Northern Territory Government
Department of Infrastructure, Planning and Environment

ALICE SPRINGS TOWN BASIN, REVIEW 2003

Report No.: 42/2003A

VOLUME 1

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December 2003

EXECUTIVE SUMMARY

The Alice Springs Town Basin has been extensively studied for over 50 years. In earlier times it was the water for Alice Springs, more recently it has become an environmental problem.

It is a small alluvial basin recharged primarily from the Todd River, though significant direct infiltration occurs in years of high rainfall such as 1974.

The major management problem in the basin is salinity. Over most of the basin salinity has increased dramatically since about 1972. The increase corresponds to the unusually wet period around 1974, which resulted in substantial diffuse recharge and large rises in water table. The consequences of the large recharge event in 2000 are not yet evident, possibly partly due to lack of monitoring.

The major management objective should be to increase extraction to nearer the basin's maximum. This will have the following benefits:

- Lowering of water levels will reduce the impacts of high water levels on infrastructure.
- Pumping induces recharge from the Todd with lowering of water levels, hence extraction in drought periods can lower TDS (total dissolved solids). However large rainfall events result in direct infiltration which moves salt down to the water table increasing TDS.

Pumping bores have shown varied and sometimes hard to understand salinity trends. The salinity of bores located close to saline water near the eastern margin has increased with time, and some of those will need to be replaced.

An attempt was made to establish a salt balance for the basin. Unfortunately the large uncertainties associated with the rating curve at Heavitree Gap and the very limited set of TDS measurements for flows in the gap have made this impossible at this stage. A conductivity probe is needed on the data logger at the gap.

A digital model of the basin is needed to allow better prediction of the effects of siting new bores and the response of the basin to seasonal conditions. Such a model should incorporate salt transport to try to improve understanding and management of the salinity problems.

The weathered metamorphic rocks around the edges of the basin contain highly saline water. Without due care development will cause problems with a rising saline water table in some areas.

SYNOPSIS

Keywords

Subject	Groundwater resource assessment Groundwater resource management Salinisation
Geology	Town Basin Cainozoic Proterozoic
Location	Alice Springs Braitling Sadadeen Golf Course Gillen Larapinta

LIST OF ABBREVIATIONS

BMR	Former Bureau of Mineral Resources of Commonwealth Department of National Development
B.P.	before present
DIPE	Department of Infrastructure Planning and Environment
ft	foot, 0.3048 m
g	gram
gal	Imperial gallon, 4.54 L
HYDSYS	the DIPE electronic data base
ID	internal diameter
km	kilometres
m	metres
m^2	square metres
m/d	Metres per day, the unit of hydraulic conductivity
m^2/d	metres squared per day, the unit of transmissivity
mg/L	milligrams per litre
ML	megalitres
mm	millimetres
PAWA	Former Power and Water Authority
PWC	Power Water Corporation, successor to PAWA
L/s	litres per second
RN	registered number
T	tonne
TDS	Total dissolved solids
y	year
µS/cm	micro Siemens per centimetre

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1 Description of the Alice Springs Town Basin

1.1 Extent/study area

The Town Basin has historically been defined as the area of alluvial sediments extending north from Heavitree Gap, as mapped by Quinlan and Woolley (1969). The present study encompasses not only the Town Basin, but also the entire town area and all catchments draining into it (Fig. 1).

1.2 Zones

For the purposes of this study the Town Basin can be divided into the following zones:

Northern Zone, roughly under the Central Business District.
Southern Zone.

The above are shown in Figure 1.
The surrounding areas of weathered rock:

