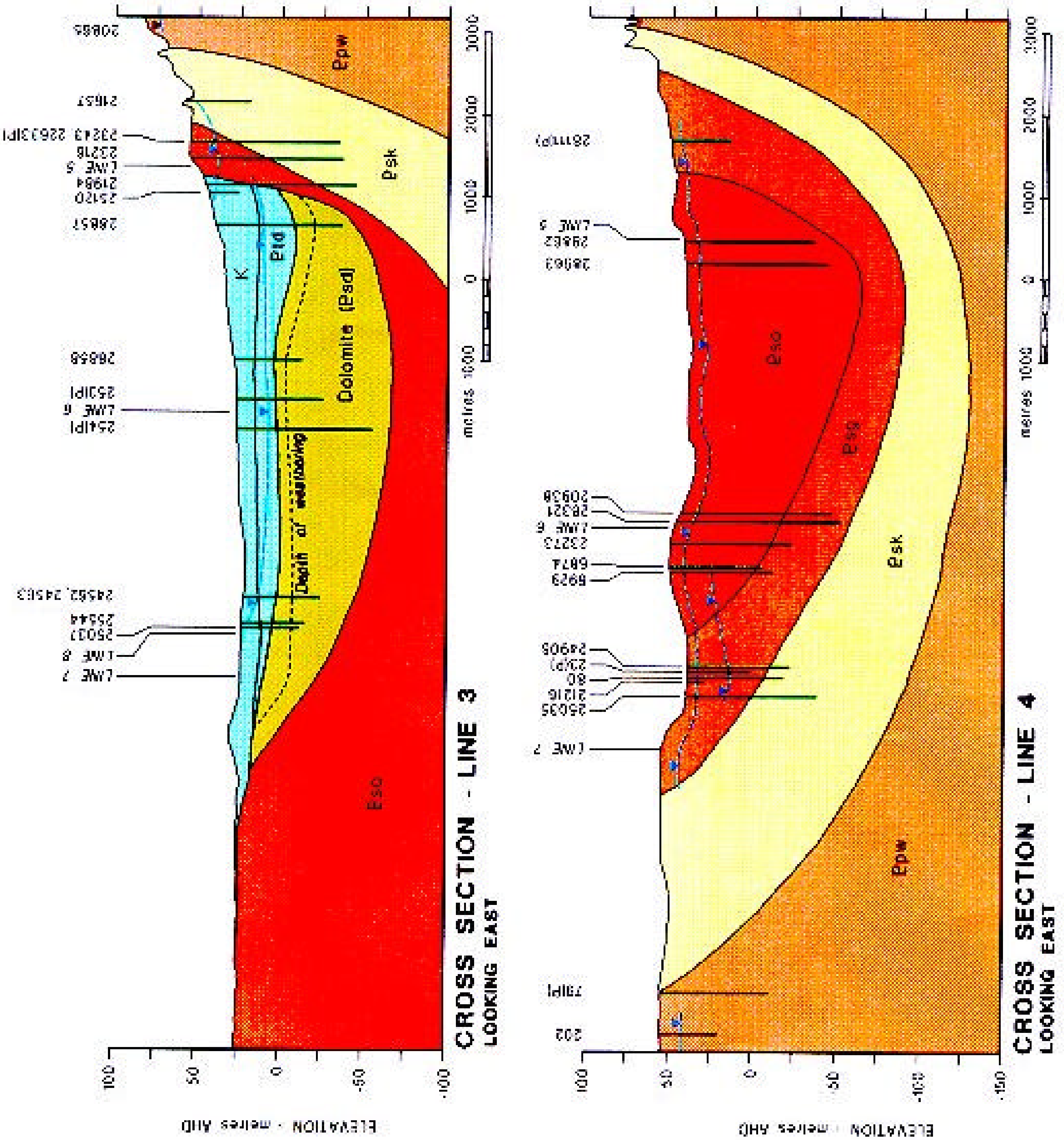
Rum Jungle Complex (*Ar*) of the Archaean age is the oldest rock in the area occurring as a dome and consists of leucocratic granite; large felspar granite; coarse granite; meta-diorite; granite-gneiss; schist & gneiss; banded iron formation. Early Proterozoic sediments deposited all around this Archaean dome. Groundwater potential is very low to nil in these rocks and most of the Archaean rocks are under the Darwin River Dam water.

Mount Partridge Group rocks is exposed along the southern boundary of the *South Alligator Group* where the topographic elevation is high on the steep slopes of the Archaean rocks. In the southeast corner of the hydrogeological map, a significant displacement, within these formations due to the *Giant Reef Fault,* can be seen. This group consists of a) Crater Formation *(Ppr)*, b) Coomalie Dolomite *(Ppc)*, c) Whites Formation *(Ppi)*, d) Acacia Gap Quartzite Member *(Ppa)* and e) Wildman Siltstone Formation (*Ppw*) which are briefly described below and these sequences are shown on all the geological cross sections (Figures 4 to 7).



GEOLOGICAL CROSS SECTIONS
LINES 1 AND 2

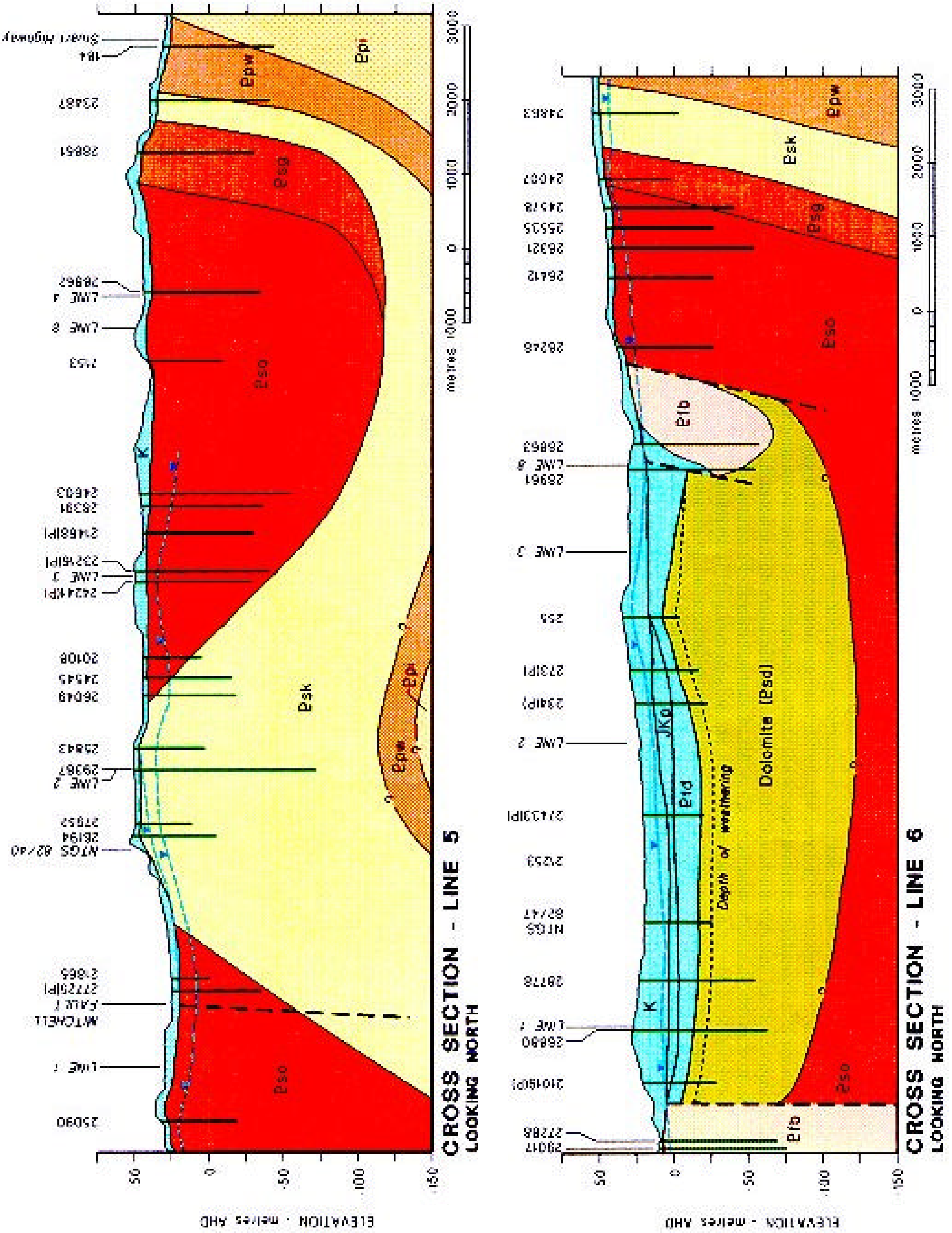
Figure 4



Note : See Figure 4 for Legend

GEOLOGICAL CROSS SECTIONS
LINES 3 AND 4

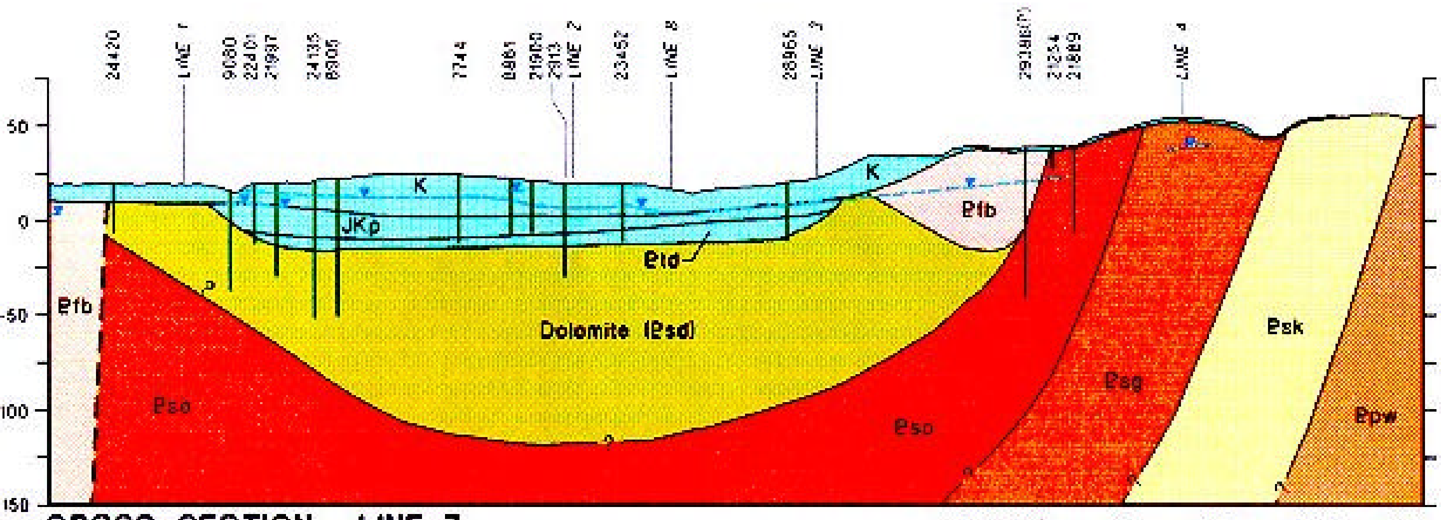
Figure 5



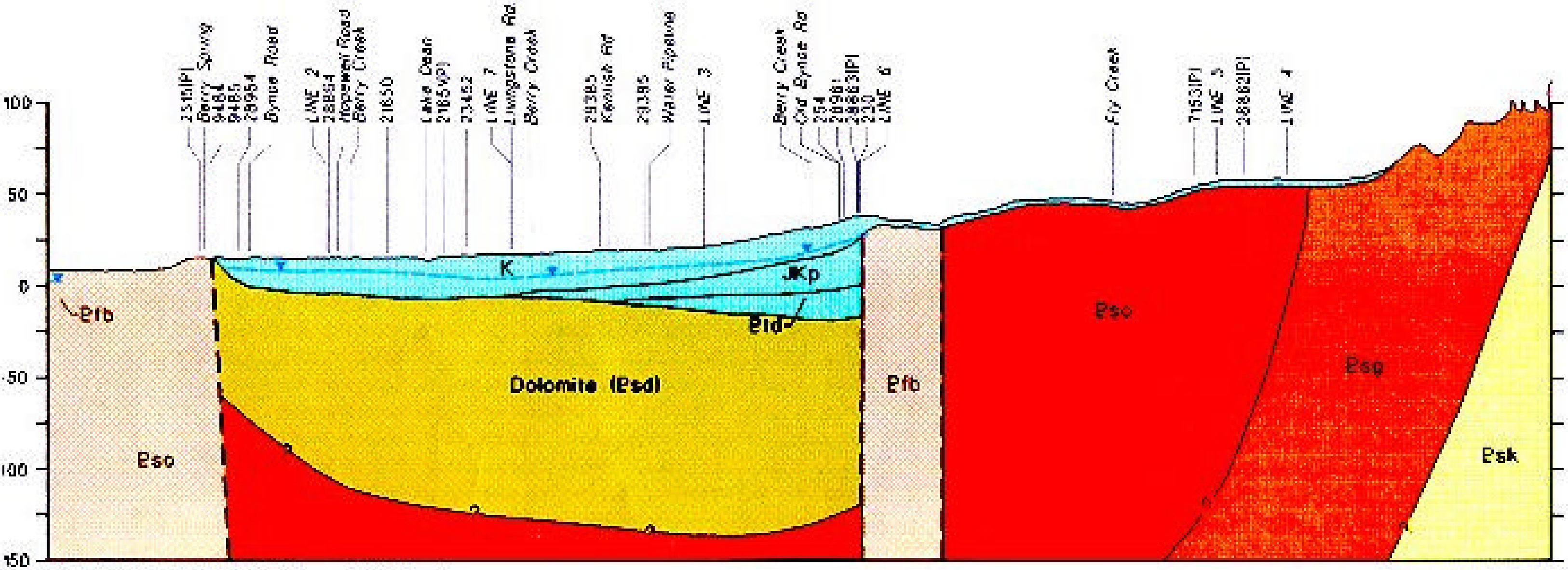
Note : See Figure 4 for Legend

GEOLOGICAL CROSS SECTIONS
LINES 5 AND 6

Figure 6



CROSS SECTION - LINE 7
LOOKING NORTH



CROSS SECTION - LINE 8
LOOKING NORTHEAST

Crater Formation *(Ppr)* was deposited in the fluvial and shallow marine conditions. It consists of haematite boulder conglomerate, cross-bedded pebbly arkose, pebble conglomerate, quartzite, sandstone, minor siltstone & shale. Groundwater potential in this formation is generally 0.5 to 5.0 L/s, which may be higher if fractures and/or weathering are present.

Coomalie Dolomite *(Ppc)* was deposited in sabkha condition. It consists of silicified dolomite, magnesite & marble, in places chloritic & tremolitic. Groundwater potential in this formation is generally good averaging higher than 5.0 L/s which may be much higher up to 32.0 L/s if dolomite is weathered and/or fractured. However, at the same time the yield could be very low if clays or fine sands are present and the water would be very clayey, silty or sandy.

Whites Formation *(Ppi)* was deposited during the inter-tidal condition. It consists of calcareous and carbonaceous pyritic argillite, dololutite dolarenite, shale, rare quartzite & calcareous amphibolite. Groundwater potential in this formation is generally 0.5 to 5.0 L/s, which may be higher if fractures and/or weathering, are present similar to the Crater Formation.

Acacia Gap Quartzite Member *(Ppa)* was deposited in the fluvial condition. It consists of quartzite commonly pyritic, sandstone, interbedded shale & phyllite-commonly carbonaceous. Groundwater potential in this formation is generally < 0.5 L/s, which may be higher if fractures and/or weathering are present.

Wildman Siltstone Formation (*Ppw*) was deposited in the shallow marine environment. It consists of laminated colour-banded shale (pyritic & carbonaceous at depth), silty shale, siltstone, sandy siltstone, minor silicified dolomite, fine quartzite, medium to coarse sandstone (pyritic in places). Groundwater potential in this formation is generally < 0.5 L/s, which may be higher if fractures and/or weathering are present.

Ella Creek Member (*Pse*) is the oldest sequence of the *South Alligator Group.* It is confined in a very small area in the southern part and due to its very small areal coverage, it is not shown on the map. It consists of haematite boulder conglomerate; cross-bedded pebbly arkose; pebble conglomerate; quartzite; sandstone; minor siltstone and shale. No bore has been drilled into this formation so the yield is not known.

South Alligator Group consists of the *Koolpin Formation (Psk*), *Gerrowie Tuff (Psg*), *Mount Bonnie Formation (Pso*) and *Dolomite Undefined Layer (Psd*). They occur mostly in the south and tightly folded and continuing to the east and then north. Groundwater potential in this group varies from 0.5 to 5.0 L/s. Depth of aquifers depend on the geographical location of the bore. Water is generally clean. *Koolpin Formation (Psk*) has been found to be the best in this group, however in the fractured siltstone and shale of *Mount Bonnie Formation* (*Pso*), a yield of 10.0 L/s was obtained (bore 28386).

