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REHABILITATION OF FLOWING BORES IN THE NORTHERN TERRITORY PORTION OF THE GREAT ARTESIAN BASIN

DRAFT

NOTE – this report was unfinished when staff involved left the Department. It was subsequently tidied up and updated with subsequent monitoring data. It has the status of DRAFT in recognition of some gaps and inconsistencies.
John Childs, Alice Springs, 2008.

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CONTENTS

EXECUTIVE SUMMARY

"REHABILITATION OF FLOWING BORES IN THE NORTHERN TERRITORY PORTION OF THE GREAT ARTESIAN BASIN"

This report documents the rehabilitation of three uncontrolled artesian bores in the Northern Territory portion of the Great Artesian Basin.

The work was jointly funded by the Northern Territory and the Commonwealth through a Natural Heritage Trust (Land and Water Partnerships) project, with the objective of preventing the wastage of an estimated 6,000 megalitres of groundwater annually, and the associated loss of pressure head.

All three bores are on an Aboriginal Land Trust. The traditional owners requested that all bores be rehabilitated such that the opportunity for future groundwater use was maximised.

Two of the bores (Anacoora and Dakota) had deteriorated to the extent that no surface flow existed at either. In both cases access to the hole was re-established and attempts were made to cement inert casing into the old hole. McDills, the third bore, was still flowing vigorously into an interdunal swale forming a lake/swamp some three kilometres long.

Anacoora rehabilitation was unsuccessful in re-establishing a (controlled) flow. The leakage of artesian groundwater into overlying formations is now believed to be insignificant.

Dakota rehabilitation was unsuccessful however after works there is no flow to the surface. Subsequent monitoring will be required to confirm whether or not artesian flows have been substantially limited.

McDills rehabilitation was successful in establishing headworks able to control the groundwater flow and eliminate almost all wastage. Rehabilitation was not able to take a fully eliminate the possibility of inter-aquifer mixing.

The work was completed on budget but over time as several unusually wet years delayed site access.

Section 1 - INTRODUCTION

1.1 The need to rehabilitate Great Artesian Basin bores

The Great Artesian Basin (GAB) is one of Australia's most important water resources. It is about 1.7 million square kilometres in area. It is the largest artesian basin on Earth, with estimated water storage of 8,700 million megalitres.

For more than 100 years, groundwater from the Great Artesian Basin has contributed to pastoral, mining and community development needs over a fifth of Australia's landmass. For thousands of years natural discharge from springs around the Basin has been significant for indigenous Australians. A number of these springs also support nationally significant environment and heritage values (GABCC 2000).

Previous generations have contributed considerably to Basin development using the technology of the day. It is now clear, however, that unsustainable extraction from uncontrolled bore discharge and inefficient water distribution via bore drains has led to falling artesian pressures across much of the Basin and in many areas increased erosion, land degradation and the spread of pest plants and animals. In some cases, natural discharge has ceased, causing the loss of associated biodiversity and heritage values and increased costs of pastoral production. (GABCC 2000).

The effective management of the GAB to ensure its sustainability is the key objective of the rehabilitation of flowing bores in the Northern Territory portion of the Great Artesian Basin (GAB).

1.2 Significance of the GAB to the Northern Territory

The GAB underlies 85,000 square kilometres of the southeast corner of the Territory. The amount of water stored in the GAB aquifer in the Territory has been estimated to be 1,000 million megalitres. Recharge to the GAB aquifer in the Territory is estimated at about 30 megalitres per day, or 11,000 megalitres per annum (ML/a).

In the arid areas of the Territory that are underlain by the GAB, water from the GAB is the only reliable source of water, supporting human activity as well as a range of unique ecosystems. GAB water is important for both aboriginal communities and pastoralists; they rely on it as their primary source of drinking and stock water.

About half of the GAB in the Territory is artesian. A little over half of the sub-artesian part has confining beds present, while the outer fringe contains recharge or intake areas where ephemeral rivers and associated shallow aquifers flow across the GAB outcrop and sub-crop. See the hydrogeological map in Matthews (1996).

All productive consumptive use is from the sub-artesian parts.

Recharge that occurs in the Territory is believed to sustain a large proportion of the spring flow at the Dalhousie Springs complex in Wiltjira National Park. Aborigines have a long association with natural flows from the GAB and more recently communities such as Finke (Apatula) rely on GAB water.

The location of Dalhousie springs is shown on **Figure 1** as the concentration of springs immediately below the Northern Territory / South Australian border.

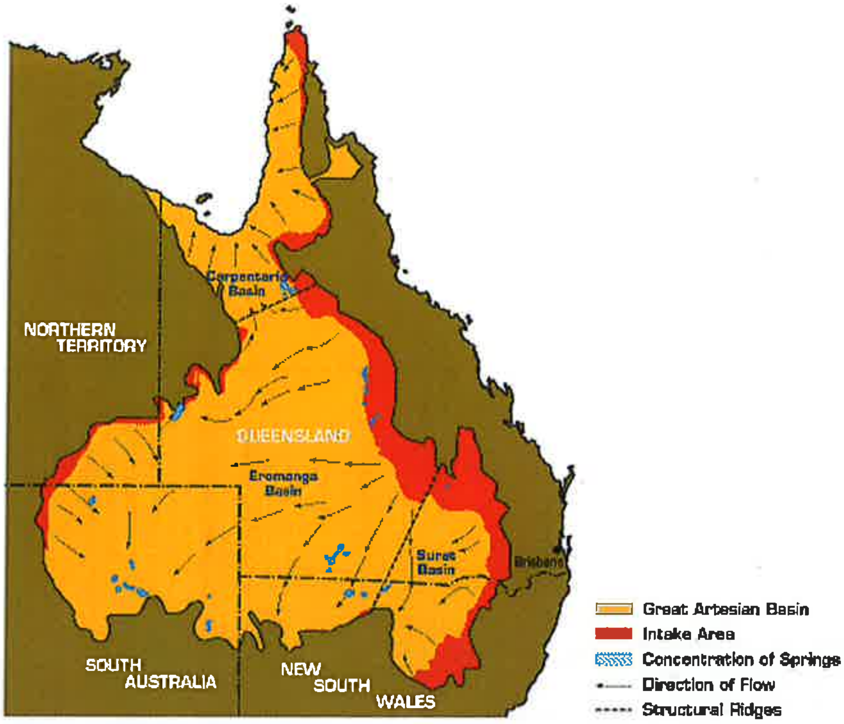


FIGURE 1 – Great Artesian Basin

1.3 Bores in the Great Artesian Basin in the Northern Territory

Within the Territory 9 bores have been drilled into or through artesian parts of the GAB (Matthews 2005 lists 8 of these, the ninth is Etingimbra No 1 approximately 15km SSW of McDills). Seven were petroleum exploration holes as shown in Table 1; six of those were plugged on completion and do not require rehabilitation; McDills is the seventh. The 2 non-petroleum bores are Anacoora and Dakota.

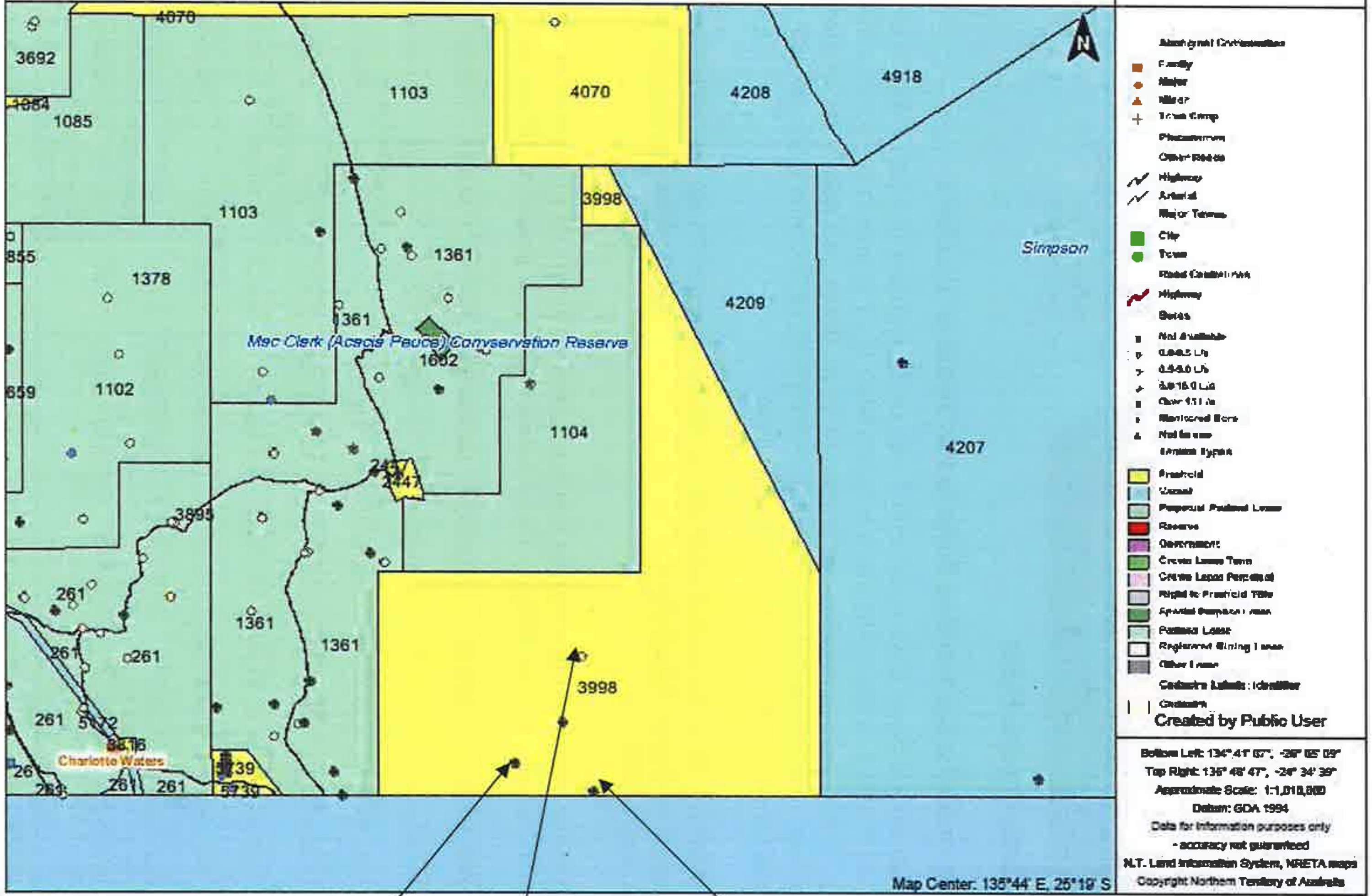
Within the Territory there are numerous bores in the sub-artesian fringe and recharge or sub-crop area of the GAB. Matthews (1996) shows these areas and the distribution of water bores within them.

