John Armstrong
Submission #92

Fracking enquiry Issues March 2017.

Thank you for the chance to contribute to the Board of Enquiry (the board). My name is John Armstrong, joint Owner of Gilnockie and Banjo Pastoral leases (Gilnockie) on the Sturt plateau within the exploration footprint of Pangaea Pty Ltd. (Pangaea)

Under an agreement between Gilnockie and Pangaea, activities have been seismic survey only, which was completed most satisfactorily. Apart from contracted work we have never received payment gratis or any compensation from any gas exploration company, despite many allegations that we have from within social media.

I agree with the use of hydraulic fracture anywhere on Gilnockie except for mutually agreed no go areas. Pangaea have advised they would strike another mutually agreed contractual protocol arrangement for any further work.

Executive summary -as per the themes from the Issues paper. Expanded summary as per paragraph numbering follows the executive summary.

1 Water, manageable risk.

a) Supply

I agree that alternative supplies should be found for drilling unless new bores from the usual aquifer level can be found that could later be left for station stock supply. **To estimate requirements can the Board clarify the actual dimensions from the drilled hole of the fracturing events and how many such events may be required ?**

b) Number of drill / frack events.

What total area and how many well heads will be required in total and / year, quantified against the known costs of developing each well head site, the number of available drill rigs or any other contingencies which might accelerate or slow down such progress?

c) Aquifer Risk.

I ask the board to qualify for the public record the possible risk of well failures, type of failure which might be envisaged including shutdown and seal off procedures to include the nature and life of impervious materials used to seal off? Can it be clarified as to how a failure may be noticed say in well pressure abnormalities and how the shut down procedure works?.

d) Chemical Toxicity.

Can the board clarify and publicise exactly the toxicity as Lethal Dosage of each of the drilling agents used and the dilution required to render it safe for humans or stock.?

e) Perceived aquifer damage due to incorrect well construction.

Can the board confirm and publicise that Northern territory drilling regulation stipulate that no casing can be suspended from the well head and the full breakdown of well construction in correct format? Can the board verify the construction technique of the well which is alleged as faulty?

f) Extraneous reasons for aborting a drill hole, such as fractured basalt strata.

Can the board clarify that previously undetected basalt or other strata fractures may lead a driller to a decision to abandon a well to guard against a risk of compromising an aquifer, not necessarily shallow above-basalt aquifers.

g) Casing Erosion.

Can the board clarify the expected life of the high grade casing used in gas well construction?

h) General Aquifer Health.

I offer to conduct a tour of aquifer outflows in the Flora River by the board to witness actual permanent ground water (sub artesian) out-flows.

i) Natural and non natural seismic activity.

Being mindful of later discussion regarding "the precautionary principle", Can the board quantify; 1)Fracking causes earthquakes? 2) The question fielded at Daly Waters to publicise the released energy in kilojoules of the 12,000 pounds per Square Inch pressure forcing to yield cracks in the shale strata as a comparison to energy released during a natural seismic event? 3) The likelihood of naturally occurring seismic events causing well failures by comparison with how many such damage events have occurred over the life of the thousands of artesian wells within Australia?

2. <u>Land, negligible and manageable risk.</u> With regard to soil quality;- negligible and only for a short duration prior to annual rainfall. Say 900 grams of contaminant was spilt on a sq meter of ground which received 760 mm of rain/pa. dilution each year would be 1.18 grams / Kg f water.

3. <u>Air</u>. <u>No Risk</u> I have not addressed this elsewhere. Each drill event if successful, includes the worldwide accepted practice to flare off of surplus gas. I do not believe that would impact locally as all of those exhaust gases will be lighter than air and rise, neither do I believe there will be any risk of escaping product gas as normal drilling and construction protocols and regulation as I understand them will diligently guard against it. There is a very strong reason for this and it is to guard against inadvertent ignition of escaped gas which could involve dangerous explosion. Neither do I believe there will be any other escaping gases, as all returned drill material and cuttings will be saturated in solution or dissolved in water as it returns to the surface catchment pit..**Does the board agree with those claims?**

4. <u>Public Health. No Risk</u>. Gilnockie will not be allowing any member of the public anywhere near any drilling on Gilnockie. I conclude that if the rigidly controlled workplace health and safety systems associated with drilling regulations is observed, there would be no risk to either the drilling crew or anyone further afield from public barriers around such procedures.

5. <u>Aboriginal. No Risk.</u> There are no aboriginals anywhere on Gilnockie. As part of the access agreement I will provide any information that I have with regard to sacred sites to the drilling explorers. It will be the drillers responsibility to establish clearances, if required.

6. <u>Social Impacts. No Risk</u>. a) In the physical sense there will be no public access to either the Gilnockie pastoral lease or drilling operations, therefore there will be no social risk.

b) In a financial sense, benefits of gas production will greatly benefit society generally.

c) If this refers to social License, I refute it is an issue or risk. Gilnockie assessment will be on objective merit only. **I ask the board to clarify that they will not be swayed by such nebulous talk and refer to discussions and issues in a fully objective sense only?**

7. <u>Economic Impacts;- as meaning upon Gilnockie Station</u>. <u>No Risk. I</u> believe the small areas eventually to be required for well heads and assuming that pipelines are laid deep enough that the total sum of land used will not impact upon my viability as per a future arrangement.

8. <u>Land Access. Minimal and manageable Risk.</u> This will be negotiated and agreed with both Government and Pangaea prior to work commencing. The appropriate sections of the Pastoral Land Act which administers the Gilnockie Pastoral lease should cater for the separation of responsibilities.

Can the board clarify the legal arrangements required to separate land from a Pastoral Lease and any pecuniary arrangements if required or allowed as per explanation 8 a) below?

<u>1 a) Water Supply.</u> Scale 1 cu M = 1,000 litres; 1 Mega-litre = 1 Million litres.

Pangaea advise they intend to harvest water for drilling operations from aquifers different from our current above basalt ground water supply.. On Gilnockie we utilise research from the Department of Water Resources, particularly a study titled - "Water resources of the Sturt Plateau". *(Attached) That study shows in detail the underground basalt strata at approx 80 to 100 meters depth draining to the North West. There are relatively few aquifers on top of that strata with high enough saturation levels to enable water extraction. Therefore water is hard to find at a success rate of about 50 to 60%, despite there being large amounts of water within our water table The geomagnetic data map in the study shows areas where water might be located but that is no guarantee.

* Reference on page 20 Figure 4, Stuart Highway to the right of the picture with the road West from Larrimah at the top of the picture, Gilnockie ois situated left centre whee the blue changes to Green.

The Gilnockie rainfall is approx 760 mm and area of 1250 sq Kilometres gives a total of 952 million cubic meters (952,000 Mega litres). Most rain soaks into the ground to form the water table. Gilnockie has one only surface drainage, Western Creek. This year, a 250 mm higher than average rainfall the flow was approx 403 mega litres over a twelve week period. (.04% of the rainfall)

Only a low percentage of rainfall evaporates from the land systems as it soaks into the surface and is not available to direct sunlight. During the wet season there is little evaporation due to cloud cover and a cooler ambient temperature. The growth pattern of the pasture of several weeks only, prior to seeding down and then dying off indicates that what is not used for plant growth, quickly descends below the root zone of those plants.

The Gilnockie stock water requirements is approx 219 Mega-Litre /year, or .023% of the rainfall. We intend to double water consumption with herd increases and may wish to spot irrigate more intense fodder crops, therefore that usage may escalate sharply.

Indications are that the NT gas resources will be 200 years or more. Assuming drilling will progress @ 3 to 4 drill pads per year @ say 6 drill events /pad @30 mega litres per frack drill radial would = water use / year of 520 Mega-litres, or 0.05% of the Gilnockie annual rainfall average. Re-use of a lot of the drill water would reduce the total required.

The Board's briefing paper did not define actual water usage, the actual length of each radial drill hole or the total number of fracking events which might be required . That information gap will allow detractors to easily claim far greater water usage than may be the case. The public needs to be better informed including the number of layers of facture drilling against the estimated depth of the Shale bands.

<u>1 b) Number of drill / frack events.</u>

It is often stated publicly there will be a total of 56,000 or more drill pads within the NT. No timeline is quoted but the implication is it will happen quickly and that population of wells will starve the water aquifers. Current advice is the radiated drill hole for fracking can extend up to 5,000 meters but more usually, much less. Say 2,000 meters on average or a total of 12.5 sq Kilometres (Sq K) each well head. 56,000 well heads would = 700,000 sq Kilometres. As much of the Armedius basin is fairly well developed and the balance of likely development areas as per the issues paper information, would equal to far less than 1 million Sq K of the total NT area of 4.2 million Sq K I believe this 56,000 figure is very confusing?

Even to accommodate 56,000 drill events at the rate of six /well head would mean a total of 9,333 well heads. I.E. A total area of 116,662 Sq Kilometres.

Gilnockie fully drilled at 1:12.5 sq K would equate to 100 drill pad sites at say 4 hectares during the drilling= 400 hectares total. After drilling the well head area would be less than 1 hectare or 100 hectares total. These small area are not a concern to Gilnockie. The amount of county required to erect service roads, including for gravel extraction pits, may be a larger imposition.

<u>1 c) Aquifer risk</u> There has been many claims of a well failure rate of up to 6%.. These claims include the corrosive nature of drill liquids as corroding the well casing

None of those claims quantify the type of failure or at which stage of the drilling the failure will occur; I.E. A fractured drill rod, well casing or something very minor during a well drill event.. The claims state that each and every well failure will result in the injection of large quantities of the well development liquids onto either the surface or into the aquifers directly. It is claimed these liquids will be highly dangerous to any environment and will ruin whole aquifer systems at each failure.

Those claims seem in conflict with the Issues paper and briefings from both APPEA and Pangaea as to well construction methods, the liquid ingredients and their general security neither do they extend to the separate functions within a well. That is, initial well construction of an empty cased hole which is pressure tested to ensure nil leakage, the second phase of drilling along the shale beds which in turn is sealed to prevent leakage for the final stage of the fracking events..

1 d) <u>Chemical Toxicity</u>. Well failure claims always rightly or wrongly emphasize the toxicity of the chemicals used. This aspect is frightening to those who do not know the toxicity of these chemicals The best measure to use would be to compare its toxicity by use of the common practice under the Chemicals training courses of 'Lethal Dose' rate (LDR). Every container of farm chemicals contains the LDR on its label. By law all users of farm chemicals must be able to read those labels. Each chemical used in the drilling process would have the same nomenclature. This can be understood by examining the meanings of the Material Safety Data Sheet. If hazardous, it will contain the placard;- **"**This material is hazardous according to health criteria of Safe Work Australia."

Below is a sample sheet for Bostik, a Plastic (PVC) pipe glue. Lethal dose for rats is prescribed as "Oral LD50 (rat):636 mg/kg"

https://www.msds.com.au/MSDS/bostik_findley/Bostik_1850.pdf

Without good explanation, generalised information is meaningless and will be misinterpreted.. I quote a generic phrase oft used, "Oh it's no more toxic than the chemicals used every day in your kitchen." That type of talk is ineffectual and a nonsense.

1 e) <u>Perceived aquifer damage due to incorrect well construction.</u>

The pictorial presentation on page 6 (pp6) in the Issues Paper of well construction appears in conflict with drilling practice. It is usual that every well is commenced only after a larger diameter hole is drilled to a shallow depth and a surface collar installed, known as a drill collar or in the Issues paper as a 'conductor casing' in pp6.

As the Northern Territory Regulations stipulate that casing cannot be suspended, that is it must be seated at the bottom of the hole drilled for that casing. Therefore even the conductor casing would be seated into a solid base. The conductor casing/ drill collar is to provide a clear hole to work in and prevent surface trash and material from falling into the drilling hole. **It** would usually be cemented into position inside its drilled hole.

The pp6 shows the next 'surface casing' as being cemented in position within the conductor casing. I assume that cementing process would only continue to the extent of the conductor casing. It could not extend through the aquifer as by definition the aquifer is a very porous material and usually has a high degree of saturation. That is - lots of water - which will not resist pumped in cement, thus there would be no solid barrier to stop the flow of cement . It would be incorrect to think that the cement could be deposited in such a surrounding. Criticism will be openly encouraged with incorrect pictorials.

That surface casing would extend securely into the impermeable barrier below the aquifer, on Gilnockie that would be the basalt. That is, there would not be a cement shield around that surface casing for its position within the aquifer, in contradiction with pp6.

At the Daly Waters enquiry it was alleged that a gas exploration well drilled in the vicinity had not sealed off the aquifer, in contradiction to statements regarding gas / oil well construction. The issues paper describes at least two layer extra of casing outside the cased well proper within which the drilling occurs. It describes a procedure of forcing high grade concrete into the voids between those layers of casing even though pp6 does not show cement between the intermediate casing to the depth of the seated surface casing.

Pp6 shows the drilling fluid returning outside the intermediate casing. I am positive this is incorrect as the drilling returns would all be between the final inner casing and the actual drill rod. That is, the drilling agent, either air or water is forced down the inside of the drill rod through the cutting bit and will return immediately outside the drill rod, between it and the inner well casing.. Utilising the outside of the pictured intermediate casing would be impossible as that casing should be seated into bed-rock with a non permeable seal at the bottom as is the inner casing within which the drilling rod can move and perform the work it is required to. It is from the bottom of the drilling rod that drilling agents will be pumped to return to the surface inside the inner secure pressure tested casing. The inner casing being 'pressure secure' will return all drill liquids and cuttings to the surface to be collected in the pondage pit which is dug and sealed for that purpose.

Close attention to detail is imperative and the pp6 detail must be gotten correct as per NTG regulations. That fact needs strong clarification otherwise it will lead to deserved criticism.

1 f) Extraneous reasons for aborting a drill hole. Basalt underlay fractures. Sometimes the usually impermeable basalt is fractured and those cracks were not detected by seismic search, to the extent that the driller will decide that drilling through that area would not be advisable. There may be many other inputs to the drillers decision, to abandon a well which need not be assumed by the public and noted, as 'another' well failure.

1 g) Casing Erosion. It is often claimed the gas well casing will erode and allow leakage into aquifers. The NT gas field production may have a life of 200 years, but each well would have a much shorter life than that and the casing steel is of a much higher and more resistant to erosion grade from that which has already lasted well more than 100 years in artesian wells.

1 h) General Aquifer health

Gilnockie and indeed much of the local Sturt plateau area ground (sub artesian) water drains into the Flora River from on top of the underground basalt. Should the board wish I would be happy to escort an aerial tour of some of those groundwater outflows to demonstrate the massive flows which will evidence the more than adequate recharge of those aquifers and for the board to grasp just how much chemical would be needed to impact any significant risk to that water health or the health of the aquatic life within it. I refer to an area of the Flora River immediately upstream of the Kathleen falls for a distance of 15 kilometres or so. There are also many claims that leakage will occur from storage pits that are used for return materials during drilling and destroy a total aquifer without respect for the annual dilution effect of rainfall. A recent study n the subject. http://www.foxnews.com/us/2017/04/25/fracking-isnt-contaminating-groundwater-study-finds.html

1 i) Casing failure due to fracking induced seismic activity and or natural seismic activity.

Frack activity. This is a very important subject as it draws a lot of currency in social media. Claims are that the actual fracking events situated thousands of feet deep will lead to fracture of the total strata separating the deep shale from the 200 to 300 feet deep station water supply aquifers, thus leading to large amounts of leakage from the shale beds or perhaps from other intermediate salty aquifers, directly to the water aquifers thousands of feet above. There has been many claims on social media that Fracking causes earthquakes. I put a question to the Daly waters enquiry (taken on notice) regarding the amount of energy released in Kilojoules per each frack event. We were also advised at Daly Waters that say 1 Mega-Litre is used for each frack event, this would equate to one thirtieth of the drilled length of each radial for fracking, say 66 meters each pressure fracture event, given the quoted 30 mega litres for each frack radial of 2,000 metres.

Earthquakes One main point of criticism in social media is the high chance of well disruption due to seismic activity, which it is also stated will cause widespread uncontained environmental poisoning from production gas and / or other poisonous shale released elements and / or other non defined drilling products. In Japan where there is a very high risk of seismic activity underground utilities passageways, including for train-ways are considered much safer than on surface. A recent comprehensive Televised documentary predicted negligible risk at relatively shallow depths for these services to be constructed.

I take the liberty of posting some random cpomparisons..

How many peta joule in 1 terajoule? The answer is 0.001..

Comparisons of explosive energy of TNT.

https://en.wikipedia.org/wiki/TNT_equivalent

https://en.wikipedia.org/wiki/Richter_magnitude_scale

Richter established a magnitude 0 event to be an earthquake that would show a maximum, combined horizontal displacement of 1.0 µm (0.00004 in.) on a seismogram recorded with a Wood-Anderson torsion seismograph 100 km (62 mi.) from the earthquake epicente

- Magnitude 3 = 2 gigajoules
- Magnitude 4 = 63 gigajoules
- Magnitude 5 = 2 terajoules
- Magnitude 6 = 63 terajoules = .063 petajoules
- Magnitude 7 = 2 petajoules

shttp://hypertextbook.com/facts/2000/AlexKerzhner.shtml The report indicates that total **energy consumption** in **Australia** is projected to grow at an average **annual** rate of 1.4% between 1997-98 and 2014-15 to reach 6087 PJ.(petajouls) =6,087,000 Terajoules.

https://en.wikipedia.org/wiki/Underground_nuclear_weapons_testing "Although there were early concerns about earthquakes arising as a result of underground tests, there is no evidence that this has occurred.[25] However, fault movements and ground fractures have been reported, and explosions often precede a series of aftershocks, thought to be a result of cavity collapse and chimney formation. In a few cases, seismic energy released by fault movements has exceeded that of the explosion itself.[25]""

6 c) Social License;-

This topic is shouted very often from public forums such as face book to sway those who are naive of any real facts on the this issue of fracking or are allowing their decision to be bullied on the subject. The following was posted on a recent public forum and as yet has not been disputed by anyone to my knowledge. The blogger says he heard it first in connection with the current dispute on Greyhound racing in New South Wales. I quote;-

""The repeated citing of a “social licence’’ rankles with greyhound enthusiasts, including Brenton Scott, head of the Greyhound Racing Industry Alliance. He says the industry understands tangibles: clear rules, legislation and policy. Something as subjective and airy-fairy as a “social licence’’ is harder to follow. It is also a key part of (a recent) legal challenge.

Scott says: “No one has ever seen, touched, smelt, heard, tasted or sensed a social licence. No one has ever owned a social licence. A social licence has never been bought or sold, inherited, transferred, copied, faked or handed in …(yet) the Premier has announced his intention to ban an entire industry based on it ‘losing its social licence’.""

For the sake of the Premier, I hope he does not have to legally defend his "Social License".

8 a) Access.

The Pastoral Land Act (PLA) is the Act which exclusively allows and governs the activities of Leases for 'Pastoral Use' with ' greater animals.'   With approval from the Minister for Lands a Sub Lease can be used for an applied for 'non Pastoral Use', and can be facilitated under Part 7 Sections 85A to 91 (incl) of PLA which deals with "alternate Use." With regard to access;-PLA, Part 6 especially section 84 might adequately refer. Would such mechanisms cater adequately for the separation of responsibilities regarding Third Party Insurance? A Pastoral Lessee assumes exclusive use of the Pastoral Lease as per the Lands Minister's granted Land Title. If any Minister of the Crown then over-rides that title by granting some of that Pastoral Lease away from the "purpose " of the original lease, without referral to the Lessee, say as "Access" for Mining where quite some land will be permanently useless for Pastoralism, then some form of resumption and restitution payments and arrangements should be made for the sum total of land required.

Conclusion.

At Daly Waters I asked of the Board the rules of Evidence for this enquiry. The answer was inconclusive. I again ask for clarification in line with the following discussion..

I believe it irresponsible and impossible to present an argument based on risk without quantifying that risk. Therefore such claims would be invalid, as would be the findings of this enquiry did it not firmly establish those risks, if any, and deal with each of them in entirety..

Notwithstanding that, should any parties not understand any issue then via the board they should be able to have facilitated answers as a matter for public explanations as desired.

It will serve no purpose for the board or any contributing party to merely list subjective or anecdotal evidence as a possibility of being accepted in the objective sense; There should be clearly defined and explained rules of evidence so that there will be no misunderstanding on any issue. If those base guidelines are not addressed then it will be the case the board will have wasted our time as well as theirs and have served no useful purpose whatsoever.

The fact is, to sway the court of public opinion, non qualified subjective claims are being forcefully lodged daily by some parties as a matter of very public record via public forums and media outlets..

For the board's credibility it would be extraordinary if it did not have at least as a guiding principle for their rules of evidence, that proponents should spell out their claims of the significance of the impact(s) / issues including;-

- what biodiversity and/or landscape feature(s) are affected;
- what are the effect(s), over what area, and how significant is/are the impact(s);
- what **evidence** supports this assessment; and
- how significant are the impact(s) with respect to the proposal/property as a whole and the region.

Detractors from any sort of development often utilise the so called 'precautionary principle' to sway those who are naive of the technology of whatever they are being lobbied against. By doing so the detractors are fully aware of the political clout of polled numbers to further their cause whether it be against the better interests of a country or not.

This quote recently arrived on a public forum blog site; It has not yet been disputed on that forum. It excellently disqualifies the precautionary principle in its remotest forms.

I quote;- ""posted on March 17, 2017 at 12:55 pm

Earlier talk of nuclear powered warships reminded me of this incident from my former days, which may be of interest to (sic - another blogger).

Back in the mid-eighties, there was a Senate Inquiry into nuclear powered warship visits to Australia – something of hot topic, given that NZ had recently banned them and the Democrats and the Nuclear Disarmament parties in the Senate – no Greens in those days – were making similar noises.

My job, as a middle-level policy officer in Defence, was, among other things, to attend the Inquiry hearings and then race back to Russell (defence headquarters) over lunch and prepare – before question time – briefs for the government on any issues that might be raised in parliament or by the media.

One day the Nuclear Disarmament Party brought in a big gun, an American professor, expert on nuclear accidents, who gave evidence at length about the apocalyptical outcomes of a nuclear accident in a warship in an Australian port – fire, flood, pestilence, famine, huge mutated centipedes coming up out of cracks in the pavement…..

When he had finished his jeremiad, Senator Hamer – Liberal, ex RAN, IIRC(insofar as I recall) served at Leyte Gulf on HMAS Australia – got up and put a proposition to him, along the following lines:

would you agree, Professor, that if the ceiling of this room collapsed, there would be catastrophic results, multiple deaths and serious injuries yet the chance of this happening is so infinitesimal that we all sit here in confidence and conduct our business

You have described the catastrophic effects of a nuclear accident on board a warship

What are the chances of this actually happening?