Koolpin Formation (*Psk*) of the *South Alligator Group* is highly iron-rich formation. It consists of interbedded ferruginous, carbonaceous and often very graphitic siltstone and shale, and minor dolomite lenses. This sequence is shown on the geological cross sections (Figures 4 to 7). Groundwater potential in this formation is generally 0.5 to 5.0 L/s which may be higher if fracture or weathering is present viz bore 29387 with a yield of 25.0 L/s with clean water. In the eastern region, east of the Stuart Highway, this formation has some dolomitic lenses in which yield averages up to 10.0 L/s in fractured dolomitic lenses. There are numerous such bores around east of the abandoned Hughes Airstrip and some around Noonamah.

Gerrowie Tuff Formation (Psg) overlies the *Koolpin Formation* and consists of mostly chert and is well exposed in southern part of the area. It covers the surface with chert rubble and the vegetation is sparse. This sequence is shown on the geological cross sections (Figures 5 to 7). Groundwater potential in this formation is generally < 0.5 L/s which may be higher if fracturing and/or weathering is present.

Mount Bonnie Formation (*Pso*) of the *South Alligator Group* overlies the *Gerrowie Tuff Formation* and consists of interbedded pelite, felspathic greywacke, sandstone, pyritic siltstone & shale, phyllite and rare banded iron formation (BIF). *Mount Bonnie Formation* can be distinguished from *Koolpin Formation* by their lower carbon content and paler grey colour. This sequence is shown in all the geological cross sections (Figures 4 to 7). Groundwater potential in this formation is generally < 0.5 L/s which may be higher if fracturing and/or weathering is present.

Dolomite (*Psd*) is the *Undefined Layer* of the *South Alligator Group* in the top layers and overlies the *Mount Bonnie Formation* (*Pso*). Weathered dolomite is exposed in the northern region - along the springs inside the Wildlife Park and the Berry Springs Nature Park; and in the Berry Creek at the Hopewell Road crossing. Previously, this dolomite layer was named as Berry Springs Dolomite *(Pmd)* of the Middle Proterozoic age in the Interim Report 63/94 (Verma, 1994) and it was referred as younger than the Burrell Creek Formation. However, after personal communication with P. Jolly, 1994, it was referred and labelled as the Undefined Layer *(Psd)* in the top layers of the South Alligator Group. It consists of silicified dolomite, dolomitic siltstone, saccharoidal quartzite (after carbonate), calcite crystals, siltstone, shale, phyllite, commonly carbonaceous, pyritic, cherty & siliceous. This sequence (*Psd*) is shown in all the geological cross sections (Figures 4 to 7). Groundwater potential in this formation is generally > 5.0 L/s, which may be higher if fracturing and/or weathering, is present. The highest sustainable yield in this aquifer was 32.0 L/s in bore 26686. Dolomite structural contours have been generated by the computer, which is shown in Figure 8.

Burrell Creek Formation (*Pfb*) of the Finniss River Group conformably lies over the South Alligator Group and consists of mica schist, siltstone, shale, phyllite, greywacke, slate which are very similar to the that of the *Mount Bonnie Formation*. However, their much lower iron content than that of the Mount Bonnie Formation can distinguish them. This sequence (*Pfb*) is shown on the geological cross sections (Figures 4, 6 & 7). Groundwater potential in this formation is generally < 0.5 L/s which may be higher if fracturing and/or weathering or fractured quartz veins are present. Higher yields (up to 5.0 L/s, airlifted) have been obtained in the highly fractured graben between the eastern boundary of the Dolomite (*Psd*) and the Mt Bonnie Formation (*Pso*).

Depot Creek Formation (*Ptd*) of the *Tolmer Group* (*Pt*) lies unconformably over the Lower Proterozoic sediments (mostly dolomite in this area) and they are nearly flat lying. This formation is not exposed in the area. It consists of pink quartzite, quartz sandstone, ripple marks. This sequence (*Ptd*) is shown in all the geological cross sections (Figures 4, 5, 6 & 7). Water worn quartzite and sandy layers have been intersected in this formation which indicate that it can't hold water and it is only a medium for recharging the underlying dolomite aquifers. Therefore, groundwater potential in this formation is very low.

Petrel Formation (JKp) of the Jurassic age consists of friable quartz sandstone, quartz-pebble, conglomerate, conglomeratic sandstone, ferruginous sandstone, and minor breccias. This formation is flat lying and overlies the *Depot Creek Formation* (*Ptd*) and it has been intersected in boreholes. The base of this formation is exposed along the Darwin River near Old Bynoe Road. This sequence (JKp) is shown on the geological cross sections (Figures 4, 5, 6 & 7). This formation is also very porous and good for recharging the underlying layers. Therefore, groundwater potential in this formation is very low.

Darwin Member (*Kld*) of the Bathurst Island Formation of the Cretaceous age consists of kaolinitic claystone, silty in places, glauconitic & calcareous, basal conglomerate, clayey, sandstone & sandy claystone, radiolarian, montmorillonitic. This formation is flat lying and overlies the *Depot Creek Formation* (*Ptd*) and is shown as K in all the geological cross sections (Figures 4, 5, 6 & 7). This formation unconformably lies over the Proterozoic age rocks. Groundwater potential in this formation is very low, because this formation also is a good recharging medium for the underlying dolomite aquifers. Without the thick Cretaceous sediments cover over either *Coomalie Dolomite* or *Undefined Dolomite Layer of* the South Alligator River Group, aquifer doesn't have a good yield (i.e. < 1.0 L/s).

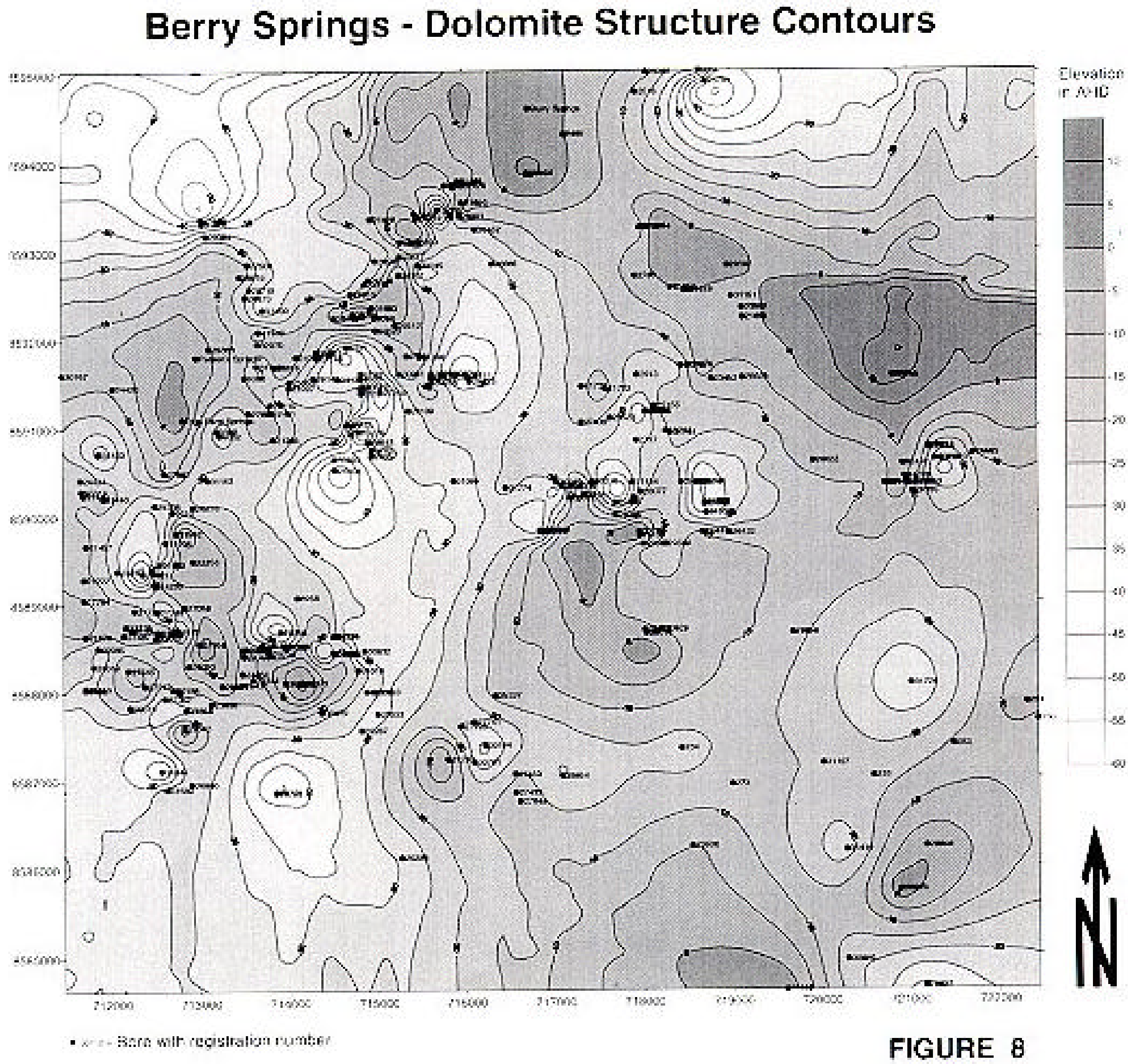


Figure 8 Dolomite Structure Contours

Table 1 Stratigraphy of the Berry Springs - Noonanmah Region

CAINOZOIC:

Quaternary (**Q**) & **Tertiary** (**T**) — mud, silt, clay, sand, shelly sand, coralline sand, gravel unconsolidated sand, Ferruginous & clayey, sandy, gravely soils, limonite, pisolite, sandy & gravely

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MESOZOIC:

LOWER CRETACEOUS (**K**)

Bathurst Island Formation

Darwin Member (**Kld**) — kaolinitic claystone, silty in places, glauconitic & calcareous, basal conglomerate clayey, sandstone & sandy claystone, radiolarian, montmorillonitic - Shallow marine deposit, <**52 m** thick

JURASSIC-CRETACEOUS (**JK**)

Petrel Formation (**JKp**) — friable quartz sandstone, quartz-pebble, conglomerate, Conglomerate sandstone, ferruginous sandstone, minor breccias - Fluvial deposit <**5 m** thick

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PALAEOZOIC:

Middle PROTEROZOIC

Tolmer Group (**Pt**)

Depot Creek Sandstone (**Ptd**) — pink quartzite, quartz sandstone, ripple marks - Nerirtic deposit

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Lower PROTEROZOIC

Finniss River Group (**Pf**) - Conformably overlies & possibly laterally inter-fingers South Alligator Group - Neritic deposit

Burrell Creek Formation - (**Pfb**) — shale, siltstone, phyllite, fine to coarse sandstone, quartzite, quartz pebble Conglomerate, minor graphitic phyllite, quartz-mica-schist and gneiss

South Alligator Group (**Ps**) - Shallow marine deposit

Undivided Dolomite Layer (**Psd**) — Silicified dolomite, dolomitic siltstone, saccharoidal quartzite (after carbonate), calcite crystals, siltstone, shale, phyllite, commonly carbonaceous, pyritic, cherty & siliceous

Mount Bonnie Formation (**Pso**) — Laminated reddish brown shale and siltstone with minor laminated black chert bands, and nodules; minor pyritic banded iron formation; argillite; crystal tuff ; tuffaceous chert; massive medium felspathic greywacke and rare silicified dolomite

Gerrowie Tuff (**Psg**) — Laminated, grey, brown and red silicified siltstone; blue-grey and brown argillite; siliceous siltstone and shale; glassy black spotted crystal tuff & tuffaceous chert; minor tuffaceous greywacke and arsenite

Koolpin Formation (**Psk**) — Ferruginous siltstone and shale with chert bands, lenses & nodules; siltstone and shale, commonly carbonaceous; silicified dolomitic lenses

Ella Creek Member (**Pse**) — Massive goethitic ironstone, commonly containing angular clasts of saccharoidal quartzite & black shale; ferruginous quartzite breccias consisting of tabular and spherical quartzite fragments; ferruginous chert breccias with oolites; ferruginous siltstone; rare ferruginous grit, pebble and boulder conglomerate - Not shown on the map due to its very small areal coverage)

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Mount Partridge Group (**Pp**)

Wildman Siltstone (**Ppw**) — Laminated colour-banded shale (pyritic and carbonaceous at depth); silty shale; siltstone; sandy siltstone; minor silicified dolomite; medium to coarse quartz sandstone (pyritic in places); fine quartzite - Shallow marine deposit

Acacia Gap Quartzite Member (**Ppa**) — Quartzite, commonly pyritic; sandstone; interbedded shale and phyllite commonly carbonaceous, 50-300 m thick - Fluvial deposit

Whites Formation (**Ppi**) — Calcareous and carbonaceous pyritic argillite; dololutite dolarenite; rare quartzite and calcareous para-amphibolite - Inter Tidal deposit

Coomalie Dolomite (**Ppc**) — Tremotolitic, magnesite and marble, in places chlorotic and tremolitic, commonly silicified or laterised at the surface; metalutite, commonly graphitic - Sabkha deposit

Crater Formation (**Ppr**) — Haematite boulder conglomerate; cross-bedded pebbly arkose; pebble conglomerate; quartzite; sandstone; minor siltstone and shale - Fluvial & shallow marine deposit

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ARCHAEAN (**A**)

Rum Jungle Complex (**Ar**) — Leucocratic granite; large felspar granite; coarse granite; meta-diorite; granite-gneiss; schist & gneiss; banded iron formation
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Source: 1:250 000 Geological Map, NTGS, 1987 and *Undivided Dolomite Layer* is given a new name "dolomite *Psd*", 1994

ii) Structure

Local geology is significantly controlled by the geologic structures. Early Proterozoic sediments were laid on the slopes of the Archaean dome, and were displaced by the Giants Reef Fault and then tightly folded. This can be seen on the east and southeast sides of the area where the east-west strike changes to almost north south. This tight folding created a small oval shaped basin structure, which lies in the middle of the study area. In this basin the younger Proterozoic carbonates were deposited which don't show any structural disturbances (bore 28856).

On the eastern side of the Dolomite (*Psd*) boundary, there is a small graben trending north south in which highly sheared Burrell Creek Formation (*Pfb*) of the Finniss River Group occurs. Yield in this graben is usually higher than the average yield of this formation elsewhere.

Existence of the Berry Springs is mainly due to local fault along the geological boundary between the Dolomite (*Psd*) of the South Alligator and the Burrell Creek Formation (*Pfb*). This fault can be traced by following the breccias along the fault. But few springs along the Darwin and Blackmore Rivers and Berry Creek in the northern region exist due to the topographic low and not fault.

Generally, the Burrell Creek Formation is fractured over entire area and therefore, water supply may be higher than the average yield (0.5 L/s) in these rocks.

b. Aquifer

i) Types, Yields and Parameters

Both the major and minor aquifers have been identified in this region and their boundaries have been established. A typical range of yield in each aquifer is shown below in Table 2.

Table 2 Aquifer Type & Yield Range

Aquifer Type	Yield (L/s)	Group	Formation
Fractured Carbonate	>5.0	South Alligator (*Ps*)	Dolomite Layer (*Psd*)
(Major Aquifer)		Mt Partridge (*Pp*)	Coomalie Dolomite (*Ppc*)
Fractured	0.5 - 5.0	South Alligator (*Ps*)	Koolpin (*Psk*)
(mostly carbonaceous)		Mt Partridge (*Pp*)	Whites Formation (*Ppi*)
		Mt Partridge (*Pp*)	Crater Formation (*Pp*r)
Fractured & Weathered	<0.5	South Alligator (*Ps*)	Mount Bonnie, (*Pso*)
(Minor Aquifer)		South Alligator (*Ps*)	Gerrowie Tuff (*Psg*)
		Mt Partridge (*Pp*)	Wildman Siltstone (*Ppw*)
		Mt Partridge (*Pp*)	Acacia Gap Member *Ppa*)
		Finniss River Group	Burrell Creek Formation (*Pfb*)
		Archaean (*Ar*)	Rum Jungle Complex (*Ar*)

In addition to above there are few localised aquifers such as shallow & weathered Bathurst Island (*K*) & Petrel Formations *(JKp*) of the Cretaceous-Jurassic age and the Depot Creek Sandstone (*Ptd*) of the Middle Proterozoic age, which have not been investigated due to their very limited capacity. These formations behave as recharge media to the carbonate aquifers.

Yield in each formation has been obtained higher than indicated above provided the geologic structures and/or pronounced weathering were present. As in the case of bore (29387) in the Koolpin Formation (*Psk*), yield up to 25.0 L/s was obtained in the fractured and weathered graphitic siltstone and shale. It should be noted however that the sustainable yield in fractured rocks is usually much lower than the airlifted yield.