There are possible issues of inter-aquifer contamination arising from inadequate bore construction in the sub-artesian fringe. These issues are not addressed in this report.

Petroleum Well No.	Well Name	Latitude	Longitude	Completed	Depth (m)	Operator	Status
22*	McDills No. 1	25 43 50	135 47 25	5/09/1965	3,204	Amerada Petroleum	Abandoned
23*	Hale River No. 1	25 15 48	136 43 36	11/11/1966	1,732	Amerada Petroleum	Abandoned
48*	Colson No. 1	25 57 45	136 40 00	13/12/1978	2,432	North Broken Hill	Abandoned
50	Thomas No. 1	25 51 29	137 38 25	9/11/1981	2,613	Argonaut	Abandoned
126	Poeppels Corner No. 1	25 47 36	137 57 06	22/09/1984	2,590	Arco	Abandoned
205	Beachcomber No. 1	25 22 43.89	137 48 8.5	14/11/1988	1,829	Beach Petroleum	Abandoned
230*	Etingimbra No. 1	25 51 26.63	135 45 09.67	20/01/1990	1,006	Horizon Operating Company	Abandoned

Table 1: Extract from Northern Territory Petroleum Database for the Great Artesian Basin

Figure 2: Location of bores rehabilitated



Anacoora bore
RN 977

McDills bore
RN 5028

Dakota bore
RN 12431

1.4 Bores requiring rehabilitation

The three bores which were uncontrolled - Anacoora, Dakota and McDills - are located to the north-north-east of Dalhousie Springs, just above the NT / SA border, as shown on Figure 2. The three bores had been flowing into pools in the Simpson Desert for many years at a total rate of up to 17 megalitres per day, or up to half of the estimated recharge rate to the GAB in the Northern Territory.

The three bores are located on aboriginal owned land. When drilled all were on Crown Land. Most of the pre-rehabilitation flow was coming from McDills Bore, a petroleum exploration bore drilled in 1965.

The primary objective of the project was to eliminate wastage of groundwater and assist in maintaining artesian pressure.

The secondary objective was to provide water for possible outstation and community requirements, and for any environmental needs which were identified.

1.5 Natural Heritage Trust funding

A new project application to the Natural Heritage Trust was submitted in 1997 seeking a total of $276,000 NHT funds for a four-year project. The project summary as originally submitted for NHT funding is as follows:

> *There are three uncontrolled artesian bores (Anacoora, Dakota and McDills) in the portion of the Great Artesian Basin in the Northern Territory. These bores flow to waste and create swamps in a naturally arid environment. The project will rehabilitate the uncontrolled bores and allow the flow to be reduced to that which is required for community water supplies and any assessed conservation values. Bore repair is the first step toward eliminating waste and thereby removing a cause of land degradation.*
>
> *Overuse of the resource has led to pressure and flow loss and current rates of flow are unsustainable. The bores are upgradient of the unique Dalhousie Springs complex(north-eastern South Australia) and continued wastage may affect this area.*
>
> *The project supports regional development as new industry will rely on artesian water and some of the water saved may be available on a sustainable basis for future use. The project is part of an interstate initiative with complementary projects operating in Queensland, New South Wales and South Australia. The project has strong support from the Northern Territory GAB Advisory Committee.*

The application was approved in late 1997 and work commenced in May 1998.

Further financial details are included in Section 7.

1.6 Summary of outcomes

Both Anacoora and Dakota bores had deteriorated to the extent that when project work started, no surface flow existed at either. In both cases access to the hole was re-established and attempts were made to cement inert casing into the old hole.

Anacoora rehabilitation was unsuccessful in re-establishing a (controlled) flow. The leakage of artesian groundwater into overlying formations is now believed to be insignificant.

Dakota rehabilitation was unsuccessful however after works there is no flow to the surface. Subsequent monitoring will be required to confirm whether or not artesian flows have been substantially limited.

Before rehabilitation, McDills bore was still flowing vigorously into a swamp three kilometres long. Rehabilitation was successful in establishing headworks able to control the groundwater flow. Rehabilitation was not able to fully eliminate the possibility of inter-aquifer mixing which may be occurring below the depth reconstructed during rehabilitation.

Section 2 – STAKEHOLDER LIAISON

The principal stakeholder groups are:

- The Central Land Council representing aboriginal landowners constituted as the Pmer Ulperre Ingwemirne Arletherre Aboriginal Land Trust.
- The Great Artesian Basin Consultative Council representing the interests of best management of the overall Basin.
- The Northern Territory Great Artesian Basin Water Advisory Committee representing the interests of residents and industries in the Territory portion of the Basin.

In April 1997 the original NHT application stated the objectives of the rehabilitation project as:

- *To reduce flow to that required for community water supplies and any assessed conservation values.*
- *To equip the bores with headworks to allow a flow sufficient for small outstation-type developments to occur at each bore.*

The Northern Territory Great Artesian Basin Water Advisory Committee endorsed the application.

In September 1998 after the project had been approved, the Water Advisory Committee noted that "The general opinion of aboriginal residents surveyed was:

- *Anacoora:* *there was no foreseeable need for a living area supply here; nevertheless if possible reconstruction should allow for a controlled flow if required in the future. Therefore attempt to rehabilitate with headworks, and leave flow shut off unless needed sometime in the future.*
- *Dakota:* *attempt to rehabilitate with headworks for a living area here.*
- *McDills:* *should be plugged and abandoned, as it produces water too salty for human consumption, and the wetland which has developed is not natural.*

and that the CLC would provide formal advice in due course."

In March 2001 the Central Land Council advised:

> "With respect to the Traditional Owners' wishes for the rehabilitation of all three bores, the CLC has instructions that the rehabilitation work should be undertaken to result in the maximum possible flows being potentially available. The actual flows available immediately from each bore would preferably be enough to supply outstations at Anacoora and Dakota and an emergency supply at McDills."

The CLC also acknowledged that difficulties during work-over could require the plugging and abandoning of one or more of the bores.

Traditional owners, through the CLC, approved all planned access and site works in advance of each year's field program.

Section 3 – OVERVIEW OF PROGRAM

3.1 Locality and logistics

Figure 2 shows the locations of the bores. Access from Alice Springs is along 275km of bitumen to Kulgera and 326km of unsealed public roads to the Dakota turnoff then 10 km of private tracks to Dakota and a further 25km to McDills. The turnoff to Anacoora was some distance west of the Dakota turnoff then along approximately 15km of new tracks and existing seismic lines.

The final 10 km into Anacoora and 15 km into McDills are through sand-dune country which required a dozer or a large-tyred loader to pull the drill rig and support trucks through.

Where possible, field work was programmed for the cooler months of late autumn through early spring.

3.2 Timelines

The original time-line was:

- 1998 – initial field reconnaissance and planning
- 1999 – Anacoora rehabilitation
- 2000 – Dakota rehabilitation
- 2001 – McDills rehabilitation

The actual time-line was:

- 1998 – initial field reconnaissance and planning
- 1999 – Anacoora rehabilitation
- 2000 – following record summer rains, access was not possible except for checking
- 2001 – following another wet summer, access was not possible except for checking
- 2002 – McDills and Dakota rehabilitation

Section 4 – ANACOORA BORE

4.1 History of Anacoora bore

Anacoora Bore has the most detailed lithological and water quality record available for any bore within the Northern Territory section of the Great Artesian Basin.

Waldron (1916) described Anacoora bore – "In the midst of some 300 square miles of sandhills Anacoora bore was sunk by the South Australian Government in 1898. The bore was an experiment to test the country for artesian water, with a view to providing a stock route to Queensland. The question of stocking the country surrounding the bore was scarcely deemed worthy of consideration, and when water was located, therefore, and an inspection of the country a few miles eastward disclosed a continuation of sandhills, all future boring operations were cancelled, and a bore with a flow of 700,000 gallons per day was left unoccupied."

The bore, which has Northern Territory registered number RN 977, was drilled with a rig constructed on site, parts being carried in by camel, and was completed using casing delivered from England. The driller's log, including daily progress reports, is retained on the bore data file.

Construction details are well-documented (WRD report Rooke 44/1991 particularly Figure 7). Total depth was 381 m with artesian water struck at 346 m and casing set to 363m. The 1898 completion flow converts to about 37 L/s and drilling records record the groundwater temperature as 57°C. TDS from the open hole was approximately 2,800mg/L; after casing was run the TDS was approximately 750mg/L. Pressure head at first water strike was recorded as 11.3m; no record of completion head has been found.

In 1990, flow was estimated as 0.3 L/s and recorded temperature 54.6°C with total dissolved solids (TDS) of 860 mg/L.

In 1991, flow rate was estimated as 2 L/s, temperature was 55°C and TDS was 915 mg/L.

In 1996, flow was estimated as 1 L/s and TDS was 889 mg/L.

By July 1999 when the rig arrived on site flow was measured as 0.6 L/s.