The Professor had to admit that he had no idea and, IIRC, left the building shortly after this exchange.""

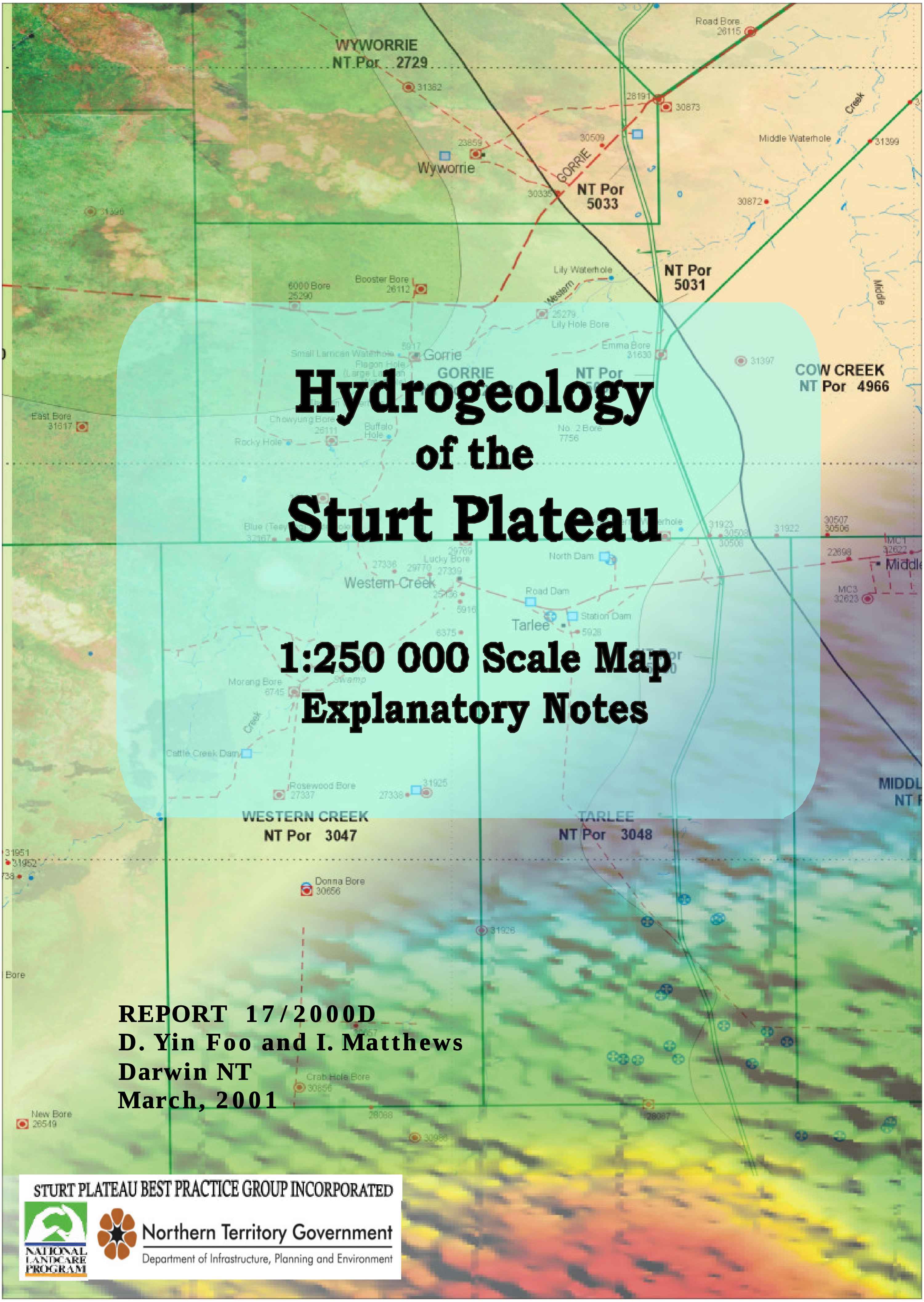
Conclusion;-

I plead with the board they verify all findings transparently and objectively with clear explanation of safety procedures, the actual techniques used, actual risk which may be expected, if any and how those risks might be managed. That such explanations be accompanied with accurate diagrams, E.G., the bore hole structure at pp6.

Most importantly, I plead directly to her Honour of the board, that all explanations include explanations for people who may be unable to understand the technical procedures, as to how they may trust the decisions of those whose task it is to make those decisions?

Yours Faithfully

John Armstrong 20/03/2017



Hydrogeology
of the
Sturt Plateau

1:250 000 Scale Map Explanatory Notes

REPORT 17/2000D
D. Yin Foo and I. Matthews
Darwin NT
March, 2001

STURT PLATEAU BEST PRACTICE GROUP INCORPORATED
NATIONAL LANDCARE PROGRAM
Northern Territory Government
Department of Infrastructure, Planning and Environment

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SUMMARY

A hydrogeological map of the Sturt Plateau is presented as part of the assessment of the water resources of this region. The map shows major aquifer types and their potential yields.

Groundwater within this region is derived from a number of rock types including limestone, sandstone, siltstone, and basalt. Most of the rocks have low primary porosity and aquifer development is dependent on secondary porosity associated with cavities, fractures and zones of deep weathering. Prospects range from excellent, particularly from limestone aquifers in the eastern part of the plateau, to poor in the basalts of the central region.

The Cambrian limestones are extensive regional aquifers where adequate submergence is available above the underlying basalt. The water generally has a TDS of around 500 mg/L in the western part of the region, while in the eastern area around Daly Waters, TDS levels of around 1000 mg/L are common. The water is mostly suitable for domestic and stock purposes.

The fracture-dependent basalt aquifers occur as isolated and independent aquifers with inconsistent yields and water quality. The water has higher sodium chloride levels than found in the overlying limestone aquifers, but is usually potable, and always suitable for stock watering.

Aquifers developed within the Proterozoic sediments in the eastern part of the plateau, and under the basalt, generally supply small yields of good quality water. Some higher yields have been attained at the weathered basalt/sandstone contact, but aquifer development and water quality is highly irregular. The water quality in the sandstones is good (about 500 mg/L) but is typically around 1000 mg/L in the siltstone and shale sequences.

Groundwater flow is from south to north, with most of the recharge occurring in the central parts of the plateau. The majority of recharge is considered to be associated with the large number of sinkholes. The mean annual recharge rate for the Sturt Plateau ranges from 6 to 18 mm/year.

Discharge from the area is mainly through spring flows into the Flora and Roper Rivers. The mean annual regional groundwater discharge into both the Flora and Roper Rivers is in the range 60,000 to 120,000 ML/year.

1.0 INTRODUCTION

1.1 General

This map and accompanying notes were produced as part of a water resource assessment covering the Sturt Plateau region.

The Sturt Plateau covers approximately 30000 km^2 and defines an area which extends from Mataranka in the north to Dunmarra in the south. The eastern boundary is featured by an upland area parallelling the Stuart Highway. Its western extremity is marked by 'breakaway' country. The regional location is indicated in Figure 1. Road access is good throughout the region in the dry season. During the wet season, the main roads are generally accessible by light vehicles except during periods of flooding in the local creek systems.

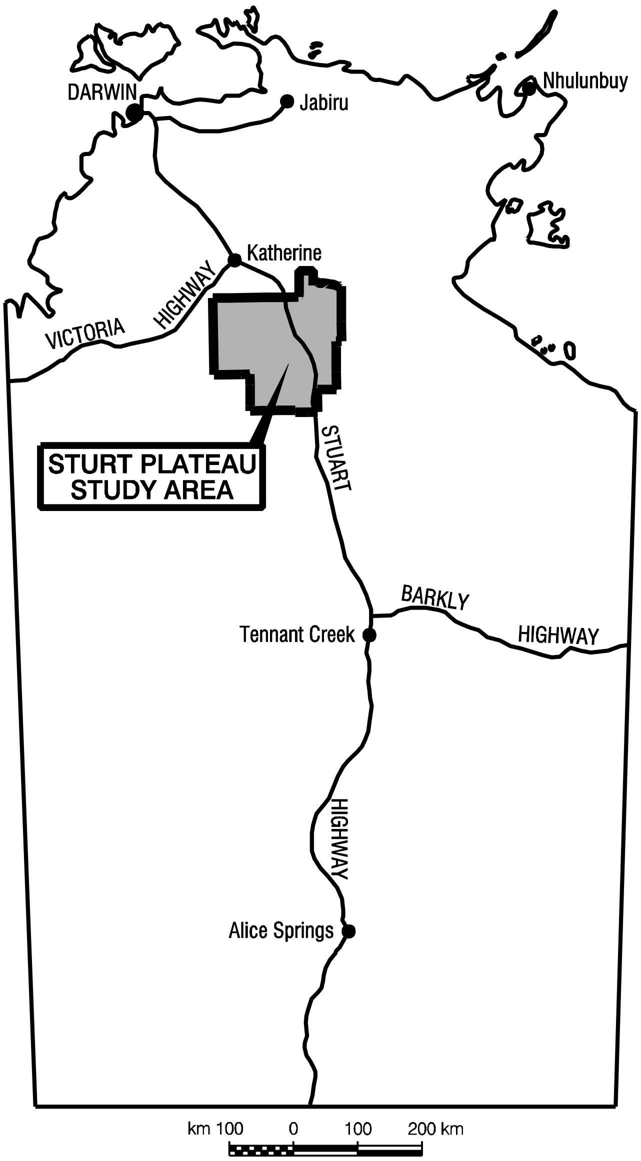

Figure 1 Location Map

Nearly all of the annual rainfall occurs in the short hot monsoonal wet season between December and March. Rainfall events may occur as intense thunderstorms or as the result of widespread monsoonal activity. Little rainfall is experienced during the remainder of the year. The average rainfalls vary only slightly across the region with 790mm at Mataranka in the north, 800mm at Larrimah in the central region and 660 mm at Daly Waters in the south. Pan evaporation is between 5 and 11 millimetres per day (average about 8 mm per day or 2.8 metres per year). Air temperatures are high throughout the year. The average monthly maxima at Larrimah ranges from about 29 degrees in June to 37 degrees in December. The corresponding average monthly minima are 13 and 24 degrees. Climatic data for Larrimah are presented in Table 1.

Table 1 Climatic Averages for Larrimah

	Mean Rainfall (mm)	Rain Days	Daily Min. Temp (^{0}C)	Daily Max. Temp (^{0}C)	Daily Evap. (mm)
January	201	15	24.0	35.5	10.4
February	191	15	23.6	34.3	7.9
March	154	11	22.5	33.7	7.5
April	33	3	19.6	33.8	8.6
May	14	1	16.2	31.4	6.1
June	5	1	12.8	29.2	5.0
July	4	1	12.0	29.0	6.0
August	0	0	14.7	32.1	7.2
September	5	1	17.9	34.7	6.9
October	27	3	21.6	37.0	8.6
November	65	7	24.1	37.7	11.4
December	113	10	24.3	36.9	8.3
Total	812	67			

1.2 Landform and Drainage

The Sturt Plateau is most aptly described as being a flat to undulating plain with low rounded crests and isolated ridges. Its surface is largely of deeply weathered and laterised claystone, siltstone and sandstone sediments of the Cretaceous aged Mullaman Beds. Erosion of the surface has exposed various horizons of the laterised profile. There is a gentle south to north fall of the plateau with elevations reaching 290m above mean sea level (MSL) on the Buchanan Highway before dropping to 170m above MSL along the northern reaches of the study area. A slight ‘dish’ is apparent in the central part. A contoured physiographic map of the region is depicted as a side map on the hydrogeological map.

The northern bounds of the Sturt Plateau are featured by a dissected margin. A largely intact high plateau area in the northwest corner of the study area is represented by an entire Mullaman Bed sequence. The surface of the higher remnant platforms in this area is about 220m above MSL. However, further east, the country tends towards remnant lower plateau that has been eroded down by regional drainage features including the Dry River and the Elsey Creek systems. The land remains relatively flat across this area until it falls from 175m to 100m above MSL, downstream of the junction of the Elsey and Birdum Creeks.

The eastern margin of the study area extends south from Elsey Station adjacent to the Roper River and is bounded by upland scarps and ridges. This area represents the eastern limit of Cambrian aged sedimentary deposition and as such, forms a significant geological and hydrogeological boundary of the Sturt Plateau. Here, the Cambrian sediments abut the argillaceous and arenaceous sediments of the Proterozoic Roper Group of rocks. Physiographic features in this area are largely linear and are controlled by resilient sandstone, and erodable shale and mudstone units. The western border of the Sturt Plateau is marked by basalt exposures skirting the edge of the Dry River catchment. The country encounters a sharp rise here before meeting the adjacent tableland and scarp country of the Victoria River catchment.

Plate 1 Chowyung Waterhole on Gorrie Station

The physiological boundary representing the southern extent of the Sturt Plateau region is ill-defined and is best delineated by the Buchanan Highway. The road alignment approximately follows a ridge which runs from east to west, rising to elevations of over 280m above MSL in the south-western corner near Top Springs. From the ridge, the surface slopes gradually towards the north. On the southern side of the ridge, the country falls gently into the Lake Woods catchment area.

The Sturt Plateau encompasses two major catchment areas as indicated in Figure 2. The Roper drainage system captures all streams east of, and including the Western Creek system, while the Dry River catchment in the west eventually contributes to the Daly River. A small part of the western section is drained by the headwaters of Coolibah Creek, part of the Victoria River Catchment.

The drainage systems of the region are weakly developed. Channel incision is poor in the southern and central areas and it is not until the lower reaches of the Dry River and Elsey Creek are approached that some maturity is observed.

Generally less than 5% of rainfall will contribute eventually to streamflow. This is attributed to the flat terrain of the Sturt Plateau and apparent high storage capacity of waterholes and swamps. In particular, the existence of sinkholes across the region probably has the most significant effect on overland flow. Anecdotal reports of flow directly into sinkholes are common and the subsidence rate of runoff water captured in sinkholes after heavy rain events has been indicated to be "a matter of hours". Some of the larger sinkholes, including Chowyung (Plate 1) and Thragin Waterholes, occur across the central region on Gorrie Station.

Plate 2 Sinkhole on Avago Station

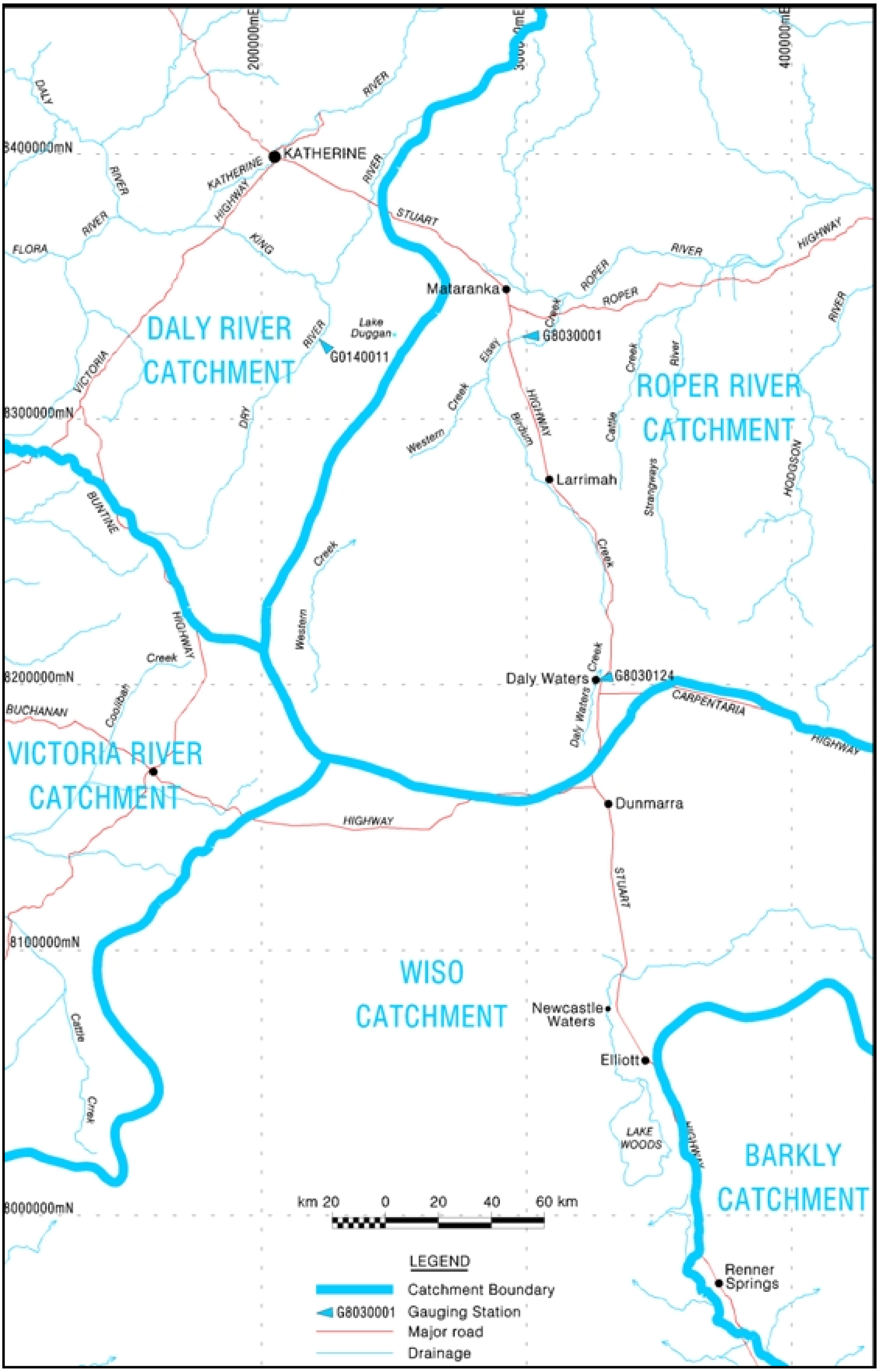

Figure 2 Regional Surface Water Catchment Boundaries and Drainage

Table 2 presents discharge and runoff data for the three gauging stations in the region. Wet season streamflows are generally event based.

The upper reaches of the systems at the southern end of the plateau have some definition where greater slope in the land surface has allowed increased channel incision to occur. However, towards the middle reaches of both Daly Waters and Sunday Creeks the drainage paths become less defined and only exceptional rainfall events result in a continuity of flow to Birdum Creek. Less than threshold rainfalls contribute only to floodouts, waterholes and low lying swampy areas within the main drainage path. The Western Creek and Dry River systems are similar.

Migration of the drainages is evident across the plateau as their relict paths and flood plains are often signified by shallow cracking clays. Of note is the evolution of the Elsey system, which has captured Western Creek, formerly a major tributary of the Dry River.

Along the eastern margin, the Strangways River and Cattle Creek form the main avenues of drainage.

Table 2 Annual Discharge and Runoff Data for Dry River at G8140011, Elsey Creek at G9030001 and Daly Waters Creek at G9030124

Gauging Station	Start of Record	Catchment Area (km^2)	Min	Max	Mean
			Annual Discharge (x 10^5 ML)		
G8140011	1970	6290	0.05	11	1.5
G8030001	1966	18785	0.03	8.6	0.97
G9030124	1961	777	0.005	0.37	0.09
			Annual Runoff (mm)		
G8140011	1970	6290	1	177	23.4
G9030001	1966	18785	0.16	46	5.2
G9030124	1961	777	0.6	48	11.6

2.0 GEOLOGY

The geology of the Sturt Plateau has been summarised by Kennewell and Huleatt (1980) as part of a study into the geology of the greater Wiso Basin. The Sturt Plateau covers parts of the limestone dominated Daly, Wiso and Georgina Basins which are unconformably underlain by basalt subjugated by early Cambrian volcanics. In turn, these are unconformably underlain by Proterozoic sediments of the Roper Group and the Tomkinson Creek Beds. From oldest to youngest, the units are described below.

The Proterozoic Roper Group and Tomkinson Creek Beds underlie all of the Sturt Plateau. These rocks are usually folded and faulted, sometimes intensely, and consists of sandstone, siltstone and shale with minor sills and acid volcanics.

The early Cambrian Antrim Plateau Volcanics is generally a flat lying dark grey/green coarse grained tholeiitic basalt. Minor interbeds of marine sandstone, conglomerate, chert and limestone, generally less than 3 m thick, are present. The overall thickness of the volcanics is in the order of 150 m. The Helen Springs Volcanics are also flat-lying tholeiitic basalts and are correlatives of the Antrim Plateau Volcanics. These basalts exist beneath the great majority of the Sturt Plateau but due to lack of outcrop and distinguishing features, it is not possible to determine the location of the different basalt units.

The volcanics are overlain by the Cambrian Limestone formations in the Daly, Wiso and Georgina Basins. The boundaries between the basins have been shaped by the underlying basement structure and have been delineated by Kennewell and Huleatt (1980). The limestone formations host the major aquifer systems in the region. These sediments are time-equivalent and contain many stratigraphic similarities. Randall (1973) recognised lithological similarities which were supported in part by diagnostic fossil based linkages. The correlation between the sediments of the Montejinni Limestone in the Wiso Basin, and the Tindall Limestone in the Daly Basin has been recognised by Beirer et al (2001) in recent mapping.

Although outcrop is not continuous between the Wiso and Georgina Basins, stratigraphic similarities and middle Cambrian fossils found in the Gum Ridge Formation of the Georgina Basin correlates it to the Montejinni Limestone in the Wiso Basin (Kruse, 1998). However, Hussey et al (2001) finds that there are sufficient stratigraphic differences to justify separate formation names.

A comparison of gamma logs from bores 31392, 24817 and 27958 which intersect each of the formations, is presented on Figure 3. The stratigraphic relationship, and hence aquifer correlation between the Cambrian Limestone formations is important in hydrogeological terms as this establishes continuity in the groundwater flow regimes through the region.