The major aquifer exists primarily within the weathered layer which consists of mainly the basal conglomerate, coarse sandstone, some clay, silt and sand of the Cretaceous sediments, and weathered and fractured silicified dolomite in the upper karstic layer of the Undivided Dolomite Layer (*Psd*). Sustainable yield up to 32.0 L/s has been obtained in this aquifer. However, in the fresh dolomite, below this weathered zone, yield is very low to nil. This indicates that the fracturing and/or cavities are not significant at depth, however there are some exceptions. Depth of this aquifer varies from 10 to 88 m bgl, because this aquifer is in a small basin and its depth varies with the geographic location. Average thickness of the aquifer is about 50 m and it is exposed in the northern region where the Berry and Parson's springs flow combined with topographic low (7 to 0 m AHD). Parson's and Twin Farm Springs are within tidal zone. The Lake Deane is a groundwater window through which discharge occurs. The water level from south of Lake Deane to the north of Berry Springs is nearly constant and therefore, in this region swampy condition prevails until almost mid dry season. In the northern region, the Goose Lagoon and surrounding areas are also groundwater discharge points, which have created swampy condition. Numerous discharges are in the southern part of the Darwin River. Woodfords Lagoon in the southwest corner of the dolomite aquifers can be seen along the Darwin River in the northern region in the dry season.

ii) Groundwater Movement

A total of ten (10) bores are being monitored at present for standing water levels and water quality. To assess the extraction from bores, flow meters and electric hour meters were installed on few selected private bores, and regularly readings were taken from those private bores. Readings are also being taken from those bores on which already their owners installed either flow meters or electric meters.

Standing water levels measured in five (5) monitoring bores during the wet season (Figure 9) indicated that its relation to the rainfall is direct thus indicating that recharge of the aquifer is from rain. Bores drilled after the wet season showed that the water level declined during the dry season (Figures 9 and 10). The rainfall for the period (Jan-Dec. 94) is shown in Figure 11 and rainfall at Manton Dam (DR014035) and Palmerston (DR014210) for the period from 1.1.1992 to 1.1.1993 are shown in Figure 12. Rainfall at Noonamah (DR014080), Lake Deane (DR014150) and Darwin River Dam (DR014183) for a period of 35 years (1960-95) with the stream flow at March Fly (G8150027) are shown in Figure 13.

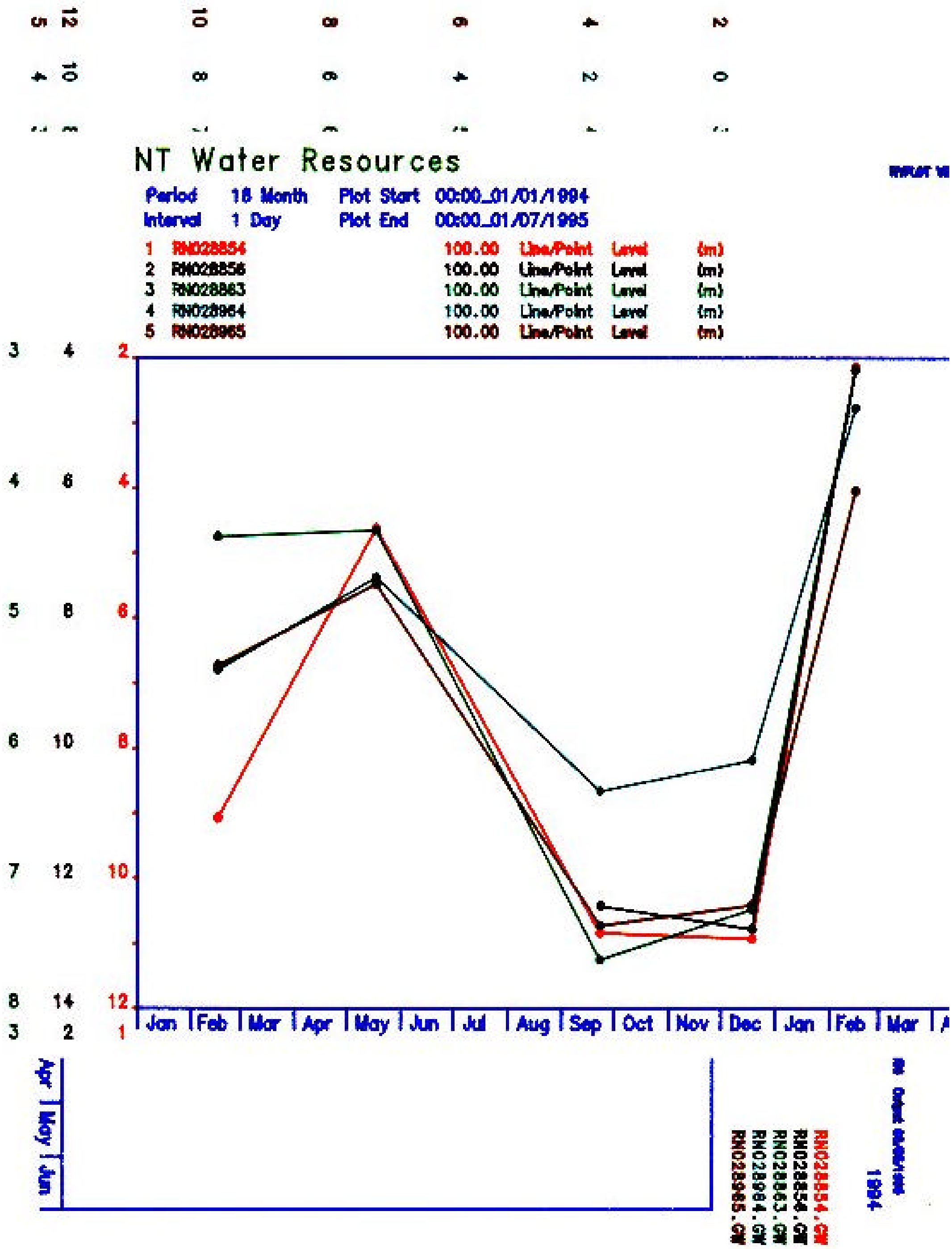

Figure 9 Standing Water Levels of Bores 28854, 28856, 28863, 28964 & 28965

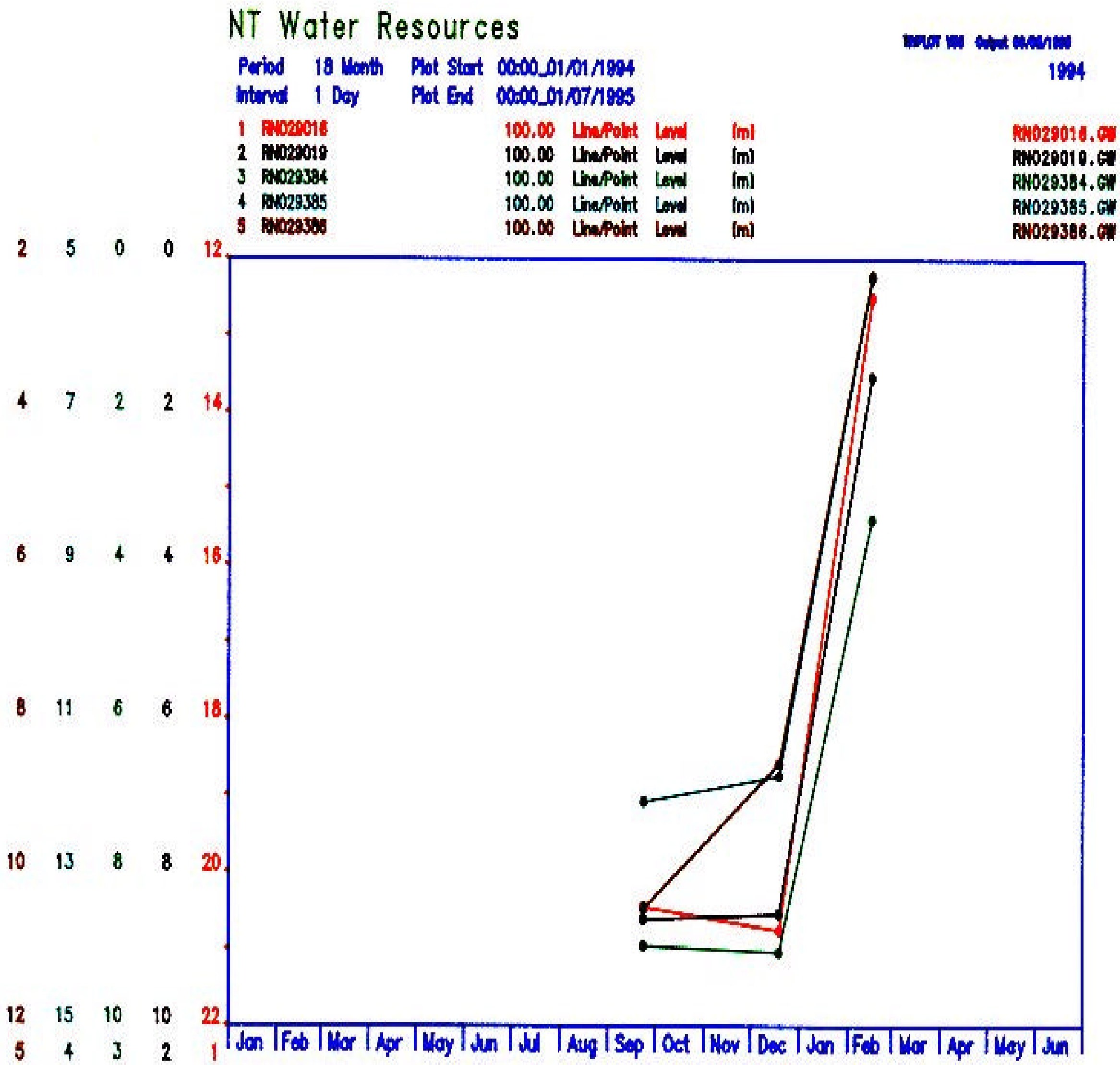

Figure 10 Standing Water Levels of Bores 29016,29019, 29384, 29385 & 29386

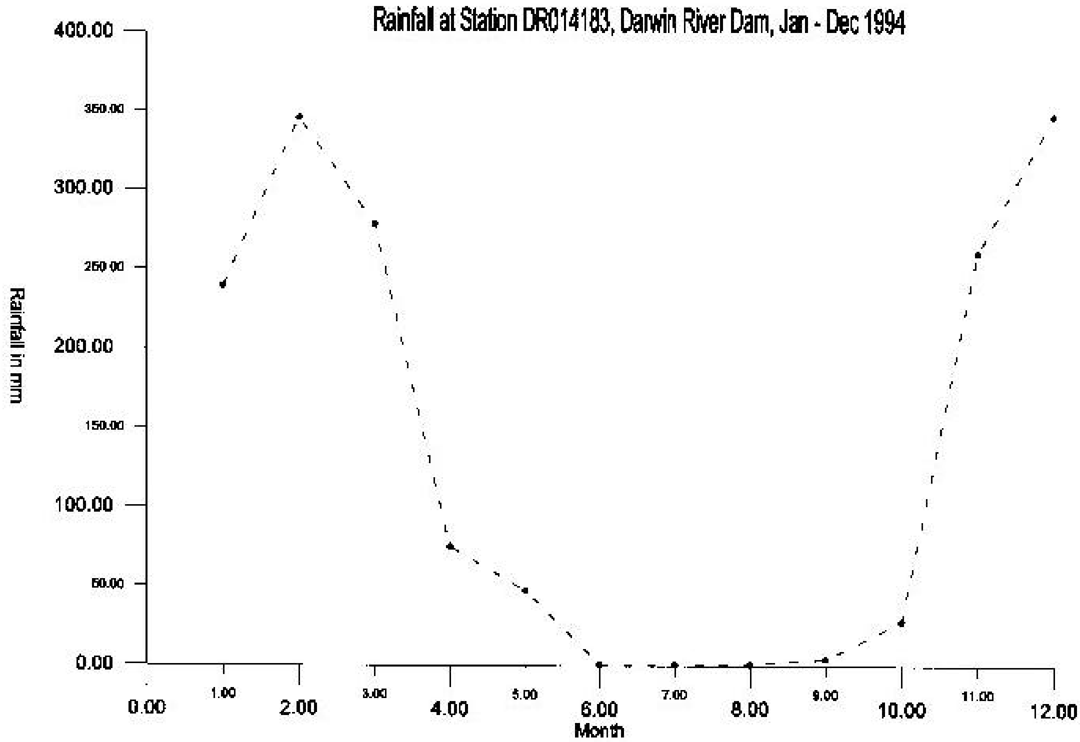

FIGURE 11 Monthly Rainfall Graph

Groundwater movement is to the north (to Berry Springs area) and northwest (to the Parson's and Twin River Farm Springs area) as shown by the water level contours of both the dry and wet seasons in Figures 14 & 15, respectively. These water levels from existing bores as well as the monitoring bores, which are being monitored regularly on quarterly basis. During both the dry and wet seasons, the groundwater movement direction is towards the Parson Springs and Twin River Farm Springs in the northwest where the topographic elevation is low (sea level) and within tidal zone and to the Berry Springs in the north. During the dry season, the groundwater slope is 0.68 m/km (4.4 m drop in 6,500 m) and in the wet it is 1.37 m/km (8.91 m drop in 6,500 m). Therefore, the groundwater gradient in wet is twice the dry season gradient and the discharge through rivers, creeks, springs and lagoons during the wet therefore is very significant. As the aquifer gets saturated, runoff is also very significant. This also indicates that the aquifer is recharged annually by the rain.

No test pumping was carried out to determine aquifer parameters, however aquifer parameters were estimated by simulating using the MODFLOW Modelling program (Chiang & Kinzelbach) which is discussed in the next chapter.

iii) Modelling of the Dolomite Aquifer

Pump test was not carried out to determine various aquifer parameters, therefore it was estimated by simulating the different parameters using the MODFLOW modelling program (Chiang & Kinzelbach, 1993).

Known aquifer parameters were - thickness of aquifer (b), Evapotranspiration (ET) and maximum and minimum water levels. Transmmissivity (T) was assumed to be between 500 and 1000 m^2/day. To the immediately north in the Palmerston area the transmmissivity value in the similar dolomite was found to be around 1500 m^2/day (Power & Foo, 1988).

For the modelling, the dolomite aquifer area was divided into x-cells (42 x 250 m) and y-cells (45 x 258 m). Two stress periods were simulated representing Dry season for 215 days and Wet season for 150 days. Average aquifer thickness (b) of 50 m from 20 to -30 m AHD was adopted & initial head as 20 m AHD. Recharge was assumed mainly from the rainfall and was calculated at 30% of annual rainfall of 1.6 m (Pidsley, 1994) over 150 days of the wet season as there is no recharge during the Dry season. Dolomite aquifer was assumed as homogeneous and isotropic and its boundary was subject to no flow condition, either inflow or outflow. Calibration of the model was carried out to reproduce field measurements with seasonal variation.

Modelling results indicated that there was a large amount of water, which must be taken out of the system to bring the model, generated water level to the real water level. Few bores were incorporated as discharge points, however rate of pumping during the wet season was lowered accordingly. River, creek and springs cells were discharge points, therefore they were

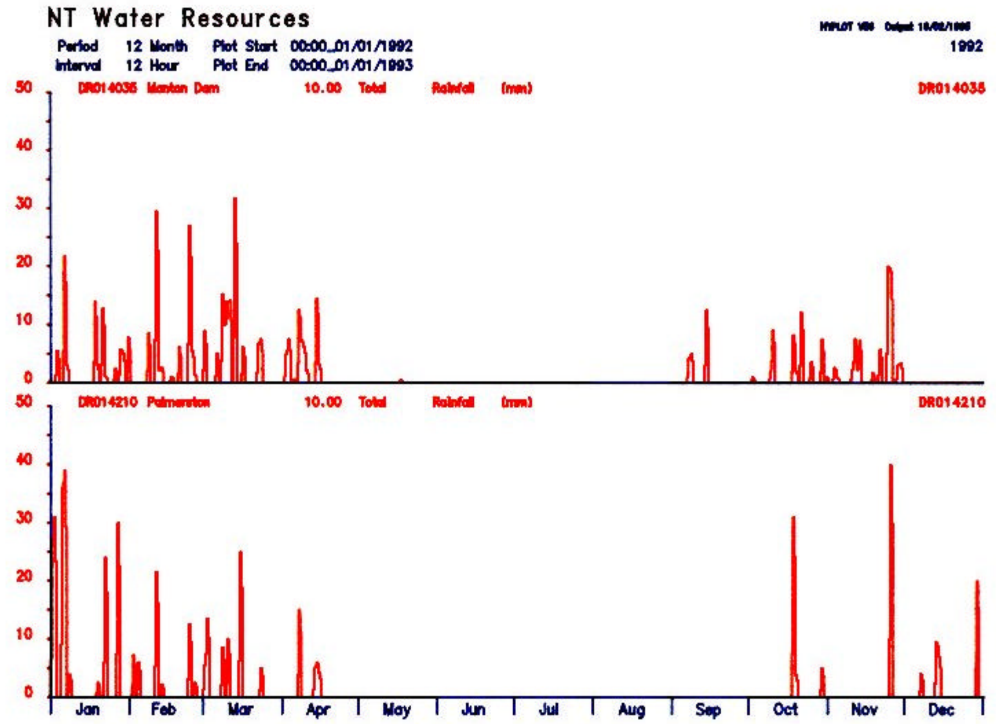

Figure 12 Rainfall at Stations DR014035 & DR014210

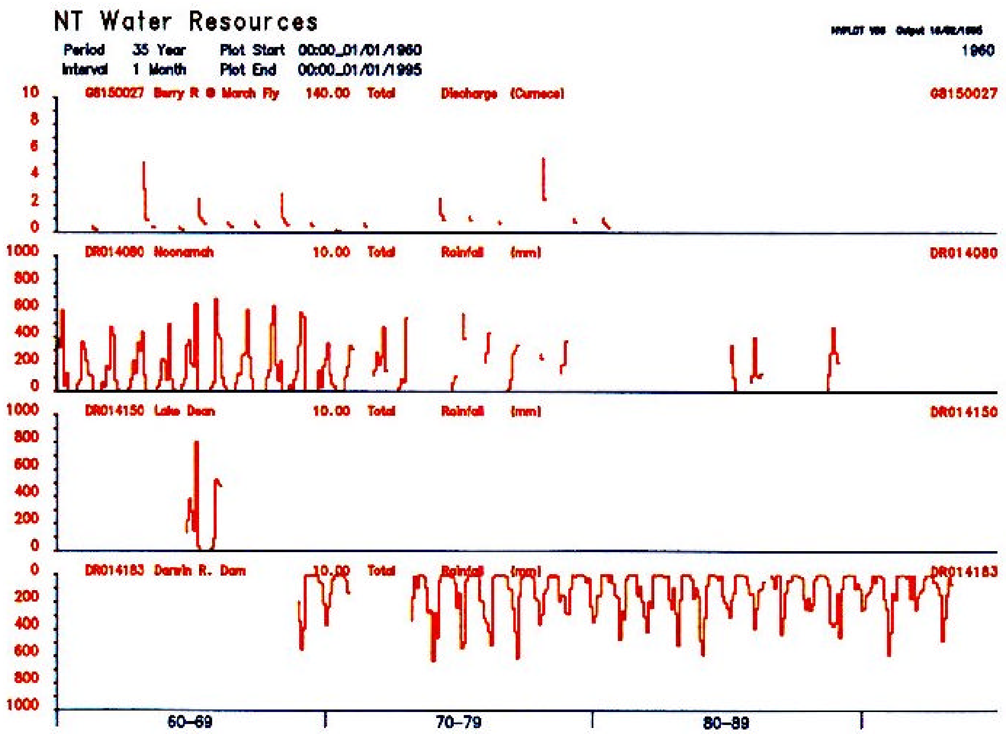

Figure 13 Rainfall at Stations DR014080, DR014150 & DR014183 and Stream Flow at G8150027