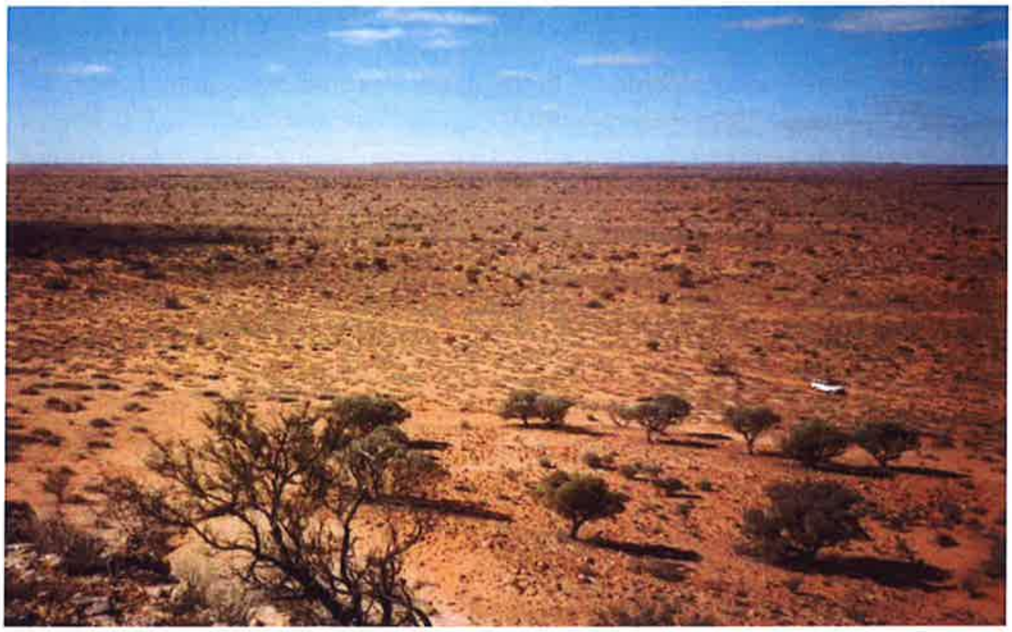
4.2 Optimum rehabilitation

Ideally the bore would be reconstructed to its original condition, with inert casing set at approximately the same 363 m depth of the original bore, and cemented back to the surface.

4.3 Preliminary investigation

Site access had been arranged beforehand with the Central Land Council and was mainly along existing seismic lines.

Access to the area for the drilling rig was established by constructing one short track north from the road between Mt Dare and Purni, then over Horse Hill, then following the existing north-south seismic line running from the Finke River near Horse Hill for eleven kilometres and then via an intersecting seismic line running east for two kilometres to the bore site. Access was difficult due to soft sand, and was made possible with the assistance of a D6 dozer hired from New Crown station to tow the drill rig over the dunes.



Pic: Access to Anacoora Bore along Seismic line

The condition of the bore prior to this project was that no surface casing was visible. A rusted 4-inch pipe was lying horizontally at the surface with a trickle of warm water coming from it and around it.

An attempt to enter the bore with geophysical logging tools in December 1998 revealed a complete blockage between 5 & 8 metres, with the flow probably coming up an annulus and into the 4-inch surface pipe from which the small flow was issuing.

4.4 Adopted approach to rehabilitation

Practically, it was recognised that after 100 years the original casing was expected to be severely deteriorated, definitely not structurally reliable, and reconstruction to total depth was unlikely to be possible. It was likely that parts of the Rumbalara shale formation had collapsed into the hole. The aim of the reconstruction was therefore to run stainless steel casing to as great a depth as possible, ideally to the depth of 200m but at least into fresh Rumbalara shale, and then to cement the stainless steel to the surrounding fresh rock. The shale is known to be relatively impermeable, so leakage into the shale should be much less than the leakage which would occur if groundwater was flowing into near-surface sands. The cement at bottom of the stainless steel was to be drilled out to re-establish artesian flow and a control tap and protective fencing set up at the surface.

4.5 Anacoora field work

Work commenced on site on 3/7/99. Drill Rig No. 22 (a top-head drive rotary rig) was used, and borehole logs run when needed during the work.

On arrival, the flow rate from the bore was 0.5 L/s. Pits were dug at the out-flow and lined with plastic in order to establish a store of water.

A firm pad for the drill rig was constructed with the use of bags of Rip Rap (a sand & cement mix product). A 2-metre length of 273mm bore casing was run over the bore and cemented in to provide a suitable flow line.

Work-over commenced with a 3 7/8'' rock roller bit. Returns contained pieces of wood, tree roots and decomposed steel casing. At 36 metres there was a flow rate of approximately 1 L/s.

The bore was cleared out to 218 metres (some 120 m above the Rumbalara shale / Algebuckina (De Souza) sandstone contact). At that depth, flow increased to 11 L/s. This was allowed to flow over night to obtain a good storage of water.

The following day the geophysics tools were run into the hole. A dummy probe stopped at 150m and the caliper log only went to 92m. The caliper showed the hole to be in extremely bad condition with sections of casing corroded away.

Attempts to re-establish open hole to 218m failed with the hole condition progressively becoming worse. Polymer mud was used in an attempt to stabilise the hole. Formation shale from around 60m began slumping causing blocking of the hole.

In order to provide headworks and some degree of rehabilitation, 90mm stainless tube was run as far as possible - to 70m. The tubing was sealed into the shale with cement. This construction is less than optimum. Nevertheless it was the best that could be done in the circumstances.

The increase in flow around 200m suggests that the hole had been effectively blocked at that point by slumped formation.

Final flow of the bore was 0.15 L/s. Head pressure was measured at 19 metres.

4.6 Anacoora completion details

A steel railing was run around the cemented pad. A stainless steel valve was fitted at the borehead so that the supply can be closed off later (eg, for periodic connection of a pressure gauge). A stainless steel outlet pipe was run from the bore head outside the railings, and the small supply was left to flow freely to the existing water hole.

Date	Flow rate (L/s)	Shut in pressure (kPa)
27 May 2002		180
28 May 2003	Initial 1.5 L/s, 0.03 L/s after 15 min	200
02 August 2006		196

A diagram of the final construction is in Appendix 1. Results of water chemistry analyses are in Appendix 2.

Pic: Anacoora Bore Construction June 2000

4.7 Possible future uses

There is little hope of recovering Anacoora to full flow, since the formations are unstable, and fall into the hole. Reconstruction to major flow would need another drilling method, redrilling the same hole. This would mean drilling out the stainless steel casing and carefully controlled drilling to keep inside the original hole while holding up the fractured shale above. Cost for this exercise is likely to be similar to the cost of drilling a new bore ($200,000 to $400,000 depending on specification and construction method).

Samples of metal from the original casing, and a concretion from the annulus around the surface pipe have been retained for chemical analysis if reconstruction is ever considered.

If the head remains at 19 m then the bore is sufficiently open to the aquifer to retain as a pressure monitoring point. If pressure is significantly lower, then Anacoora has no use for monitoring or for water supply, and we should consider further cementing.

May 2002 – flow was only 1.3 litres per minute (0.02 L/s) with dead horses in the area of the pool– take pressure reading and flow was shut off, forcing horses to go elsewhere. Pressure was 180kPa.

May 2003 – Shut-in pressure reading was 200kPa: pressure readings seem to be fairly constant, showing that the aquifer remains open and the aquifer pressures may even be rising after the three bores have been controlled.

4.8 Review of Anacoora rehabilitation

The attempt to rehabilitate Anacoora Bore was unsuccessful in establishing a significant flow. A 10L/s flow had been achieved at the stage when the hole had been cleaned out to depth of 218m, but this flow was lost when further attempts were made to work in the hole. Loss of flow and blockage are most likely caused by slumping of the Rumbelara shale. This slumping could have happened as a result of the original casing failing for one of three reasons:

- Damage to original casing by running logging tools or during pull-out of the drill-rods
- Upward flow of water tearing the casing
- Changes in pressures after clearing the hole caused breakup of the remaining casing

Alternatively the casing could have already corroded completely, and the shale slumped under its own weight, possibly after disturbance by the logging tools.

By cementing the stainless steel casing to the surrounding shale, upward losses of GAB groundwater have been contained. Losses into the sand and limestone bands within the shale but below the cemented casing are expected to be minimal, and the rehabilitation has been successful in restricting wastage.

In similar circumstances of attempting to recover flows in GAB bores with very old iron/steel casing, a good artesian flow coming from below the impervious shale should be considered as successful recovery, and the stainless steel casing should be run immediately, then cemented and the plug drilled through.

Pics: Anacoora Bore subsequently

Section 5 – DAKOTA BORE

5.1 History of Dakota bore

No construction data or geological records exist for Dakota bore (designated RN 12431). There is no knowledge of the drilling date, purpose, or original flow – total depth is stated as 1600 ft (488m) on the bore data file, but the information on file is clearly not original.

In 1986 flow into a significant artificial wetland formed partly by bunded earthworks was estimated as 20 L/s. In November 1988 the flow was estimated to be between 5 & 10 L/s. The temperature was stated to be 54°C. In 1990, the wetland was still present around the bore and athel pines had established along bunds; the estimated area of the wetland was 4 hectares. In May 1995 no flow, nor any sign of the bore-head, were visible at the surface and the wetland had dried up.

When the hole and water supply disappeared, a two-metre crater was left. Local lore holds that gelignite was detonated in or near the bore.

A shallow hole (used later as a monitoring bore) was drilled 15m away in 1994 (on behalf of Pitjanjatjara Council by "Punch" Hall – RN 16609) to about 20m depth and at a depth of 8m encountered hot water (50°C) which did not flow to the surface. This suggests that a significant quantity of artesian water was still flowing from the top of the residual, buried casing of Dakota Bore into shallow alluvium. Hall drilled other holes to the same depth 200m and 1km distant; that at 200m encountered water at 1m greater depth. There are no records in the NT database for that at 1km.

The athel pines were still vigorous, and as a weed of national significance were cut down and poisoned in 2002.

5.2 Optimum rehabilitation

The stated total depth of 488m suggests that drilling ceased shortly after first encountering artesian flows.

The objective was therefore to cement inert casing at the greatest depth possible and construct headworks to permit a continuing controlled flow. The greater the depth achieved, the lower would be any residual inter-aquifer leakage into the confining Rumbalara shale.

5.3 Preliminary investigations 1999

The earliest water analysis on file has TDS 1300 mg/l in 1980. Most subsequent analyses are 1285mg/L.

In December 1998, the base of the crater (approx 2m below ground level) was excavated with a shovel, and hot water was found about 4m below ground level. The ease of digging suggested that the shovel-hole was over the original bore.

On 22-July-1999 more extensive investigation was undertaken after finishing work on Anacoora bore. The likely position of the bore was established by digging in the centre of the surface crater.

A 2m length of 400mm steel casing and 6 metres of 250mm ID casing was inserted in the crater where the hole used to be and the earth filled in around the casing. 219mm casing was inserted in the hole to 15 metres.