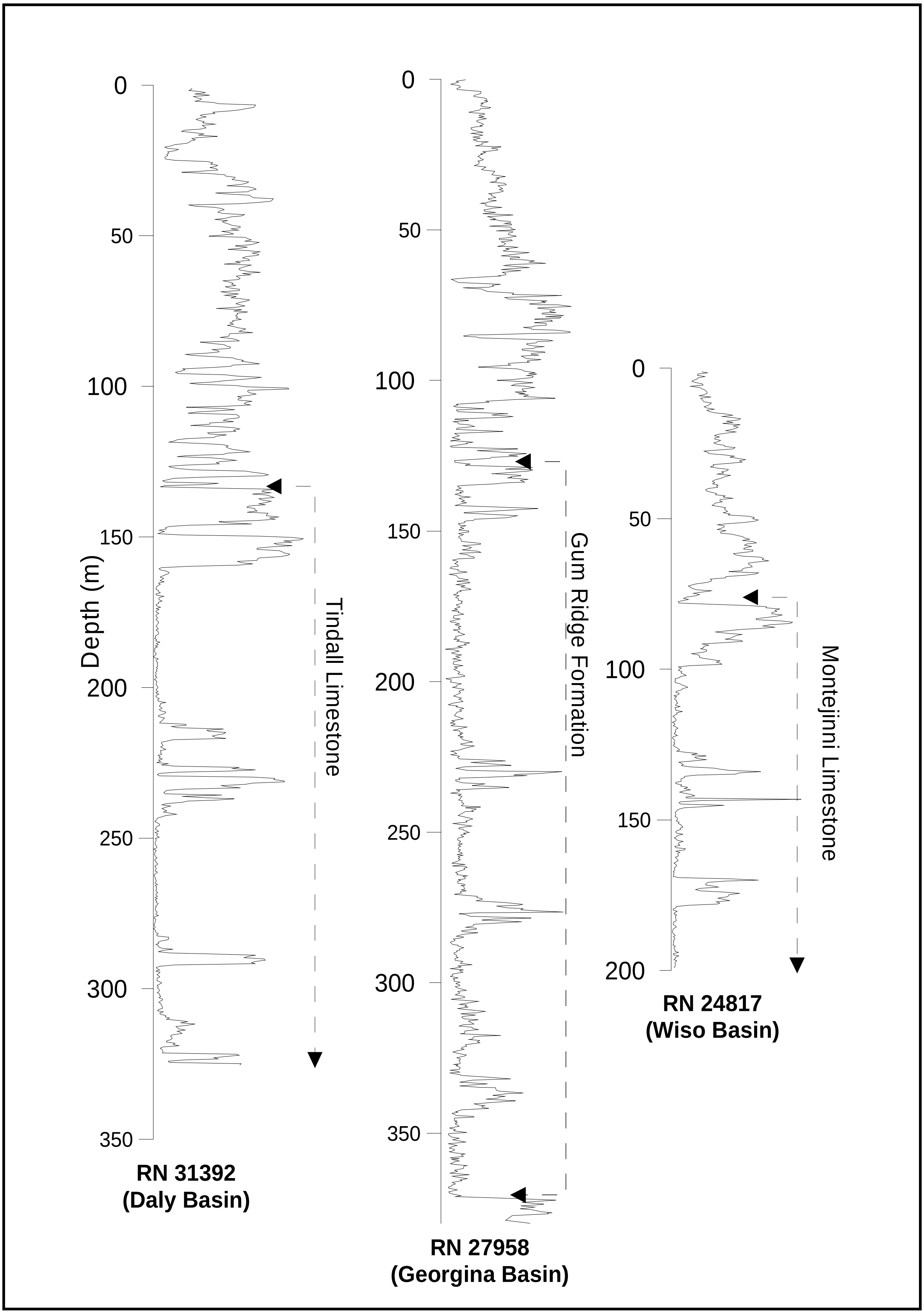

Figure 3 Comparison of Gamma Logs from bores drilled in the Daly, Georgina and Wiso Basins

The Daly Basin sequence within the study area comprises the Tindall Limestone overlain by the Jinduckin Formation. The Tindall Limestone is a massive, thinly bedded, multi-coloured crystalline, dolomitised limestone with some chert nodules and mudstone bands, particularly in the lower layers. The lower mudstone layers tend to be more developed on the Sturt Plateau, compared to further north in the larger Daly Basin.

The Montejinni Limestone of the Wiso Basin consists of limestone, dolomitic limestone, dolomite and calcareous mudstone and siltstone. In many parts of the basin, a threefold division has been recognised with an upper and lower limestone unit each approximately 25 m thick and an intervening red/brown mudstone about 10 m thick.

The Gum Ridge Formation, although similarly sequenced to the Tindall Limestone Formation, is generally described as consisting of limestone, fine grained sandstone and siliclastic mudstone and nodular chert. The depositional environment of this formation has resulted in a greater proportion of carbonate sediment.

The known maximum thickness of the Cambrian Limestone formations may be up to 180m (Kruse et al, 1994) in the deepest parts of the respective basins. However, the formation thickness in the study area is variable and generally, only the lower units exist. With reference to the 'Basement Contours' side map accompanying the main Hydrogeological map, these formations may generally be seen in their entirety within the areas where basement levels are indicated to be less than 25m AHD.

Conformably overlying these formations are dominantly mixed carbonate-siliclastic sediments. The Jinduckin Formation and the Anthony Lagoon Beds overlying the Tindall Limestone and Gum Ridge Formations respectively, are mainly of dolomitic siltstone, interbeds of dolomitic sandstone-siltstone and dolostone. The Jinduckin Formation has eroded off over most of the Sturt Plateau and only exists in part in the north of the map area where it is overlain by Mullaman Beds. Similarly, partial section of the Anthony Lagoon Beds is seen in the Larrimah area where highly weathered remnants may be detected in gamma logs. The formation continues to thicken towards the south-east into the Georgina Basin where approximately 60m of its lower section may be identified in bore 27958 east of Dunmarra.

In the Wiso Basin, the Hooker Creek Formation (previously named Merrina Beds) is the lateral equivalent to the Jinduckin Formation and Anthony Lagoon Beds of the Daly and Georgina Basins respectively. This formation is present in the southern extremity of the study area.

The Cretaceous aged Mullaman Beds form a mantle of lateritised claystone and sandstone over most of the plateau. The formation may be divided into a cream claystone and siltstone unit and a basal marine sandstone unit. The Mullaman Beds are thickest in the north-west scarp area of the map and across the southern map area parallel to the Buchanan Highway. In these areas, the formation may be up to 75 metres thick with the clayey upper unit comprising 60m of its thickness. The thickness of the sandy unit is variable across the mapped area and ranges from less than 5 metres thick on the eastern and western edges to up to 25 metres thick in parts of the central plateau area. The sandstone is generally friable, however, siliceous outcrops of the unit are located in the vicinity of Gorrie Station. Where the upper claystone is thin and eroded, the potential recharge to the underlying limestone aquifer is increased. The cross-sections included on the main Hydrogeology map indicate the Mullaman Beds as separate units. In all places, the Mullaman Beds are above the regional water level.

Occupying parts of the map area are the Tertiary fossiliferous limestone Birdum Creek Beds. This formation has been mapped as scattered outcrops within the Birdum Creek and Dry River channel incisions. They are believed to be largely concealed by a surficial cover of alluvium in the palaeochannels of the Dry River, Western Creek and Birdum Creek systems. This formation may be correlated to the Camfield Beds which exist to the south-west of the study area in the Bullock Creek and Cattle Creek systems (Bultitude, 1973, Kennewell et al, 1980).

3.0 HYDROGEOLOGY

Groundwater prospects across the area have been assessed using information on geology, ground and airborne geophysical surveys and from existing boreholes. On the accompanying map, 'Basement Contour' and 'Water Level Contour' side maps may be used as guides only. The water level contours are applicable to the Tindall Limestone aquifers only.

Technical information on bores in the area is held in the Natural Resources Division's files and is available on request. Appendix 1 provides the lithology, stratigraphy and gamma logs of selected bores. The Registered Number (RN) of all bores which have been gamma logged are contained in Appendix 2.

3.1 Jinduckin Formation, Anthony Lagoon Beds and Hooker Creek Formation

These formations overlie and confine the major limestone aquifers of the region. Where they exist below the water table, they may host viable aquifers, however, are generally of low permeability and yield. Dissolution of evaporite beds within these formations result in water with significant levels of sulphate and sodium chloride salts.

In the central-northern part of the Sturt Plateau, aquifers may be intersected in the Jinduckin Formation on the down thrust side of a regional fault (refer Section 2). However, the formation is situated above the water table in the north-west of the map.

The Anthony Lagoon Beds exist below the water table south of Maryfield Station. Moderate yielding stock bores on Kalala Station exploit this formation.

The Hooker Creek Formation does not exist within the study area. However, it is considered to underlie the surficial cover of aeolian sands and Mullaman Beds south of the Buchanan Highway.

3.2 Tindall Limestone, Gum Ridge Formation and Montejinni Limestone

The Cambrian limestone formations – the Tindall Limestone, the Montejinni Limestone and Gum Ridge Formations host the vast majority of the water resources in the region. For the purposes of this study, no hydrogeological distinction is made between each of the formations as they represent a single, extensive aquifer system and are referred to generally in this report as 'the limestone'. Within the mapped area, they underlie all but the eastern margin.

The discharge from this system is known to sustain the many springs in the Flora River in the vicinity of the National Park and the Roper River between Mataranka and Elsey homesteads.

The aquifer system is termed karstic - a term which describes a landscape resulting from dissolution and weathering of dolomite or limestone, and usually noted for cavern development. An aquifer thus formed comprises a myriad of interconnected cavities and fractures within the host rock, which allows groundwater to move through it. Successful bores intersect submerged cavities, voids and fractures in the rock. The surface expression of underlying limestone is often in the form of sinkholes where a cavity has collapsed.

There are many sinkholes throughout the Sturt Plateau. They range in size from several metres in diameter and depth, to the largest, which is about 800 m long and has collapsed over an area of approximately $0.25km^2$. This feature, known as Chowyung Waterhole is located on Gorrie Station and is one of many sinkholes concentrated in a band running east-west from Middle Creek to the Dry River. The floor of this waterhole is approximately 20m below the regional ground level.

The thickness of the limestone varies across the Sturt Plateau. In a large part of the central Sturt Plateau area, only the bottom 30 to 40m of the limestone still remains following post Cambrian erosion. In terms of the aquifer system, this unit of the formation is often the only viable target, representing the only unit below the water table. Usually, such areas where the formation thickness is between 0 and 20m, aquifer development is either limited or does not occur.

A major feature of the region is an extensive geological fault, which has been be tracked from north of the Nenen/Manbulloo boundary to as far south as the Buchanan Highway, aligning approximately with Birdum Creek for some distance. This fault has resulted in the limestone occurring at depth in the eastern part of the region. The vertical displacement associated with the fault in the vicinity of Larrimah is in the order of 200m. This fault line is informally known as the 'Birdum Creek Fault'.

3.3 Lower Cambrian Basalts

A few bores exploit basalt aquifers in the region. However, there is low likelihood for groundwater in the basalt as occurrences depend on fractures in the rock due to faulting. The fractures are difficult to locate as generally, they are masked by a cover of Cretaceous sediments and Cambrian limestones.

A number of bores have been drilled through the Antrim Plateau Volcanics uinderlying the study area and these indicate there is variation in thickness – from less than 50m to 200m. The thinnest zones overlie outliers and highs on the former Proterozoic land surface. On the eastern margin of the study area, the basalt is seen in outcrop where it has infilled former valleys and topographical lows.

3.4 Proterozoic Sandstones

Ridges and low hills of Proterozoic sandstone, siltstone and shales are present along the eastern flank of Elsey Station. These rocks are part of the Roper Group Formations. The rocks are generally highly weathered and aquifers have developed in localised fractures and weathering features.

The sandstones appear to be more favourable targets, however most bores produce useable yields. Data on these aquifers are scant.

Proterozoic sediments of either or both the Roper Group and the Tomkinson Creek Beds have been struck beneath the basalts of the Antrim Plateau Volcanics and the Helen Springs Volcanics. Some aquifer development has occurred at the contact between the basalt and the sandstone and siltstone. However, only a small number of bores penetrate through the basalt into the underlying sediments and the extent of the resource, its recharge mode, water quality variations and resource sustainability cannot be adequately assessed.

4.0 BORE YIELD MAPPING

The aquifers of the Sturt Plateau were mapped according to average yield and aquifer type. In general, the water quality is good enough for most domestic and all stock purposes, so was not considered an issue. Available yields are grouped into four classes, along with typical uses for bores within these yield ranges:

- Less than 0.5 L/s — Small domestic supplies
- 0.5 – 5.0 L/s — Stock, domestic, communities to 350 people
- More than 5.0 L/s — Irrigation. town supplies, large scale stock

The yields shown on the map are intended to provide an indication on the most likely yield which could be expected. Natural variation in the properties of rocks means that variation also occurs in groundwater yields.

The expected yield is based on knowledge of the type of aquifer, and in some cases, the submergence characteristics. For example, consider the predominant aquifer in the Tindall Limestone. Where the aquifer submergence is greater than 20m, a bore intersecting a cavity or fractured rock will likely yield in excess of 5L/s. Where the submergence is less than 20m, but more than 5m, a yield of between 0.5 and 5L/s may be expected. In an area where the submergence is less than 5m, the likelihood of intersecting a cavity or fracture in the formation within this interval, is low. Therefore it is considered that there is a poor likelihood of success.

There are six different groundwater environments identified on the Sturt Plateau.

- Yield less than 0.5 L/s
  - (i) Antrim Plateau Volcanics in the central plateau area
  - (ii) Lower Proterozoic basalt/dolerite/siltstone sequences on the eastern margins

- Yield between 0.5 and 5.0 L/s
  - (iii) Tindall Limestone, Gum Ridge and Montejinni Limestone Formations
  - (iv) Jinduckin Formation and Anthony Lagoon Beds
  - (v) Lower Proterozoic Roper Group sandstone/shale formations

- Yield more than 5.0 L/s
  - (vi) Tindall Limestone, Gum Ridge and Montejinni Limestone Formations

4.1 Yields less than 0.5 L/s

Most low yielding bores intersect the underlying Antrim Plateau Volcanics (basalt). In areas where this formation subcrops above or near the water table, aquifer development will only occur on the weathered contact surface or at depth in fractures. The fractures are difficult to locate as they are generally masked by a cover of Cretaceous sediments and/or the Cambrian limestone. Bores intersecting the weathered surface of the basalt, may yield 0.3 L/s, and fractured basalt may yield about 1 to 2 L/s.

The other low yielding aquifers are developed within the Proterozoic basalt, dolerite, siltstone, shale and greywacke rock types of the Roper Group Formations. These are sometimes featured as intrusions or sills within the sandstone beds of the area. While some consistency in locating successful bore sites in weathered shale and siltstone beds is noted, the other rock types are generally not favourable unless associated with faulting. Successful bores RN 3545 (No. 5 bore) and RN 5047 (Mt. Sir James bore) are exceptions in this low yielding group, intersecting a viable supply *beneath* the basalt/dolerite sequence.

The assistance of geophysical techniques or aerial photograph interpretation is recommended to enhance the likelihood of success in the low yielding areas. An appropriately designed investigation should aim to locate fractures, which can then be targeted with drilling.

4.2 Yields between 0.5 L/s and 5 L/s

This yield category is considered to provide the minimum required for stock watering. There are three groundwater environments identified within this category. They are the areas in the limestone where there is limited submergence, the areas underlain by the Jinduckin Formation and Anthony Lagoon Beds and the Lower Proterozoic Roper Group sandstones which flank the north-eastern margin of the map region.

Bores in the limestone can range in yield from nil to more than 5 L/s. It is recognised that there is inconsistency in success and yield from bores in limestone. This is due mainly to the natural variations and arbitrary occurrence of cavities and fractures in the rock. On the Sturt Plateau, the depth to the underlying basalt basement is also an important factor.

In the central southern part of the plateau, a system of parallel ridges and troughs trending north-west/south-east on the surface of the underlying basalt has a major effect on groundwater prospects (see Section 5). Where the higher ridges intersect or approach the water table, success rates are usually low. An aeromagnetic map indicating these features, supplemented with ground magnetic traverses are considered essential tools in bore site selection within these areas.

The higher ridges affect groundwater flows where they intersect or approach the water table and represent distinct corridors which are not prospective for groundwater. Therefore, where these features are prominent, bore site selection is critical. It is important that troughs be targeted to optimise aquifer submergence. As such, the submergence characteristic of the limestone represents the single most important factor determining bore success.

Aquifers in the Jinduckin Formation and Anthony Lagoon Beds will usually yield adequate stock water. The aquifers may be intersected in the laminated and interbedded siltstone and dolomitic sandstone units.

Sandstone outcropping as ridges and low hills form the upland country in the north-east of the map area. Localised aquifers occur in fractures and weathering features and most station bores drilled in this area obtain adequate stock supplies from this aquifer type. Site selection for stock bores does not appear to be critical.

4.3 Yields more than 5 L/s

Such yields are available where the thicknesses of the limestone beneath the water table exceeds 20m. Within this zone, there is a high likelihood of successful bores.

One of the primary areas of potential high yield is featured in the north-west corner near Dry River Station. This area may be identified as the southern extent of the Daly Basin. From here northwards, the trend of the Tindall Limestone is to descend northward towards the basin’s regional centre.

Similarly, these trends are repeated in the south near Hidden Valley, and south-east from Kalala as the Montejinni Limestone and Gum Ridge Formations deepen into the Wiso and Georgina Basins respectively.

5.0 THE CENTRAL BASALT STRUCTURES

In the central part of the Sturt Plateau groundwater prospects are good, however bore site selection is critical. An element of predictability in locating borehole targets is provided by aeromagnetic mapping. This mapping, supported by ground magnetic traversing to optimise the site location, is considered essential in successful bore site selection within this area. Airborne magnetic data delineates a series of ridges and valleys in the top of the basalt in this area. The unprocessed total magnetic intensity (TMI) image of the Sturt Plateau is shown in Figure 4.

A report by Knapton (2000) details the geophysical investigations undertaken on the Sturt Plateau and includes interpretation of various types of airborne and ground based data. Good correlation between the airborne and ground magnetic data was obtained. He states that the mapped aeromagnetic values are not likely to be due to :

- variations in the thickness of the basalt as ground magnetic and other geophysical data suggests that the basalt was extruded onto an even surface or;
- variations in the depth to the top of the basalt since these fluctuations would be small compared to the total magnetic field.

The distinct magnetic signature is attributed to weathering effects. It is postulated that the basalt valleys are the result of regional faulting and subsequent weathering and erosion. This process has replaced the highly magnetic minerals with minerals of lower magnetic susceptibility. A difference in elevation of possibly up to 20 m from the top of the ridges to the base of each valley is proposed in the most prominent areas. Relative levels in a number of boreholes support this.

The Cambrian limestones were deposited over a generally flat basalt landscape. However, in this region, the system of parallel ridges and valleys existed before the deposition of the limestone and interbedded shale/mudstone sequences. Typically, at commencement of deposition, the basal member of the Tindall Limestone filled the troughs. As deposition continued up to and above the top of the basalt ridges, the sediments became more argillaceous. This means that bores sited on the ridges will intersect the basalt at a higher elevation and encounter the mudstone sequences before entering the basement. Bores sited in the valleys have a prospect of intersecting a thickness of limestone.

In terms of the groundwater flow regime, this basement feature represents the major controlling factor to flows trending northwards. In particular, where the basalt ridges emerge above the water table, flows are restricted to within the valley system. The reduced capacity of the valleys to effectively transmit the regional thoughflow has resulted in a localised steepening of flow gradients across this area.

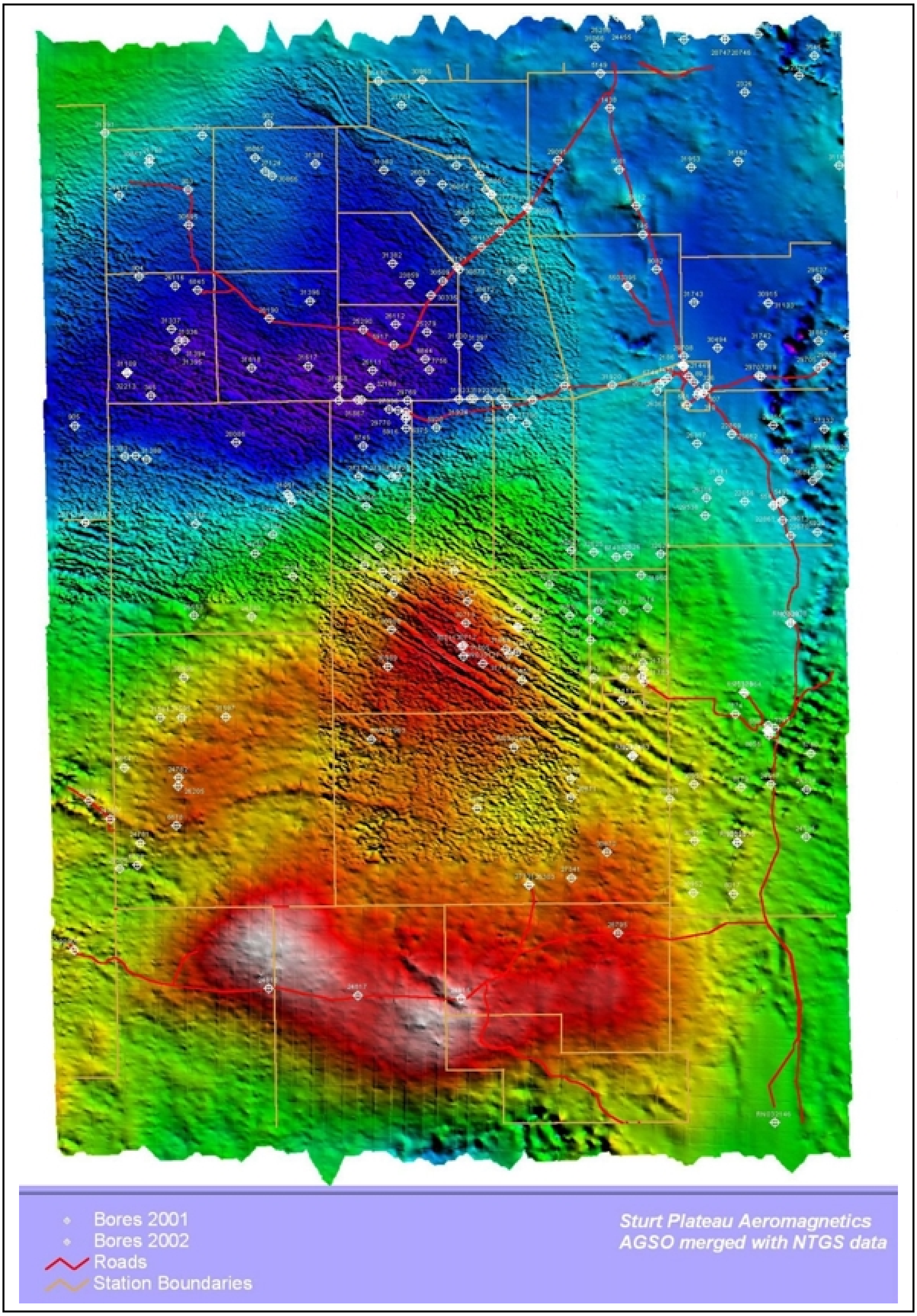

Figure 4 Total Magnetic Intensity Image

6.0 RECHARGE/DISCHARGE RELATIONSHIPS

As discussed in Section 1.2, the Sturt Plateau exhibits little surface water flow with less than 10% of rainfall resulting in streamflow. Thus, most precipitation is either lost to evapotranspiration or recharged to the aquifer.