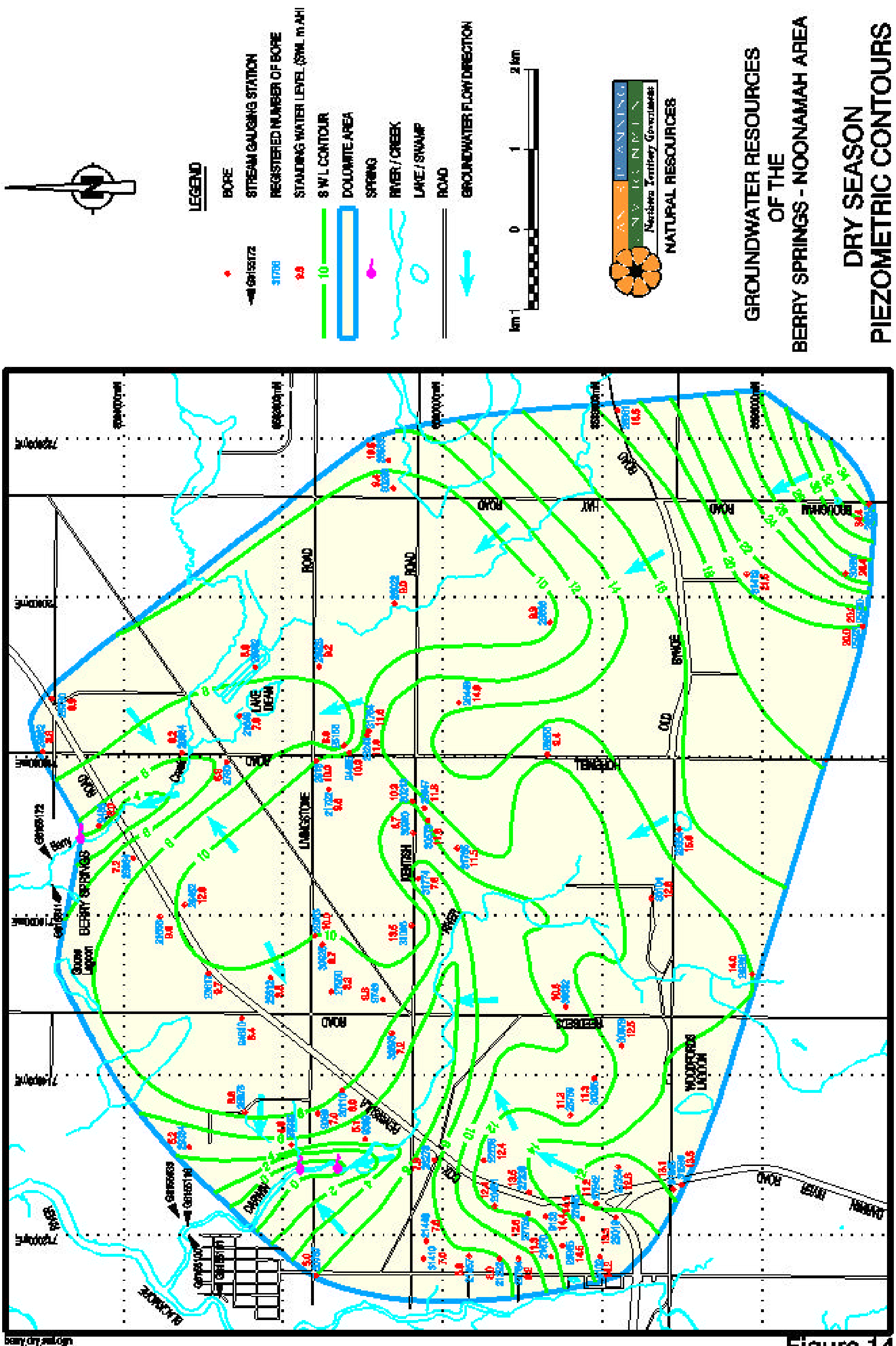
LEGEND
BORE
STREAM GAUGING STATION
REGISTERED NUMBER OF BORE
STANDING WATER LEVEL (SWL m AHD)
S W L CONTOUR
DOLOMITE AREA
SPRING
RIVER / CREEK
LAKE / SWAMP
ROAD
GROUNDWATER FLOW DIRECTION
NATURAL RESOURCES
GROUNDWATER RESOURCES
OF THE
BERRY SPRINGS - NOONAMAH AREA
DRY SEASON
PIEZOMETRIC CONTOURS

Figure 14

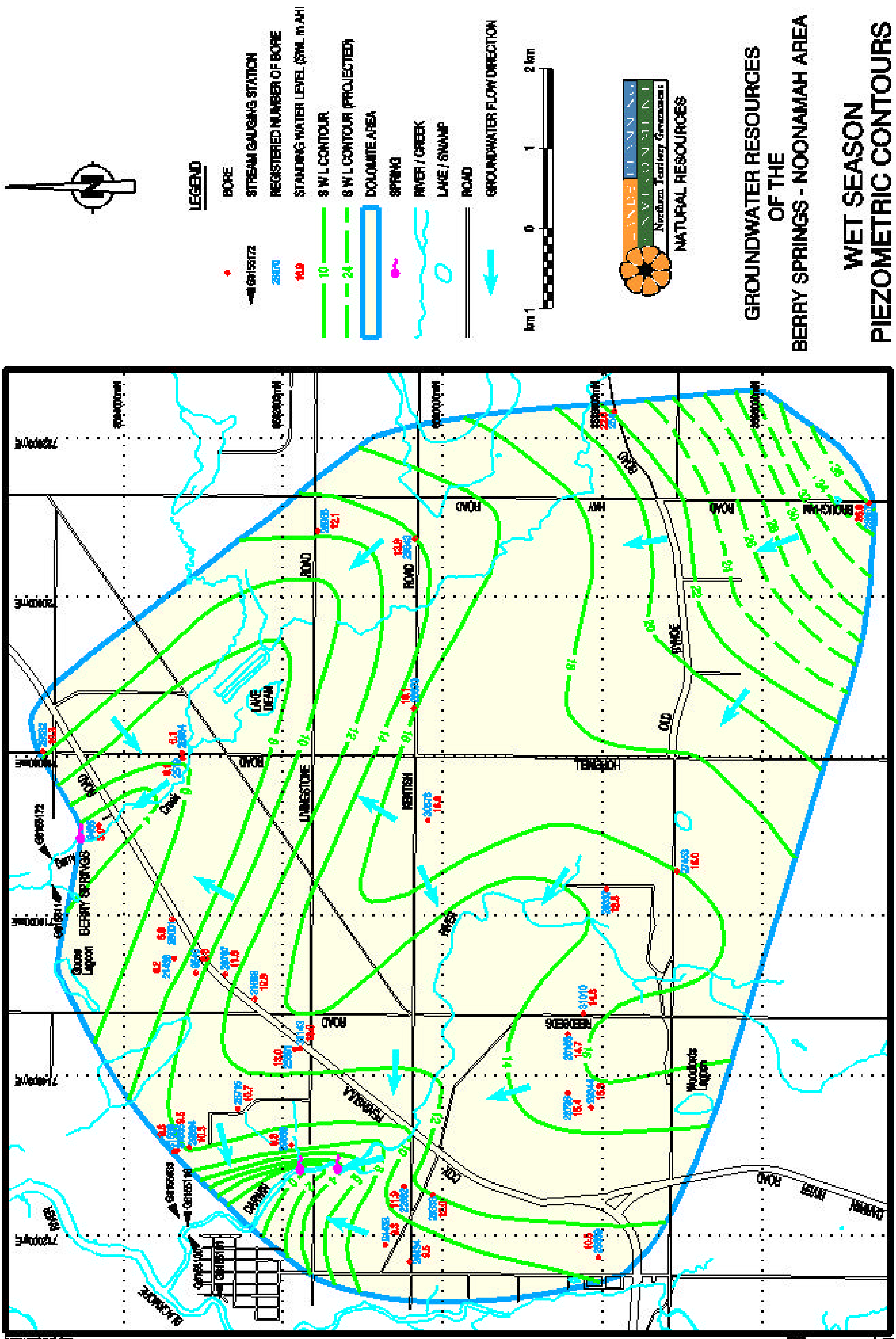
WET SEASON
PIEZOMETRIC CONTOURS
GROUNDWATER RESOURCES
OF THE
BERRY SPRINGS - NOONAMAH AREA
NATURAL RESOURCES
LEGEND
BORE
STREAM GAUGING STATION
REGISTERED NUMBER OF BORE
STANDING WATER LEVEL (SWL m AHD)
S W L CONTOUR
S W L CONTOUR (PROJECTED)
DOLOMITE AREA
SPRING
RIVER / CREEK
LAKE / SWAMP
ROAD
GROUNDWATER FLOW DIRECTION
LAKE DEAN
BERRY SPRINGS
Woodlands Lagoon
berry.wet.swl.dgn

Figure 15

Incorporated as wells with values around 50 m^3/day and higher for springs. The Evapotranspiration (ET) value was arrived at 0.004 m/day by the simulation and the value was established to be 0.001 m/day during a specific project in the Howard East in the Darwin Rural area (Pidsley et all, 1994). So, there is a discrepancy in the ET value. Discharge by the drain was incorporated. Porosity was arrived at 5% though this is normally around 10% or more in carbonate rocks. Lower porosity may be accounted for clayey and silty materials in the aquifer. Porosity, hydraulic conductivity and Evapotranspiration were three main factors during the sensitivity modelling and any increase or decrease in any of these three values accounted for significant change, which did not satisfy the real condition. Porosity value

For computation, SIP method was used. Parameters used in modelling simulation are shown below. Model was run for 20 time steps for each stress period and at the end of 20 time steps in stress period 2 required parameters were derived. The discrepancy in water balance was finally arrived was 10.10% which is dependant on the parameters used.

Parameters used in the modelling:

Aquifer thickness (b)	50 m
Transmmissivity (T)	750 m^2/day
Hydraulic Conductivity (K)	15 m/day
Porosity (Specific Yield) (Sy)	0.05
Specific Storage (Ss)	0.001
Initial Head (IH)	20 m AHD

Initially the modelling was carried out for a single stress period at a time simulating dry and wet seasons separately to see the changes in the water level. Model simulation indicated that the minimum water level in the wet season was 10.87 m AHD and in the dry season it was 4.97 m AHD. These values are very close to the water levels measured in the field (bore 29383), was 4.97 m AHD in dry season and 9.79 m AHD in the wet season (Table 3).

When two stress periods representing dry and wet, were simulated together the minimum head (H) obtained was 5.49 m AHD which is close to the water level in the bore 29383 (4.97 m AHD) and in bore 29384 (5.94 m AHD) measured in the field. For the simulation the maximum head (initial head) was taken to be 20 m close to the maximum water level. This was measured in the field 18.7 m (28854) in the wet season while in the dry season the maximum water level measured in the field in the same bore (28854) was 9.37 m (Table 3). Water balance derived by the modelling using above parameters is shown below.

WATER BALANCE

Time Step 20 of Stress Period 2 representing Dry (Period 1) and Wet (Period 2)

Flow Term	In	Out	In-Out
Storage	0	9.1327334E+03	-9.1327334E+03
Wells	0	1.9692000E+04	-1.9692000E+04
Drainage	0	2.5990186E+03	-2.5990186E+03
Recharge	2.9701391E+05 0	2.9701391E+05	
ET	0	2.3702389E+05	-2.3702389E+05
Sum	2.9701391E+05 2.6844766E+05	-2.8566250E+04	

Discrepancy 10.10%

Table 3 Standing Water Levels in Monitoring Bores

Bore	CAG	SWL TOC	SWL GL	AHD GL	SWL AHD	DATE	REMARKS
28854	1.21	9.08	7.87	19.0	11.13	16.2.94	Located off Old Bynoe Road in a big sinkhole
		4.62	3.41		15.59	18.5.94	
		10.84	9.63		9.37	23.9.94	Highest level in the Dry season
		2.14	0.93		18.07	16.2.95	Highest level in the Wet season
		2.42	1.49		17.51	4.5.95	After highest recorded rainfall in 1994-5
28856	0.89	12.43	11.54	18.30	6.76	3.9.94	Located on the east side of the Pipeline in low
		4.19	3.30		15.00	16.2.95	lying area
		4.50	3.61		14.69	4.5.95	
28863	0.95	4.38	3.43	25.0	21.57	16.2.94	**Not in Dolomite**. Beside the Berry Ck
		4.33	3.38		21.62	18.5.94	
		7.63	6.68		18.32	23.9.94	
		3.09	2.14		22.36	16.2.95	
		3.29	2.34		22.66	4.5.95	
28964	0.70	4.80	4.10	13.6	9.50	16.2.94	Lowest level in the Wet season. Wildlife Park
		3.38	2.68		10.92	18.5.94	
		6.66	5.96		7.64	23.9.94	
		0.77	0.07		13.53	16.2.95	
		1.34	1.27		12.33	5.5.95	
28965	0.86	6.73	5.87	18.0	12.13	16.2.94	Located on Livingstone Rd, east of Berry Ck
		5.48	4.62		13.38	18.5.94	
		5.34	4.48		13.52	12.5.94	
		10.70	9.87		8.13	23.9.94	
		4.04	3.18		14.82	16.2.95	
		3.77	2.91		15.09	4.5.95	
29016	0.90	20.45	19.55	27.0	7.45	23.9.94	Located on Hopewell Rd beside bore 28855
		12.50	11.60		15.40	16.2.95	
		12.89	11.99		15.01	4.5.95	
29019	0.65	8.61	7.96	14.0	6.04	23.9.94	Located on the Cox Peninsula Road
		1.54	0.89		13.11	16.295	
		1.72	1.07		12.93	4.5.95	
29157	0.25	15.41	15.16	23.5	8.34	23.9.94	Private bore on Lot 8, Livingstone Road
29383	0.76	5.53	4.77	10.0	5.23	23.9.94	Lowest in the Dry season. Near Parson Spring
		0.71	+0.05		10.05	16.2.95	Artesian bore
		1.14	0.38		10.38	4.5.95	
29384	0.56	8.96	8.40	14.4	6.00	23.9.94	Located 1 km north of Parson Springs
		3.40	2.84		11.56	16.2.95	
		3.89	3.30		11.07	4.5.95	
29385	0.95	12.08	11.13	20.0	8.87	23.9.94	Located near Power Line on Kentish Road
		5.40	4.45		15.55	16.2.95	
		4.47	3.52		16.48	4.5.95	
29386	0.89	10.47	9.58	27.5	17.92	23.9.94	**Not in Dolomite**. In Mount Bonnie Formation
		2.22	1.33		26.17	16.2.95	Located on Kentish Road
		3.17	2.28		25.22	4.5.95	
29387	0.60	7.19	6.59	49.5	42.91	23.9.94	**Not in Dolomite**. In Koolpin Formation
		0.43	+0.17		49.67	16.2.95	Artesian bore. Located on Duddell Road and
		1.45	0.85		48.65	4.5.95	close to Leonino Road

CAG - Casing above ground, TOC - Top of casing, GL - Ground level, AHD - Australian Height Datum (derived from the topography map),
+ means above ground level

The groundwater slope in this area is 2.0 m per km (13.01 m drop in 6,500 m)

WATER QUALITY

Water quality in this area varies significantly from one aquifer to another. Average pH ranges from 5.4 to 7.8 and TDS from 25 to 200 mg/L. Chloride is generally low ranging from 2 to 10 mg/L and sodium is also low ranging from 2 to 6 mg/L. As the waters from different aquifers have different chemical compositions, they have been grouped into four categories according to the aquifer type based on their chemical quality and also shown their yield range, lithology and structure such as fractured rock or so in Table 4.