The hole was drilled out to 18m with a 5 5/8'' bit; 219mm casing then ran freely to 15.4m and was driven down 17.3m where resistance increased. This was postulated to be the top of the original bore casing. An attempt was made to clean the hole out by airlifting. The airlift brought pieces of rusted casing which appeared to be approximately 150mm diameter, star picket fragments, and coarse sand to the surface.

Pic: Metal scraps recovered from Dakota Bore

Attempts were made to drill on below the 219mm casing. Drilling went to 28m, however sections of steel falling across the hole kept causing the drill bit to deviate from the presumed original hole. Casing (150mm) was run to 27.7m to provide greater directional control for the drill string, however fresh shale fragments were returned to the surface: it appears that the bit kicked off out of the previous hole. Further drilling was not successful in regaining the original hole. The 150mm casing was retrieved and work was abandoned.

A 150mm horizontal flow line was attached to the 219mm casing and was allowed to flow unrestricted at 0.3 L/s. This flow had ceased when subsequently inspected in May 2000.

5.4 Dakota field work 2002

Works commenced on the site 7-may-2002. Several attempts were made to clean out the old casing without success as the drilling tools kept running off and creating a new hole. A section of casing was recovered and measured: it was 127mm OD. 219mm casing was run while milling the old casing to 54 metres but attempts to mill the old casing further were unsuccessful. The hole was drilled to 60metres. 6,000 litres of cement/barite slurry was pumped in the hole at 60 metres which overcome the flow (previously 1.3 L/s).

Subsequent monitoring is necessary to confirm that flow has been successfully stopped.

The bore RN 16609 located 30metres to the south of Dakota Bore provides a monitoring point for later SWL and temperature records, but due to the poor nature of its construction can only be considered an indicator of trend.

5.5 Dakota completion details

No artesian supply has been established at Dakota, and the bore has been cemented below surface.

Monitoring of water level and temperature in the nearby RN 16609 has continued since completion of the work:

Date	Temperature (°C)	SWL (m from top of casing)
11 June 2002	45	11.2
01 July 2002	45	11.0
27 May 2003	42	11.2
02 August 2006	38	11.7

A diagram of the final construction is in Appendix 1. Results of water chemistry analyses are in Appendix 2.

5.6 Possible future uses

No supply has been established at the site of Dakota Bore. If the traditional owners wish to establish a community water supply at the location, then a new bore would need to be drilled to current standards. The monitoring bore was drilled to 30m deep, but only 13m of casing was inserted as "soft flowing sands" caused the hole to collapse beneath that point. The casing has no surface cement or concrete block, and is crooked at shallow depth, so should not be used as a water supply. In any case the water chemistry recorded for Dakota is not potable, although would be suitable for an emergency supply.

Section 6 – McDILLS BORE

6.1 History of McDills bore

McDills No 1 was drilled by Amerada Petroleum in 1965 to a depth of 10,515 feet, with outer casing 13 3/8inch and inner casing 9 5/8 inch to about 1000m. Artesian water was struck at 715m. The bore was cement-plugged then the casing shot from 594 – 596m and was completed with headworks as a water bore (designated RN 5028). It is not known why the bore was completed in this way. Soon after completion the headworks corroded, allowing the bore to flow freely (D. Woolley pers comm). The TDS of 2,600mg/L is higher than expected from the De Souza sandstone in the Territory. It is believed that the water is coming from several aquifers including the more saline basal units of the overlying Rumbalara shale.

Various estimates of flow were made: 100 L/s (1986), 200 L/s (1991), 50 L/s (1998) followed by an accurate measurement of 120 L/s in 2002. The traditional owner view, as reported through the Water Advisory Committee, is that this bore can be completely shut down, as the water, with 2500 mg/L TDS, is too salty for human consumption.

Pic: McDills flowing uncontrolled in 1999

An artificial lake surrounding the bore had developed, with reedbeds on the banks and migratory birds often sighted on the water.

Before rehabilitation the "lake" had an estimated area of 300,000 m^2. Assuming an annual evapotranspiration, of say 4m (assumed higher than usual because the water was hot) gives an evaporative loss of 1200 ML/a. The flow from the bore is more than three times this rate (see section 6.3 below). Water was clearly recharging an extensive alluvial aquifer.

Pic: McDills before rehabilitation – flowing approx 125 litres/sec

Pic: McDills artificial wetland, before rehabilitation

6.2 Optimum rehabilitation

McDills has the largest flow of the three and is therefore the most important to control from a water wastage viewpoint. One option was to kill the flow and cement the hole as thoroughly as possible. It was however considered more desirable, both from the stakeholder point of view and as the only opportunity to establish a pressure monitoring location in this part of the Basin, to reconstruct the bore.

Note also that McDills was drilled to a much greater depth than the other two bores, and intersected several formations below the De Souza sandstone which is the shallowest aquifer unit in the Territory part of the GAB. Groundwater in deeper aquifers is believed to be of poorer quality. In particular the Crown Point sandstone, which lies immediately beneath the De Souza sandstone, may be contributing to the flow from the bore. The original drilling of McDills was controlled by mud. An artesian water flow exceeded the mud head near the top of the Crown Point formation. The only water analysis from the original drilling came from this flow, being 2,423 mg/L total dissolved solids, although this may have been a blended sample from several depths in the hole. Subsequent analyses on file show TDS 2,390 (in 1980) 2,420 (1986) 2,570 (1991).

Casing was later run just beyond the bottom of the Crown Point and its annulus cemented to a target just above the top of the Crown Point. The weight of cement used, if diluted at the standard rate of 25L/bag, would only have been sufficient to cement 150m of the 203m annulus estimated. We can only assume that a greater dilution rate was used (34L/bag by calculation), or that the interval was not fully cemented.

Ideally a new cement plug would be placed in the hole towards the base of the De Souza (717m) to ensure that no flow was coming from the Crown Point. This assumes that the hole was completely open to cementing at that point, with no annular flow possible, or that oil-well tools were used to cut any casing present at that depth.

Inert casing would then be inserted some depth into the De Souza, that is beyond 463m, and pressure cemented back to surface.

The above design has the possibility of gaining a flow of with improved water quality.

6.3 Preliminary investigations

In July 1999 an earth ramp was pushed from the shore to the bore. A four-wheel-drive vehicle was then able to run borehole-logging tools.

There was an irregular obstruction at the surface, which prevented tools from going into the hole easily. The hole was very rough internally, and 43mm-diameter tools had some difficulty in running down. Maximum depth reached by the in-hole tools was 242m; there seemed to be a firm bottom.

In August 2000 the ramp was upgraded and a steel platform sufficient to withstand the weight of a drill rig was constructed over the site. The earthen bank was continued to the eastern side of the dunes to prevent water flow to the southern side of the bore. As the wall was built completely across the swamp, flow to the south ceased. The southern areas was dry when next visited in. All water then flowed to the north; in April 2002 the northern swamp had extended an estimated 700m. The extra area was completely colonised by Typha species reeds.

Pic: McDills – attempting to lower logging tool into uncontrolled bore

Pic: McDills first ramp to allow inspection and light vehicle access 1999

Pic: McDills Ramp across lake, no flow to south (left of picture)

Pic: McDills constructing platform for heavy vehicle access

A South Australian Government borehole camera system designed to operate in water temperatures above 50C was contracted to run inside the bore to investigate casing conditions. The camera showed that the original casing had badly corroded and was severely damaged in some locations.

On 02-08-2000 the downhole camera was lowered into the bore to a depth of 340m. The upper 100m of casing was in fair/poor condition. Holes can be seen in the casing. From below about 120 m the casing is very badly damaged and corroded. Some sections of casing are completely missing, where the casing is gone it can been seen that the casing is paper thin. At 340m the operator declined to run the camera any further due to loose casing in the hole posing a risk of entanglement.

That 13" casing was originally run to 364m, seated at the top of the subsequent 12¼" hole. It may be that we were seeing the top of a 23m section where casing debris was "piling up" at the hole reduction. It is a pity that a dolly or spear was not run to clear this, to see if the camera could then go further: the assumption that the hole was not accessible below this point constrained further thinking about rehabilitation design options.

In 2002 a hydrographic crew accurately measured the outflow where it was confined to a single channel within 10m of the bore. The average flow was 120 L/s, that is 10 ML/day or 3,800 ML/annum.

Pic: McDills – Flow gauging after platform constructed

6.4 Adopted approach to rehabilitation

The video log showed that the cementing of the 13" casing was good, and that the hole will be sound to 364m where the 13" was seated. The top of the De Souza is at 463m, overlain by transition beds (top 438m), overlain by Rumbalara Shale (top 31m) finally overlain by quaternary alluvium.

It was therefore decided to pressure-cement fibreglass casing into the shallowest / most extensive section of 13" where the 9" was absent.

Data from the video log and the flow measurement were used to refine calculations for mud densities and quantities and calculate upper and lower bounds for the quantity of cement needed.

6.5 McDills field work

Drill rods of over-sized internal diameter were run to 340m. Two mud pumps were coupled to a manifold on the top of the drill string to pump 12,000 litres of 1.65 SG barytes-bentonite mud which stopped the artesian flow and caused a flow of water from the swamp back down the hole on top of the mud.

The drill string was retracted to 180m and a temporary plug of 1,500 litres of cement / 5% bentonite slurry was pumped to form a plug calculated to be 20m long. When the cement had set, it was located with the drill string at 199m.

A 193m casing string was run, consisting of 21m of plain steel casing at the bottom, 2.5m of stainless steel casing at the top, and the balance 127mm ID fibreglass. The bottom steel section included a drillable connection for the drill string to deliver the pressure cement, a non-return valve, slots for the cement to flow to the annulus, and a drillable leader to guide it down the hole.

Two metres of 650mm surface casing was placed to bring the completed bore-head up to the level of the platform which had been constructed, ensuring that all headworks are well above natural surface.

11,000 litres of cement / 5% Bentonite slurry was pumped through the cement shoe to pressure cement the new casing in place. Good-quality cement returned to the surface up the annulus, also filling the surface casing and overflowing to further stabilise the final pad. The quantity of cement used to fill the annulus suggested that 60m of the 9" – 13" annulus had still been intact. This is consistent with drilling records of 40 sacks cement being pumped down the annulus when the bore was originally completed.