Recharge to the aquifer is predominantly through point sources. The point sources are represented by many open sinkholes. Anecdotal reports indicate that they some may hold water for "only a few hours" after significant rainfall. This is reflected in the low values of chloride in the central Sturt Plateau area.

Diffuse regional recharge is determined by the nature of the overlying strata. This mode of recharge probably contributes proportionately less than sinkholes due to the widespread coverage of clayey sediments in the overlying Mullaman Beds. While no attempt has been made to map the variation at this stage, the cross sections A-B, C-D, E-F and G-H in the accompanying Hydrogeological map provide an indication of the distribution and relative thicknesses of the clayey and sandy sediments overlying the limestone.

Continuous groundwater level data is being acquired at recorder installations on two bores – RN 28087 (Tarlee) and RN 30695 (Dry River). Figure 5 presents the existing data and rainfall recorded at Larrimah (DR014612) over the corresponding period. However, there is currently insufficient data to define the relationship between groundwater levels and rainfall.

A collation of available regional water level information has enabled mapping of groundwater movements on Figure 6. Most of the groundwater discharge from the region is identified as spring flows in the Flora and Roper Rivers. The flow regime mapped on the Sturt Plateau may be considered primarily as separate flow components to the west and east of the Birdum Creek Fault with contributions from both the Wiso and Georgina Basins respectively.

6.1 West of the Birdum Creek Fault to the Flora River

6.1.1 Groundwater Levels

This section discusses that area west of the Birdum Creek Fault to the western boundary of the sedimentary basin, to the springs along the Flora River.

Of note is the steep flow gradient in the middle-western portion between two basalt highs. In a section from 20 km south of the Gilnockie/Birrimba boundary (bore RN 24782) through to north of bore RN 26546, the groundwater gradient falls slightly from south to north. The gradient then steeply increases across the zone near bores RN 31109 and RN 31336. This corresponds to an area where the basement ridges and troughs are within proximity of the water table.

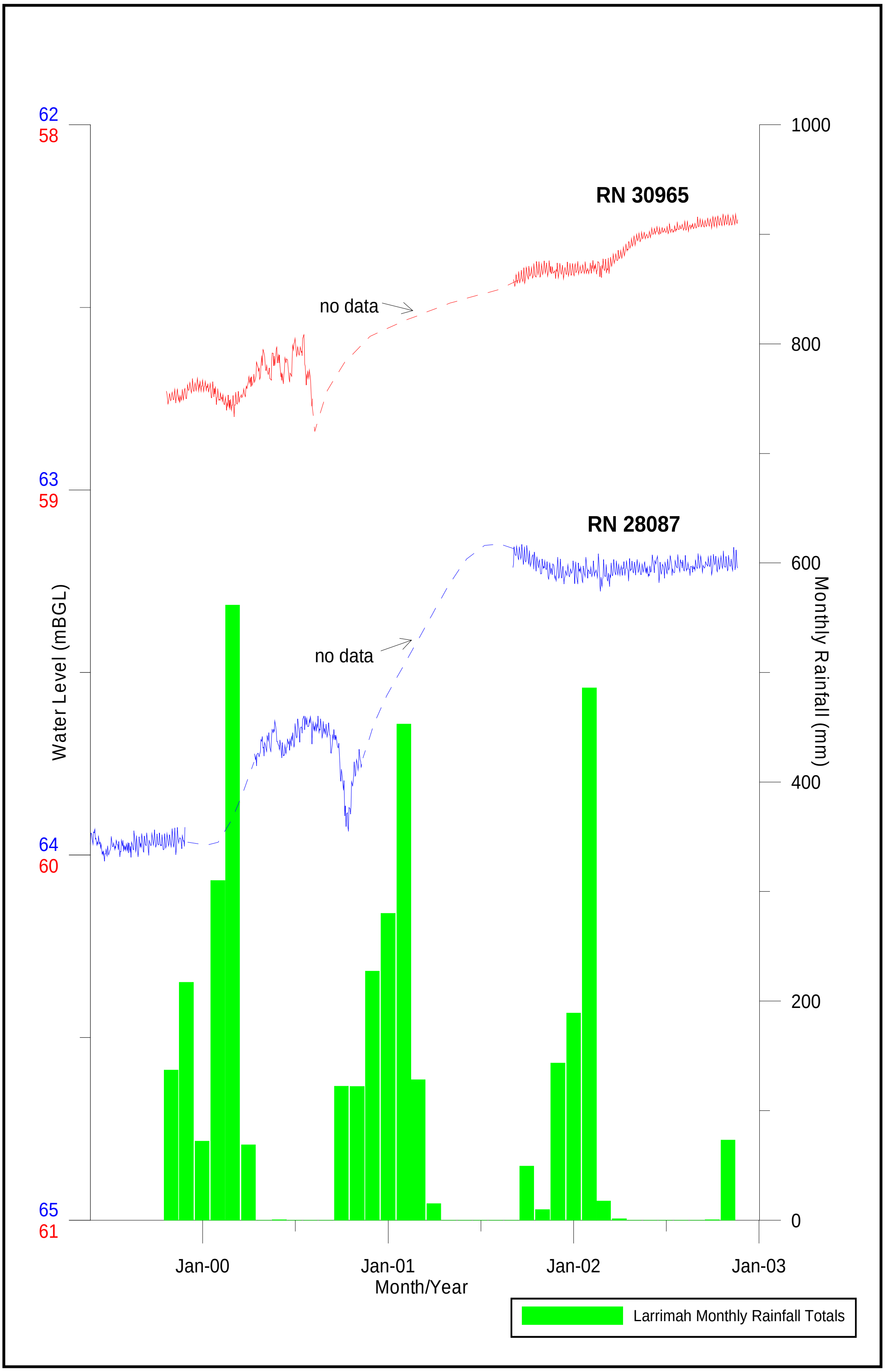

Figure 5 Monitoring Water Level and Rainfall Data

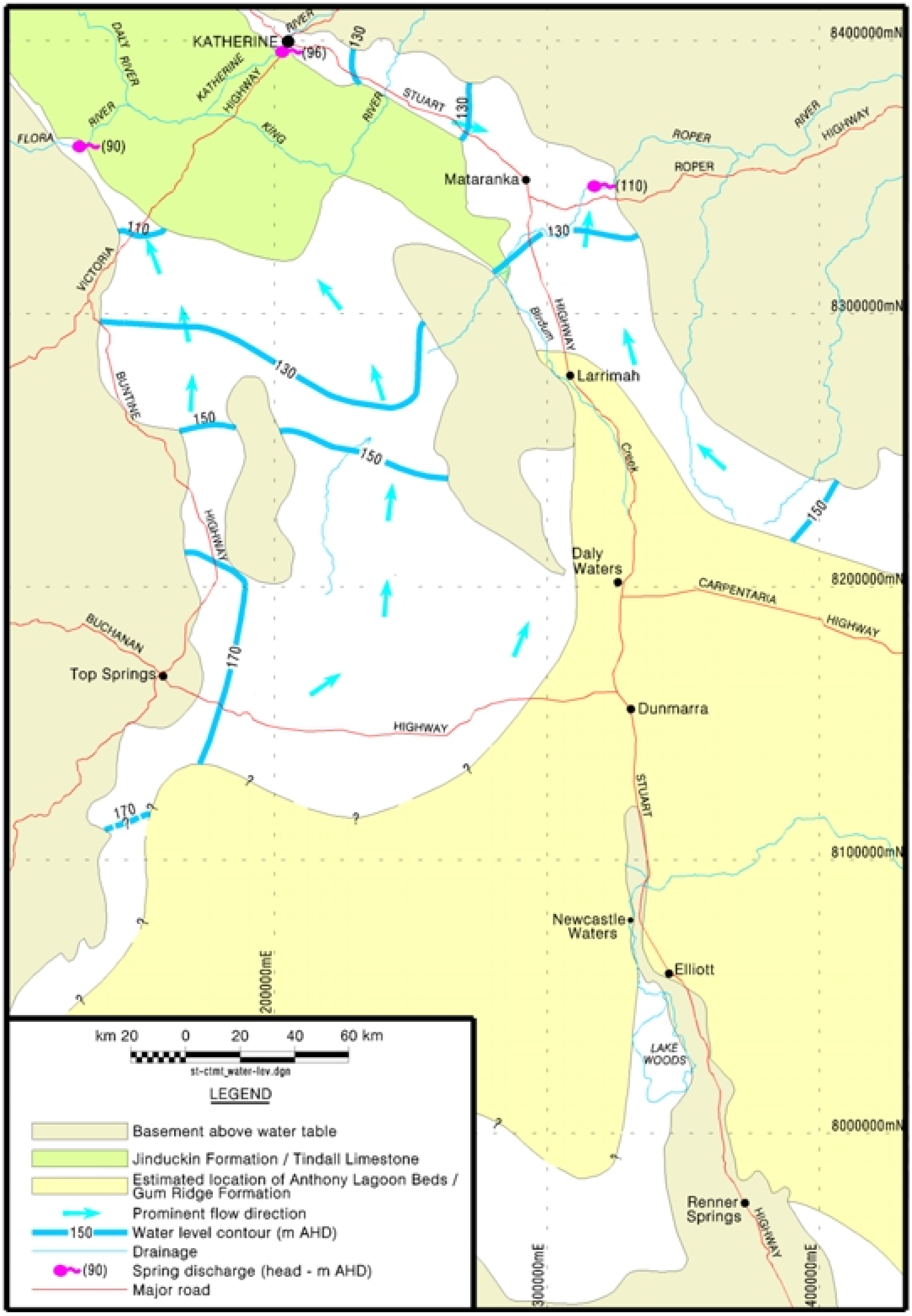

Figure 6 Regional Groundwater Movements

The influence on the groundwater flow regime is indicated by the transition in water level gradient. The effect is similar to that of a 'barrier or overflowing dam' where there is an appreciable change in groundwater levels between the upstream and downstream sides.

This area also corresponds to a reduction in the thickness of the clay rich upper unit of the Mullaman Beds. As such, this zone is considered to represent an area of possible diffuse recharge (refer to section 6.3 for details).

Further north, the flow gradient flattens. An increase in aquifer thickness due to the fall in elevation of the basalt is the primary factor for the greater transmissivity. However, increases in transmissivity are also attributed to enhanced fracturing and weathering patterns of the limestone. Features in the limestone are often enhanced by flexure in the basement and changes in basement elevation. As an example, further north in the Daly Basin, drilling on the slightly folded edges of the basin has resulted in areas of higher than usual permeability. An order of magnitude estimate of sustainable yield for this part of the aquifer is contained in Appendix 4. Calculations based on throughflow indicates that it is in the order of 175 to 350ML/d or 2 to 4 cubic metres per second (cumecs). The flow concentration in the section of the Flora River between the Mathison Creek confluence and Kathleen Falls represent spring discharges and are indicative of aquifer throughflow. Dry season base flows sustained by the springs in the Flora River are in the range of 2 to 4 cumecs.

The seasonal fluctuation in regional groundwater level (indicated in Figure 5) is in the order of 0.6 to 0.8m. The annual volume of water added to the aquifer is estimated to be 130,000 ML/year, equating to an average recharge rate of 9 mm/year (see Appendix 4).

6.1.2 Chloride Mass Balance

Chloride mass balance analysis may also be used to derive an order of magnitude indication of recharge. This method assumes that the chloride in the aquifer is sourced from rainfall and therefore reflects the degree to which chloride in rainwater has been concentrated by evaporation. In relation to the study area, the application of this is limited to the northern and southern part of the Sturt Plateau where the recharge mode does not appear to be dominated by direct infiltration of sinkholes (ie. where diffuse recharge is significant). Figure 7 indicates the areal distribution of chloride in the aquifer.

The analysis in Appendix 4 indicates that the recharge ranges between 1% and 3% of the annual rainfall (or 6 and 18mm).

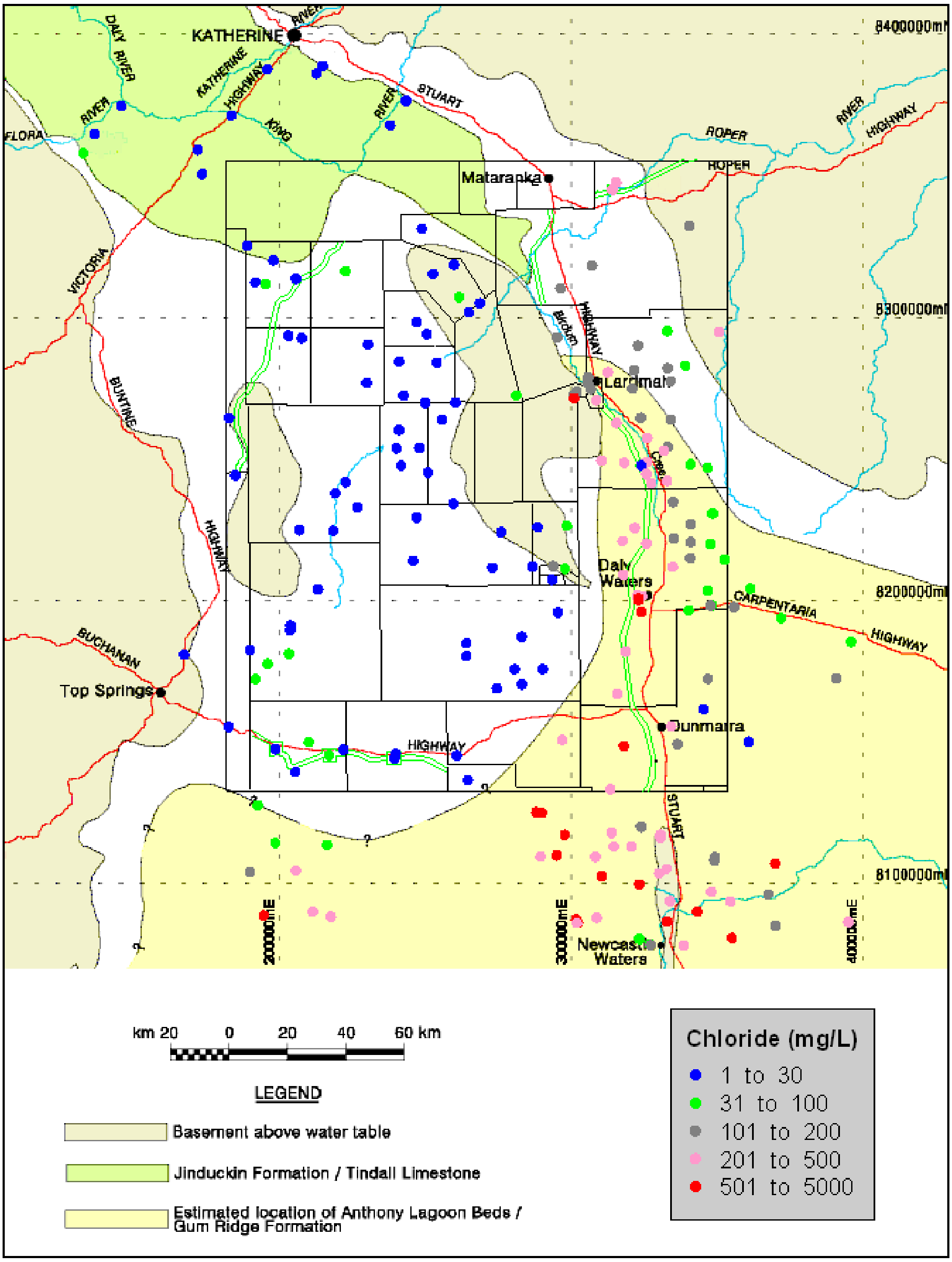

Figure 7 Chloride Distribution Map

6.1.3 Stable Isotopes

Analyses of the isotopes Oxygen-18 and deuterium were undertaken on 22 groundwater samples from the Sturt Plateau and one from East Mathison Station, 20 km to the north-west. The results of all surface water and groundwater isotope analyses are tabulated in the Technical Data Report (Yin Foo and Matthews, 2000). Apart from RN 31397, all waters were sourced from the main limestone aquifer.

The yield of the bores varied from less than 2 L/s to over 20 L/s. In all cases, the bore was pumped for a number of hours, or until the water quality had stabilised before sampling was undertaken.

The results from bores within the Sturt Plateau are shown in Figure 8. The World Meteoric Water Line (WMWL) has also been plotted. A Local Meteoric Water Line (LWML) was constructed from analyses of stream samples (following a monsoonal rain event) between Elliot and the Elizabeth River. This data, collected by Yin Foo and Jolly (1994) plotted very close to the WMWL and has therefore not been included in the diagram.

Most of the groundwaters plot on or near the WMWL and infers that the water is subjected to little evaporation before reaching the aquifer. This conclusion is consistent with the concept of point source recharge through the sinkholes in the area, where fairly rapid movement of rainwater to the aquifer is expected. In comparison, a much higher rate of evaporation would be indicated in a diffuse recharge scenario.

The water from bore RN 21784 has undergone significantly more evaporation than all other waters sampled. This bore is located immediately down gradient of Lake Duggan. This is a small, near permanent, freshwater lake and is effectively a perched water table. The more highly evaporated sample taken from bore RN 21784 would be a result of slow infiltration of surface water from Lake Duggan into the aquifer.

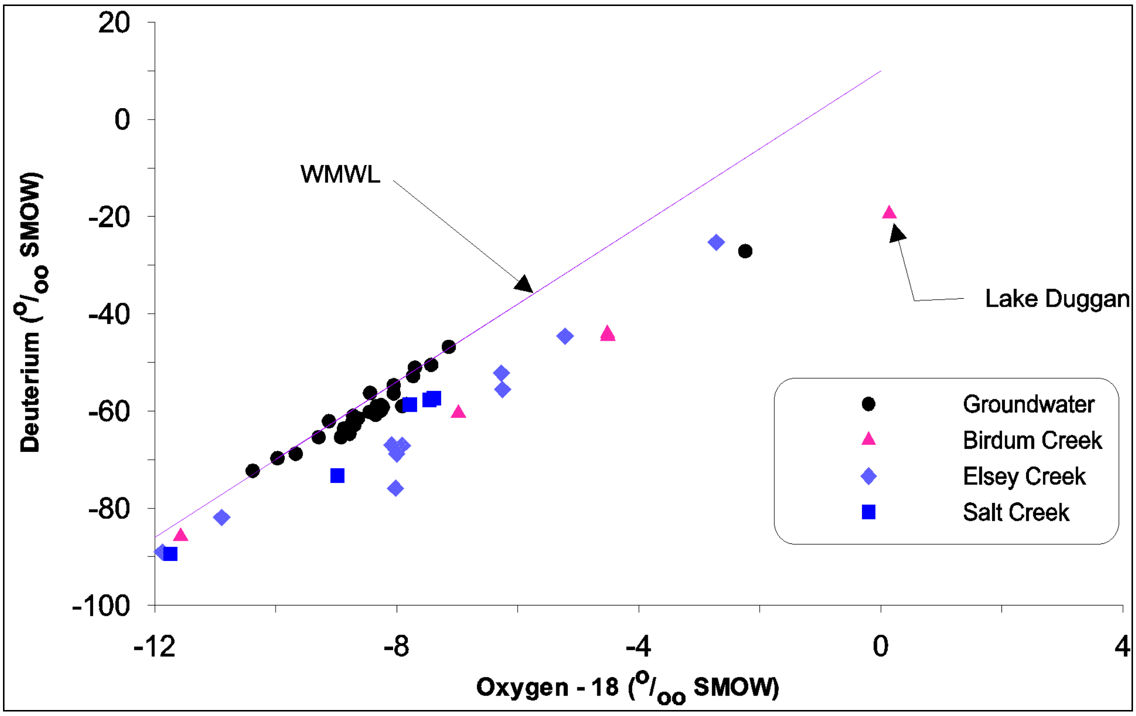

Figure 8 Stable Isotope Plot – Deuterium vs Oxygen-18

6.1.4 Carbon-14

Radiocarbon concentrations range from 38 percent modern carbon (pmc) to 96.9 pmc. The radiocarbon concentrations are uncorrected, however are used to calculate the groundwater ages. For the purposes of this study, the relative ages of the groundwaters are of more importance. The bore registered number and groundwater ages are shown on Figure 9. (See tabulated results in Yin Foo and Matthews, 2000). The northern limit of the ferricrete/thick Mullaman Beds and the southern limit of the Jinduckin Formation are delineated.