Table 4 Typical Chemical Compositions in Different Aquifers

Aquifer/Ion	pH	TDS	Ca	Mg	Na	K	SiO_2	Cl	SO_4	F	HCO_3	Aquifer Type, Yield
Fractured & Karstic Rocks (Psd, Ppc)	7.8	200	35	28	2	1	15	5	8	0.1	250	Major, Yield >5.0 L/s
Fractured Rocks (Psk, Ppi, Ppr)	6.6	25-90	7	2	6	3	10-17	6	2	0.1-0.9	44	Moderate yield 1.5-5 L/s
Fractured & Weathered Rocks (Psg, Ppa,Ppw,Pso)	6.5	120	15	10	3	1	15	10	12	0.2	105	Minor Yield <0.5 L/s
Shallow Weathered (K, JKP, Ptd, Pfb)	5.4	25	2	2	2	2	15	2	15	0.1	10	Local Minor 0- <0.5 L/s

All values are in mg/L except pH value

In the dolomite aquifer the water is very hard due to the total dissolved solids (TDS) averaging about 200 mg/L and bi-carbonate (HCO_3) about 250 mg/L. Calcium and magnesium are derived by the dissolution of the carbonate rock by the acidic rainwater producing bi-carbonate and giving rise to TDS. Source of sodium, chloride and sulphate is rainwater and their contents are low in the dolomite water. Value of pH and electric conductivity (EC) is much higher than that of other aquifers due to higher HCO_3 and TDS, respectively.

Various chemicals plot (Figure 16) for the dolomitic water has been drawn to show relationships among major ions and electric conductivity (EC). These plots show that potassium, EC, sulphate (SO_4) and Cl does not affect TDS and this correlation can be seen in Table 5 also. The magnesium (Mg) Vs calcium (Ca) plot indicates that they are directly related. Another plot (Figure 17) shows the total hardness ($CaCO_3$) against Ca, Mg and Ca+Mg, and also HCO_3 against Ca, Mg and Ca+Mg. These plots indicate that the total hardness is directly related to Ca and Mg and these cations are derived from the bedrock (dolomite) resulting in hard water. Similarly, plots of HCO_3 against Ca and Mg also indicate the same. Water quality of the water from all four aquifers can be seen at a glance in the Durov diagram shown in Figure 18.

This dolomitic water from a bore (9485) near Berry Springs Nature Park is bottled as *mineral water* for its commercial quality and an analysis result of the mineral water from this bore is shown in Table 5.

Chemical Plots of Cl vs Na, K, EC, SO4 & TDSand Ca vs Mg

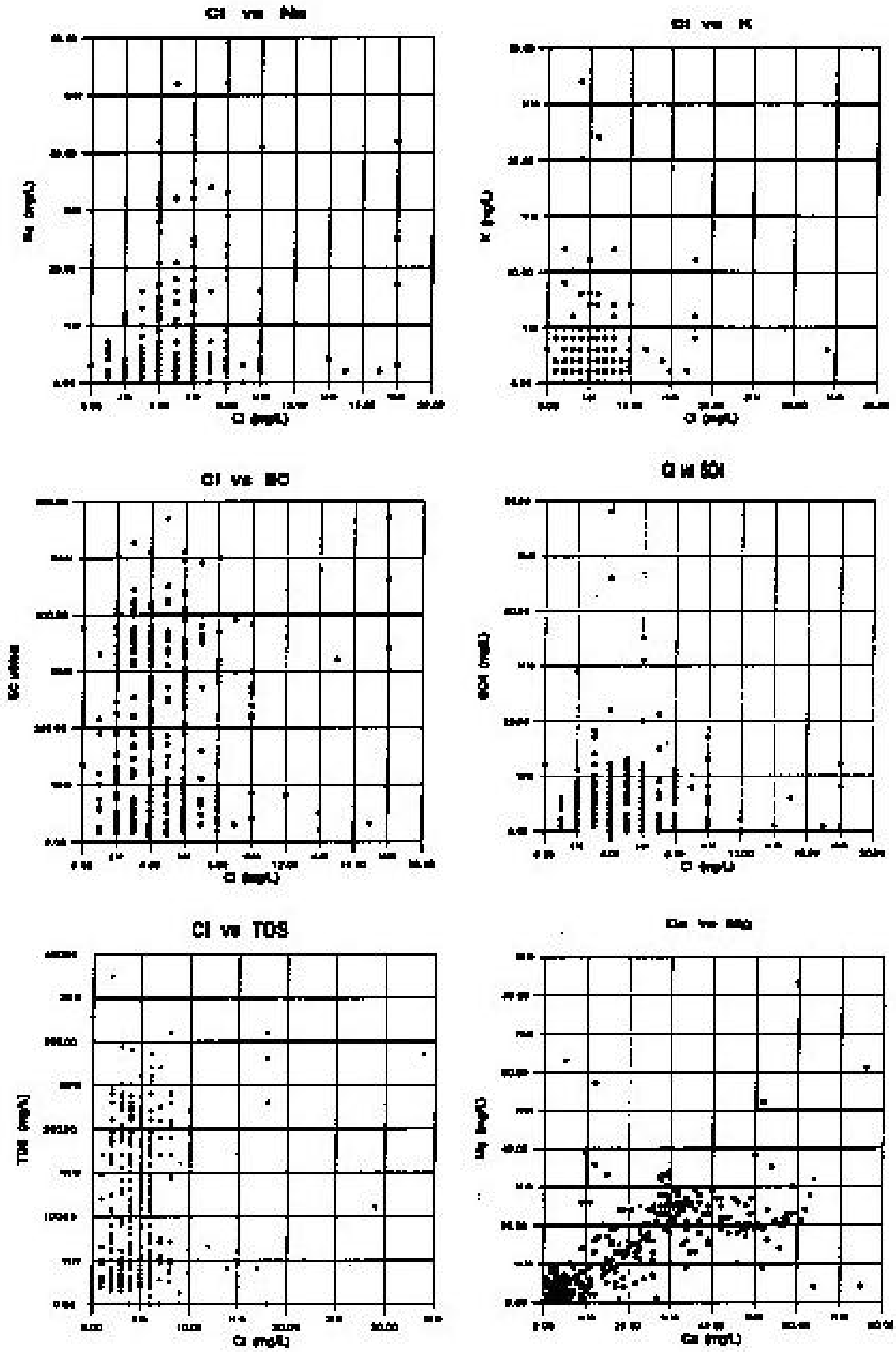

Figure 16 Chemical Plots of Cl vs Na, K, Mg, SO_4, TDS & EC

Chemical Plots of Cl vs Na, K, EC, SO4 & TDSand Ca vs Mg

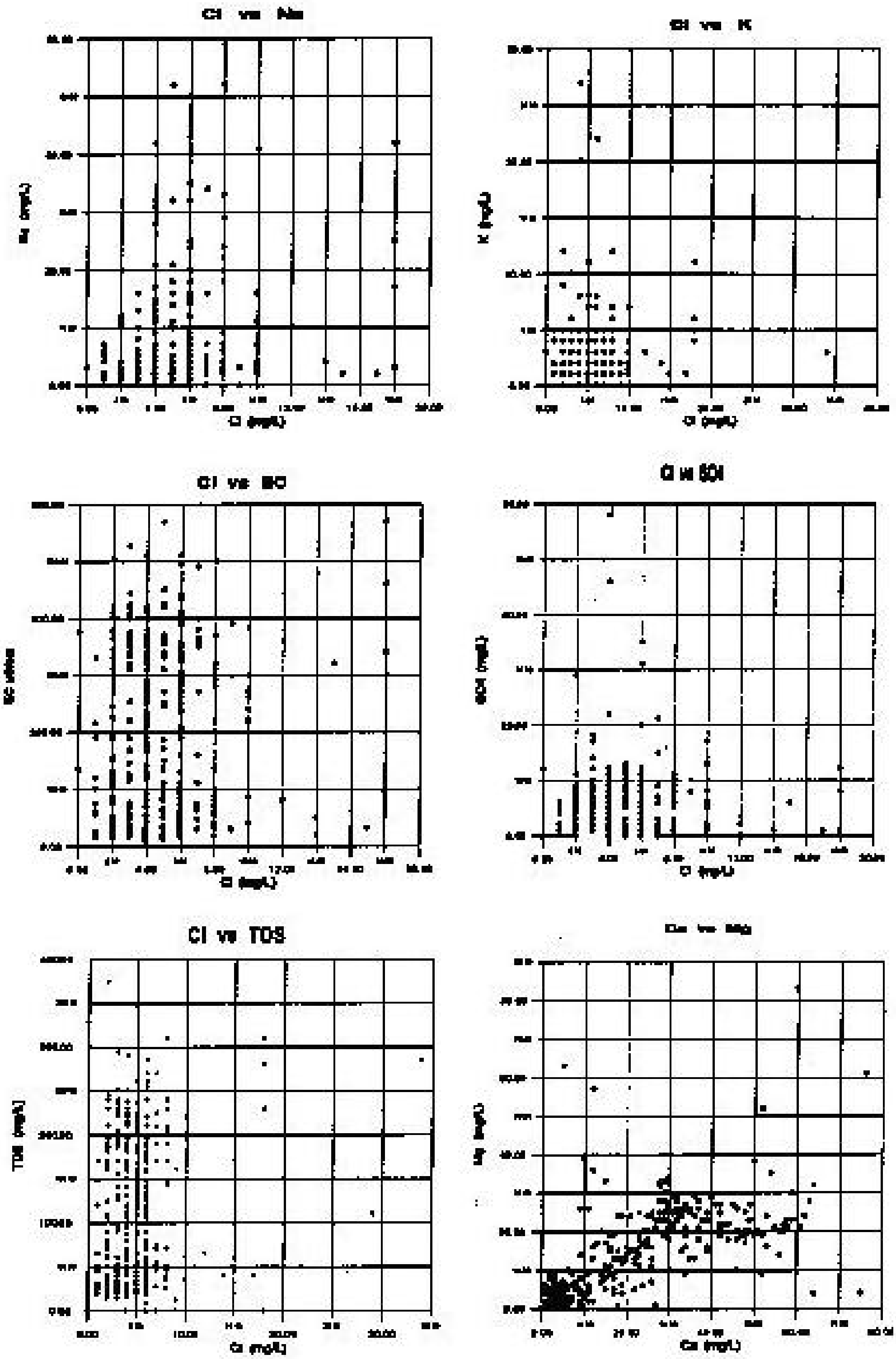

Figure 17 Chemical Plots of $CaCO_3$ (Total Hardness) vs (Ca, Mg, Ca+Mg)

and HCO3 vs (Ca, Mg & Ca+Mg)

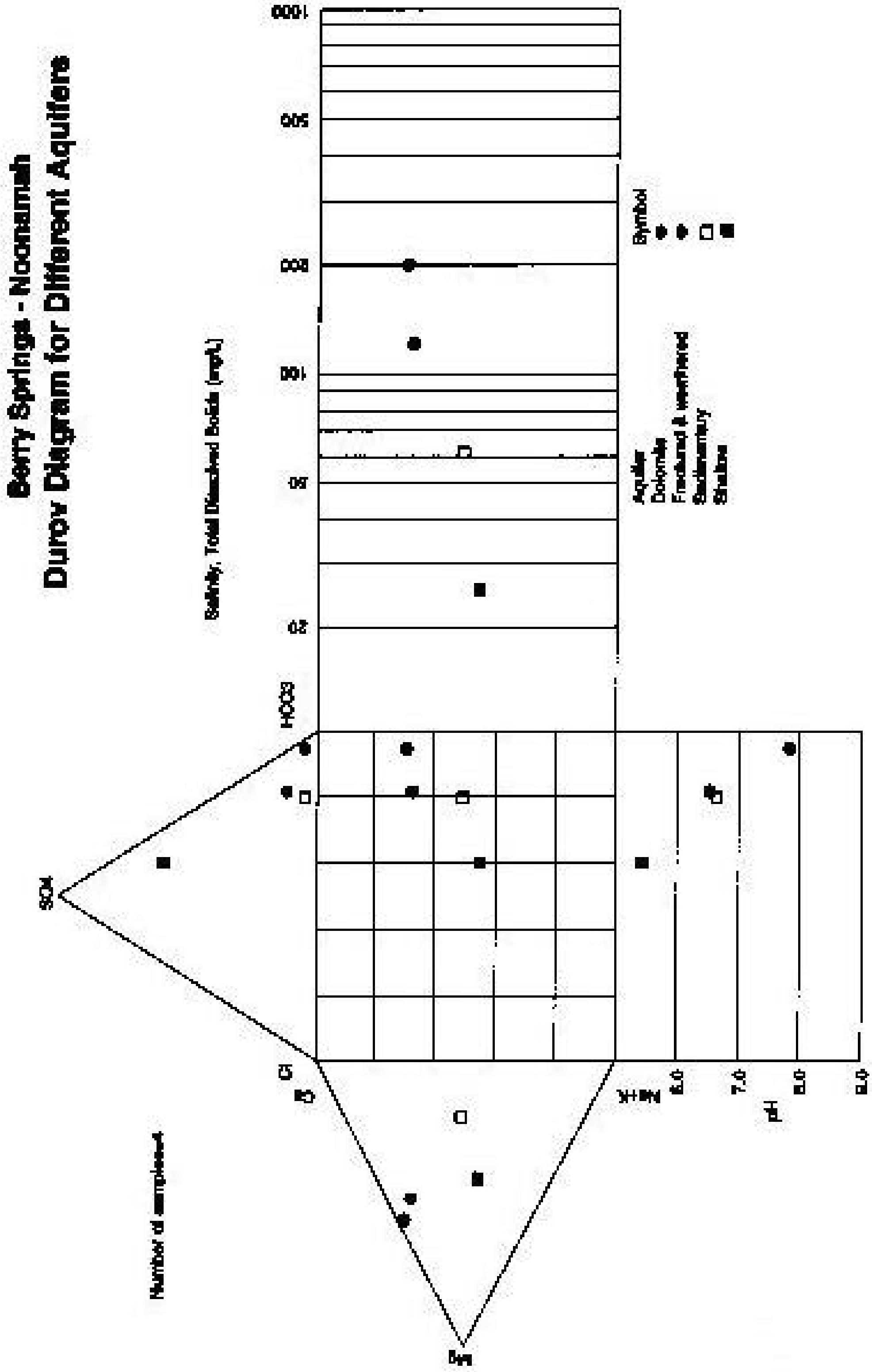
Berry Springs - Noonamah
Durov Diagram for Different Aquifers
Salinity, Total Dissolved Solids (mg/L)
Aquifer
Dolomite
Fractured & weathered
Sedimentary
Shallow
Symbol
Number of samples
HCO3
SO4
Cl
Ca
Mg
Na+K
pH
6.0
7.0
8.0
9.0

Figure 18 Durov Diagram showing Water Quality

Table 5 Analysis of Mineral Water from bore 9485 and Creek run off & Springs Water

Ions	Limit	Bore 9485 Water April 1990	Berry Spring Water 7.3.1983	Ck Run off near 28863 5.12.95	Parson Spring Water 12.6.1980	23.9.1995
Arsenic (As)	0.05	0.001	-	-	-	-
Barium (Ba)	1.00	0.002	-	-	-	-
Borate (H_3BO_3)	30.00	0.039	-	-	-	-
Cadmium (Cd)	0.005	0.0001	-	-	-	-
Calcium (Ca)	-	-	26	1	31	32
Chlorine, free	0.10	0.00	-	-	-	-
Chloride Cl)	-	-	8	3	18	11
Chromium	0.05	<0.0005	-	-	-	-
Copper (Cu)	1.00	0.002	-	-	-	-
Cyanide (CN)	0.10	<0.01	-	-	-	-
Cyanide Free	-	0.02	-	-	-	-
Fluoride (F)	1.50	0.10	0.1	0.1	<0.1	0.1
Iron (Fe)	0.30	0.004	<0.1	1.0	<0.1	<0.1
Lead (Pb)	0.05	<0.001	-	-	-	-
Magnesium (Mg)	-	-	28	1	30	29
Manganese (Mn)	2.00	0.0005	-	-	-	-
Mercury (Hg)	0.001	0.0001	-	-	-	-
Nitrate (N)		0.099	-	-	-	-
Nitrate (NO_3)	45.00	0.44	<1	<1	<1	<1
Nitrite (NO_2)	0.10	<0.02	-	-	-	-
Phosphate	-	-	10(g/L)	-	-	-
Potassium (K)	-	-	<1	1	1	<1
Radium (Ra^{226})	1.00 (mBq/L)	<1.0 (mBq/L)	-	-	-	-
Selenium (Se)	0.01	0.0005	-	-	-	-
Silica (Si)	-	-	9	5	15	16
Sulphide (H_2S)	0.05	Undetectable	-	-	-	-
Sluphate	-	-	6	3	7	8
Sodium (Na)	-	-	3	3	9	7
Sodium chloride (NaCl)		-	12	5	30	18
Zinc (Zn)	5.00	0.01	-	-	-	-
Bicarbonate		208.00	214	9	195	236
Hardness ($CaCO_3$)		178.00	180	7	201	199
Alkalinity ($CaCO_3$)		171	175	7	160	194
DO (O_2)	3.00	3.60	-	-	-	-
Conductivity (µS/cm)		335	350	24	425	385
pH		7.30	7.3	6.1	8.5	7.4
Coliform	10/100 mL	0.0/100 mL	-	-	-	-
E.Coli	0.0/100 mL	0.0/100 mL	-	-	-	-
Plate Count	100/mL	2/mL	-	-	-	-
TDS	-	-	-	34	-	215

All values in mg/L unless indicated, except pH values

Water analysis results indicate that the water in the fractured and weathered rock aquifer is softer than that of the dolomite aquifer. However, the concentration value of TDS is still higher than that of the sedimentary and shallow aquifers due to greater mixing of water which infiltrate from various aquifers in to fractures and weathered areas. Mixing of water in this aquifer appears to be pronounced because majority come from the dolomitic aquifer giving rise to calcium, magnesium and bi-carbonate contents. Chloride, sodium and sulphate contents are low and similar to the sedimentary rock aquifer.