The base of the casing string and the cement plug were drilled out, with the bottom of the cement plug and being at 208.7m, and mud bailed from an initial 20m down the hole before artesian flow was re-established. The following morning the bore was flowing at approximately 50 L/s through a 100 mm outlet.

6.6 McDills completion details

A diagram of the final construction is in Appendix 1. Results of water chemistry analyses are in Appendix 2.

Headworks consist of a 5" full-flow stainless steel knife valve with a locked, heavy steel protection cap. A 25 mm orifice in the top flange provides a primary flow restriction, further controlled with a 40 mm gate valve before flowing 130 m through 40 mm stainless steel pipe to establish a small wetland area.

Pic: McDills headworks after rehabilitation

Pic: McDills headworks after rehabilitation

Water level in the swamp dropped 150mm in the first 66 hours after artesian flow was killed. This is far in excess of evapotranspiration, confirming that recharge into shallow alluvium was significant.

Date	Flow through 100 mm outlet (L/s)	Temperature (°C)	Conductivity (uS/cm)	Shut in pressure (kPa)	Controlled flow to wetland (L/s) and area
25 May 2002	61	60	5300	280	5.5
09 June 2002		57.5	6000 at 57.5° 5080 at 32°	280	5.5
27 May 2003		59		300	8 (0.15Ha)
02 August 2006		58		308	8 (0.75 Ha)

6.7 Possible future uses

Good for horticulture, eg dates, but very remote.
OK for emergency use.
Not suitable for long-term potable consumption.
Being used by large herds of camels, herds of horses, and numbers of cattle with Andado pastoral lease ear tags.

Pics: McDills outlet to maintain small wetland habitat:

2002

2008

2008

<u>Section 7 – FINANCIALS</u>

Total cost of $500,000 –

$ 255,408 Commonwealth government component
(As per NHT funding), includes:

- materials
- miscellaneous hire costs (including down-hole camera)
- field costs (travel allowance)
- field costs (overtime)
- plant hire costs

$ 215,408 Territory government component
Compared with $ 172,000 estimated in the NHT application.

- field costs (salaries of project managers and supervisors)
- travel and vehicle-hire costs for project managers
- miscellaneous project management, reporting etc costs

$ 40,000 CLC and traditional owner consultation costs (in-kind contributions).
As per NHT application estimate.

Section 8 – CONCLUSIONS & RECOMMENDATIONS

8.1 Outcomes of NHT project

None of the reconstructions were ideal.

The overall aim of significantly reducing wastage of water and of artesian pressure was achieved.

8.2 Ownership

Ownership of all bores should remain with the Northern Territory Government. The Government would then continue to be responsible for maintaining the headworks of Anacoora and McDills, and monitoring pressures and water levels. The Controller of Water Resources can issue specific use licenses under the Northern Territory Water Act for use of water from any of these bores by any user, including an Aboriginal Land Trust, if the requested.

8.3 Recommended maintenance

Headworks of Anacoora and McDills should be inspected annually, valves operated, and pressures taken as part of the regional monitoring program. Any significant changes in condition, or in aquifer pressures should trigger further assessment and appropriate action.

8.4 Recommended monitoring

McDills is the most reliable source for continual pressure data of the GAB aquifers in the Territory, although it represents a mixture of aquifers.

Some estimate should be obtained of the relative heads in the De Souza and Crown Point formations. If they are significantly different, then there is little point in monitoring McDills UNLESS the head measured is in line with expectations for the De Souza.

Anacoora, which presumably taps only the top aquifer, would be a good monitoring point if the bore remains open.

Annual pressure data records are recommended, and visits to the bores should be integral to the Territory government groundwater monitoring program.

The water level and the temperature of the shallow bore adjacent to Dakota bore should continue to be monitored. If there is no decline in these, then it must be concluded that leakage is still occurring, and consideration be given to a further attempt to shut off the underlying flow.

8.5 Other recommendations

The constructions of the other abandoned petroleum bores in the Territory's portion of the GAB (table 1) should be assessed for risk and the assessment and construction diagrams placed on file.

REFERENCES

Rooke, E 1991 — Prospects for Artesian Water Supplies: Andado Pastoral Lease. Water Resources Report 44/1991.

Matthews, ID 1995 — Preliminary Report on the Great Artesian Basin in the Northern Territory. Water Resources Report 07/1995.

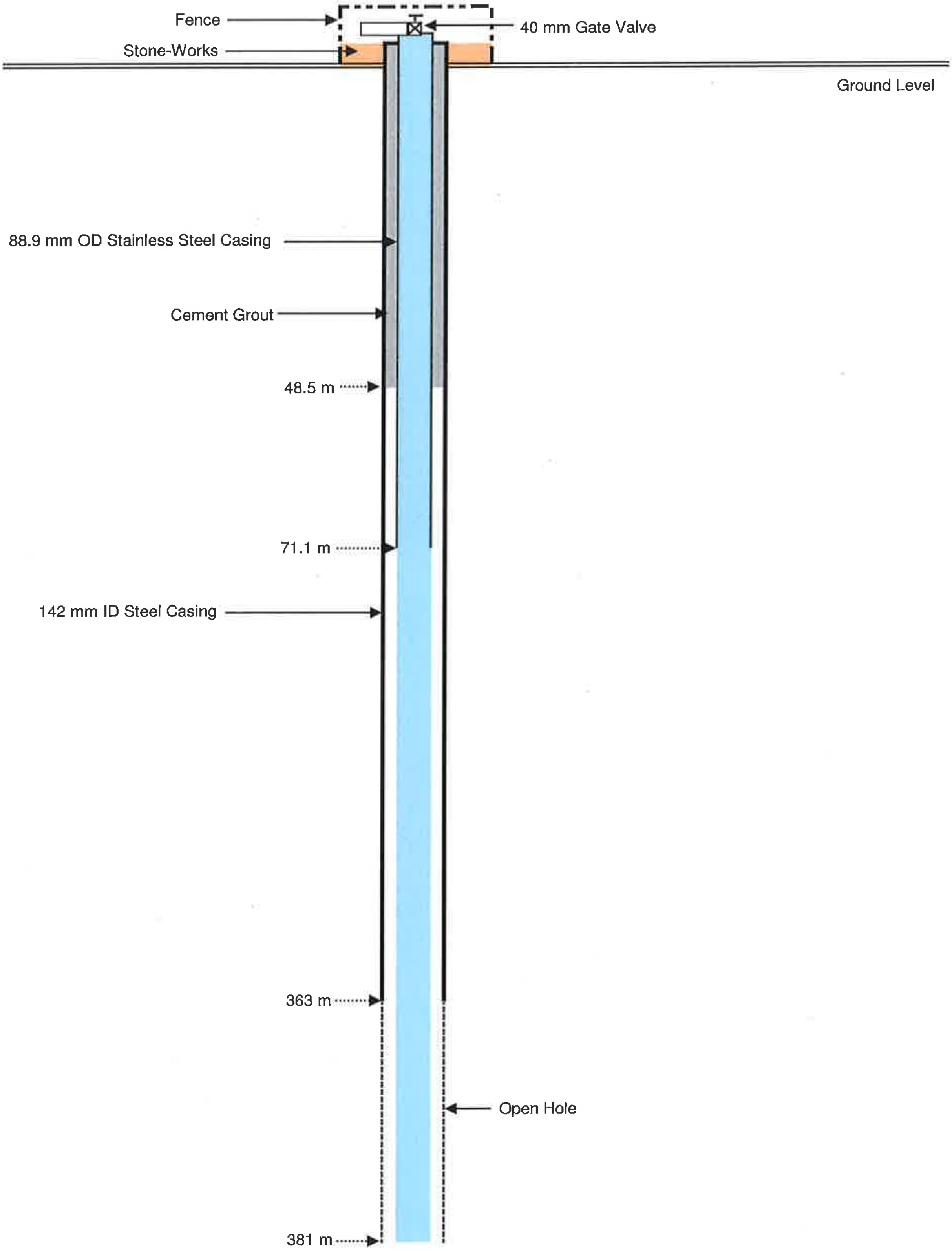
Matthews, ID 1996 — Hydrogeology of the Great Artesian Basin in the Northern Territory. Water Resources Report 52/1996.

GABCC 2000 — Great Artesian Basin Strategic Management Plan. Great Artesian Basin Consultative Council. September 2000.