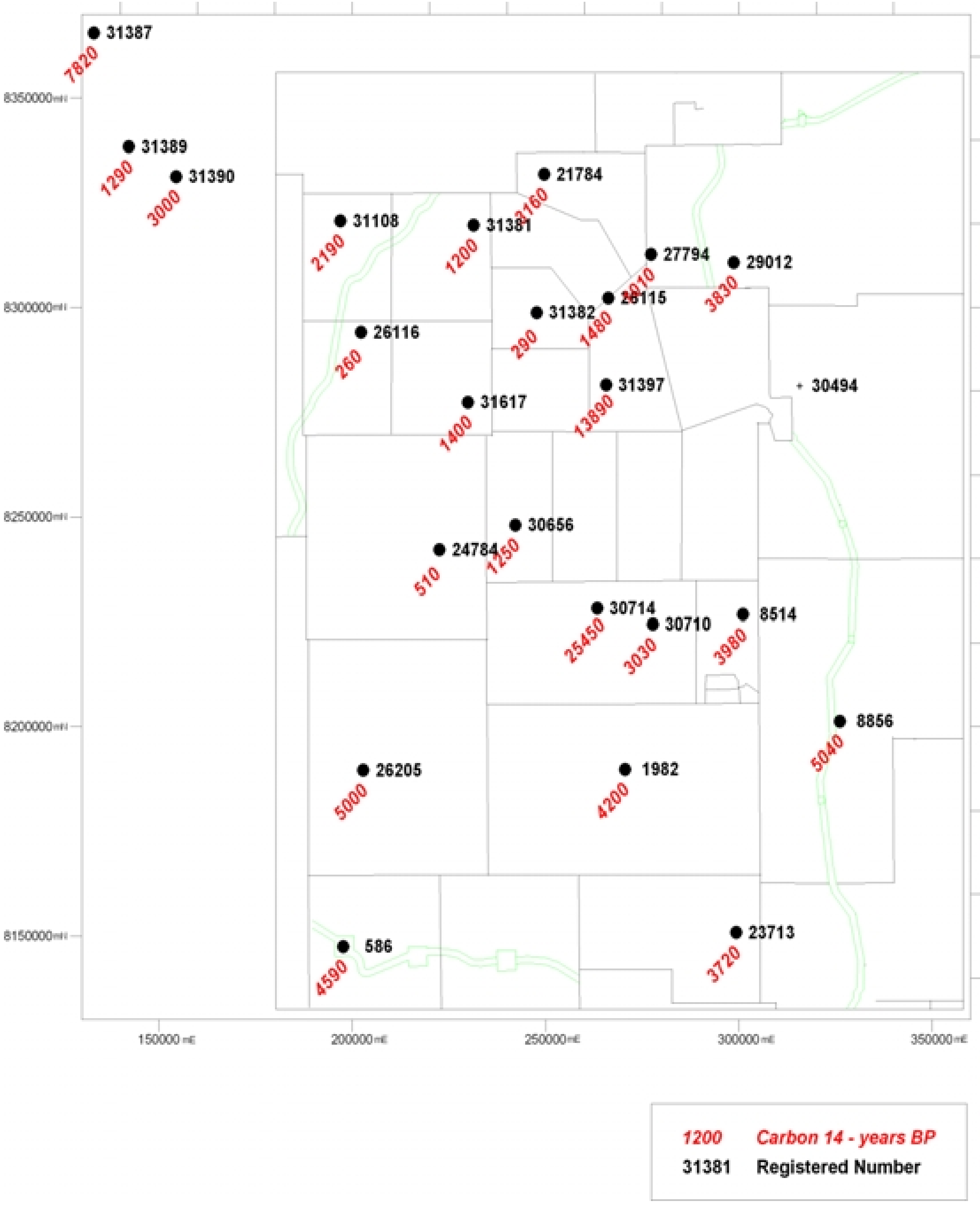

Figure 9 Carbon-14 Map

The Carbon-14 results divide the area into 3 zones:

- a southern zone with groundwater ages more than 3500 years
- a central zone with groundwater ages less than 1500 years
- a northern zone with groundwater ages more than 2000 years

Within the Sturt Plateau, it is apparent that the thickness and clayey nature of the strata in the overlying Mullaman Beds control variability in diffuse recharge. In the vicinity of Hidden Valley, Birrimba and the Buchanan Highway, the Mullaman Beds consist of a sandy basal unit up to 20 m thick, overlain by a clay and siltstone dominated unit up to 75 m thick. Slow, diffuse recharge through the thick clay sequence appears to be responsible for groundwater ages greater than 3500 years.

In the central zone encompassing Gilnockie, Western Creek and Gorrie, the clay and siltstone dominated upper unit have been largely eroded. It is evident that recharge is enhanced and due to the more permeable basal unit. With apparent dilution, the age of groundwater in the central zone generally lies between 260 years and 1000 years.

Groundwater ages then steadily increase from the central region through to the discharge areas near the Flora River, where the age may range up to 7800 years. Recharge to the limestone aquifer over the northern zone is low due to the confining Jinduckin Formation.

Dating of a water sample from bore RN 31397 was also undertaken. This bore investigated the Proterozoic sandstone aquifer underlying the basalt. An age of 14000 years was determined. Considering the possible recharge scenario of this aquifer, this result might be expected.

6.2 East of the Birdum Creek Fault to the Roper River

The mapping of water level data indicates that the predominant flow direction on the eastern part of the Sturt Plateau is towards the north where it is channelled between the Lower Proterozoic Sandstones of the eastern upland country and the “Birdum Creek Fault” to the west. The flow emerges in the Roper River as springs between Mataranka and Elsey.

An order of magnitude estimate of throughflow for this part of the aquifer system is between 160 and 320ML/d or 2 to 4 cumecs. In comparison, spring discharges into the Roper River range from 260 to 430 ML/d or 3 to 5 cumecs (refer Appendix 4).

A component of flow originates from the Georgina Basin and enters the Sturt Plateau across the south-eastern quadrant of the map near Daly Waters. Water quality data also indicates there is a small flow component from the Wiso Basin in the west. The remainder of the flow is accumulated from local recharge along the flow path. The direct infiltration of sinkholes is considered to provide the main avenue for this recharge.

Water quality data indicates that poor quality water enters the Gum Ridge Formation in the vicinity of Daly Waters. The source of this water is probably the Anthony Lagoon Beds as aquifers in it are extensive in the area. The interconnection of aquifers in this area may be associated with nearby faulting, as shown on cross-section G-H on the accompanying Hydrogeological map or lensing of the Anthony Lagoon Beds in the area.

6.3 Regional Groundwater Flow

The regional flow regime presented in Figure 6 indicates that most of the groundwater beneath the Sturt Plateau has either originated via sinkhole recharge on the Sturt Plateau, or as throughflow moving from aquifers in either the Wiso or Georgina Basins to the south of the Sturt Plateau. Flow predominantly moves towards major springs occurring in the Flora and Roper Rivers.

Throughflow emanating from the Wiso Basin is considered to provide only a minor proportion of the flow along the western flank of the Sturt Plateau. Recharge to the Montejinni Limestone in the northern part of the basin is considered be low as sediments of the Hooker Creek Formation generally overlie it. The aquifer receives recharge mainly where the formation outcrops on the margins of the basin.

The northern part of the Wiso Basin may be considered separately from the remainder of the basin. A basement high of Lower Proterozoic age runs in a south-east/north-west direction from the Ashburton Range near Renner Springs across to the basin’s western edge, and represents the southern boundary to the system. The basin is bounded to the east by the Lower Proterozoic Tomkinson Creek Beds, which form the Ashburton Range.

The ‘breakaway’ country delineating the western edge of the basin, has developed as a result of the Victoria River drainage system actively eroding into the limestone sediments. The aquifer is recharged through the outcropping formation in this area and minor springs may be found at the resulting contact exposure with the underlying Antrim Plateau Volcanics. A small component of this flow is directed towards the Sturt Plateau.

A feature of the region is Lake Woods - a large ephemeral lake at the base of the Ashburton Range west of Elliott and a source of recharge to the system. Groundwater levels are some 20 to 30 m below the ephemeral lake surface.

Groundwater flow on the eastern side of the Sturt Plateau as discussed in Section 6.2 is predominantly northwards towards the Roper River. Most of this flow is due to recharge on the Sturt Plateau. Flow emanating from the Gum Ridge Formation in the Georgina Basin is likely to be much lower since groundwater movement within this aquifer is limited. This formation is extensively confined by the Anthony Lagoon Beds across the Georgina Basin and recharge occurs in the narrow margin areas where it exists in outcrop or abuts the Ashburton Range.

Palaeo features in the region provide evidence of the much wetter environment during the Cainozoic. The elevation of limestone and fossil rich deposits in the Birdum Creek Beds and Camfield Beds indicate that the regional water level once existed at approximately 200m AHD. The former is located in outcrop in the topographic lows of the Sturt Plateau such as Birdum Creek, Middle Creek and Dry River. These areas were permanently inundated and formed part of the perennial creek systems that fed the Elsey Creek and Flora River systems. Cainozoic tufa deposits within in these systems are evidence that permanent flows existed.

The Camfield Beds in the headwaters of the Cattle Creek and Bullock Creek areas were deposited in the inundated environment on the western edge of the Wiso Basin. Springs emanating from the exposure of the Montejinni Limestone along this edge fed into the local drainage systems.

In the northern part of the aquifer near the discharge zones along the Roper River, shallow limestone deposits of Cainozoic age are featured, and tufa deposits line parts of Elsey Creek (Kruse et al, 1994).

Former water table lakes, now mapped as “old lake beds”, are a particular ground feature across the northern part of the Wiso Basin. Lake Woods existed as the largest water table lake in the region. The regional elevation map on Figure 10 clearly indicates the palaeo shoreline that developed at the time of its greatest occupation. This represented a lake area of approximately $3600km^2$. Of interest is a palaeo drainage feature from the lake towards the west joining the Cattle Creek system.

Work in caves in the region provide some evidence that groundwater levels were previously much higher. A karstic network may be observed at the top of the limestone some 30 to 40m above the present day water level.

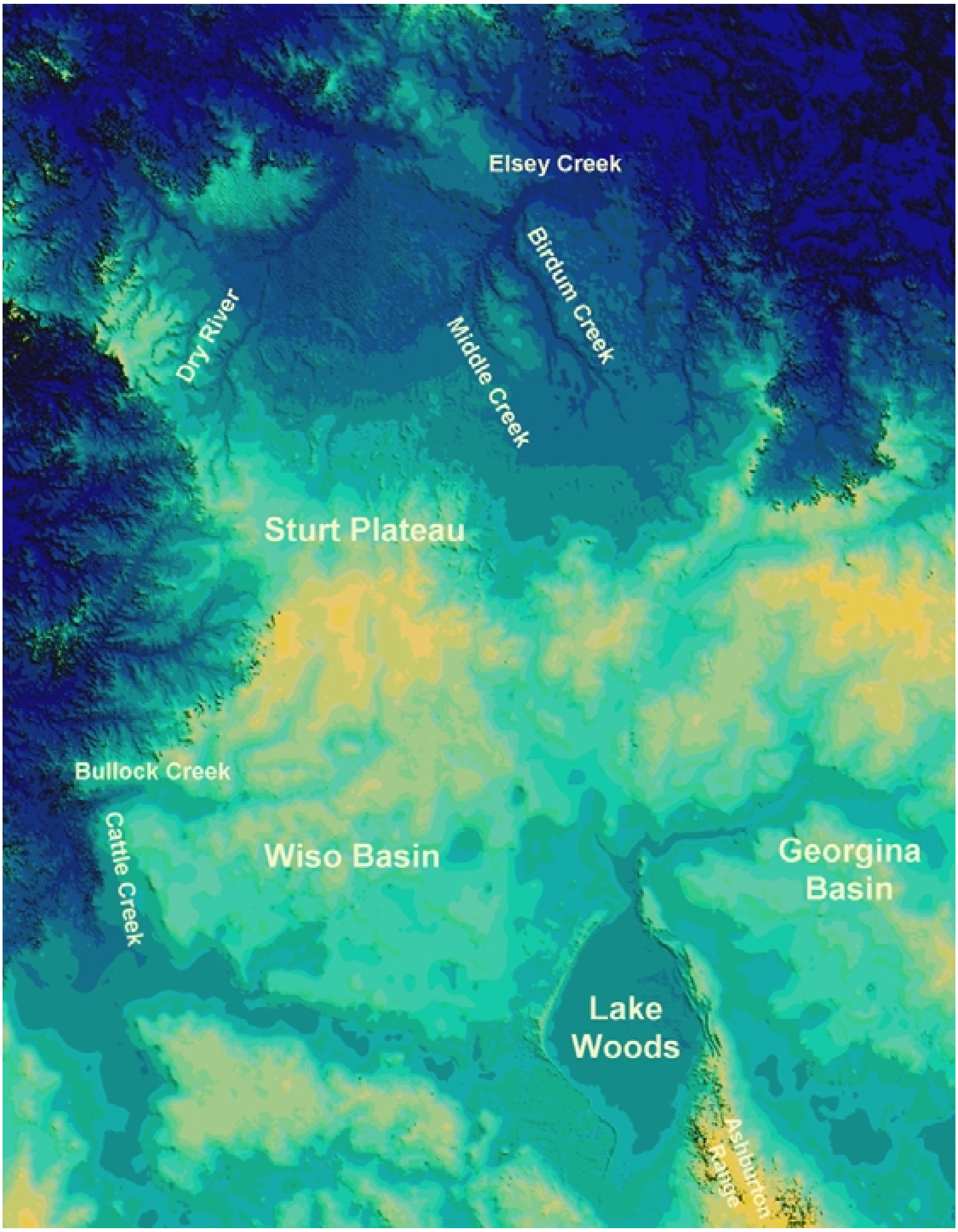

Figure 10 Regional Elevation Map

7.0 POTENTIAL HORTICULTURAL AREAS

The areas within the Sturt Plateau which can potentially provide the required yields for irrigated agriculture are essentially mapped as 'Yields >5 L/s'. Existing bore data indicates there is consistency in obtaining conditions suitable for large yields from the Tindall Limestone in these areas and well designed and constructed production bores should individually yield over 20 L/s. The north-western map sector and the area east of the Birdum Creek Fault are considered the most prospective in terms of resource availability. The latter section is continuous from the south-eastern limit of the plateau through to the Roper River and is also favourable in terms of viable pumping levels. Water quality is generally not an issue throughout the Sturt Plateau.

Current utilisation of the resource is relatively minor and the impact of foreseeable pastoral development is not likely to be of concern. However, despite the apparent high yield potential of individual bores within these areas, the issue of resource sustainability needs to be addressed if intensive horticultural development is proposed.

Initial assessment of groundwater resource availability may be made by examining the aquifer discharges. Resource development will be at the expense of the natural discharge regime to the Flora and Roper Rivers which maintains river base flows at around 2 to 4 cumecs and 3 to 5 cumecs respectively. Sufficient flows to the Flora and Roper Rivers will need to satisfy environmental, tourism and other riparian requirements as an initial condition.

8.0 WATER QUALITY

The groundwater quality in the area is usually suitable for human consumption in accordance with the National Health and Medical Research Council (NHMRC) guidelines 1996 for potable water and always suitable for stock. See Tables 2 and 3 for guidelines for potable and stock use respectively. Appendix 3 provides all water quality data for the mapped area.

It may be noted that there is a significant range in water quality. As well as the existence of a number of aquifer types, regional flow regimes and recharge conditions have a significant influence on water quality.

Although the limestone aquifer is largely continuous across the plateau, a number of different water quality groups may be identified within it. The zonation of water quality in the western part of the aquifer (Section 6.1), is largely influenced by direct infiltration of sinkholes. Under this scenario, throughflow emanating from south of Hidden Valley with an average value of 450mg/L are diluted as flow continues north. TDS in the central region decreases to about 350mg/L.

As flow proceeds towards the discharge zones in the Flora River, there is a discernible change in the water quality due to travel and diffuse recharge. TDS values generally increase by up to 100mg/L as flow moves towards the north-west corner of the map. The presence of the Cainozoic Birdum Creek Beds in this area may have some influence on the water quality.

The water quality on the eastern side of the Sturt Plateau is notably different to that on the western side. It is dominated by higher salinity, indicated by TDS levels ranging from 500 to over 1200mg/L, which are the result of a combination of carbonates, sulphates and sodium chloride salts.

The area around Daly Waters represents a zone of mixing where waters from the Georgina and Wiso Basins enter the Sturt Plateau. A significant difference in quality as compared to the groundwater in the central part of the plateau, is indicated on the plots of chloride distribution (Figure 7) and sulphate distribution (Figure 11). The introduction of poor quality waters, probably sourced from aquifers in the Anthony Lagoon Beds, result in typical chloride and sulphate levels of 300 and 250 mg/L respectively in the water supply for Daly Waters Township.

Figures 7 and 11 indicate that interconnection of these aquifers may occur along the axis of major faulting activity in the area. The fault locations are shown on the accompanying Hydrogeological map.

Local recharge in the area is identified as another possible cause of the poor quality water. During the much wetter Cainozoic period, an accumulation of evaporites within the drainage line enveloping the Daly Waters and Birdum Creeks may provide a possible source.

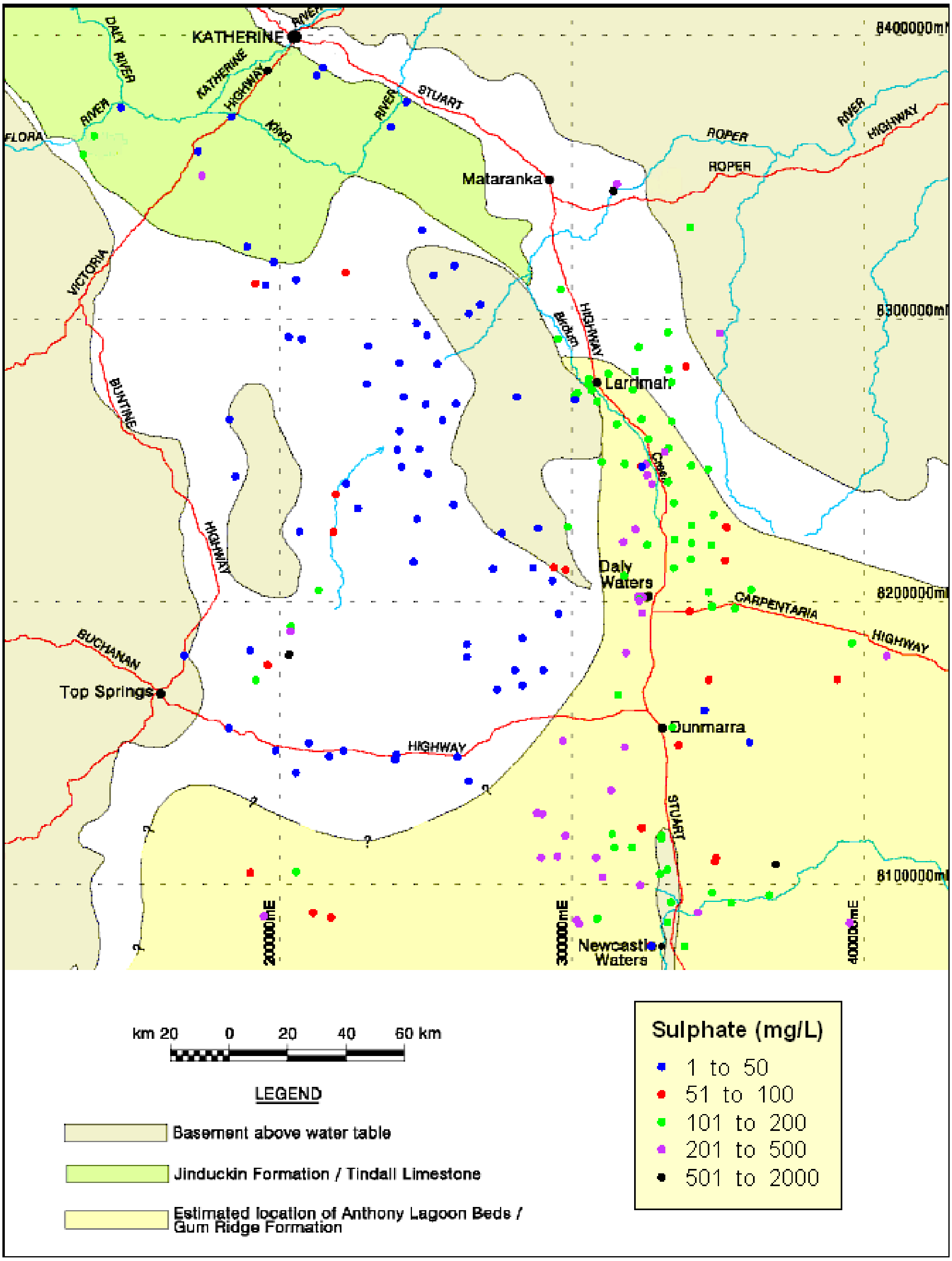

Figure 11 Sulphate Distribution Map

As flow progresses northwards towards the discharge zones in the Roper River, fresh recharge along the eastern fringes of Maryfield and Kalala provide some dilution. Typical values for chloride and sulphate are 130 and 150 mg/L respectively in the Larrimah area.

A marked decrease in water quality is featured in the region of Djilkminggan, where TDS is typically between 1000mg/L to 2000mg/L. This is attributed to local effects.

Overall, the limestone water is hard to very hard (total hardness over 200mg/L) and scale forming. Measures can be taken to minimise the occurrence of scale development on elements of the reticulation. These include control of thermal variation of the reticulated water and limiting the aeration of the water.

The basalt aquifers that have been encountered underlie the limestone and occur as isolated and poorly interconnected aquifers. Hence water qualities from different bores vary. However, they are usually potable and always suitable for stock.

Basalt-derived groundwater differs in general chemistry to that in the overlying limestone aquifers. Of particular note are higher sodium chloride (NaCl) and lower alkalinity levels. The hardness levels tend to be high, and the water ranges from hard to very hard and can be scale forming. Where higher salinities are observed, it is usually due to the presence of sodium chloride.

Other aquifer types exist in the Lower Proterozoic rocks on the eastern side of the Sturt Plateau and water quality data from this area is scant. The bores intersecting sandstone in this region typically produce water of TDS less than 500mg/L. Water quality in shale varies significantly and TDS values range to a maximum of 1000mg/L.

Table 3 Water Quality Standards For Domestic Use

SUBSTANCE	GUIDELINE VALUE	
pH range	6.5 - 8.5	*
Total dissolved solids	500mg/L	#
Chloride	250mg/L	#
Sulphate	250mg/L	#
Nitrate	50mg/L	+
Fluoride	1.5mg/L	
Hardness (as Calcium Carbonate)	200mg/L	*
Sodium	180mg/L	*

Analyses of water intended for human consumption should lie within the guidelines listed below. Discussion relating to the quality of domestic water should be addressed to the Northern Territory Department of Health and Community Services.

(*) Values outside of the guidelines for pH and hardness may result in either build-up of scale in pipes or corrosion of pipes but they do not pose a health problem.

(#) Above these limits the taste may be unacceptable but they do not pose a health problem.

(+) For nitrate, a limit of 50mg/L is recommended for babies less than 3 months old, 100mg/L is the guideline for older children and adults.

Table 4 Water Quality Standards For Stock Use

SUBSTANCE	GUIDELINE VALUE
pH range	6.5 - 8.5
Total dissolved solids	7000mg/L
Sodium chloride	Not more than 75% when total dissolved solids near limit
Sulphate	2000mg/L
Nitrate	400mg/L
Fluoride	2.0mg/L
Magnesium	300mg/L

The composition of mineral supplements to stock feed must be considered when stock waters are near to the guideline limits, especially for fluoride and sulphate. Further information is available from the Chief Veterinary Officer, Northern Territory Department of Primary Industry and Fisheries.