Water analysis results indicate that the water in the sedimentary aquifer is soft, having lower values of TDS, calcium and magnesium than that of fractured and weathered rock aquifer. This is due to less mixing of the water in stratified layers of the sedimentary aquifer than in the fractured and weathered rocks. Chloride, sodium and sulphate are low due to their lower contents in the source (rainwater).

In the very minor or local shallow aquifer, water is acidic due to its closeness to the source (rainwater) and typical pH value is about 5.4 which goes down to 4.8 or so. The rainwater is acidic and infiltrate directly into the shallow aquifer first, apart from the fractured rocks. Water analysis result of the Berry Creek run off water (Table 5) shows the similarity between the rainwater and the shallow aquifer water.

Correlation among major anions and cations has been shown in the Table 6 and value closer to one (1) indicates that their relationship is direct or very strong.

TABLE 6 Correlation of Cations and Anions of the Dolomite Aquifer

	Na	**K**	**Ca**	**Mg**	**Alkali**		**Hard**		**Fe**	**SiO_2**	**Cl**	**SO_4**	**NO_3**	**HCO_3**		**CO_3**	**F**
Na	1																
K	0.606	1															
Ca	0.080	0.044	1														
Mg	0.366	0.220	0.748	1													
Alkalinity	0.311		0.091	0.086	0.087	1											
Hardness	0.242	0.138	0.0887	0.089	0.927	1											
Fe	-0.024	0.058	-0.030	-0.037	-0.045	-0.038	1										
SiO_2	0.300	0.290	0.025	0.078	0.111	0.029	0.010	1									
Cl	0.848	0.623	0.129	0.412	0.243	0.297	0.009	0.091	1								
SO_4	0.712	0.681	0.338	0.540	0.401	0.457	-0.002		0.219	0.726		1					
NO_3	0.138	0.092	0.001	0.104	0.072	0.035	0.005	0.080	0.049	0.064	1						
HCO_3	0.276	0.084	0.726	0.726	0.843	0.776	0.044	0.152	0.202	0.323	0.056	1					
CO_3	0.064	0.006	0.016	0.036	0.037	0.019	-0.020	0.000	0.006	0.05	0.011	0.025	1				
F	0.581	0.463	0.096	0.204	0.252	0.151	-0.030	0.490	0.325	0.415	0.079	0.248	-0.004	1			
TDS	0.692	0.515	0.678	0.802	0.780	0.752	0.036	0.0	0.371	0.656	0.722	0.116	0.672	0.030	1		
pH	0.190	0.132	0.498	0.486	0.618	0.509	-0.025	0.195	0.080	0.237	0.000	0.519	0.160	0.264	0.475	1	
EC	0.642	0.428	0.736	0.878	0.871	0.869	-0.046	0.164	0.643	0.713	0.081	0.731	0.033	0.377	0.926	0.515	1
	Na	**K**	**Ca**	**Mg**	**Alkali**		**Hard**	**Fe**	**SiO_2**	**Cl**	**SO_4**	**NO_3**	**HCO_3**	**CO_3**	**F**	**TDS**	**pH**

CONCLUSIONS

A major carbonate aquifer was identified in this region and its boundary was established during this investigation. This aquifer is in both a) the weathered karstic layers at the top of the Undivided Dolomite Layer (*Psd*) of the South Alligator Group (*Ps*) overlain by the Cretaceous (*K*) sediments (siltstone, sandstone, clay and conglomerate) and b) also at depths up to 199m below the ground surface (as per this investigation) in the fractured dolomite, which is connected to the above aquifer. Aquifer sediments were deposited during the Lower Proterozoic age in a small basin, which was created by the faulting (Giant Reef Fault) and tight folding.

Average sustainable yield in dolomite aquifer is more than 5.0 L/s, however airlifted yield up to 45.0 L/s (28854) and sustainable yield up to 32.0 L/s (26686) were obtained. Modelling of the dolomitic aquifer using Modflow program was carried out to establish unknown parameters like transmmissivity (T), porosity (Sy) and hydraulic conductivity (K).

Moderate aquifers in the primary porosity of sedimentary rocks were found in the Koolpin Formation (*Psk*) of the South Alligator Group (*Ps*) and Crater Formation (Ppr) of the Mount Partridge Group (*Pp*). General yield range in this aquifer was found to be from 1.5 to 5.0 L/s, however, fractures and weathering enhances yield, which has been found in numerous bores. Yield up to 25.0 L/s was obtained in bore 29387 in the Koolpin Formation (*Psk*) of the South Alligator Group.

Minor aquifers with a general yield < 0.5 L/s was found in fractured and weathered rocks of Gerrowie Tuff (*Psg*) and Mt Bonnie Formation (*Pso*) of the South Alligator (*Ps*) and Acacia Gap Quartzite Member (*Ppa) and* Wildman Siltstone *(Ppw*) Formations of the Mt Partridge (*Pp*). However, yield up to 10.0 L/s has been obtained in fractures in the Mt Bonnie Formation (*Pso*), bore 29386.

RECOMMENDATIONS

Pumping of individual bore is recommended to be not more than 24 hours (continuos) 20.0 L/s per km^2 to avoid interaction between bores. If pumped at higher rate than 20.0 L/s then the pumping should be for shorter i.e. the time between the pumping and recovery period should be longer in order to allow the water level to come up. This can be determined after a detail modeling. Estimated sustainable yield from the Dolomite Aquifer is 25,000 ML/year.

It is recommended to carry out a detail modeling for a long term water supply strategy. Number of meters were installed on certain bores and numerous bore owners were requested to record the amount of discharge bores were recorded from their bores. Therefore, there are good representative of water extraction rate/amount available.

Standing water level monitoring should continue for modeling purposes.

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Water Supply Investigations- Berry Springs School File - 468/02/0374

APPENDICES

A. **Appendix A**

1. Geophysical Investigation

Between April and October 1994, geophysics was conducted in the Berry Springs - Noonamah area to assist in defining the boundaries of the major dolomite aquifer. The survey followed the first stage of investigatory drilling during September-October, 1993. A second stage of drilling occurred during June-July, 1994, which incorporated the geophysics performed up to that date. Location of geophysical traverses are shown in Figure 19.

To define lateral extent of the dolomite, the pole-pole resistivity method was found most efficient. In total 11 traverses consisting of 39 line kilometres of pole-pole resistivity measurements at 50 m station spacings were carried out. Figure 19 shows the location of the traverses. Several Vertical Electrical Soundings (VES) were also performed to determine the relationship between resistivity and depth over the dolomite.

<u>Geophysical Line 1</u>

Line 1 along Duddell Rd was performed as a trial to test the effectiveness of the pole-pole method to locate the southern dolomite boundary as mapped in geological cross-section 2 (Figure 4), particularly the contact with the Mount Bonnie Formation which appears to surround the dolomite on most sides. The geophysics mapped two contacts represented by resistivity contrasts:

At 1200 N is a contact between the Depot Creek Sandstone (700 ohm.m) and the Mount Bonnie Formation (150 ohm.m).

At 600 N is a contact between the Mount Bonnie Formation and the Graphitic shales of the Koolpin Formation (< 10 ohm.m).

Although the dolomite is not considered to have been detected, the Depot Creek Sandstone was distinguished from the Mount Bonnie Formation. Apart for some overlap into the Mount Bonnie Formation at the boundary (as seen in bore 28859, geologic cross-section 2) it is considered that the Depot Creek Sandstone is mainly deposited over the dolomite by virtue of ancient weathering of the dolomite in preference to siltstone of the Mount Bonnie Formation.

A VES was performed at bore 28962, approximately 1 km North of the end of the line. Comparison of the inversion with the drill log shows highly resistive sandstone (1500 ohm.m) between 16 and 38 metres. This is clearly the Depot Creek Sandstone. From 38 to 48 metres is a zone of low resistivity (41 ohm.m) corresponding to highly weathered sandstone with some air lift yields. This is thought to represent the upper weathered surface of the dolomite. Beyond 48 metres the interpreted resistivity climbs to 643 ohm.m however this value is relatively uncontrolled. The drill log indicates siliceous fine grained sandstone and air lift yields of up to 5 L/s. This is interpreted as fresh dolomite.

<u>Geophysical Line 2</u>

This extensive 15700 m line along Kentish Rd was performed to observe the apparent resistivity along a continuous traverse over the dolomite, and map the Eastern and Western boundaries.

The Western margin of the Depot Creek Sandstone (and nearby underlying dolomite) is interpreted at 250 e. The small 'kick' in the profile at this point is a characteristic of the pole-pole array as it crosses a near surface dipping contact. Similar contact features are also visible in other profiles.

The geologically mapped eastern boundary of the dolomite is located at about 11000 E, which bears no correlation with the geophysics. Bore 29385 at 10000 E contains Mesozoic clays to 28 metres, underlain by fresh dolomite. At this location the profile has an apparent resistivity of 400 ohm.m, the moderate resistivity value being due to the conductive nature of clay layer,

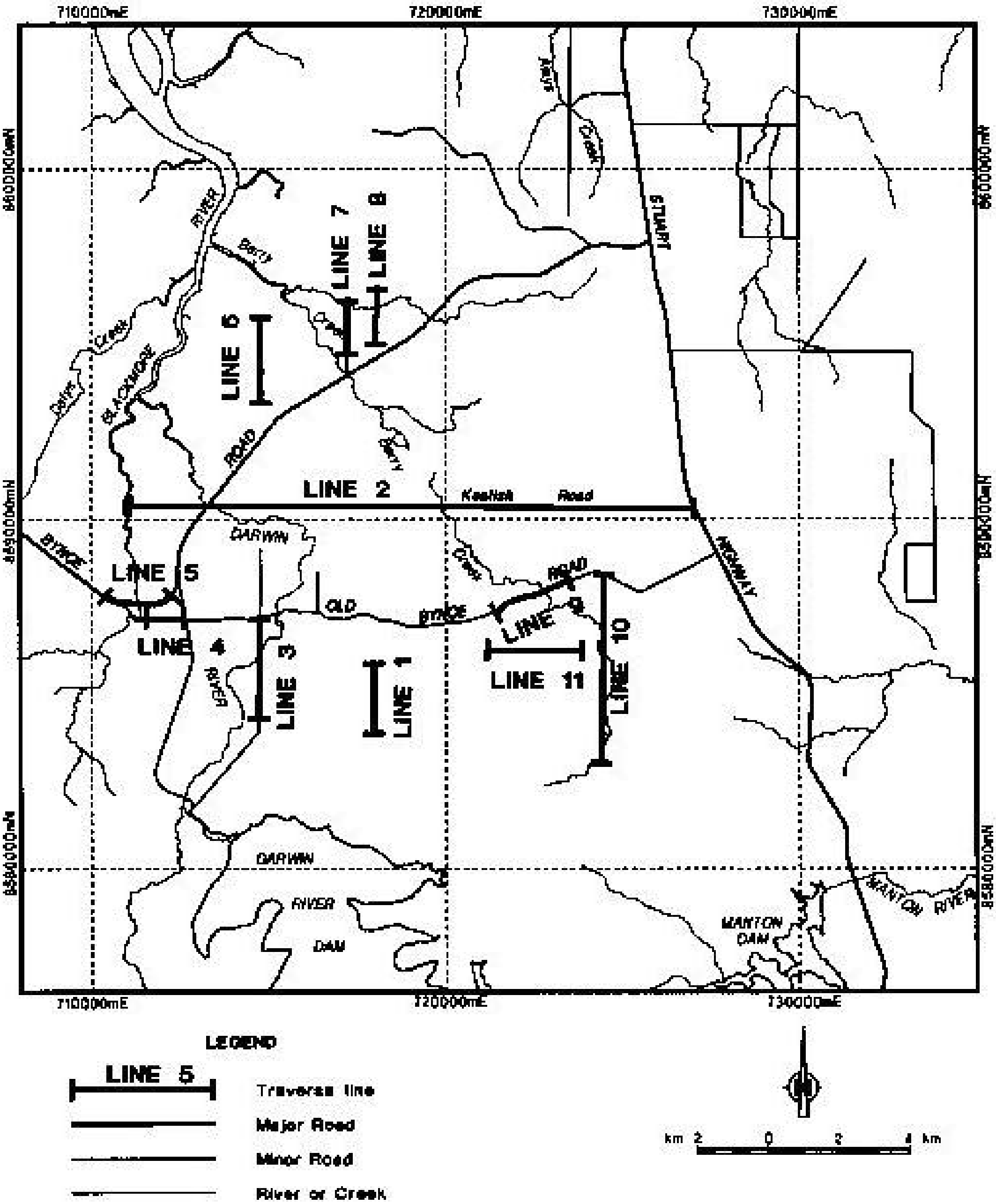

Figure 19 Location of Geophysical Traverses

which has masked the high resistivity of the underlying Depot Creek Sandstone/dolomite. Analysis of air photos shows that between 8800 E and 11100 E, the ground is covered by the alluvial fines, which was deposited as a sheet wash, which may be a function of the near surface clays. The clays appear to be the cause of the 'IP effect' which was noticed while performing the survey over this locality.

Siltstone occurs to the east of the dolomite boundary. The conductive anomaly occurring around 13000 E has not been drilled but may be a relatively conductive layer within the dipping strata.

Geophysical Line 3

This line along Reedbeds Rd was performed to map the Southern Boundary of the dolomite in an area with little drilling control. The profile is similar to line 1, however it contains greater near surface in homogeneity than the predominantly erosion, higher ground, of line 1. This distorted the 'ideal' profile somewhat, introducing noise and the overall smoothing of the extreme upper and lower apparent resistivity values. The geophysics mapped the contacts as follows:

1000 S between Depot Creek Sandstone (~400 ohm.m) and Mount Bonnie Formation (~150 ohm.m).

2600 S between Mount Bonnie Formation and Koolpin Formation (~40 ohm.m).

Geophysical Line 4

This traverse was performed along Trenow Rd to define the Western boundary of the dolomite. The profile correlates well with Line 2 to the North. The line shows a contact in the vicinity of m W, plus or minus 100 m. The line was cut short by the Blackmore river to the West, which makes picking the location of the contact inaccurate. To the East of the contact, high resistivity consistent of the Depot Creek Sandstone occur, while to the West the resistivity distinctively drop off and can be correlated to outcrops of siltstone in the river bed nearby.

Geophysical Line 5

This traverse along Cox Peninsula Rd was performed to locate the Western boundary of the dolomite. It correlates with Line 4 to the South, mapping the boundary at 500 W. To the West of the Blackmore River the readings become quite noisy, but typical of local siltstone (100-400 ohm.m). Drilling occurred at three locations along this line, confirming approximately, the position of the boundary as shown in geological cross-section 6 (Figure 6).

Geophysical Line 6

This traverse was performed along Cyrus Rd (Western boundary of Wildlife Park) to map the location of the Northern boundary of the dolomite. The contact has been previously mapped at approximately 1500 N with controls provided by; (i) Goose Lagoon, occurring over the dolomite, (ii) the contact mapped by geophysical Lines 7 and 8 to the East, and (iii) bore 29384 containing dolomite to the West. The measurements were performed 10 m from a well-grounded chain mesh fence. Previous surveys performed along fence lines showed no correlation between the geophysics and the fence because of the high contact resistances encountered in the dry surface materials, however this line may be the exception. The apparent resistivity are noisy and have a fairly constant average of around 200 ohm.m, showing no evidence of the resistive Depot Creek Sandstone/dolomite units to the South, or their boundaries with the siltstone to the North. These low resistivity may be due to the fence or a localised conductive zone in or over the Depot Creek sandstone/dolomite. It thus appears at that this line has failed to detect the contact however this does not mean that the contact has not been covered by the traverse.