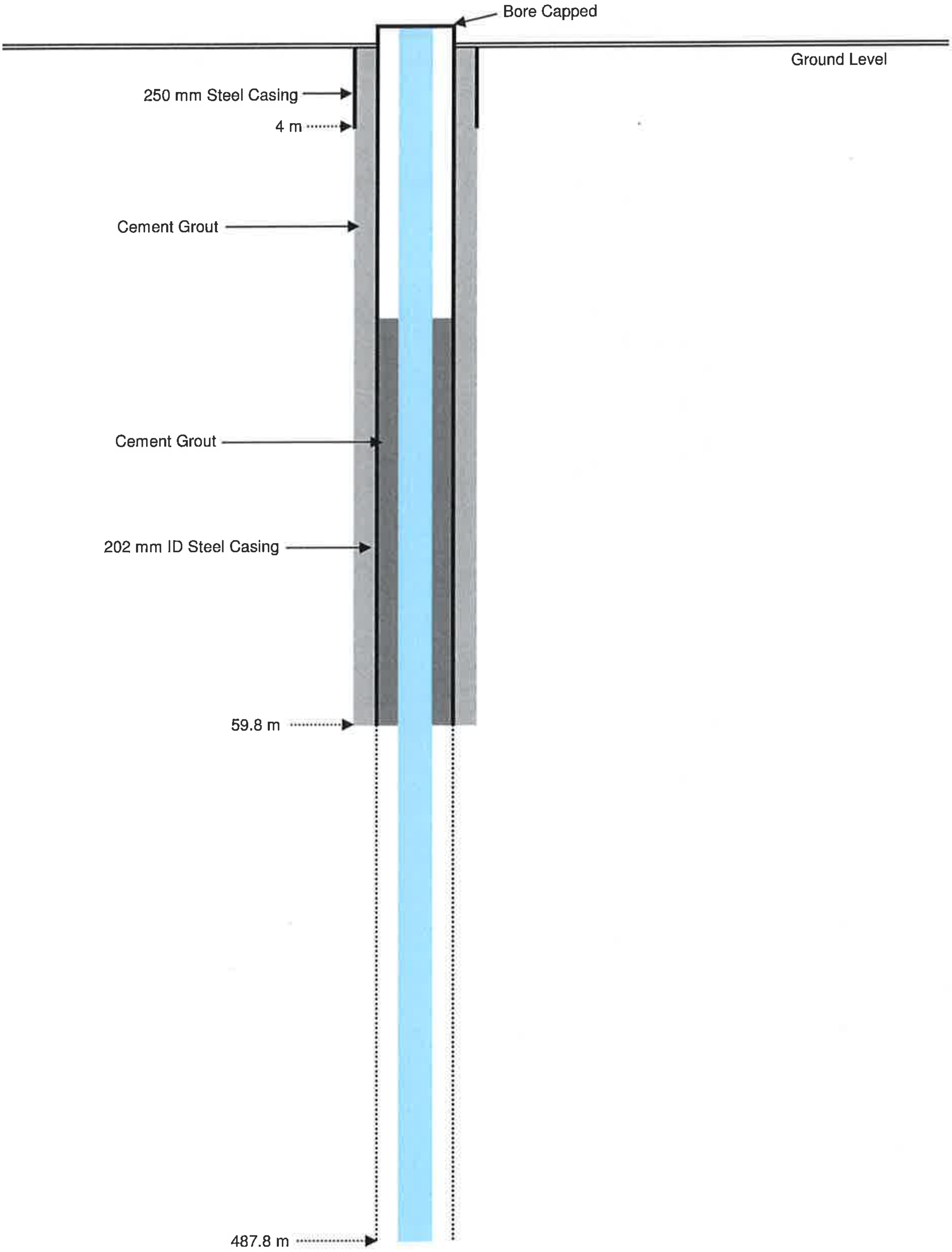
Waldron, JJ 1916 — Central Australia, the Macdonnell Ranges and surrounding country, having in reference the possibility of railway extension from Oodnadatta to Alice Springs, published McCarron, Bird.

APPENDIX 1 – BORE CONSTRUCTION DIAGRAMS

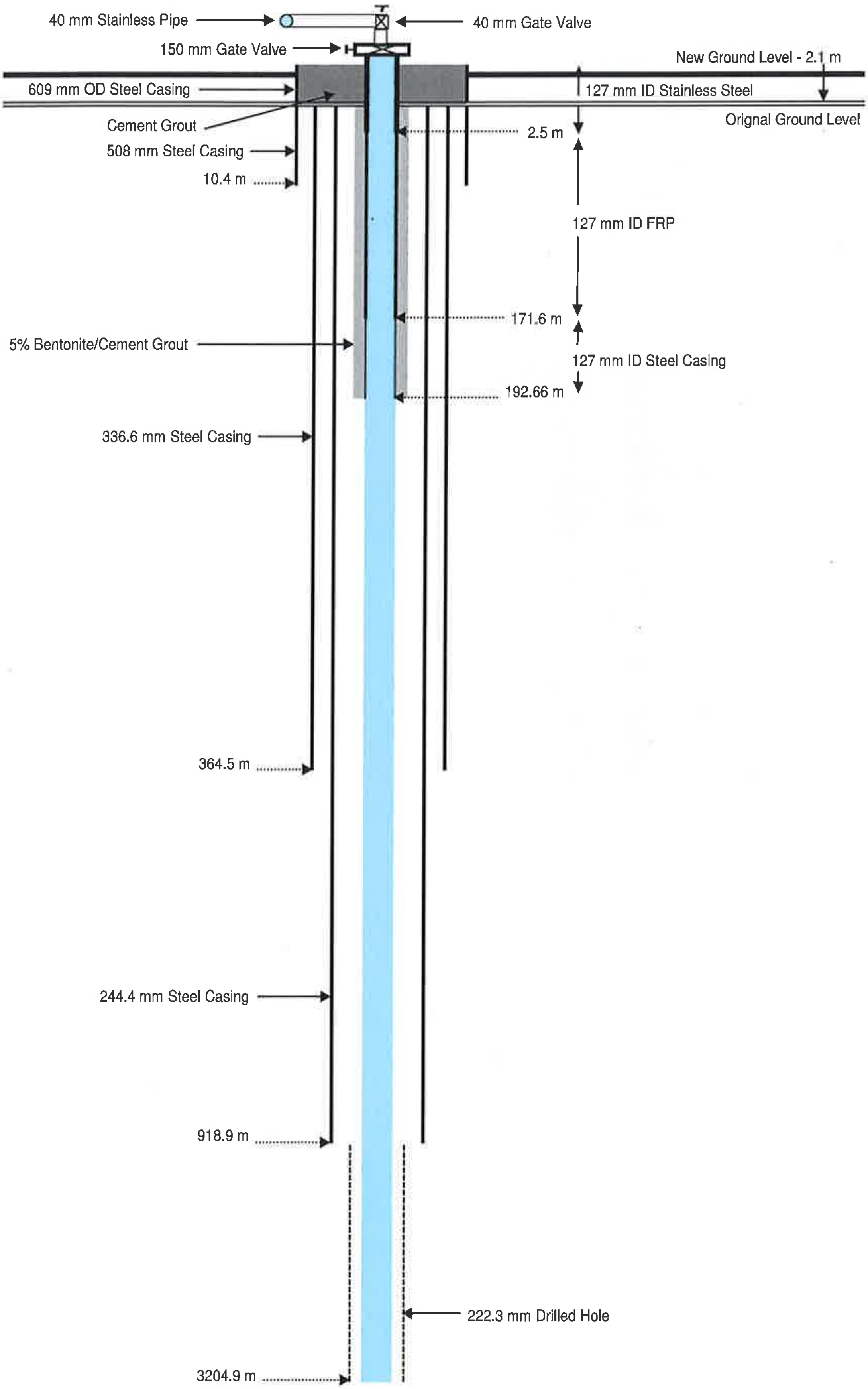
RN 977 Anacoora Bore



RN 12431 Dakota Bore



RN 5028 M^c^Dills Bore



APPENDIX 2 – WATER QUALITY ANALYSES

The most recent major ions analyses for all 3 bores follow.

Full scans (ICPMS) are available for Anacoora and McDills only, and may be found on the bore data files.

Northern Territory Government
Department of Business, Industry & Resource Development

RESOURCE PROTECTION DIVISION
WATER CHEMISTRY LABORATORY

GPO Box 3000, DARWIN NT 0801
BERRIMAH AGRICULTURAL FARM
STRATH ROAD, BERRIMAH NT 0828
TELEPHONE (08) 89992192
FAX (08) 89992191

Bottle No: DAKOTA	Lab Register No: 192		
Date Received in Lab: 13/05/02	Time Sampled:	Date Sampled: 12/05/02	
Bore RN: 5028	Depth (m)	Q:	Map:
G.S.No:	G.H. (m)	Q:	G.R. :
Sampler: KUNDE			
Location: G.A.B. DAKOTA BORE	020514k	Project No : DIPE - B. KUNDE	

ANALYSIS - PHYSICAL

	pH [4500-H$^+$B]	7.0	
	Electrical Conductivity 25°C (uS cm^{-1}) [2510B]	2,283	
/	Total Dissolved solids (mgL^{-1}dried 180°C) [2540C]	1,288	
	Colour (Hazen units) [2120B]		
	Turbidity (NTU)'s [2130B]		
	Suspended Solids (mg L^{-1}) [2540B]		

ANALYSIS - CHEMICAL (mg L^{-1})

/	Sodium, Na [3111B]	356
	Potassium, K [3111B]	17
	Calcium, Ca [3111D]	55
	Magnesium, Mg [3111B]	24
/	Iron (total), Fe [3111B]	3.1
	Total Hardness (as $CaCO_3$) calc [2340B]	236
	Total Hardness (as $CaCO_3$) titr [2340C]	
	Total Alkalinity (as $CaCO_3$) [2320B]	146
	Silica, SiO_2 [4500-Si D]	23
/	Chloride, Cl [4500-Cl$^-$ B]	514
	Sulphate, SO_4 [G]	219
	Nitrate, NO_3 [4500-NO_3^- B]	< 1
	Bicarbonate, HCO_3 [2320B]	178
	Carbonate, CO3 [2320B]	0
	Hydroxide, OH [2320B]	0
	Fluoride, F [4500-F$^-$ C]	0.5
	Sodium Chloride, NaCl (calc from Cl)	847
	Dissolved Oxygen [4500-O B]	

ANALYSIS - ADDITIONAL (mg L^{-1})

#	U/S	DENOTES UNSUITABLE FOR ANALYSIS
#	I/S	DENOTES INSUFFICIENT SAMPLE
#	F	DENOTES FILTRATE ANALYSIS
#	T	DENOTES TOTAL ANALYSIS

C1 192 020514k

This report relates specifically to the "samples tested as received".

The test methods used (denoted within brackets) refer to the 1992 18th edition of "Standard Methods for the examination of Water and Wastewater", A.P.H.A. Except [G] which refers to the method of R. Goguel, Anal. Chem. 1969, 41. 1034.

DATE : 22/05/02

CHECKED : KRon

SIGNATORY : K Coop

Boxes marked thus indicate :

- [ ] Levels are within the limits as quoted in the "Guidelines for Drinking Water Quality in Australia". 1987 N.H.& M.R.C. and the A.W.R.C.
- [/] Levels exceed non health related limits.
- [X] Levels exceed health related limits.