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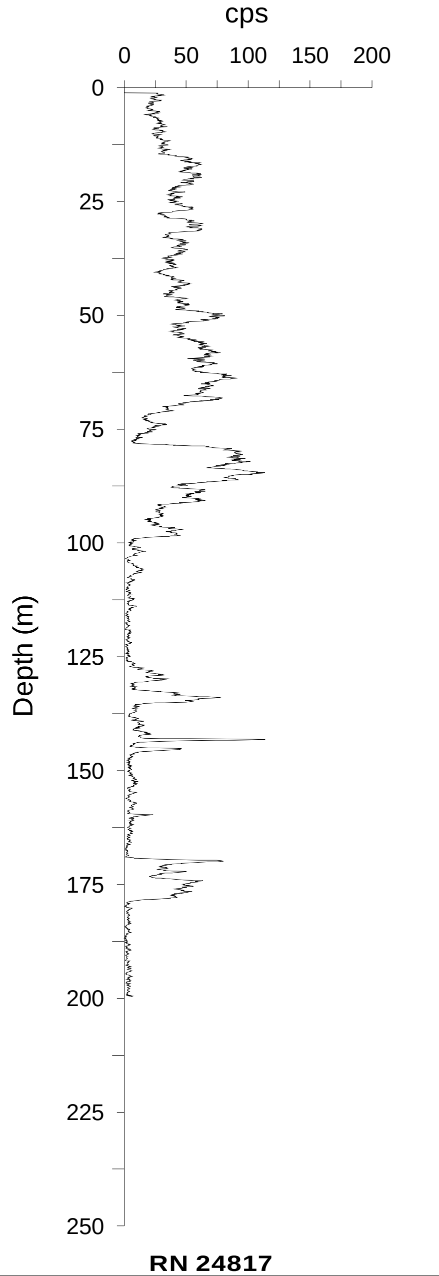
APPENDIX 1

Lithology, Stratigraphy and Gamma Logs of Selected Bores

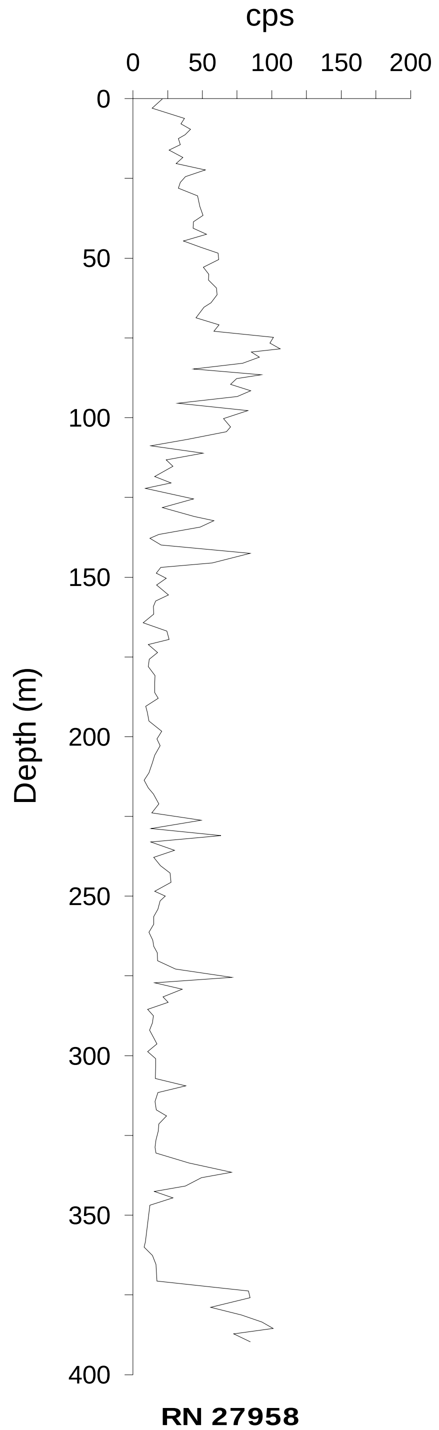
RN 24817

Interval	Lithology	Stratigraphy	
0 –2 2 – 3 3 – 20 20– 70 70 –75	Clay Limestone Weathered Limestone Powdery Sandy Clay Sandstone	Mullaman Beds	
75 – 200	No circulation (limestone with mudstone beds 75 – 100, 127 – 145m, 167 – 180m)	Montejinni Limestone	

Location : Australian Map Grid Zone 53 : 240350E 8145950N
Elevation : 273m AHD

RN 27958

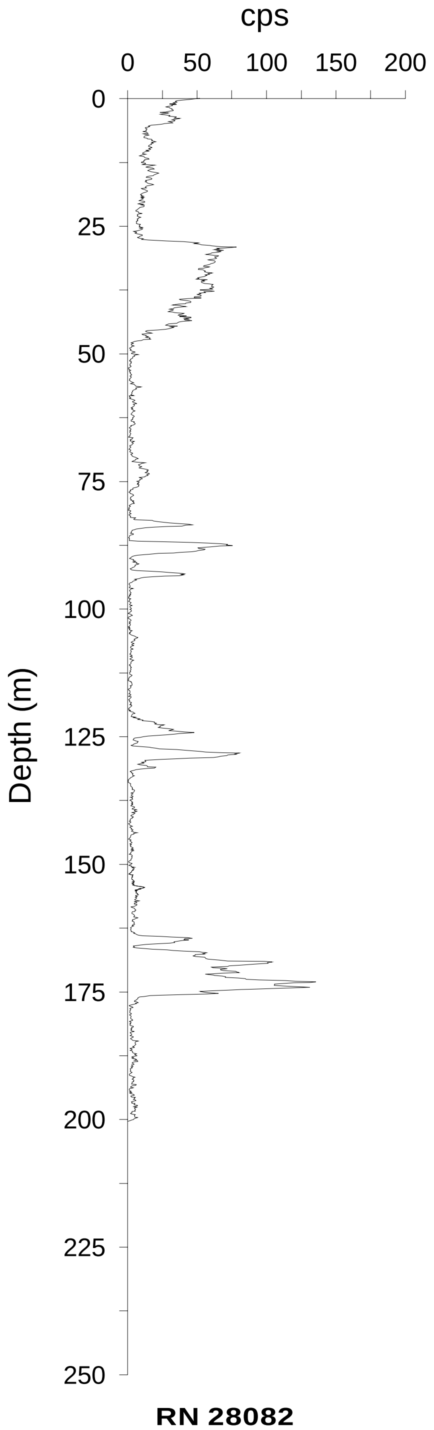
Interval	Lithology	Stratigraphy
0 – 10	Sand and clay	Mullaman Beds
10 – 48	White, grey and yellow, soft claystone	
48 – 63	Pale yellow, soft arenitic claystone	
63 – 78	Claystone with minor sandstone	
78 – 92	Claystone and brown/grey limestone	Anthony Lagoon Beds
92 – 105	Limestone and sandstone	
105 – 135	Orange and yellow claystone and sandstone	
135 – 204	White to pale orange, hard, oolitic, cavernous limestone, minor yellow sandstone	Gum Ridge Formation
204 – 230	Pale orange to off-white, hard sandy limestone	
230 – 241	Light grey soft claystone	
241 – 255	Hard grey limestone	
255 – 268	White, calcareaous claystone	
268 – 285	Grey, black and white cherty limestone	
285 – 328	Pale orange to off white cherty limestone with minor pale yellow claystone	
328 – 345	White and yellow, calcareous claystone	
345 – 361	Off white and grey cherty limestone	
361 – 377	Off white claystone with fine to coarse grained, calcareous sandstone	
377 – 475	Dark grey to black basalt	Antrim Plateau Volcanics



Location : Australian Map Grid Zone 53 : 368483E 8313102N
Elevation 260m AHD.

RN 28082

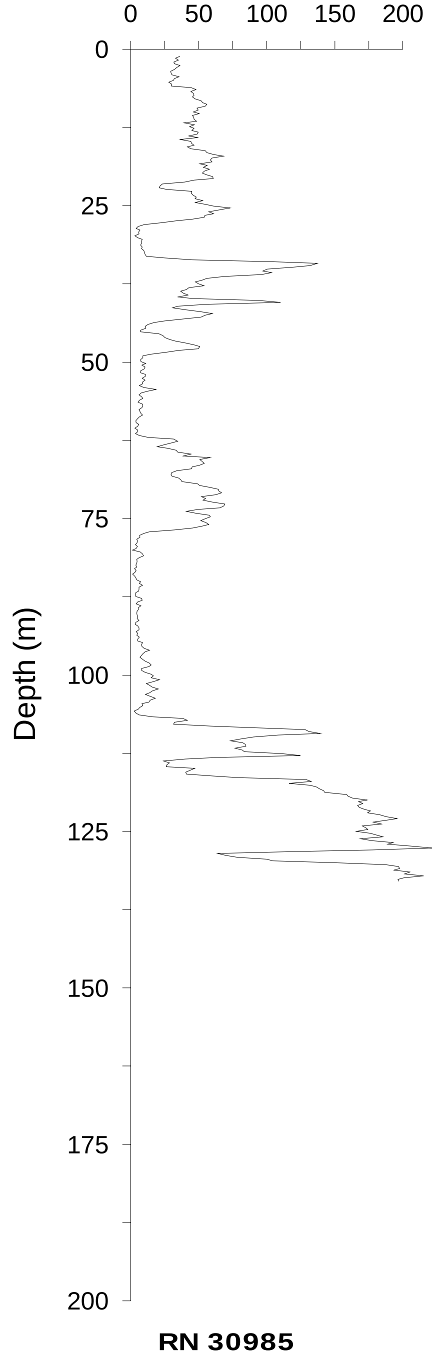
Interval	Lithology	Stratigraphy
0 – 4	Laterite and clay	Mullaman Beds
4 – 21	Yellow, red and white clay, minor quartz sand	
21 – 29	Red clay & quartz/sand	
29 – 39	Red/brown mudstone	Anthony Lagoon Beds
39 – 46	No circulation, probable mudstone	
46 – 54	No circulation, possible limestone	Gum Ridge Formation
54 – 102	Limestone, minor returns	
102 – 203	No circulation, possible limestone	



Location : Australian Map Grid Zone 53 : 309550E 8275150N
Elevation 184m AHD.

RN 30985

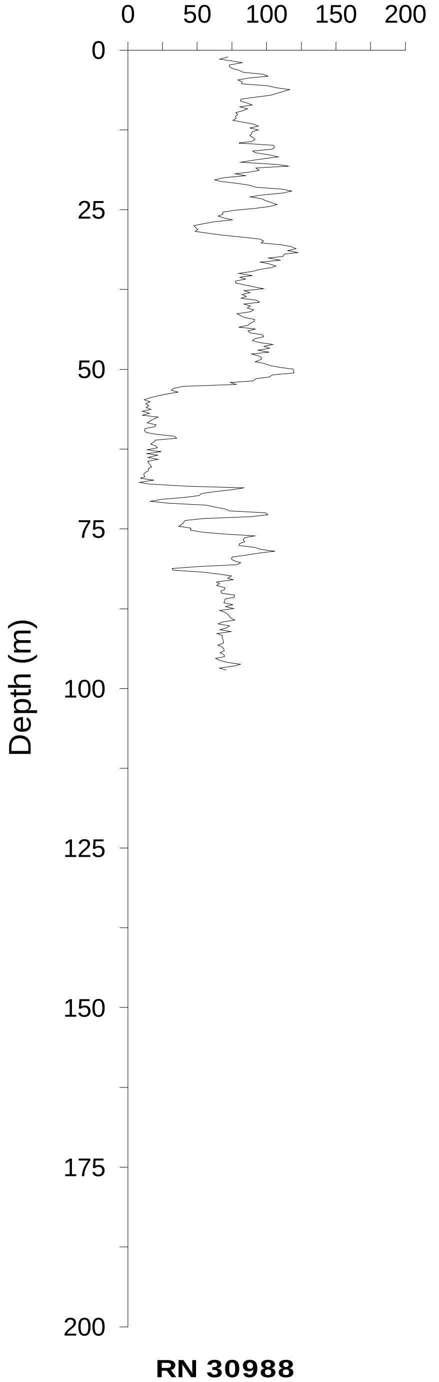
Interval	Lithology	Stratigraphy
0 – 7 7 – 15 15 – 21 21 – 27 27 – 33 33 – 36	Yellow clay and laterite Yellow, red and white clay Pink and purple siltstone Red and yellow siltstone White and yellow sandstone Yellow clay	Mullaman Beds
36 - 76	Khaki to yellow clays, chert and dark grey limestone	Anthony Lagoon Beds
76 – 98 98 - 107	Light grey limestone Dark and light grey crystalline limestone	Gum Ridge Formation
107 – 112 112 – 116 116 – 133	Green and white coarse sandstone, pink granite and scoria (various rubble), dark green/grey or black fine siltstone (basalt?) to 112m, Red and white sandstone Brown and white mudstone, siltstone and sandstone	Roper Group sediments



Location : Australian Map Grid Zone 53 : 326060E 8202230N
Elevation : 208m AHD (approx)

RN 30988

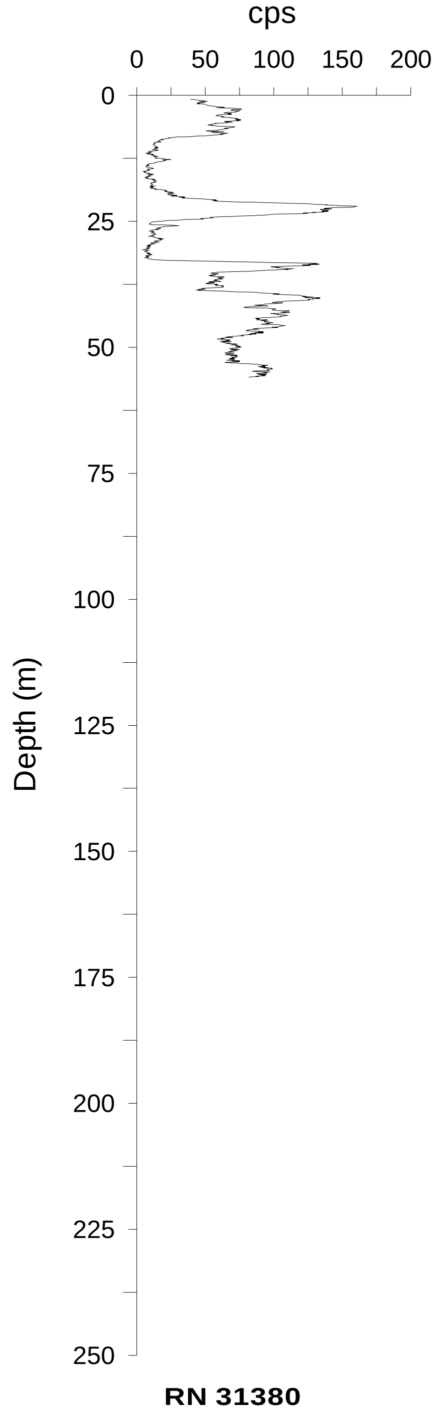
Interval	Lithology	Stratigraphy
0 – 3 3 - 8 8 – 20 20 – 51	Laterite and clay White claystone White siltstone Pink, yellow and white siltstone	Mullaman Beds
51 – 68 68 – 71 71 – 81 81 – 83	Grey and yellow limestone Yellow muddy limestone Brown mudstone Grey limestone and mudstone	Tindall Limestone
83 – 98	Blue/grey basalt	Antrim Plateau Volcanics



Location : Australian Map Grid Zone 53 : 247290E 8221980N
Elevation : 232m AHD

RN 31380

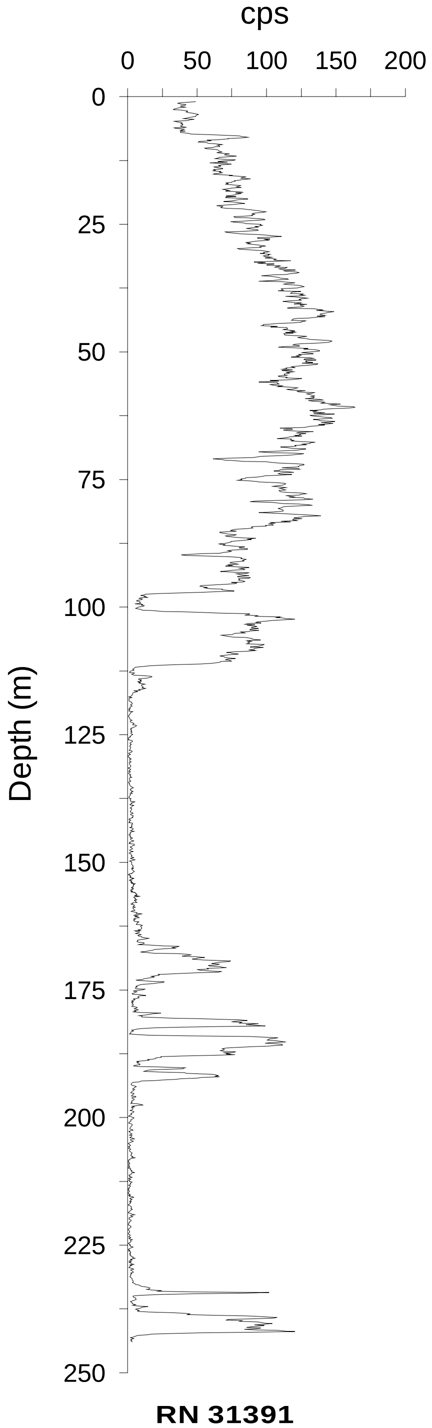
Interval	Lithology	Stratigraphy
0 – 2	Laterite and clay	Mullaman Beds
2 – 10	White, brown and red siltstone	
10 – 16	Brown sand	
16 – 20	Siltstone and black sand	
20 - 24	Yellow and brown siltstone	
24 – 33	White limestone	Tindall Limestone
33 – 44	Red mudstone	
44 – 51	Red, brown and green mudstone	
51 – 56	Basalt	Antrim Plateau Volcanics



Location : Australian Map Grid Zone 53 : 196340 E 8257810N
Elevation : 200m AHD (approx.)

RN 31391

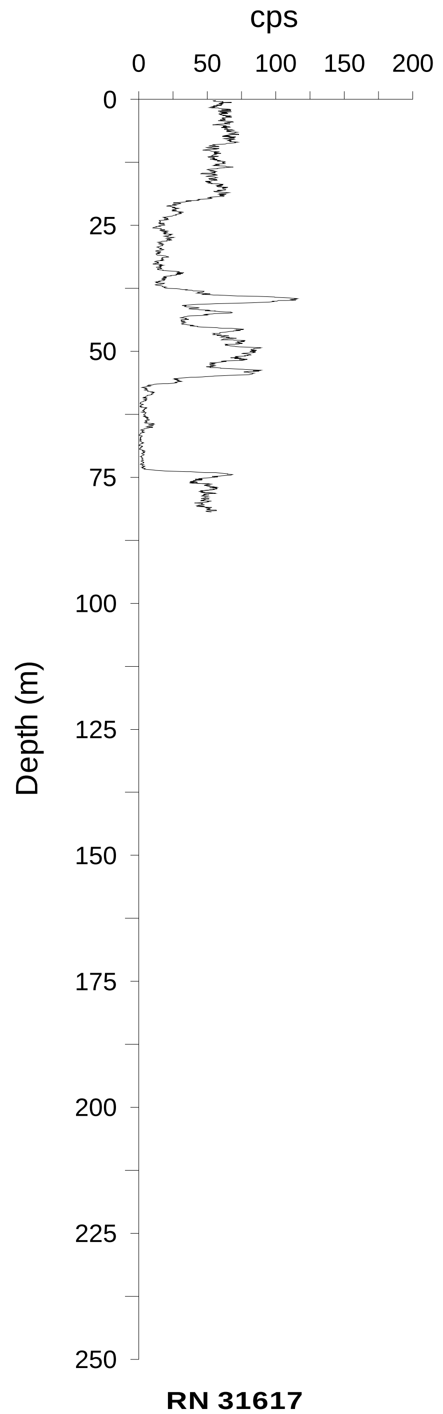
Interval	Lithology	Stratigraphy
0 – 13	White and brown sands	Mullaman Beds
13 – 70	Red, yellow and brown banded siltstone	
70 – 72	Yellow and brown limestone	Jinduckin Formation
72 – 88	Brown siltstone	
88 – 97	Brown and grey mudstone	
97 – 102	Green and yellow limestone	
102 - 112	Brown and grey mudstone	
112 – 126	White limestone	Tindall Limestone
126 – 140	Fresh white limestone	
140 – 145	White and yellow limestone	
145 – 170	No circulation	
170 – 179	Brown and yellow limestone	
179 – 185	Grey limestone	
185 – 188	Brown mudstone	
188 – 199	Brown and yellow limestone	
199 – 242	Fresh grey limestone	
242 - 244	White and yellow highly weathered limestone	



Location : Australian Map Grid Zone 53 : 187600E 8326000N
Elevation : 226m AHD (approx.)

RN 31617

Interval	Lithology	Stratigraphy
0 – 18	Clays	Mullaman Beds
18 – 24	Black basalt clays	
24 – 36	Sand	
36 – 51	Sand and gravels	
51 – 75	No circulation – broken limestone	Tindall Limestone



Location : Australian Map Grid Zone 53 : 229995E 8277330N
Elevation : 178m AHD (approx.)