Geophysical Lines 7 and 8

These traverses along the Nature Reserve fence line and Finn Rd were required along with line 6 to accurately map the Northern dolomite boundary, so that the occurrence of the Berry Springs may be better understood. These N-S lines are located m apart and show very good correlation with each other. High resistivity of the Depot Creek Sandstone/dolomite is apparent to the south (up to 900 ohm.m) and with the moderate resistivity of the Mount Bonnie Formation to the north (up to 200 ohm.m). The contact has been mapped at 500 N on line 7 and 900 S on line 8.

Geophysical Line 9

This traverse along Old Bynoe Rd was performed to locate the contact with the dolomite and what is considered to be the Burrell Creek Formation adjoining the dolomite as a graben. The results show a general trend of resistivity gradually dropping off to the East making the location of the contact difficult to pick. Two bores are located along the line:

Bore 28961 at 1325 W, containing Depot Creek Sandstone from 6 to 48 m at the end of the hole. Dolomite is expected at depth.

Bore 28863 at 800 W, containing Depot Creek Sandstone between 0 and 28 m, followed by siltstone, interpreted geologically as Burrell Creek Formation.

Depot Creek Sandstone occurs here over the siltstone but the extent of this is thought to be limited. The gradual drop off of the apparent resistivity to the East agrees with the bore hole data, showing the quartz sandstone also becoming thinner to the East, and suggesting the presence of dolomite to the West where the sandstone is thicker.

Geophysical Line 10

Line 10 along Parkin Rd was performed in a N-S direction. This was in order to locate the dolomite according to a theory that its boundary 'bulged out' to the Southeast in such a way that it better followed the trends of the other units in the area, for instance the Mount Bonnie Formation - Gerrowie Tuff contact. Line 10 did not intersect the dolomite, resistivity remaining moderate (70-400 ohm.m). There appears to be three distinct electrical units within the profile:

0-1000 S, apparent resistivity 200-500 ohm.m with noisy variations (Noise due to near surface effects or survey noise, not deep seated geological changes).

1000-4400 S, apparent resistivity 100-400 ohm.m with smooth variations.

4400-5600 S, apparent resistivity 70-100 ohm.m.

The above mentioned units all correspond to the geologically mapped Mount Bonnie Formation. The differing electrical properties due to variations of rock type within the formation. It is thought that the units from 0-4400 S may be greywacke and the less resistive material between 4400-5600 S shale or siltstone.

Geophysical Line 11

Line 11 was traversed in an East-West direction towards Line 10 to intersect the boundary of the dolomite missed by Line 10.0 E appears to be moderately conductive however bore 28858 at this location intersects a fairly thin horizon of Depot Creek Sandstone from 12 to 24 m followed by dolomite. 1000 ohm.m at 1000 E indicates Depot Creek Sandstone/dolomite further down the line and the contact with the siltstone may be confidently located at 1450 E. The response to the East of the contact shows a unit with resistivity 200-500 ohm.m having noisy variations, similar to the portion 0-1000 s of line 10.

Appendix B

1. INVESTIGATION DRILLING

- Methods used, Problems encountered during the investigation drilling & Bore Logs

Investigations drilling in the Berry Springs area were carried out in two stages. The first stage from 8 September to 26 October 1993 and the second stage from 16 June to 21 July 1994. First stage of drilling was aim mainly to find and establish both the major and minor aquifers and it has been documented in the Report 63/94.

This reports summaries the second stage drilling as given below. Please note that all the water supply rates are shown below are *airlifted yield* and all depths are *below the ground level* (bgl) unless mentioned otherwise. All the *casing diameters* are *internal* unless otherwise mentioned.

Selection of bore sites was based on the results of the first stage drilling and geophysical surveys carried out prior to drilling. Some bores were located on privately own land, but prior approvals were taken from the landowners.

Drilling was carried out with using a Kelly drive rotary-drilling rig, (Ingersoll-Rand rig number 23). As the area lies in the *Water Management District*, all bores were drilled according to *Water Act*. A total of eleven (11) bores were drilled and out of which eight (8) bores were constructed as monitoring bores during this period.

Bores were drilled mostly with air and some with mud. Drilling methods and difficulties have been discussed already in the previous report (63/94). Drilling in dolomite was found to be more suitable with the mud than air in order to prevent collapsing of wall, however to position the screen or perforations, geophysical logging down the hole may be necessary.

In following the paragraphs, various criteria used in the selection of bore sites are given with a brief hydrogeological description, drilling method and problems encountered during the drilling.

RN 29016
This bore was drilled during the period from 16 to 20 June 1994 and it was constructed as a monitoring bore with 100 mm pvc casing and 3 mm slots from 26.0 to 35.0 m. A surface steel casing (152 mm) was cemented to 5.4 m bgl (below ground level).

This bore was drilled only 10 m away from an existing bore 28855 to be constructed as a monitoring bore, therefore the lithology was known- the *dolomite* (*Psd*) of the South Alligator Group (*Ps*). It was drilled with mud to the required depth (37.3 m) where the dolomite was expected and then it was constructed. Bore 28855 was drilled with air only and it had started collapsing as soon as went through the weathered rocks, therefore either the mud drilling or casing the bore to drill further is required in this type of rocks. An airlifted yield was 6.0 L/s after the construction of the bore. Water supply was intersected between 25.5 and 31.5 m and the water was slightly dirty. The standing water level (swl) was 17.0 m on 20.6.94 and 19.85 m on 23 Sept 94.

RN 29017
This bore was selected on the basis of the geology interpreted after the first stage of the fieldwork and the geophysical resistivity survey carried out during 1994. It was drilled during 28 to 29 June 1994 to establish geological boundaries within the South Alligator Group (*Ps*) and/or boundary with the *Burrell Creek Formation* (*Pfb*). The bore was located 100 m north of the Blackmore River on Mandorah Road, on the Section 2230 (Finniss 09.10 map 1:10,000) in the Hundred of Cavenagh. The land belongs to the Conservation Commission of the Northern Territory (CCNT) and their permission was obtained prior to drilling this bore.

Mount Bonnie Formation (Pso) of the South Alligator Group was intersected below the *Burrell Creek Formation (Pfb)* at 43.5 m depth *bgl*. There was no existing bore around this site.

A water supply of 0.5 L/s was intersected from 31.5 to 37.5 and 5.0 L/s from 37.5 to 61.5 m in fractures and the water was dirty.

Drilling with air did not create any problem, however the bore collapsed to 17.4 m after pulling out the drilling rods. The swl could not be taken as the bore collapsed. The total depth drilled was 85.5 m. The bore was backfilled.

RN 29018
This bore was selected on the same basis as that of 29017 to establish geological boundaries and the site was selected on the geological and geophysical basis. It was drilled during 29 June to 1 July 1994 with air and then mud.

Mostly siltstone and sandstone with quartz gravels were intersected which were highly weathered up to 74 m depth bgl. Sandstone from 74 to 75 m was medium to slightly weathered.

Mount Bonnie Formation (Pso) of the South Alligator Group was intersected below the *Burrell Creek Formation (Pfb)* at 49.5 m depth *bgl*.

The bore was opened to 72.8 m only after the rods were pulled out and it was geophysically logged at the end of the day. Next day the bore had collapsed, so no further drilling could be done. Water supply in this bore was 0.3 at 18.8 m, but the yield below this depth is not known, which is believed to good (>10.0 L/s). The bore was backfilled.

RN 29019

This bore was also selected on the same basis as that of 29017 to establish geological boundaries and the site was selected on the geological and geophysical basis. It was drilled during 1 to 5 July 1994 with air and then mud to a total depth of 49.3 m bgl. Mud drilling is the best way if the bore has to be constructed.

The *dolomite* (*Psd*) sequence of the *South Alligator Group (Ps)* was intersected in this bore at 24.8 m depth below the Cretaceous rocks (*K*). The bore was geophysically logged which confirmed the strata.

A water supply of 3.0 L/s (after the construction) was intersected from 38.0 to 42.0 m in dolomite. Water was slightly dirty which may clean up after proper development. The yield however is thought to be in excess of 20.0 L/s due to cavities from between 36.8 and 42.7 m also indicated by the geophysical log. On 23 Sept 94, the swl was 8.01 m bgl.

The bore was constructed as a monitoring bore with 100 mm pvc casing up to 48.0 m depth with 4 mm slots from 38.0 to 42.0 m. A 152 mm surface steel casing was installed up to 5.4 m.

RN 29381

This bore was selected on the both the geological and geophysical basis to determine the boundary between the *dolomite* (*Psd*) and the *Mount Bonnie Formation(Pso)* of the *South Alligator Group (Ps)*. Geophysical line was run along the Finn Road.

It was drilled with air to a total depth of 103.4 m bgl on 6 July 1994. Drilling was easy with air and hammer. However, the bore collapsed to 11.57 m depth after the rods were pulled out.

The *Mount Bonnie Formation (Pso)* of the *South Alligator Group (Ps)* was intersected in this bore and a water supply of 1.0 L/s was from 30.? to 49.4 m depth. Water was dirty and highly ferruginous red. Geophysically logging could not be done as the bore had collapsed.

The standing water level was 9.2 m on 6 July 94. Bore was backfilled.

RN 29382

This bore was selected on the same basis as for the bore 29381, to determine the boundary between the *dolomite* (*Psd*) and the *Mount Bonnie Formation (Pso)* of the *South Alligator Group (Ps)*. Geophysical line was the same run along the Finn Road.

It was drilled with air to a total depth of 37.5 m bgl from 7 to 8 July 1994. Hole started caving in therefore heavy foam was used to stabilise until it was cased. *Dolomite (Ps)* was intersected at 29.3 m depth below the Cretaceous rock. The *Mount Bonnie Formation (Pso)* was not found in this bore.

The bore was constructed as monitoring bore with 142 mm pvc and 4 mm slots from 24.5 to 31.5 m. A water supply of 5.2 L/s was intersected from 24.0 to 32.5 m. Water was good and the airlift after the construction was 2.2 L/s. Standing water level was 13.1 m on 8 July 94.

RN 29383

This bore was selected mainly on the basis of geological interpretation to establish the western boundary of the *dolomite (Psd)* of the *South Alligator Group (Ps)*.

It was drilled with air to a total depth of 37.5 m bgl during 7 to 8 July 1994. The hole started to cave in below 12.8 m due to loose gravels and moist clay. Highly broken dolomite *(Psd)* of the *South Alligator Group (Ps)* was intersected at 15.3 m.

The bore was constructed as monitoring bore with 50 mm pvc to a depth of 16.2 m and 4 mm perforation from 10.2 to 16.2 m. Due to clays no water could be airlifted, however water supply in this bore may be higher than 10.0 L/s. Standing water level was 2.2 m on 14 July 94.

There is a spring known as Parson's Spring, 200 m to the west and the flow was estimated to be >10 L/s.

RN 29384

This bore was selected mainly on the basis of geological interpretation to establish the western boundary of the *dolomite (Psd)* of the *South Alligator Group (Ps)* to the north of the bore 29383.

It was drilled with air to a total depth of 32.2 m bgl during July 1994 and the dolomite *(Psd)* of the *South Alligator Group (Ps)* was intersected at ? m below the Cretaceous sediments. A water supply of 15.0 L/s was obtained from 24.9 to 31.2 m, which was slightly silty. A 150 mm steel surface casing was cemented to a depth of 5.5 m and a 50 mm pvc casing with 4mm perforations from 24 to 30 m was installed to a depth of 30.0 m. It was constructed as monitoring bore and is was geophysically logged (γ).

Standing water level was 7.2 m bgl on 14.7.94 & 8.76 bgl on 15.8.94.

RN 29385

This bore was selected on the basis of geophysical anomaly to confirm the boundary of the *dolomite (Psd)* of the *South Alligator Group (Ps)* with the *Mt Bonnie Formation (Pso)* of the *South Alligator Group (Ps)* on the eastern side.

It was drilled with air to a total depth of 31.0 m bgl during 14 & 15 July 1994 and the *dolomite (Psd)* of the *South Alligator Group (Ps)* was intersected at 28.6 m below the Cretaceous sediments. At the contact, some yellow clay and water-worn silicified dolomite were intersected. A water supply of 5.0 L/s was obtained which was slightly silty.

The bore was constructed as monitoring bore with 50 mm pvc to a depth of 16.2 m and 4 mm perforation from 24.5 to 29.5 m. It was geophysically gamma (γ) logged.

Standing water level was 9.2 m on 15 July 94.

RN 29386

This bore was selected on the basis of geophysical anomaly to determine the contact of the *Mt Bonnie Formation (Pso)* of the *South Alligator Group (Ps)* with the *Burrell Creek Formation (Pfb)* of the *Finniss River Group (Pf)* on the eastern side.

It was drilled with air to a total depth of 31.0 m bgl during 15 & 19 July 1994. Ferruginous siltstone of the *Mt Bonnie Formation (Pso)* was intersected at 38.0 m below the *Burrell Creek Formation (Pfb)*. At the contact, a water supply of 0.6 L/s was obtained. Yield in the *Mt Bonnie Formation (Pso)* increased to 10.0 L/s in the fractures between 42 and 49.5 m and the water was clean.

The bore was converted to monitoring bore as open bore with the surface casing. It was geophysically logged, both resistivity (Ω) and gamma (γ).

Standing water level was 17.4 m on 19 July 94.

RN 29387

This bore was selected on the basis of geology to intersect the carbonate sequence at the bottom of the *Koolpin Formation (Psk)* of the *South Alligator Group (Ps)* at depth.

It was drilled with air to a total depth of 120.9 m bgl during 1.7.94 & 19.7.1994. Ferruginous and graphitic interbedded siltstone and shale of the *Koolpin Formation (Psk)* was intersected. A water supply of 0.4 L/s was obtained at 25.5 m which kept increasing up to 25.0 L/s with the depth in fractures to the depth of 72.9 m and the water was clean.

The bore was converted to monitoring bore as open bore with the surface casing. It was geophysically logged, both resistivity (Ω) and gamma (γ).

Standing water level was 5.3 m on 20 July 94.

Appendix C

1. INVESTIGATION BORE LOGS

GEOLOGICAL LOGS OF INVESTIGATION BORES BERRY SPRINGS - NOONAMAH AREA

16.6.94 TO **21.7.94**

<u>RN 29016</u>

Date drilled: 16.6.94 - 20.6.94

Location: Sec 638, Middle Arm 10.06, H of Cavenagh. Permit 8056, 10 m from 28855, Hopewell Road

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Depth metre	**Lithological Description** with aquifer depth, airlift yield and field pH & EC
00.00- 9.00 m	Laterite, clay, sandstone
09.00- 27.00 m	Sandstone, breccia, conglomerate, airlift 0.3 L/s @25.0 -25.5 m
27.00- 37.30 m	Dolomite, airlift 6.0 L/s @ 25.5 to 31.5 m

================================ **End of Hole 37.3 m** ================================

<u>Summary of Bore RN 29016</u>

<u>Stratigraphy</u>

00.00- 9.00	Sandstone ***(K)***
09.00- 27.00	Sandstone, breccia, conglomerate ***(JKp)***
27.00- 37.30	Dolomite ***(Psd)***

Yield:: 0.3 L/s @25.0 -25.5 & 6.0 L/s @25.5 - 31.5 m, Dirty

SWL: **17.0 m** on 20.6.94

TOC: **0.6 m** agl

Construction: 0.0- 5.4 m **152 mm** Steel cemented

0.0-35.0 m **100 mm pvc** 3 mm slots from 26.0 to 35.0 m & 3 mm slots

Bore Status : Monitoring Bore, Bore was opened to geophysically (γ) logged.

RN 29017

Date drilled: 28.6.94 - 29.6.94

Location: Sec 2230, Finniss 09.10, H of Cavenagh, Permit 8051, CCNT Reserve, Mandorah Rd, Blackmore River

Depth metre	Lithological Description with aquifer depth, airlift yield and field pH & EC
00.00- 3.00	Laterite, red-brown, silty clay
03.00- 6.00	Dark brown clayey silt & quartz-vein chips
06.00- 9.00	Yellow clayey silt, slightly moist- Siltstone
09.00-19.50	Light grey, slightly sandy clayey silt, micaceous, moist with yellow clayey silt
19.50-43.50	Grey to dark grey clayey silt, slightly micaceous, H.W. to M.W. Siltstone with vein-quartz around 30 m S.W. to fresh rock- dark grey siltstone, slightly schistose- sheared, some water-worn quartz and pyrite, micaceous Airlifted @ 33 m - Yield 0.3 L/s Airlifted @ 37.5 m - Yield 0.5 L/s, pH 6.4 EC 135 Airlifted @ 43.5 m - Yield 1.2 L/s
43.50- 85.50	Fresh, dark grey siltstone with pyrite, sheared Airlifted @ 49.5 m - Yield 1.5 L/s Airlifted @ 61.5 m - Yield 5.5 L/s Fresh light grey siltstone with more quartz content as this bands of vein quartz, slow drilling due to hard rock Airlifted @ 67.5 m & 73.5 m - Yield 5.5 L/s, no increase in yield.