RECEIVED
27 MAY 2002
D.I.P.E. - N.R.D

Northern Territory Government Department of Business, Industry & Resource Development RESOURCE PROTECTION DIVISION WATER CHEMISTRY LABORATORY	GPO Box 3000, DARWIN NT 0801 BERRIMAH AGRICULTURAL FARM STRATH ROAD, BERRIMAH NT 0828 TELEPHONE (08) 89992192 FAX (08) 89992191	Bottle No: DAKOTA	Lab Register No: 192
	Date Received in Lab: 13/05/02	Time Sampled:	Date Sampled: 12/05/02
Bore RN: 12431 ~~5028~~ / Depth (m)	Q: / Map:		Sampler: KUNDE
G.S.No: / G.H. (m)	Q: / G.R.:		
Location: G.A.B. DAKOTA BORE			020514k Project No : DIPE - B. KUNDE

ANALYSIS - PHYSICAL

	pH	[4500-H⁺B]	7.0		Colour (Hazen units)	[2120B]	
	Electrical Conductivity 25°C (uS cm^{-1})	[2510B]	2,283		Turbidity (NTU)'s	[2130B]	
/	Total Dissolved solids (mgL^{-1} dried 180°C)	[2540C]	1,288		Suspended Solids (mg L^{-1})	[2540B]	

ANALYSIS - CHEMICAL (mg L^{-1})

/	Sodium, Na	[3111B]	356	/	Chloride, Cl	[4500-Cl^- B]	514
	Potassium, K	[3111B]	17		Sulphate, SO_4	[G]	219
	Calcium, Ca	[3111D]	55		Nitrate, NO_3	[4500-NO_3^- B]	< 1
	Magnesium, Mg	[3111B]	24		Bicarbonate, HCO_3	[2320B]	178
/	Iron (total), Fe	[3111B]	3.1		Carbonate, CO3	[2320B]	0
	Total Hardness (as $CaCO_3$) calc	[2340B]	236		Hydroxide, OH	[2320B]	0
	Total Hardness (as $CaCO_3$) titr	[2340C]			Fluoride, F	[4500-F^- C]	0.5
	Total Alkalinity (as $CaCO_3$)	[2320B]	146		Sodium Chloride, NaCl (calc from Cl)		847
	Silica, SiO_2	[4500-Si D]	23		Dissolved Oxygen	[4500-O B]	

ANALYSIS - ADDITIONAL (mg L^{-1})

\# U/S DENOTES UNSUITABLE FOR ANALYSIS
\# I/S DENOTES INSUFFICIENT SAMPLE
\# F DENOTES FILTRATE ANALYSIS C1 192 020514k
\# T DENOTES TOTAL ANALYSIS

This report relates specifically to the "samples tested as received".

The test methods used (denoted within brackets) refer to the 1992 18th edition of "Standard Methods for the examination of Water and Wastewater", A.P.H.A. Except [G] which refers to the method of R. Goguel, Anal. Chem. 1969, 41. 1034.

DATE : 22/05/02

CHECKED : KRon

SIGNATORY : [signature]

Boxes marked thus indicate :

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- [/] Levels exceed non health related limits.
- [X] Levels exceed health related limits.

RECEIVED
27 MAY 2002
D.I.P.E. - N.R.D.

RESOURCE PROTECTION DIVISION WATER CHEMISTRY LABORATORY	GPO BOX 990, DARWIN NT 0801 BERRIMAH AGRICULTURAL FARM STRATH ROAD, BERRIMAH NT 0828 Telephone: (08) 8999 2192 Fax: (08) 8999 2191		Bottle No.: DAK 431	Lab Register No.: 1105
	Date Received in Lab: 29/10/99	Time Sampled:		Date Sampled: 15/9/99
R/N No.: 12431	Depth (m) :	Q:	Map: SG 53-7	Sampler:
G.S. No.:	G.H. (m):	Q:	G.R.:	
Location: DAKOTA STATION		Field Temp °C:	Field pH:	Field Cond µScm⁻¹:
		RSP:	Project No.: 174RA3D01352001	

ANALYSIS - PHYSICAL

☐ pH	[4500-H⁺B]	8.0	☐ Colour (Hazen units)	[2120B]	
☐ Electrical conductivity (microsiemens/cm at 25°C)	[2510B]	2290	☐ Turbidity (NTU's)	[2130B]	
☑ Total dissolved solids (mg L⁻¹ - dried at 180° C)	[2540C]	1290	☐ Suspended solids (mg L⁻¹)	[2540D]	

ANALYSIS - CHEMICAL (mg L⁻¹)

☑ Sodium, Na	[3111B]	374	☑ Chloride, Cl	[4500-Cl⁻ B]	530
☐ Potassium, K	[3111B]	17	☐ Sulphate, SO_4	[G]	210
☐ Calcium, Ca	[3111D]	57	☐ Nitrate, NO_3	[4500-NO_3^- B]	<1
☐ Magnesium, Mg	[3111B]	25	☐ Bicarbonate, HCO_3	[2320B]	186
☑ Iron, (total) Fe	[3111B]	1.3	☐ Carbonate, CO_3	[2320B]	0
☐ Total Hardness (as $CaCO_3$) Calculation	[2340B]	245	☐ Hydroxide, OH	[2320B]	0
☐ Total Hardness (as $CaCO_3$) Titration	[2340C]		☐ Fluoride, F	[4500-F⁻ C]	0.7
☐ Total Alkalinity (as $CaCO_3$)	[2320B]	153	☐ NaCl (calc. from chloride)		873
☐ Silica, SiO_2	[4500-Si D]	21	☐ Dissolved Oxygen	[4500-O-C]	

ANALYSIS - ADDITIONAL (mg L⁻¹)

☐ Copper, Cu	[3111B]		☐ Manganese, Mn	[3111B]		☐ Zinc, Zn	[3111B]	
☐			☐			☐		

- U/S DENOTES UNSUITABLE FOR ANALYSIS
- I/S DENOTES INSUFFICIENT SAMPLE
- F DENOTES FILTRATE ANALYSIS
- T DENOTES TOTAL ANALYSIS

C1 64513 991102j # 11

This report relates specifically to the "sample tested as received".

The test methods used (denoted within brackets) refer to the 1992 18th edition of "Standard Methods for the examination of Water and Wastewater", A.P.H.A. Except [G] which refers to the method of R. Goguel, Anal. Chem. 1969, 41, 1034.

DATE: -5 NOV 1999

CHECKED: [signature]

SIGNATORY: [signature]

Boxes marked thus indicate:

☐ Levels are within the limits as quoted in the "Guidelines for Drinking Water Quality in Australia". 1987 N.H. & M.R.C. and the A.W.R.C.

☑ Levels exceed non-health related limits.

☒ Levels exceed health related limits

R: 977 RN977
ANACOORA BORE
* Pool adjacent to bore
Sampled Aug 2000 D. Miller

CHEMNORTH

DEPARTMENT OF LANDS, PLANNING & ENVIRONMENT
TECH SERVICES DIVISION
PO BOX 1512 ALICE SPRINGS NT 0871

Chemnorth Pty Ltd
ACN 073 547 207
3407 Export Drive
Berrimah NT 0828
Ph 08 8947 0510
Fax 08 8947 0520

REPORT CODE	**DW03383**
Report Date	14/09/00
Samples Received	8/09/00
Number of Samples	1
Reference	
Project	
Cost Code	

Note levels As, Cu

Report Distribution;
Mr G Humphries
Mr E. Czobik
Phone 8999 2192
Fax 8999 2191

Sample Details:

Water samples, 1 bottles for 1 samples.

Report Details:

Comments:

Due to high levels of total dissolved solids, detection limits have been raised to allow for sample dilution.
The dilution factors for each sample are listed at the end of the job.

Samples with concentrations greater than the LINEAR WORKING RANGE (>LWR) of the ICPMS were reanalysed by ICP

Authorisation: [signature]

Fiona Dunbar-Smith

RN977

CHEMNORTH

REPORT CODE **DW03383**

Methodology:

Analysis		Analytical Method	Digest	Technique	Accuracy / Precision	Detection Limit	Data Units
Ag	Silver	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Al	Aluminium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
As	Arsenic	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Au	Gold	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
B	Boron	W210M	W210	ICPMS	ACC±10%	0.5	µg/L
Ba	Barium	W210M	W210	ICPMS	ACC±10%	0.02	µg/L
Be	Beryllium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Bi	Bismuth	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Br	Bromine	W210M	W210	ICPMS	ACC±10%	1	µg/L
Ca	Calcium	W210M	W210	ICPOES	ACC±10%	10	µg/L
Ca	Calcium	W210I	W210	ICPOES	ACC±10%	100	µg/L
Cd	Cadmium	W210M	W210	ICPMS	ACC±10%	0.02	µg/L
Ce	Cerium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Co	Cobalt	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Cr	Chromium	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
Cs	Caesium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Cu	Copper	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Dy	Dysprosium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Er	Erbium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Eu	Europium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Fe	Iron	W210M	W210	ICPMS	ACC±10%	20	µg/L
Fe	Iron	W210I	W210	ICPOES	ACC±10%	50	µg/L
Ga	Gallium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Gd	Gadolinium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Ge	Germanium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Hf	Hafnium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Hg	Mercury	W210M	W210	ICPMS	ACC±10%	0.02	µg/L
Ho	Holmium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
I	Iodine	W210M	W210	ICPMS	ACC±10%	5	µg/L
In	Indium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
La	Lanthanum	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Li	Lithium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Lu	Lutetium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Mg	Magnesium	W210M	W210	ICPMS	ACC±10%	10	µg/L
Mg	Magnesium	W210I	W210	ICPOES	ACC±10%	100	µg/L
Mn	Manganese	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Mo	Molybdenum	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Nb	Niobium	W210M	W210	ICPMS	ACC±10%	0.02	µg/L

RN977

CHEMNORTH

REPORT CODE **DW03383**

Methodology:

Analysis		Analytical Method	Digest	Technique	Accuracy / Precision	Detection Limit	Data Units
Nd	Neodymium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Ni	Nickel	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Os	Osmium	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
Pb	Lead	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Pd	Palladium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Pr	Praseodymium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Pt	Platinum	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Rb	Rubidium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Re	Rhenium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Ru	Ruthenium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Sb	Antimony	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Sc	Scandium	W210M	W210	ICPMS	ACC±10%	0.5	µg/L
Se	Selenium	W210M	W210	ICPMS	ACC±10%	0.2	µg/L
Sm	Samarium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Sr	Strontium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Ta	Tantalum	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Tb	Terbium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Te	Tellurium	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
Th	Thorium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Ti	Titanium	W210M	W210	ICPMS	ACC±10%	2	µg/L
Tl	Thallium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Tm	Thulium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
U	Uranium	W210M	W210	ICPMS	ACC±10%	0.001	µg/L
V	Vanadium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
W	Tungsten	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Y	Yttrium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Yb	Ytterbium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Zn	Zinc	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
Zr	Zirconium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L