APPENDIX 2

List of Bores with Gamma Logs

Bores are referred by Registered Number

319	5425	5942	6767
7246	7710	7741	7876
8016	8017	8513	8514
8857	21545	21784	22670
22858	24612	24616	24815
24817	26111	26112	26115
26116	26317	26546	26549
26553	27327	27331	27668
27793	27794	27958	28082
28085	28086	28087	28088
28190	28795	29012	29013
29026	29090	29091	29429
29430	29510	30335	30494
30507	30508	30509	30621
30656	30660	30695	30708
30709	30710	30711	30712
30714	30856	30866	30867
30870	30871	30873	30950
30951	30952	30985	30986
30987	30988	30989	30990
31108	31111	31133	31199
31380	31381	31382	31383
31387	31388	31389	31390
31391	31392	31393	31394
31395	31396	31397	31398
31399	31480	31482	31483
31384	31485	31489	31596
31605	31606	31617	31618
31630	31738	31749	31861
31867	31868	31921	31922
31923	31924	31925	31926
31950	31951	31952	31953
32162	31963	31964	31965
32213	32463		

APPENDIX 3

Chemical Analyses of Groundwaters

Bore RN	Sample Date	Specific Conduct. (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nit-rate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
550	10/3/68	1900	7.7	354	216	445	810	53	180		53		14	135	119	0.7	0.1		
	5/10/90	1680	6.8	514	627	573	1015	136	182	300	57		17	141	145	0.3	10.1		
	11/8/94	1650	7.0	514	627	604	1000	156	185	305	52	3	18	143	147	0.2	0.1	43	
	2/12/97	1648	7.5	103	126	682.8	969	55	186	306	133	3	10	127	164	0.5	9.2	26	1.2L/s, 38m, pumped
553	11/1/55				642	554	1427	97	265		76		11	175	155	1.6			
	10/3/68	1900	7.7	348	212	585	1060	75	315	8	87		14	190	170	0.8	0.7	49	pumped
554	11/1/55				354	285	790	8	165		64		3	115	81	0.5			
	2/8/68	1000	7.7	440	268	500	706	90	100		68		10	60	50		0.4	35	pumped
	10/3/68	900	7.3	322	196	338	540	42	98	1	44		6	65	58	0.7	0.1	31	pumped
555	11/1/55				525	484	1396	47	305		65		42	222	189	0.7			
	10/3/68	1900	7.5	328	200	445	1070	39	305		58		31	245	198	0.8	0.1		pumped as equipped
	5/10/70	1010	8.2	172	210	335	650	37	100	165	59		10	73	183	0.9	4.1		
556	8/28/68	2100	7.2	312	190	640	1315	175	465		70		24	240	175	0.6	0.2		
	6/10/70	2200	8.3	410	500	726	1650	160	520	852	77		21	252	176	0.5	0.5		pumped as equipped
557	11/11/55				588	550	1562	110	310		67		42	235	206	0.4			
	10/17/68	1900	7.4	362	221	540	1150	42	305		60		31	240	205	1	0.2		
558	10/2/68	1550	7.4	308	188	430	940	43	254		53		22	180	138	0.7	0.1		pumped as equipped
	5/9/69	1800	6.9	434	529	448	1130	130	266		54		24	210	157	0.5	0.5		
	2/19/72	1850	7.4	446	544	577	1120	137	272		57	6	21	180	161	0.7	0.1	31	pumped as equipped
	3/8/76	1980	6.9	415	506	566	1060	136	280	461	55	7	22	184	182	0.4	0.1	38	pumped as equipped
903	26-07-67	588	7.8	312	190	308	340	46	10		46		0.6	8	1		0.1		
	01-07-69	550	7.6	317	386	300	290	76	10		27		1	9	2	0.1	0.1		
904	26-07-67	1086	7.8	96	59	155	663	6	305		34		3.2	200	1	0.9	0.3		
	01-07-69	1050	7.55	108	132	106	640	30	294		5		3	195	3	1	0.4		
905	26-07-67	303	10.1	124	76	4	254	1	22		1		0.3	90	1	0.5	0.1		
	01-07-69	310	10	132			240	1	20		1		1	95	14	0.6	0.1		
906	26-07-67	471	7.88	234	143	202	311	5.5	14		45		2.8	30	2		0.2		
	01-07-69	470	7.45	258	315	226	340	60	12		16		3	32	2	0.2	0.2		
1982	6/6/98	702	6.3	401	489	392	398	101	2	3	34	1	5	3	11	0.1	0.7	28	0.5L/s, pumped as eq.

Bore RN	Sample Date	Specific Conduct. (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nit-rate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
2186	10/8/56				522	513	1124	101	190		63		14	125	101				
	1/15/69	1450	7.2	498	304	585	960	145	180		52		13	138	104	1.3	0.2		
2326	10/15/68	1600	7.4	416	254	580	1010	65	200		78		7	160	201	0.6	0.1		
2379	10/15/68	395	7.3	222	135	218	200	50	6		5		2	3	2	0.1	0.3		
3545	10/15/68	430	7.9	220	134	190	250	27	16		28		5	22	2	0.4	6.1		
4142	10/15/68	530	7.9	276	168	72	310	14	14	23	8		7	105	2	0.2	0.2		
4495	10/14/68	690	7.8	342	209	286	360	43	16	26	44		4	39	17	0.6	0.4		
4529	10/12/64	1000	7.4	140		44	794		288										
	6/11/66	1670	6.9	527	321	690	1390	97	254		107		28	215	80	0.1	0.44		
	10/11/68	1800	7.9	1080	344	505	1080	65	295		81		22	210	203	0.8	0.3		pumped as equipped
5149	10/2/65	1900	8.1	362	192	620	1039	36	218		127		21.5	249	96		0.1		
5152	10/15/68	800	7.5	216	132	222	490	37	108		32		9	95	54	0.6	1.4		
5395	4/5/66	1900	7.2	466	284	498	1193	115	269		50		34.5	233	234	0.3	0.1		
5492	7/25/66	1552	6.8	544	332	640	1312	205	266		30.7		34	212	20	0.3	0.26		
	2/8/68	1950	7.5	436	266	520	1130	70	280		60		33	225	178	1	0.2	43	pumped
	7/6/82	2150	7.6	554	676	615	1350	146	270	440	61	3	46	222	198	0.9	0.3	42	2.2L/s, 55.3m
5557	9/1/66	758	7.8	320	195	280	422	26	56	99	52		8	60	5		0.6		
	10/15/68	700	8.1	326	199	292	390	43	60	100	43		7	55	4	0.5	0.3		
	9/1/67	1450	7.8	470	288	585	810	105	45		77	3	24	130	100		0.4		
5877	9/2/67	1500	7.8	478	291	610	922	102	45		83		23	125	100		0.2		
	10/5/67	1450	7.6	484	294	556	879	95	50		76	3.5	3	140	100		1.5		
	10/30/80	1780	6.9	481	586	580	960	135	190	305	59	4	13	131	128	0.2	0.1	43	pumped
	9/19/85	1550	7.3	436	531	530	940	120	176	290	56		12	121	131	0.2	0.3		
5928	7/9/92	845	6.7	467	570	490	520	135	20	34	37	3	4	6	20	0.1	1.6	37	1.2L/s, 53m, pumped
5929	7/20/99	1730	6.9	376	459	531	1060	124	218	359	54	5	27	245	180	0.5	0.1	37	pumped as equipped
6223	7/15/99	2240	7.1	445	543	632	1370	148	334	550	64	7	27	240	230	0.4	0.8	38	2 L/s, pumped as eq.

Bore RN	Sample Date	Specific Conduct. (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nit-rate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
6744	11/1/69	1150	7.9	299	364	368	940	69	172		52	1	15	121	116	0.4	9.2	41	43m, pumped
	5/13/84	1630	6.8	484	590	552	930	134	180	300	53		18	134	124	0.3			
	5/23/84	1580	6.7	483	589	576	970	140	170	277	55		17	134	135	0.3	2.9		4.5L/s, 37.5m
	5/24/84	1600	6.7	485	591	576	980	140	180	293	55	2	17	135	135	0.3	2.7	43	4.5L/s, 37.5m
6745	11/1/69	700	7.7	482	588	416	550	112	12		44		5	12	15	0.2	0.1	38	
	6/3/98	831	6.4	459	560	463	493	126	5	8	36	1	4	8	24	0.3	0.1	39	1.5L/s, pumped as eq.
6845	21-01-70	445	8	228	278	240	340	82	12		11		4	7	23	0.1	0.7		
	01-10-70	360	8.6	202	227	167	210	11	8		34		4	12	9	0.2	3.8		2.5L/s, 90m
	05-06-98	677	6.4	365	445	355.5	400	134	9	15	5	1	2	4	15	0.1	2	26	
7191	11/11/70	1000	7.6	249	303	307	640	54	134		42	2	28	102	130	0.7	4.6	28	53m
7192	11/11/70	1140	7.7	274	334	341	680	59	136		47	2	18	105	126	0.6	0.2	29	1L/s, 58m, pumped as eq.
7321	10/10/71	1360	8.1	308	376	327	800	37	204		57	4	30	159	146	0.5	0.1	41	3L/s, 58m, pumped as eq.
7323	11/5/70	1100	8.3	551	672	268	650	7	67		61		18	170	22	1.1	4.4		6L/s, 61m
7686	7/28/71	1180	7.8	490	598	536	720	129	72		51		9	52	105	0.5	10		
7687	7/28/71	1210	7.5	442	539	520	760	129	89		48	1	62	48	134	0.5	6.4	29	pumped as equipped
	10/3/71	1050	7.4	296	361	400	610	78	97		50	1	11	65	129	0.5	9	30	pumped as equipped
7725	10/3/71	1160	7.5	404	493	488	710	118	85		47	1	10	62	113	0.5	2.9	29	
7755	10/3/71	800	7.4	363	443	390	470	87	30		42		6	24	52	0.4	0.9		
7872	5/19/72	900	8.1	187	228	364	620	52	90	148	57		10	64	205	0.2	1		1.5L/s, 102m, airlift
	11/1/99	1210	7.5	453	552	512	744	126	102	168	48	1	9	67	140	0.4	0.1	31	2 L/s, pumped as eq.
7873	5/30/72	960	8.2	156	190	289	640	33	125	206	50	1	18	93	185	0.7	5	45	2L/s, 102m, airlift
	3/17/80	560	7.3	248	302	252	264	58	7	12	26		1	5	11	0.1	0.1		0.6L/s
	11/1/99	981	7.5	395	482	443	634	110	57	94	41	6	7	40	89	0.3	0.2	32	2 L/s, pumped as eq.
7875	5/24/72	950	8.1	211	257	285	570	36	122	204	47	2	16	90	115	0.6	5.7	33	1.5L/s, 100m, airlift
7876	11/1/99	1470	7.4	425	518	589	906	139	188	310	59	1	7	87	150	0.3	0.1	32	2.5 L/s,pumped as eq.
8017	10/10/72	1590	8.2	262	320	331	930	34	269	443	60	1	32	200	176	0.4	0.8	59	airlift (as drilled)

Bore RN	Sample Date	Specific Conduct. (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nit-rate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
8149	7/21/73	690	7.4	12	15	43	380	7	140	231	6	1	1	116	87	0.9	14	25	1.9L/s, 67m, airlift
8241	11/14/73	1010	6.9	122	148	243	650	48	141		30	3	1	120	198	0.3		12	3L/s, 60m, airlift
8361	7/18/74	2860	7.3	508	619	1000			470	775									19L/s, pumped
	7/18/74	2570	7.3	513	625	930			442	728									19L/s, pumped
8361	7/19/74	2650	7.3	510	622	940	1810	184	413	681	117	3	26	245	415	0.8	0.1	44	19L/s, pumped
8362	7/20/74	2560	7.3	511	623	940			403	664									24L/s, pumped
	7/20/74	2660	7.3	510	622	980			442	728									24L/s, pumped
	7/21/74	2570	7.3	518	631	912	1785	176	394	649	115	3	28	242	415	0.8	0.1	45	24L/s, pumped
8513	10/22/74	520	7.9	267	326	258	270	26	5	8	47	1	3	8	11	0.4	12	33	2.3L/s, 91m
8514	10/20/74	1070	7.8	312	380	462	690	76	68	120	64	2	6	43	176	0.5	6	23	1.1L/s, 73m, airlift
	6/7/98	1107	6.5	437	533	530	707	138	39	64	45	1	5	45	164	0.3	1.2	46	2L/s, pumped as eq.
8684	3/2/79	2100	6.8	545	665	630	1286	148	270	445	66	6	40	215	205	0.6	0.2	44	pumped as eq.
8699	7/8/75	1330	7.8	290	354	361	780	56	159	262	54	3	15	128	124	0.2	2.7	40	4.5L/s, 73m, airlift
	7/8/75	1610	7.7	299	365	381	780	62	186	307	55	4	16	137	124	0.2	1.6	40	4.5L/s, 73m, airlift
	4/15/81	1750	7.1	490	598	584	960	140	186	306	57	4	15	124	126	0.3	0.1	43	pumped as equipped
	4/17/84	1610	7.4	479	583	572	950	135	180	293	57	4	15	128	148	0.2	0.2	42	pumped as equipped
8856	5/17/76	1650	7.1	399	486	509	960	120	194	320	51	3	23	150	148	0.4	0.5	38	19.4L/s, pumped
	5/17/76	1880	7.5	407	496	521	1110	118	243	400	55	6	29	183	178	0.4	0.3	40	19.1L/s, pumped
	5/17/76	1990	7.3	387	472	533	1180	118	272	448	58	6	31	195	196	0.5	0.4	41	19.1L/s, pumped
	4/17/84	1800	8.2	431	526	576	1060	135	250	409	58	6	24	169	148	0.2	0.2	40	pumped as eq.
	9/19/85	1800	6.9	428	521	557	1140	129	240	390	57		20	154	151	0.3	0.6		pumped as eq.
	7/14/89	2130	7.3	458	559	555	1295	122	320	527	61	9	35	268	222	0.5	0.1	42	pumped as eq.
	6/8/98	2103	7.3	460	561	558	1281	120	305	503	63	8	31	230	230	0.4	0.2	39	2L/s, pumped as eq.
20745	4/15/81	1260	7.7	423	516	398	950	46	130	214	69		25	161	182	1	16		6L/s, 9m, airlift
	5/23/81	600	7.5	215	262	276	380	76	50	80	21		4	13	11	0.1	0.6		1.5L/s, 8m, pumped
20746	4/15/81	2420	7.5	436	531	707	1490	86	340	560	120		35	272	413	0.8			6L/s, 16m, airlift
	5/22/81	2740	7.5	533	650	815			387	638									4L/s, 12.3m, pumped
	5/22/81	2710	7.2	531	647	808	1700	120	378	620	124		38	290	430	0.8	4.4		4L/s, 12.3m, pumped

Bore RN	Sample Date	Specific Conduct. (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nit-rate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
20747	4/16/81	2400	7.6	421	513	678	1490	86	342	564	113	2	34	274	415	0.9		52	6L/s, 13.5m, airlift
	5/23/81	2720	7.3	531	647	831	1690	124	390	644	127	1	37	290	423	0.8	0.8	53	6L/s, 9.1m, pumped
	9/28/93	1880	7.3	546	666	682	1160	138	211	348	82	1	22	164	228	0.5	0.4	52	pumped as equipped
	4/24/97	3050	7.5	543	662	861	2048	90	500	824	155	2	32	345	508	0.5	0.1	56	3L/s, 30m, pumped
21117	9/30/81	680	7.6	405	494	362	420	62	7	12	51	1	4	11	19	0.4	21.5	31	0.9L/s, 114m, airlift
	10/28/81	900	8.0	220	268	108	520	24	125	203	11	1	3	156	51	0.8	0.3	20	0.5L/s, 107m, pumped
21783	8/22/83	960	7.8	442	539	475	600	118	55	91	44	1	7	38	52	0.2	3.3	25	6L/s, pumped
	6/7/98	1015	6.5	437	533	456	584	115	58	96	41	2	6	40	56	0.1	0.1	32	3L/s, pumped as eq.
21784	27-09-82	280	7.2	148	181	146	150	42	4	8	10		3	1	5	0.1		12	4L/s, 58m, airlift
	21-11-97	312	6.6	168	205	150.1	172	42	2	3	11	1	2	1	8	0.2	0.2	15	4L/s, 58m, pumped
22101	30-06-83	750	7.5	300	366	335	440	89	38	63	29	3	6	38	56	1.3	1	24	8L/s, 90m, airlift
	02-05-86	855	7.2	413	504	445	495	124	30	48	33	1	3	22	30	0.1	0.1	36	Homestead tap sample
	20-06-86	825	7.6	413	503	416	520	122	34	56	27	1	3	22	29	0.2	1.2	33	12.2L/s, 74m, pumped
22669	8/24/83	1830	7.9	276	336	357	1040	46	270	440	59	6	40	224	207	0.6		42	1.1L/s, 67m, airlift
22670	8/25/83	1970	7.6	317	387	416	1180	58	310	510	66	5	41	246	234	0.6		46	1.2L/s, 67m, airlift
22858	6/19/84	1860	7.5	374	456	474	1120	88	290	473	62	3	24	201	198	0.3	3.9	42	1L/s, 78m, airlift
22859	6/21/84	1360	7.8	295	359	377	770	44	170	285	65	1	10	137	150	0.3		14	2L/s, 66m, airlift
22860	6/23/84	1780	7.6	405	494	429	1090	70	248	409	62	5	22	196	181	0.2		43	3L/s, 66m, airlift
	7/20/99	1460	7.1	402	490	530	897	130	149	246	50	2	18	113	150	0.4	0.1	34	pumped as equipped
22861	7/2/84	700	7.4	321	392	316	410	67	36	58	36	1	4	27	35	0.1	5	32	2.5L/s, 52m, airlift
	7/2/84	720	7.4	322	393	321	400	69	36	59	36	1	5	28	34	0.1	8	31	2.5L/s, 52m, airlift
	7/20/99	829	7.1	319	389	441	492	114	18	30	38	1	4	13	29	0.1	0.1	27	pumped as equipped
23377	8/2/84	1970	7.3	306	373	409	1220	65	330	539	60	1	30	242	246	0.4		31	2L/s, 81m, airlift
23662	7/20/99	1940	7.0	443	540	606	1190	144	252	415	60	5	22	185	190	0.3	0.4	40	pumped as equipped
23833	03-05-85	330	7.4	135	165	73	260	8	24	40	13		3	41	11	0.6			
23859	26-06-85	770	6.8	420	512	419	480	130	12	20	23	1	2	11	13	0.2	0.2	55	1.2L/s, 54m, pumped

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24612	24-05-86	650	8	200	250	210	400	20	60	100	40	1	5	50	45	0.1	0.3	50	20L/s, 103m, airlift
	19-06-86	1060	7.1	483	589	494	675	135	28	44	38	1	4	49	51	0.2	0.8	46	40L/s, 85m, pumped
24616	5/29/86	1410	7.8	365	445	441	860	106	180	293	43	2	18	145	139	0.2	10	42	4.8L/s, 80m, airlift
	11/27/87	1570	6.9	100	120	560	630	75	180	295	40	2	10	80	140	0.2	0.5	45	8L/s, 37.2m, pumped
24783	10-08-86	630	7.6	266	325	269	370	50	20	31	35		7	23	54	0.3	6.3	21	2L/s, 105m, airlift
24784	24-09-86	805	7.9	442	539	434	490	116	8	13	35	1	3	9	16	0.3	0.2	43	5L/s, 65m, airlift
	03-06-98	872	6.4	496	605	483.3	517	131	7	12	38	1	3	9	18	0.1	0.1	42	3 L/s, pumped as eq.
24785	12-08-86	645	7.7	294	358	273	365	45	8	13	39	1	6	30	60	0.3	15	17	0.5L/s, 150m, airlift
24815	5/4/87	850	7.2	400	488	407	490	97	21	35	40		7	16	24	0.2	0.2		3L/s, 157m, airlift
	5/4/87	830	7.3	389	474	393	465	93	22	36	39		6	16	24	0.2	0.6		3L/s, 157m, airlift
24816	5/14/87	850	7.1	408	498	440	505	104	23	38	44	1	5	13	20	0.4	0.6	37	6.6L/s, 192.5m, airlift
	5/14/87	840	7.2	402	490	410	470	103	22	36	37	1	5	12	19	0.4		35	6L/s, 192.5m, airlift
24817	5/11/87	800	7.3	340	415	357	430	85	27	45	35	1	6	22	33	0.5	1	26	8L/s, 201.5m, airlift
25209	1/13/95	862	6.5	486	592	520	494	139	10	16	42	1	3	8	18	0.2	1.9	31	3L/s, 115m, airlift
25279	31-08-87	610	7.3	308	376	317	385	94	13	21	20	1	2	5	13	0.2		40	3L/s, 62m, airlift
25290	29-08-87	495	7.6	267	326	249	310	55	10	18	27	2	3	8	9	0.2	1.3	40	7L/s, 80m, airlift
25437	5/10/90	1680	6.8	514	627	573	1015	136	182	300	57	3	17	141	145	0.3		45	pumped as equipped
26053	17-09-88	525	8.2	205	250	56	350	16	22	36	4	1	2	96	40	1.2		47	0.4L/s, 103m, airlift
26112	01-10-88	1010	7.1	83	102	236	535	68	228	376	16		4	110	50	0.4	7.4		2L/s, 100m, airlift
26113	23-09-88	520	8.2	259	316	242	332	28	20	33	42		2	24	12	0.3	14.3		7L/s, 66m
26115	10-10-88	355	7.6	177	216	127	250	21	8	13	18	1	6	32	9	0.5	16.7	64	7L/s, 46m, airlift
	28-11-97	197	6	95	116	89.4	187	21	8	13	9	1	3.7	15	5	0.2	0.4	67	1L/s, 15m, pumped
26116	05-10-88	325	7.9	168	205	161	205	48	2	3	10	2	3	5	7	0.2	6.6	20	9L/s, 89m, airlift
	05-10-88	445	7.6	225	275	217	275	54	11	18	20	1	3	9	9	0.2		43	9.5L/s, 89m, airlift
	21-08-97	628	6.8	335	408	204	360	75	4	7	4	1	3	4	15	0.1	0.2	21	7 L/s, pumped as eq.
	03-06-98	778	6.36	434	529	411.8	465	127	13	21	23	1	2	10	17	0.1	0.1	39	13L/s, 70m, pumped