Braitling
Sadadeen
Golf Course
Gillen
Larapinta

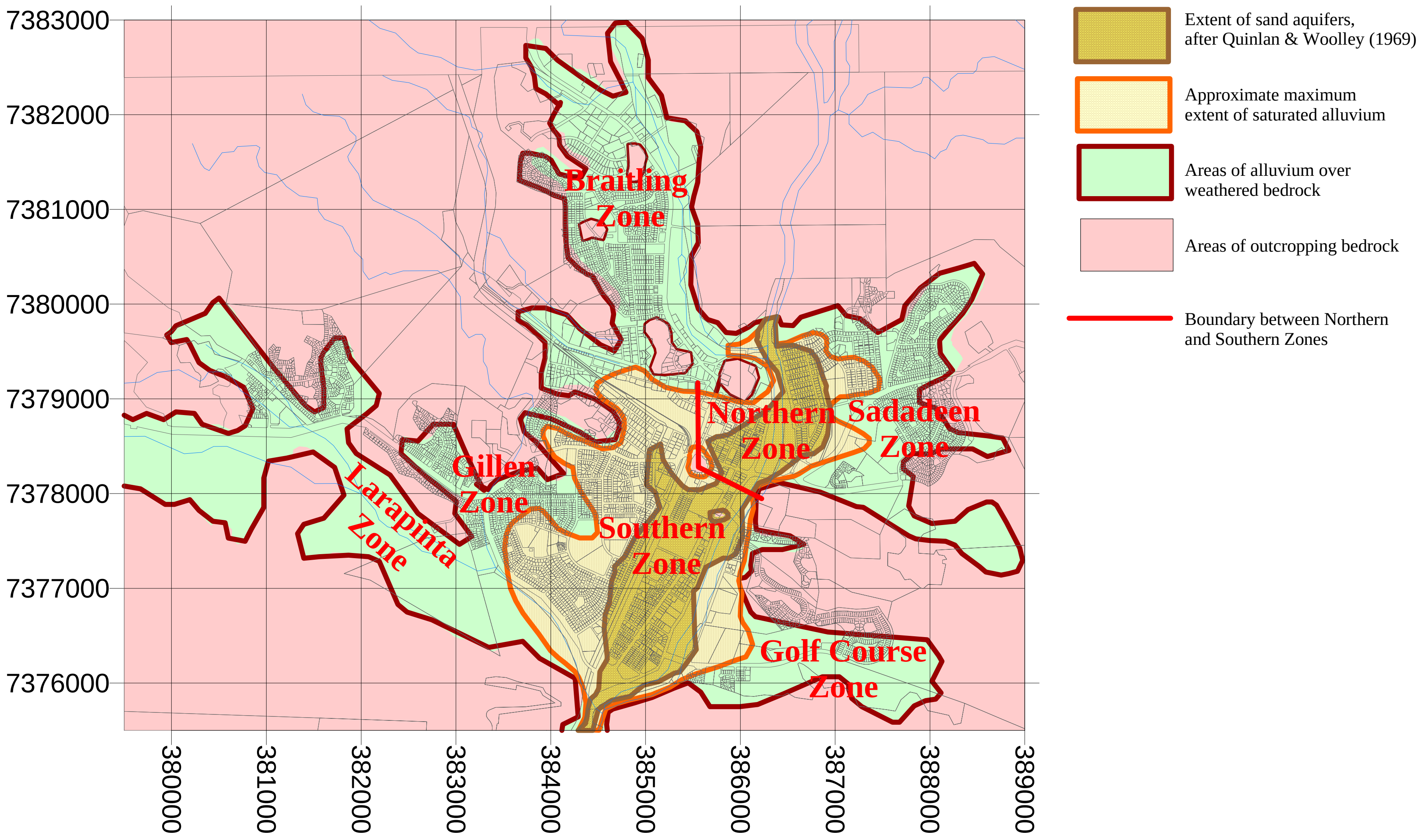


Figure 1 Town Basin and surrounds

2 Physiography

Alice Springs was developed on the flood plain of the Todd River. To the south the east west trending MacDonnell Ranges form a barrier, cut through at Heavitree Gap. Surrounding the valley of the Todd to the north, east and west are low hills, broken by valleys along minor drainages.

3 Geology

This was well described by Quinlan and Woolley (1969).

3.1 Structure

The basin is an in-filled valley of the Todd. There is a constriction between Billygoat Hill and Meyers Hill. South of this the deepest part of the basin is west of the present day course of the Todd.

The eastern side of the basin is fairly steeply defined. Much of the western side is gently shelving.

Quinlan and Woolley (1969) produced a map of the elevation of basin bedrock. A modified version of this is shown in Figure 2. With the exception of the railway yards area there is little additional information about the fringes of the basin since 1969.

Most of the basin is filled with silt of low permeability. The main aquifers are strips of sand marking former courses of the Todd and possibly the Charles River. Quinlan and Woolley (1969) mapped five sand aquifers, named the 1810, 1820, 1830, 1840 and 1850 aquifers for their elevation in feet.

3.2 Strata

BMR (1983) shows the geology of the area. Rocks of the Arunta Complex, that is Teppa Hill Metamorphics, Emily Gap Schist and Alice Springs Granite, are overlain by Quaternary alluvium of the Todd River.

In addition there are extensive areas of weathered bedrock on the fringes of the Town Basin. Some bores have obtained small supplies from these, but they have little importance for groundwater supply. They are a hazard for land development as they have shallow saline water tables and large accumulations of salt in the unsaturated zone.