REPORT CODE: DW03383

	Element	Ag	Al	As	Au	B	Ba	Be	Bi	Br	Ca
	Scheme	W210M	W210M	W210M	W210M	W210M	W210M	W210M	W210M	W210M	W210M
Sample ID	Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
RI03 LAB# 1167		<0.1	876.0	105.8	0.07	23	89.40	<0.1	0.13	3	>LWR

CHEMNORTH

RN977

REPORT CODE: DW03383

Element		Ca	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu
	Scheme	W210I	W210M	W210M	W210M	W210M	W210M	W210M	W210M	W210M	W210M
Sample ID	Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
RI03 LAB# 1167		96072	0.11	28.96	0.91	3.8	0.41	653.80	0.26	0.06	0.32

CHEMNORTH

RN977

GPO BOX 990, DARWIN NT 0801
BERRIMAH AGRICULTURAL FARM
STRATH ROAD, BERRIMAH NT 0828
Telephone: (08) 8999 2192
Fax: (08) 8999 2191

RESOURCE PROTECTION DIVISION
WATER CHEMISTRY LABORATORY

Bottle No.: ANA 977	Lab Register No.: 1104		
Date Received in Lab: 29/10/99	Time Sampled:	Date Sampled: 15/9/99	
R/N No.: 977	Depth (m):	Q:	Map: GS 53-7
G.S. No.:	G.H. (m):	Q:	G.R.:
Sampler:			
Location: ANACOORA STATION	Field Temp °C:	Field pH:	Field Cond µScm⁻¹:
	RSP:	Project No.: 174RA3D0135200I	

ANALYSIS - PHYSICAL

pH	[4500-H⁺B]	8.1	Colour (Hazen units)	[2120B]	
Electrical conductivity (microsiemens/cm at 25°C)	[2510B]	2930	Turbidity (NTU's)	[2130B]	
☑ Total dissolved solids (mg L⁻¹ - dried at 180° C)	[2540C]	1630	Suspended solids (mg L⁻¹)	[2540D]	

ANALYSIS - CHEMICAL (mg L⁻¹)

☑ Sodium, Na	[3111B]	555	☑ Chloride, Cl	[4500-Cl⁻ B]	733
Potassium, K	[3111B]	8	Sulphate, SO_4	[G]	210
Calcium, Ca	[3111D]	31	Nitrate, NO_3	[4500-NO_3^- B]	2
Magnesium, Mg	[3111B]	11	Bicarbonate, HCO_3	[2320B]	186
☑ Iron, (total) Fe	[3111B]	1.0	Carbonate, CO_3	[2320B]	0
Total Hardness (as $CaCO_3$) Calculation	[2340B]	123	Hydroxide, OH	[2320B]	0
Total Hardness (as $CaCO_3$) Titration	[2340C]		Fluoride, F	[4500-F⁻ C]	0.5
Total Alkalinity (as $CaCO_3$)	[2320B]	153	NaCl (calc. from chloride)		1210
Silica, SiO_2	[4500-Si D]	19	Dissolved Oxygen	[4500-0-C]	

ANALYSIS - ADDITIONAL (mg L⁻¹)

Copper, Cu	[3111B]		Manganese, Mn	[3111B]		Zinc, Zn	[3111B]	

- U/S DENOTES UNSUITABLE FOR ANALYSIS
- I/S DENOTES INSUFFICIENT SAMPLE
- F DENOTES FILTRATE ANALYSIS
- T DENOTES TOTAL ANALYSIS

C1 7975 991102j # 10

This report relates specifically to the "sample tested as received".

The test methods used (denoted within brackets) refer to the 1992 18th edition of "Standard Methods for the examination of Water and Wastewater", A.P.H.A. Except [G] which refers to the method of R. Goguel, Anal. Chem. 1969, 41. 1034.

DATE: -5 NOV 1999

CHECKED: [signature]

SIGNATORY: [signature]

Boxes marked thus indicate:
- ☐ Levels are within the limits as quoted in the "Guidelines for Drinking Water Quality in Australia". 1987 N.H. & M.R.C. and the A.W.R.C.
- ☑ Levels exceed non-health related limits.
- ☒ Levels exceed health related limits

09 NOV 1999
D.L.P.E - W.R.D.

RN 5028

NORTHERN TERRITORY ENVIRONMENTAL LABORATORIES PTY LTD

CHEMICAL ANALYSIS REPORT

DEPARTMENT OF INFRASTRUCTURE, PLANNING & ENVIRONMENT
NATURAL RESOURCES
P.O. Box 2130 ,
Alice Springs N.T. 0871

NTEL
ACN 095 369 289
3407 Export Drive
Berrimah NT 0828
Ph 08 8947 0510

Fax 08 8947 0520

REPORT CODE	**EL01431**
Report Date	19/07/02
Samples Received	9/07/02
Number of Samples	2
Reference	
Project	60NR01A07342111
Cost Code	

Report Distribution;

Dave Miller

Sample Details:

Water samples: 2 bottles for 2 samples.

Report Details:

Test results only apply to the samples received

Comments:

National Association of Testing Authorities, Australia

NATA ENDORSED DOCUMENT
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Authorisation:

Fiona Dunbar-Smith

RN5028

NORTHERN TERRITORY ENVIRONMENTAL LABORATORIES

REPORT CODE **EL01431**

Methodology:

Analysis		Analytical Method	Digest	Technique	Accuracy / Precision	Detection Limit	Data Units
Ag	Silver	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Al	Aluminium	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
As	Arsenic	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Au	Gold	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
B	Boron	W210M	W210	ICPMS	ACC±10%	0.5	µg/L
Ba	Barium	W210M	W210	ICPMS	ACC±10%	0.02	µg/L
Be	Beryllium	W210M	W210	ICPMS	ACC±10%	0.10	µg/L
Bi	Bismuth	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Br	Bromine	W210M	W210	ICPMS	ACC±10%	1	µg/L
Ca	Calcium	W210I	W210	ICPOES	ACC±10%	0.1	mg/L
Cd	Cadmium	W210M	W210	ICPMS	ACC±10%	0.02	µg/L
Ce	Cerium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Co	Cobalt	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Cr	Chromium	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
Cs	Caesium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Cu	Copper	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Dy	Dysprosium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Er	Erbium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Eu	Europium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Fe	Iron	W210M	W210	ICPMS	ACC±10%	20	µg/L
Ga	Gallium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Gd	Gadolinium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Ge	Germanium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Hf	Hafnium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Hg	Mercury	W210M	W210	ICPMS	ACC±10%	0.02	µg/L
Ho	Holmium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
I	Iodine	W210M	W210	ICPMS	ACC±10%	5	µg/L
In	Indium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
K	Potassium	W210I	W210	ICPOES	ACC±10%	0.1	mg/L
La	Lanthanum	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Li	Lithium	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
Lu	Lutetium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Mg	Magnesium	W210I	W210	ICPOES	ACC±10%	0.1	mg/L
Mn	Manganese	W210M	W210	ICPMS	ACC±10%	0.01	µg/L

RN5028

NORTHERN TERRITORY ENVIRONMENTAL LABORATORIES

REPORT CODE **EL01431**

Methodology:

Analysis		Analytical Method	Digest	Technique	Accuracy / Precision	Detection Limit	Data Units
Mo	Molybdenum	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Na	Sodium	W210I	W210	ICPOES	ACC±10%	0.1	mg/L
Nb	Niobium	W210M	W210	ICPMS	ACC±10%	0.02	µg/L
Nd	Neodimium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Ni	Nickel	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Os	Osmium	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
Pb	Lead	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Pd	Palladium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Pr	Praseodymium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Pt	Platinum	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Rb	Rubidium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Re	Rhenium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
Ru	Ruthenium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Sb	Antimony	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Sc	Scandium	W210M	W210	ICPMS	ACC±10%	0.5	µg/L
Se	Selenium	W210M	W210	ICPMS	ACC±10%	0.2	µg/L
Si	Silicon	W210I	W210	ICPOES	ACC±10%	0.1	mg/L
Sm	Samarium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
SO4	Sulphur as Sulphate	W210I	W210	ICPOES	ACC±10%	0.1	mg/L
Sr	Strontium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Ta	Tantalum	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Tb	Terbium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Te	Tellurium	W210M	W210	ICPMS	ACC±10%	0.1	µg/L
Th	Thorium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Ti	Titanium	W210M	W210	ICPMS	ACC±10%	2	µg/L
Tl	Thallium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Tm	Thulium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
U	Uranium	W210M	W210	ICPMS	ACC±10%	0.001	µg/L
V	Vanadium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L
W	Tungsten	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Y	Yttrium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Yb	Ytterbium	W210M	W210	ICPMS	ACC±10%	0.01	µg/L
Zn	Zinc	W210M	W210	ICPMS	ACC±10%	0.5	µg/L
Zr	Zirconium	W210M	W210	ICPMS	ACC±10%	0.05	µg/L

NORTHERN TERRITORY ENVIRONMENTAL LABORATORIES

REPORT CODE: **EL01431**

	Element	Ag	Al	As	Au	B	Ba	Be	Bi	Br	Ca
	Scheme	W210M	W210M	W210M	W210M	W210M	W210M	W210M	W210M	W210M	W210I
Sample ID	Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
RN5028	1/07/02	<0.25	6.2	5.7	<0.05	609	77.9	<0.25	<0.05	4269	131.1
RN5028 DUP	1/07/02	<0.25	6.8	5.9	<0.05	635	77.8	<0.25	<0.05	4306	130.1

NORTHERN TERRITORY ENVIRONMENTAL LABORATORIES

REPORT CODE: **EL01431**

	Element	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu	Fe
Sample ID	Scheme Units	W210M µg/L	W210M µg/L	W210M µg/L	W210M µg/L	W210M µg/L	W210M µg/L	W210M µg/L	W210M µg/L	W210M µg/L	W210M µg/L
RN5028	1/07/02	<0.1	<0.05	<0.05	0.7	2.05	5.25	<0.05	<0.05	<0.05	1069
RN5028 DUP	1/07/02	<0.1	<0.05	<0.05	1.1	2.04	4.99	<0.05	<0.05	<0.05	1037