End of Hole 85.5 m

Summary of Bore 29017

Stratigraphy

00.00- 43.50 m Dark grey siltstone *(Pfb)*

43.50- 85.50 m Dark grey siltstone, pyrite, sheared *(Pso)*

Yield: 0.5 L/s @31.5 - 37.5 m & 5.5 L/s @37.5 - 61.5 m, dirty

SWL: -

TOC: 0.6 m agl

Construction: -

Bore Status : Bore collapsed to 17.4 m, Backfilled

RN 29018

Date drilled: 29.6.94 - 1.7.94

Location: Sec 2373 Finniss 09.10, H of Cavenagh, Permit 8063, Mandorah Road, Blackmore River

Depth metre	**Lithological Description** with aquifer depth, airlift yield and field pH & EC
0.00- 0.30	Grey sandy clay
0.30- 1.20	Red & grey clay
1.20- 3.50	Yellow clay
3.50- 5.50	Yellow sandy clay, moist
5.50- 6.90	Yellow sandy clay, rounded quartz gravels
6.90- 14.80	White clayey sand- C.W. to H.W. sandstone
14.80- 49.50	Pink to dark pink clayey sand and gravels - C.W. to H.W. sandstone Airlifted @18.8 m - yield 0.3 L/s very coarse sand and rounded to sub-rounded quartz gravels H.W. pink med grain sandstone below 24.8 m, changed over to mud drilling at 24.8 m
49.50- 74.00	Yellow limonitic clay with quartz gravels - limonitic siltstone ! C.W. to H.W., fault zone colour changing to purple and dark brown around 72 m, possibly aquifer around 66.8 m
74.00- 75.00	M.W. to S.W. medium to coarse sandstone, purple, grey

================================ **End of Hole 75.0 m** ================================

Summary of Bore 29018

Stratigraphy

0 - 5.5 m	Siltstone, sandstone *(K)*
5.5 - 75.0 m	Sandstone, siltstone *(Pfb)*

Yield:	- 0.3 L/s @18.8 m, possibility of good water supply (>10 L/s?) around 66.8 m
SWL:	-
TOC:	-
Construction:	-
Bore Status :	Backfilled, Bore was geophysically (Ω) logged while it was opened to 72.8 m depth

RN 29019

Date drilled: 29.6.94 - 1.7.94

Location: Sec 2373 Finniss 09.10, H of Cavenagh, Permit 8064, Mandorah Rd, Blackmore River

Depth	**Lithological Description** metre with aquifer depth, airlift yield and field pH & EC
0- 1.0	Grey sand soil
1.0- 5.5	Red & lateritic yellow clay, some quartz
5.5- 6.9	Dark brown, white and red & yellow clay -siltstone
6.9- 36.8	Yellow and white sandy clay - sandstone, moist from 18.8 m water-worn (honey-comb) quartz from 24.8 m, very moist, collapsing, mud drilling from 30.8 m
36.8- 42.7	Very soft and no return, "*Loss circulation*" from 41 to 42.3 m Hard rock around 42.7 m- sandstone & water-worn (honey-comb) quartz
42.7- 49.3	Dark brown, some grey and pink S.W. to fresh dolomite & slightly siliceous, cavity around 46 m, water-worn (honey-comb) quartz geode, Probably yield is much higher than 3.0 L/s

================================ **End of Hole 49.3 m** ================================

Summary of Bore 29019

Stratigraphy

0 - 36.8 m	Siltstone, sandstone	*(K)*
36.8- 49.3 m	Dolomite	*(Psd)*

Yield:	3.0 L/s @38.0 -42.0 m, pH 7.1 EC 400
SWL:	-
TOC:	0.6 m agl
Construction:	0 - 5.4 m 150 mm steel casing , Cemented 40 - 48 m 100 mm pvc casing & Slotted 4 mm aperture from 38.0 - 42.0 m and gravel packed Sump from 42 - 48 m
Bore Status :	Monitoring Bore Bore was geophysically (Ω) logged, bore was opened to 42.8 m

<u>RN 29381</u>

Date drilled: 6.7.94 - 6.7.94

Location: Sec 1576, Lot 4, Permit 8058, Middle Arm 10.06, H of Ayers, Finn Road

Depth metre	**Lithological Description** with aquifer depth, airlift yield and field pH & EC
0.0- 3.0	Lateritic clay, gravels
3.0- 5.5	Red and white silty clay, some quartz
5.5- 7.5	Dark brown siltstone, S.W.
7.5- 18.4	S.W. light brown siltstone, quartz band at 13.4 m
18.4- 23.2	S.W. dark red siltstone, highly ferruginous
23.2-103.4	Fresh banded chert, grey, pink, sheared, some siltstone moist- interbedded siltstone & chert
	Airlifted @31.4 m 0.2 L/s
	Airlifted @37.4 m 0.8 L/s
	Red siltstones, some purple, fracture, sheared, highly ferruginous
	Airlifted @49.4 m 1.0 L/s pH 5.0 EC 53 dirty water- may clean up

End of Hole 103.4 m

<u>Summary of Bore 29381</u>

<u>Stratigraphy</u>

0 - 103.4 m Red siltstone, chert and quartz bands ***(Pfb)***

Yield: 1.0 L/s @30.0- 49.4 m, pH 5.0 EC 53 Dirty water

SWL: 9.2 m bgl on 6.7.94

TOC: -

Construction: -

Bore Status : Backfilled, Bore was geophysically (γ) logged, it was opened to 11.57 m only

RN 29382

Date drilled: 7.7.94 - 8.7.94

Location: Sec 305, Lot 1, Permit 8078, Middle Arm 10.06, H of Ayers, Finn Road

Depth metre	**Lithological Description** with aquifer depth, airlift yield and field pH & EC
0.0- 3.0	Laterite, clay
3.0- 21.5	Yellow & white clay
21.5- 25.5	Black & yellow siltstone
25.5- 28.7	Grey siltstone, quartz, moist
28.7- 29.3	Red & black siltstone
29.3- 31.5	M.W. light grey dolomite, broken from 30 m Airlifted @31.5 m 5.0 L/s pH 4.2 EC 120
31.5- 37.5	Above with red siltstone and quartz Airlifted @37.5 m 5.2 L/s Bore caving-in, used stiff foam to stabilise and then installed the casing

End of Hole 37.5 m

Summary of Bore 29382

Stratigraphy

0.0- 29.3 m	Siltstone	(***K***)
29.3- 37.5 m	Dolomite	***(Psd)***

Yield:	1.7 L/s @24.0- 25.5 m	dirty water
	3.3 L/s @25.5- 31.5 m	pH 4.2 EC 120 clean water
	0.2 L/s @31.5- 32.5 m	clean water
	2.2 L/s after construction	
SWL:	13.1 m bgl on 8.7.94	
TOC:	0.6 m agl	
Construction:	0 - 6.0 m 150 mm steel casing , Cemented	
	0 - 32.5 m 142 mm pvc casing & 4 mm slots from 24.5 - 31.5 m with gravels from 24 to 32.5 m	
Bore Status :	Monitoring Bore. The bore was opened to 32.4 m & it was geophysically (γ) logged.	

RN 29383

Date drilled: 8.7.94 - 14.7.94

Location: On Road Reserve Off Carveth Road & Sec 2211, 115, Permit 8052, Middle Arm 09.06, H of Cavenagh

Depth metre	**Lithological Description** with aquifer depth, airlift yield and field pH & EC
0.0- 2.0	
2.0- 5.4	White sandy clay & quartz
5.4- 5.6	Quartz gravels only
5.6- 7.5	Grey and yellow clay and quartz gravel
7.5- 12.8	Quartz gravels and white calcareous clay
12.8-15.3	as above with some seepage
15.3-19.3	M.W. to S.W. black to dark grey dolomite and some quartz, hard but all broken and caving-in Aquifer, Hole was stabilised with mud and cased with 2" pvc, yield possibly more than 10.0 L/s? It was very difficult to drill through broken materials.

End of Hole 19.3 m

Summary of Bore 29383

Stratigraphy

0 - 7.5 m	Claystone	***(K)***
7.5- 19.3 m	Dolomite	***(Psd)***

Yield:	Possibly >10.0 L/s
SWL:	2.2 m bgl on 14.7.94
TOC:	0.5 m agl
Construction:	0 - 5.5 m 156 mm steel casing , Cemented 0 - 16.2 m 55 mm pvc casing & Perforated 4 mm aperture from 10.2 - 16.2 m with gravels
Bore Status :	Monitoring Bore. Bore was opened to m & it was geophysically (γ) logged There is a *Spring* (Parson Springs) about 200 m west of this bore

RN 29384

Date drilled: 13.7.94 - 14.7.94

Location: On VCL Sec 2413 Off Carveth Road, Permit 8053, Middle Arm 09.06 H of Cavenagh, 1 km north of Bore 29383

Depth metre	Lithological Description with aquifer depth, airlift yield and field pH & EC
0.0- 2.5	Yellow limonitic sandy silt
2.5- 6.1	Lateritic dark brown clay
6.1- 7.4	Yellow and white clayey sand
7.4- 11.0	Red and white clay and quartz, moist
11.0- 13.0	Black clay & quartz
13.0- 21.0	as above with quartz pebbles
21.0- 31.2	Yellow, black silt and big quartz pebbles, water-worn, aquifer
	Airlifted @30.9 yield 10.0 L/s
31.2- 32.2	H.W. dolomite
	Airlifted @32.2 yield 15.0 L/s pH 6.5 EC 340, silty water
	S.W. to fresh dolomite at the bottom

End of Hole 32.2 m

Summary of Bore 29384

Stratigraphy

0.0 - 31.2 m	Siltstone, sandstone *(K)*	
31.2 - 32.2 m	Dolomite	*(Psd)*

Yield:	15.0 L/s @24.9- 31.2 m pH 6.5 EC 340, silty water
SWL:	7.2 m bgl on 14.7.94 & 8.76 m bgl on 15.8.94 (a drop of 1.56 m in 1 month)
TOC:	0.5 m agl
Construction:	0 - 5.5 m 150 mm steel casing , Cemented
	0-30.0 m 50 mm pvc casing & perforated 4 mm aperture from 24.0 - 30.0 m with gravels
Bore Status :	Monitoring Bore, The bore was opened to 28.8 m and it was geophysically logged (γ).

RN 29385

Date drilled: 14.7.94 - 15.7.94
Location: Sec 641, VCL, Permit, Corner Kentish Road and Pipeline, Middle Arm 10.06, H of Cavenagh

Depth metre	**Lithological Description** with aquifer depth, airlift yield and field pH & EC
0.0- 1.7	Laterite, clay
1.7- 4.5	Red, white and yellow clay
4.5- 13.0	White and pink clay and quartz bands
13.0- 18.9	Fine grained sand- sandy clayey silt- siltstone, C.W. to H.W.
18.9- 24.9	as above and quartz bands
24.9- 28.6	as above with pitted and water-worn quartz and yellow clay, aquifer around 28 m
28.6- 31.0	Fresh dark grey siliceous dolomite, aquifer Airlifted @30.9 m yield 5.0 L/s- silty water, pH 7.3 EC 340

End of Hole 31.0 m

Summary of Bore 29385

Stratigraphy

0.0- 28.6 m	Sandstone, siltstone ***(K)***	
28.6- 31.0 m	Dolomite	***(Psd)***

Yield:	5.0 L/s @25.0- 30.9 m, pH 7.3 EC 340, silty water
SWL:	9.2 m bgl on 15.7.94
TOC:	0.8 m agl
Construction:	0 - 5.8 m 150 mm steel casing , Cemented 0 - 29.5 m 50 mm pvc casing & Perforated 4 mm aperture from 24.5 - 29.5 m with gravels
Bore Status :	Monitoring Bore. Bore was opened to 27.9 m and it was geophysically logged (γ).

RN 29386

Date drilled: 15.7.94 - 19.7.94
Location: Sec 648, Permit , Kentish Road, Middle Arm 10.06, H of Cavenagh

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Depth metre	**Lithological Description** with aquifer depth, airlift yield and field pH & EC
0.0- 20.6	S.W.- fresh red siltstone
20.6- 31.3	Fresh yellowish red siltstone
31.3- 38.0	Fresh red siltstone with thin bands of dark red grey siltstone, moist from 37.5 m Airlifted @37.5 m yield 0.6 L/s, pH 7.0 EC 450
38.0- 79.5	Fresh dark grey to light grey banded siltstone with some pyrite, some brown siltstone, water supply increased at 42 m Airlifted @43.5 m yield 5.0 L/s mostly dark grey siltstone with pyrite, fractured around 49 m, water-worn quartz Airlifted @49.5 m yield 12 to 15.0 L/s pH 7.7 EC 338 Clean water Yield on weir 15.0 L/s around 67.5 m more water-worn quartz around 56.4 m and 63.5 m and thin quartz-vein at 66.0 m Airlifted @79.5 m yield 10.0 L/s pH 7.2 EC 340 Clean water

=============================== **End of Hole 79.5 m** ===============================

<u>Summary of Bore 29386</u>

<u>Stratigraphy</u>

0- 38.0 m	Grey siltstone	***(Pfb)***
38.0- 79.5 m	Dark grey Siltstone, pyritic	***(Pso)***

Yield:	5.0 L/s @34.5- 43.5 m pH 7.0 EC 450 & 5.0 L/s @43.5- 49.5 m pH 7.7 EC 338 clean water 10.0 L/s, pH 7.2 EC 340 after construction
SWL:	17.4 m bgl
TOC:	0.7 m agl
Construction:	0 - 5.8 m 203 mm steel casing , Cemented Open Hole
Bore Status :	Monitoring Bore. Bore was opened to 75.83 m depth and it was geophysically logged (γ &Ω).

RN 29387

Date drilled: 1.7.94 - 19.7.94

Location: Sec 1235, Lot 7, Permit 8080, Corner Leonino and Duddell Roads, Finniss 09.10, H of Cavenagh

Depth metre	Lithological Description with aquifer depth, airlift yield and field pH & EC
0.0- 2.8	Lateritic yellow brown and grey clay, laterised siltstone- H.W. red siltstone, slightly moist
2.8- 5.8	H.W. grey purple siltstone
5.8- 7.8	M.W. to fresh black siltstone with pyrite
	Airlifted @25.5 m yield 0.4 L/s clean water
	Airlifted @31.5 m yield 2.0 L/s, pH 6.45 EC 144 clean water
	Airlifted @37.5 m yield 4.0 L/s, clean water
	fresh black siltstone with pyrite and "green mineral" (serpentine?) along sheared & fractured
	Airlifted @49.5 m yield 6.0 L/s, clean water
	Airlifted @55.5 m yield 15.0 L/s, clean water on weir (V-notch)
	Airlifted @63.5 m yield 20.0 L/s, clean water
66.9- 77.0	as above with quartz bands, broken, water-worn
	Airlifted @72.9 m yield 25.0 L/s on weir (V-notch), clean water
77.0- 78.9	as above with vein-quartz and pyrite
	Airlifted @78.9 m yield 25.0 L/s on weir (V-notch), pH 6.8 EC 191 clean water, no increase in
78.9- 120.9	Black siltstone with interbedded black shale
	Airlifted @120.9 m yield 25.0 L/s on weir (V-notch), clean water, no increase in water

=============================== **End of Hole 120.9 m** ================================

Summary of Bore 29387

Stratigraphy

0 - 120.9 m Siltstone and interbedded black shale ***(Psk)***

Yield:	4.0 L/s @25.0- 37.5 m	pH 6.45 EC 144 clean water
	11.0 L/s @37.5- 55.5m	
	10.0 L/s @55.5- 72.9m	pH 6.80 EC 191 clean water
	25.0 L/s after construction	
SWL:	5.3 m bgl on 20.7.94	
TOC:	0.6 m agl	
Construction:	0 - 5.8 m 203 mm steel casing , Cemented	
	Open Hole	
Bore Status :	Monitoring Bore. Bore was opened to 120.49 m and was geophysically logged (γ & Ω)	

LEGEND:

K	Cretaceous	(Darwin Member - Bathurst Island Formation)

~~~~~~~~~~~~~~~~~~~~~~ *UNCONFORMITY* ~~~~~~~~~~~~~~~~~~~~~~~~~~~~

JKp	Jurassic-Cretaceous	(Petrel Formation)

~~~~~~~~~~~~~~~~~~~~~~ *UNCONFORMITY* ~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Ptd	Mid Proterozoic	(Depot Creek Sandstone)

~~~~~~~~~~~~~~~~~~~~~~ *UNCONFORMITY* ~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Pfb	Finniss River Group	(Burrell Creek Formation)
Psd	South Alligator Group	Dolomite
Pso	South Alligator Group	(Mount Bonnie Formation)
Psg	South Alligator Group	(Gerrowie Tuff)
Psk	South Alligator Group	(Koolpin Formation)

~~~~~~~~~~~~~~~~~~~~~~ *UNCONFORMITY* ~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Ppw	Mount Partridge Group	(Wildman Siltstone Formation)
Ppa	Mount Partridge Group	(Acacia Gap Member)

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H.W. - Highly Weathered
M.W. - Medium Weathered
S.W. - Slightly Weathered
TOC - Top of Casing
agl - Above Ground Level
bgl - Below Ground Level
SWL - Standing Water Level below ground level
pH - Acidity or Alkalinity measure
EC - Specific Conductivity
Ω - Resistivity
γ - Gamma