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26265	19-09-88	405	7.8	160	195	160			36	59									2L/s, 36m, airlift
26314	7/20/99	1200	7.2	413	503	548	751	142	74	122	47	1	8	56	120	0.3	1	30	pumped as equipped
26315	7/20/99	1660	7.2	390	475	542	1030	130	196	323	53	4	23	148	170	0.5	0.2	36	pumped as equipped
26316	7/20/99	1760	7.0	427	520	575	1090	135	215	354	58	3	18	158	160	0.2	0.2	39	pumped as equipped
26366	7/6/89	1595	7.0	510	622	589	1005	142	179	295	57	3	15	142	140	0.3	2.6	47	0.7L/s, 64.3m, pumped
26367	7/7/89	2720	7.5	129	157	313	1560	94	795	1310	19	1	10	456	11	1	0.5	22	1.7L/s, 51.9m, pumped
26549	06-07-89	545	7.9	263	321	270	340	47	8	13	37	1	5	10	34	0.3	6	40	5L/s, 91m, airlift
	26-06-94	912	7.7	492	600	604	532	138	11	18	63	1	5	11	43	0.3	11.2	42	
26553	03-07-89	515	7.6	269	328	259	315	48	11	18	34	1	4	10	9	0.3		38	4.5L/s, 105m, airlift
27124	11-11-90	940	7.6	326	398	342	580	58	82	135	48	1	7	71	67	0.2	0.2	51	airlift (as drilled)
27328	5/7/91	1865	7.4	318	387	523	1120	112	350	577	59	5	21	205	152	0.2	6.3	38	1.5L/s, 77m, airlift
	7/15/99	2160		468.0	571	625	1290	150	352	580	61	6	20	199	180	0.3	0.1	39	pumped as equipped
27330	7/20/99	1250	7.0	461	562	515	763	132	94	155	45	1	10	66	120	0.3	0.2	28	pumped as equipped
27331	11/1/90	630	7.2	291	355	274	360	57	27	44	32	3	7	25	20	0.7	4	26	0.1L/s, 117m, pumped
	6/5/98	702	6.4	357	435	343	412	78	15	25	36	1	6	21	25	1.3	0.1	42	0.3L/s, pumped as eq.
27332	7/20/99	1560	7.0	500	609	551	936	135	163	269	52	2	18	115	150	0.4		32	pumped as equipped
27337	6/3/98	853	6.4	476	580	479	510	126	6	10	40	1	4	9	30	0.3	0.1	42	1.5L/s, pumped as eq.
	5/28/99	831	7.8	464	566	443	500	110	5	8	41	1	4	10	31	0.2	0.1	43	2L/s, pumped
27341	6/5/98	750	6.4	422	515	421	430	111	3	5	35	1	3	5	12	0.2	0.1	32	2L/s, pumped as eq.
27793	28-06-91	1160	7.7	284	346	310		57	191	315									1.5L/s, 73m, airlift
27794	29-06-91	1240	7.5	360	440	418		83	161	265									5L/s, 75m, airlift
	24-11-97	1492	6.9	518	632	542.5	898	135	169	279	50	1	4	108	106	0.6	1.4	54	17L/s, 65m, pumped
28082	5/28/92	1615	7.0	491	598	588	975	143	183	301	56	4	16	129	142	0.4	0.2	43	10L/s, 54m, pumped

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28086	30-06-92	1010	7.9	91	111	228	520	60	243	400	19	1	4	96	8	2		41	5L/s, 85m, airlift
28087	7/2/92	825	7.5	445	543	432	480	112	12	20	37		4	15	19	0.3		38	65m, bailed
28190	07-08-92	880	7.5	285	348	342	500	89	117	193	29	1	4	56	15	0.2		35	2L/s, 68m, airlift
	28-07-92	3920	6.3	14	17	1088	2020	353	1238	2039	50	1	8	292	43	0.2		5	0.5L/s, 125m, airlift
	06-08-92	5420	7.5	109	131	292	3171	94	1792		14	0.6	18	1023	16				2L/s, 260m, airlift
	06-08-92	5460	7.8	89	109	320	3115	100	1733	2855	17	1	14	976	13	1.3		9	2L/s, 260m, airlift
28190	16-10-98	3900	7.5	245	299	254.7	2092	74	1188	1958	17	1	9	660	29	1	0.4	22	2 L/s, pumped as eq.
28314	6/25/93		7.8		397	435	670	102	83		44		8	80	114		0.1		
29012	1/11/94	1740	7.2	504	615	603	1080	149	190	313	56	4	28	164	175	0.4	0.2	42	18L/s, 76m, pumped
	11/28/97	1730	6.7	498	607	536	1060	126	211	348	54	4	24	155	190	0.1	0.2	39	1L/s, 45m, pumped
29013	1/15/94	2310	7.2	546	666	664	1360	157	282	465	66	4	37	242	232	0.4	0.1	48	10L/s, 51.5m, pumped
29014	1/14/94	1570	7.0	484	602	609	961	155	165	272	54	3	16	128	138	0.2	0.1	44	10L/s, 63.5m, pumped
29537	9/4/97	1371	6.6	238	290	307	818	59	204	336	39	6	14	144	159	0.4	3.8	29	3.3L/s, 73m
	9/4/97	1475	7.1	308	376	357	884	56	216	356	53	6	18	158	166	0.4	0.4	37	3.3L/s, 73m
	7/19/99	1250	7.3	504	614	541	776	131	82	135	52	1	8	58	110	0.4	0.1	43	pumped as equipped
29706	8/23/97	993	6.4	251	306	316	592	46	101	166	49	1	10	75	139	0.5		32	5L/s, 83m
	7/22/99	1330	7.3	496	605	540	819	134	101	166	50	1	11	72	130	0.4	0.1	30	pumped as equipped
29707	8/24/97	1146	6.4	260	317	299	679	41	154	254	48	1	18	113	135	0.5		32	2L/s, 72m
	7/22/99	1480	7.3	494	602	515	888	124	151	249	50	2	18	110	130	0.4	0.1	32	pumped as equipped
29708	8/25/97	1301	6.7	283	345	333	772	51	182	300	50	1	15	128	145	0.5		29	2L/s, 77m
	7/19/99	1590	7.3	505	616	535	963	127	183	302	53	3	15	129	130	0.5	0.1	36	pumped as equipped
29769	9/2/94	741	7.1	424	517	442	450	116	3	5	37	1	3	11	14	0.2	0.1	46	5L/s, 78m, airlift
	5/28/99	869	7.5	509	620	462	520	111	2	3	45	1	3	12	20	0.2	0.1	48	pumped
30494	4/18/98	1581	8.0	332	405	390	935	61	208	343	58	4	26	159	183	0.4	0.8	45	20L/s, 91.4m, airlift
	5/26/98	1756	6.3	511	623	609	1057	142	204	336	62	4	25	162	176	0.4	0.2	39	93L/s, 65m, pumped
30498	4/22/98	842	8.0	277	338	332	522	54	71	117	48	1	7	46	98	0.4		46	3L/s, 60m, airlift

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30507	05-06-98	621	6.3	278	339	208.6	375	49	32	53	21	1	4	48	21	0.3		48	Seepage, 60m, airlift
30654	6/10/96	516	7.6	262	319	254	290	26	10	16	46	2	5	14	23	0.2		33	0.5L/s, 76m, airlift
	8/13/96	911	7.1	522	636	508	532	113	6	10	55	1	4	10	26	0.3	2.1	46	0.3L/s, 76.8m, pumped
30655	6/11/96	678	7.4	344	419	319	375	52	14	23	46	1	6	14	27	0.2		47	2L/s, 79m, airlift
	8/15/96	834	7.2	454	553	438	498	95	11	18	49	1	5	12	26	0.3	0.1	51	2.5L/s, 77.4m, pumped
30656	6/1/96	451	7.1	236	288	237	250	62	6	10	20	1	2	5	17	0.3	3	24	3L/s, 77m, airlift
	8/21/96	797	7.0	429	523	423	474	128	8	13	25	1	3	7	27	0.2	0.2	31	14L/s, 77.4m, pumped
30660	18-04-96	1070	7.5	332	405	298	589	47	122	201	44	1	4	103	61	0.4		38	airlift (as drilled)
	23-08-96	1340	7.1	531	647	499	791	121	119	196	48	1	3	97	55	0.2	0.3	48	3L/s, 40m, pumped
30710	5/28/97	660	7.1	341	416	366	380	71	16	26	46	1	5	15	24	0.3	0.2	45	1.3L/s, 67m, airlift
	9/12/97	849	6.8	482	588.2	438	479	98	6	10	47	1	5	25	23	0.5	2.3	34	0.7L/s, 73.6m, pumped
30714	9/10/97	553	8.1	244	297	27	338	6	36	59	3	1	2	122	19	2	0.3	27	2L/s, 82.9m, pumped
	8/14/00	618	8.2	235	286	28	363	8	4	7	2	1	2	121	17	1.6	0.1	22	2L/s, pumped as equipped
30865	11-07-96	500	7.3	281	343	255	290	51	5	8	31	1	2	7	11	0.2	4.3	38	airlift (as drilled)
30866	12-07-96	639	7.6	299	364	279	378	51	29	48	37	1	3	26	30	0.2	4.5	53	airlift (as drilled)
30869	8/1/96	1472	7.6	333	406	399	888	71	194	320	54	3	23	143	166	0.5	2.9	36	4.5L/s, 61m, airlift
	7/21/99	1740	7.1	492	600	520	1040	121	218	359	53	4	26	161	170	0.4	0.1	34	pumped as equipped
30870	8/3/96	464	7.2	166	202	223	296	48	6	10	25	2	3	5	28	0.2	0.5	21	2L/s, 78m, airlift
	6/5/98	674	6.3	382	466	376	389	111	2	3	24	1	3	2	10	0.1	0.1	22	1.5L/s, pumped as eq.
30871	8/5/96	487	7.4	232	283	266	296	49	3	5	35	1	3	3	12	0.3		27	
	8/24/99	748	7.4	430	524	426	432	108	2	3	38	1	3	4	17	0.1	0.1	27	1.4L/s, 86.8, pumped
30873	27-08-96	468	7.3	238	290	124	288	30	13	21	12	1	2	61	7	0.2	0.1	52	2L/s, 46m, pumped
	05-08-96	421	8.1	214	261	79	273	12	13	21	12	1	2	65	9	0.4	1	49	2L/s, 60m, airlift
30915	7/19/99	1430	7.2	393	479	577	895	144	129	213	53	1	14	95	140	0.4	0.1	36	pumped as equipped
30985	8/22/98	1944	7.7	338	412	438	1166	72	312	514	63	6	27	217	247	0.3	6.1	36	4L/s, 133m, airlift
	10/13/98	2021	7.3	409	499	559	1226	122	332	547	62	5	24	197	233	0.4	0.2	32	6L/s, 95m, pumped

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30987	8/26/98	654	7.7	358	436	327	390	57	10	16	45	1	5	8	14	0.2		34	4L/s, 92m, airlift
	10/10/98	873	7.3	497	606	467	479	113	9	15	45	1	5	6	29	0.2	0.4	36	5L/s, 88m, pumped
30989	8/29/98	583	7.7	321	391	299	356	64	6	10	34	1	4	7	14	0.2		25	1L/s, 109m, airlift
31108	31-07-97	741	6.9	343	418.8	341.1	403	61	31	51	46	1	5	27	33	0.4		40	8L/s, 155m, airlift
	15-06-98	903	6.7	445	543	449.7	536	111	24	40	42	1	3	25	36	0.1	0.8	47	12L/s, 100m, pumped
31381	12-06-98	1198	6.8	485	591	505.7	713	117	86	142	52	1	7	72	16	0.2	0.6	48	10L/s, 60m, pumped
31382	03-10-97	638	7.6	316	385	271.2	383	56	15	25	32	1	2	28	23	0.1	0.4	54	2L/s, 70m, airlift
	25-11-97	812	6.8	420	512	331.2	515	80	18	30	32	1	2	24	40	1.2	0.2	60	2L/s, 64m, pumped
31391	03-12-97	587	6.5	247	302	252.4	331	37	30	49	39	1	6	26	42	0.5	1.1	36	2.6L/s, 244m, airlift
	15-08-98	826	7.9	424	517	402.4	489	97	27	44	39	1	4	21	30	0.3	0.5	40	
31393	22-07-98	1160	8.2	229	279	157	649	30	177	292	20	1	2	150	78	0.7	7	36	2L/s, 92m, airlift
	25-09-99	1070	7.7	285	347	245	613	65	145	239	20	1	1	135	65	0.8	0.1	48	1.2L/s, 82m, pumped
31394	24-07-98	2010	6.0	62	76	127	1120	36	572	943	9	1	4	318	1	1.4		16	5L/s, 85.3m, airlift
	18-08-98	4370	7.7	38	46	336	2780	118	1392	2294	10	1	5	723	11	1.4	0.2	22	8L/s, 70m, pumped
	22-11-99	4480	8.0	30	37	411	2630	143	1470	2410	13	1	6	805	8	1.3	0.2	22	pumped as equipped
31396	28-07-98	562	6.3	302	368	269	341	60	4	7	29	1	3	6	8	0.1		34	6L/s, 91.3m, airlift
	03-10-98	742	7.3	410	500	378.9	395	104	11	18	29	1	3	8	23	0.2	0.4	36	6L/s, 69m, pumped
31397	29-07-98	452	8.0	126	154	84.6	293	24	48	79	6	1	1.3	56	26	0.6		37	0.5L/s, 61.8m, airlift
	01-10-98	510	8.3	153	187	38.2	326	12	59	97	2	1	1	92	35	0.8	1.9	41	1L/s, 120m, pumped
	03-08-98	2570	8.2	253	308	65.3	1359	13	660	1088	8	1	6	472	1	2.1		13	4L/s, 229m, airlift
	02-10-98	1260	8.2	198	242	40.7	691	13	282	465	2	1	3	243	57	1.7	0.3	28	4L/s, 120m, pumped
31398	04-08-98	742	6.8	322	392	68.5	505	11	23	38	10	1	5	133	50	0.2		51	0.3L/s, 49.3m, airlift
31606	5/11/98	546	6.6	282	344	272	337	63	15	25	28	1	4	16	4	0.1	6.7	24	2L/s, 78m, airlift
	8/26/99	716	7.4	395	482	391	433	112	8	13	27	1	3	8	16	0.1	0.1	37	0.7L/s, 64m, pumped
31617	14-10-97	372	6.6	224	273	209.1	257	41	6	10	26	1	3	8	15	0.2		30	4L/s, 84m, airlift
	09-06-98	806	6.7	441	538	428	474	122	13	21	30	1	3	10	18	0.2	0.1	35	3L/s, 70m, pumped

Bore RN	Sample Date	Specific Conduct. (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nit-rate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
31618	15-10-97	1351	7	157	191	164.9	736	43	322	531	14	1	4	191	5	2	5.6	27	1L/s, 78m, airlift
	08-06-98	1425	6.3	174	212	184.9	747	51	339	559	14	1	4	209	19	1.6	0.9	33	0.5L/s, 62m, pumped
31742	7/21/98	1232	8.0	234	285	294	729	39	164	270	48	1	21	133	154	0.4		36	3L/s, 70m, airlift
	7/19/99	1590	7.2	499	608	528	969	126	171	282	52	3	20	128	150	0.4	0.1	34	pumped as equipped
31861	10/10/98	1390	7.5	199	243	310	872	78	327	539	28	2	4	166	19	1.4		27	0.1L/s, 77.2m, pumped
31862	7/19/99	1360	7.1	500	610	554	832	138	109	180	51	1	11	75	130	0.1		31	pumped as equipped
31921	8/5/98	568	8.1	213	260	83	341	15	47	77	11	1	4	83	25	0.3		37	0.3L/s, 72.8m, airlift
	8/5/98	490	8.4	204	241	64	302	11	38	63	9	1	3	79	13	0.3		30	0.3L/s, 66.8m, airlift
	8/5/98	477	8.0	206	251	62	296	10	31	51	9	1	2	81	32	0.3		31	0.3L/s, 60.8m, airlift
	8/5/98	670	8.5	209	247	96	397	17	69	114	13	1	6	101	48	0.8		21	0.3L/s, 60.8m, airlift
31924	13-08-98	605	8.0	208	253	259.4	369	48	66	109	34	1	3	21	32	0.2		43	Seepage, 77m, airlift
	29-09-98	883	7.3	490	598	457.2	511	114	18	30	42	1	3	11	27	0.2	0.5	52	1L/s, 52m, airlift
	07-09-99	884	7.3	526	597	485	526	122	14	23	44	1	3	11	20	0.2		50	1L/s, 51m, pumped
31925	8/17/98	513	7.6	260	317	269	306	70	6	10	23	1	3	7	18	0.2		27	0.5L/s, 73m, airlift
	11/4/98	686	7.4	383	467	184	406	39	3	5	21	1	2	3	17	0.2	3.3	27	0.5L/s, 87m, pumped
31926	8/19/98	679	7.7	358	437	351	449	88	9	15	32	1	4	8	31	0.3	11.9	35	0.5L/s, 97m, airlift
	11/6/98	777	7.4	434	529	246	461	46	7	12	32	1	3	8	19	0.2	1.6	35	1L/s, 88.9m, pumped
31953	8/18/99	1580	7.3	445	543	553	952	121	178	293	61	3	22	137	200	0.5	0.2	40	pumped
31963	9/8/00	778	7.1	415.8	507	366.7	452	86	15	24.72	37	0	7	34	35	0.6	u/s	34	0.5L/s, 100m, pumped
	9/8/00	844	7.2	455.2	555	427.2	505	102	17	28.02	42	0	7	23	35	0.5	0.6	42	2.3L/s, 100m, pumped
32037	7/22/99	1770	7.3	334	407	441	1070	83	257	424	57	1	3	215	240	0.3	1.1	38	pumped as equipped
32039	7/20/99	2100	7.5	556	678	618	1300	144	224	369	63	5	30	212	210	0.5	0.1	42	pumped as equipped
32162	09-09-99	907	7.3	313	382	332	584	87	111	183	28	1	4	59	12	0.4	0.1	40	1L/s, 82m, pumped
32169	25-10-99	617	7.8	346	422	349	379	74	5	8	40	1	3	7	17	0.2	0.1	41	pumped as equipped
32448	28/11/99	2450	8.0	371	452	621	1540	58	376	620	116	1	32	306	400	0.6		57	12m, airlift
	28/11/99	2470	7.9	447	545	651	1540	57	344	567	124	1	31	311	400	0.4		56	30 m, airlift
	29/11/99	2600	7.9	411	501	692	1650	70	399	658	126	1	32	300	430	0.4		54	66m, airlift

Bore RN	Sample Date	Specific Conduct. (uS/cm)	pH	Total Alkalinity (mg/L)	Bicarb-onate (mg/L)	Total Hardness (mg/L)	TDS (mg/L)	Calcium (mg/L)	Chloride (mg/L)	NaCl (mg/L)	Magn-esium (mg/L)	Nit-rate (mg/L)	Potass-ium (mg/L)	Sodium (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Silica (mg/L)	Sampling Data
32463	11/27/99	550	7.5	303	370	277	303	45	6	10	40	1	3	5	14	0.1		28	2L/s, 78m, airlift
32464	9/11/00	708	7.4	410.9	501	395.6	416	91	5	8.2	41	0	4	4	22	0.2	u/s	30	0.25L/s, 73m, pumped
	9/11/00	738	7.2	431.4	526	418.1	437	100	7	11.5	41	0	4	4	20	0.2	0.8	33	0.5L/s, 78m, pumped

APPENDIX 4

Sustainable Yield Estimates

An order of magnitude estimate of the sustainable yield of the limestone aquifer system on the Sturt Plateau is provided below. For the purpose of this estimation, the aquifer system is considered in two components – east and west of the Birdum Creek Fault. The methods for calculating the sustainable yield are based on determining recharge and throughflow.

A 4.1. West of the Birdum Creek Fault to the Flora River

A 4.1.1 Groundwater Levels

Formal calculations of throughflow can be made using the following relationship:

Throughflow = T x i x w

where	T	=	Transmissivity (m^2/day)
	i	=	Potentiometric level gradient
	w	=	aquifer width (m)

Little information exists to evaluate the transmissivity of the limestone aquifer in the region. Such is the variability in its permeability, a vast range of values for transmissivity (from hydraulic conductivity) may be derived for karst limestone. Driscoll (1986) and Freeze and Cherry (1979) place the range of values for hydraulic conductivity between 1 and 1000 m/day. For the sake of the following calculations, a range of values of 100 to 200m/d has been adopted as this is considered to be a reasonable estimate given the highly weathered nature of the limestone formation on the Sturt Plateau.

The following calculation considers the part of the basin between Margaret Downs, Larrizona and Nenen Stations where the aquifer is essentially contained between barrier boundaries to the east and west.

A value for transmissivity is between 5000 and 10000m^2/d for this area considering the aquifer thickness is approximately 50m across this section and the hydraulic conductivity is between the range limits above. The width of flow is 70kms and the flow gradient 1:2000. Applying the above equation, the throughflow is between 64000 and 128000 ML/y, equating to 2 to 4 cubic metres per second.

An order of magnitude estimate of recharge is made by multiplying the observed seasonal groundwater level rise by the specific yield of the aquifer. If the average annual water level rise is 1 m over the area of the aquifer as monitoring bore data may indicate (Section 6.1.1) and the specific yield is 0.03, the annual volume of water added to the aquifer is 130000 ML/year. This equates to a recharge rate of 3 mm/year.

A 4.1.2 Chloride Mass Balance

Chloride mass balance analysis may also be used to derive an order of magnitude indication of recharge.

Assuming negligible flow from adjacent aquifers and no precipitation or dissolution of chloride minerals, the chloride mass balance is empirically expressed as:

$$P.Cl_p = R.Cl_{gw}$$

where

P	=	mean annual rainfall (mm)
Cl_p	=	Cl concentration in rainfall (+ dry fallout) (mg/L)
R	=	recharge rate (mm)
Cl_{gw}	=	Cl concentration measured in groundwater (mg/L)

The values used for the chloride concentration in rainfall was adopted from Likens et al (1987) who reported for a number of areas in the NT, and Tickell (1998) with data from the Victoria River region to the west. Sampling by Yin Foo and Jolly (1994) from Newcastle Creek near Elliott after a period of heavy monsoonal rainfall indicated trace chloride was as low as 0.32mg/L. For the purposes of this estimate, values for Cl_p ranging from 0.3mg/l to 1mg/L are used in the calculations to derive the possible magnitude of recharge.

The groundwater chloride concentration varies across the study area. For example, in the aquifer south of Hidden Valley (ie. from the Wiso Basin) is typically up to 25 mg/L. Across the central zone, the chloride concentrations decrease due to direct infiltration of sinkholes. Typical values are less than 10mg/L indicating dilution of the throughflow emanating from the area south of Hidden Valley. In the vicinity of Dry River Station and towards the north-eastern extents of the basin, the chloride concentration increases to up to 30 mg/L.

The mean annual rainfall for Larrimah is approximately 800mm (refer Table 1). Therefore, if it is considered that the chloride concentration at the outflow represents an average for the region (ie. 30mg/L), then the basin recharge is in the range of 1% to 3% of the annual rainfall (or 8 to 25mm).

A 4.2 East of the Birdum Creek Fault to the Roper River

An order of magnitude estimate of throughflow can be made based on the general flow equation in Section 4.1.1.

The width of flow is approximately 40km across a control section through Elsey Station. A flow gradient of 1:2000 is calculated from water levels on the map. The average aquifer thickness is about 80m across this section (refer Cross Section A-B on map), and adopting the range of possible hydraulic conductivities, the transmissivity is in the order of 8000 and 16000m^2/d.

The throughflow range using the above values equates to 160 to 320ML/d or 2 to 4 cumecs. In comparison, spring discharges into the Roper River range from 3 to 5 cumecs or 260 to 430 ML/d. This flow includes the contribution from a separate flow regime discharging from the north of the Roper River.