4 Surface water

The Todd River carries the largest volume of water into and out of the Town area. Before European settlement drainage into the Todd from the east was obstructed by over-bank deposits, resulting in the Coolibah Swamp. With urbanisation run-off has increased and drains have been constructed to carry water into the Todd more efficiently.

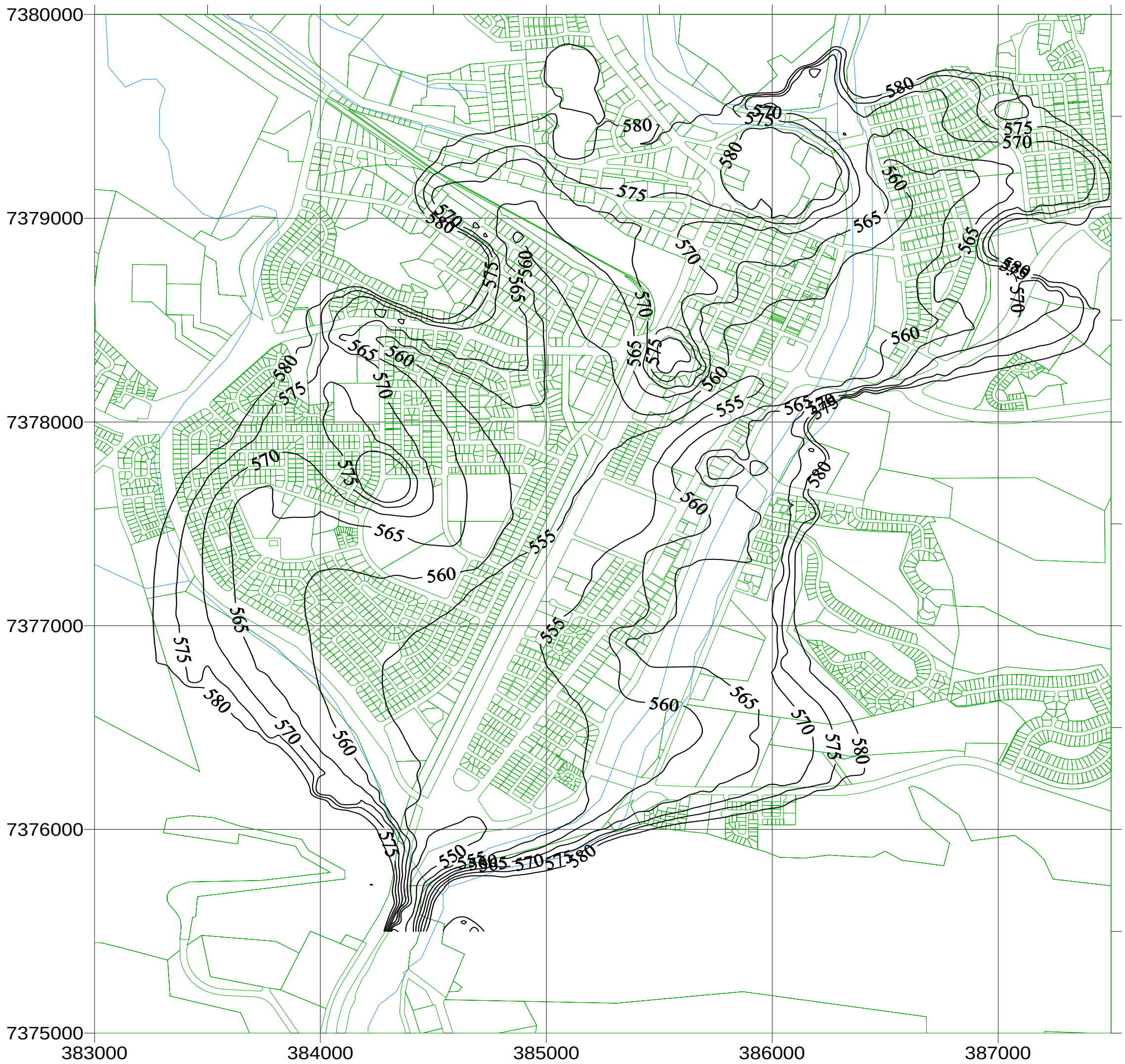


Figure 2 Contours of bedrock in m AHD, after Quinlan and Woolley (1969)

4.1 Surface Water Monitoring

There are three gauging stations of importance on the Todd, as listed in Table 1 . Locations are shown in Figure 3 .
An additional station is operated on the Charles River for flood forecasting, but this catchment’s contribution is quite minor and of little importance for resource estimation.

Table 2 shows estimates of annual average flow at each station.

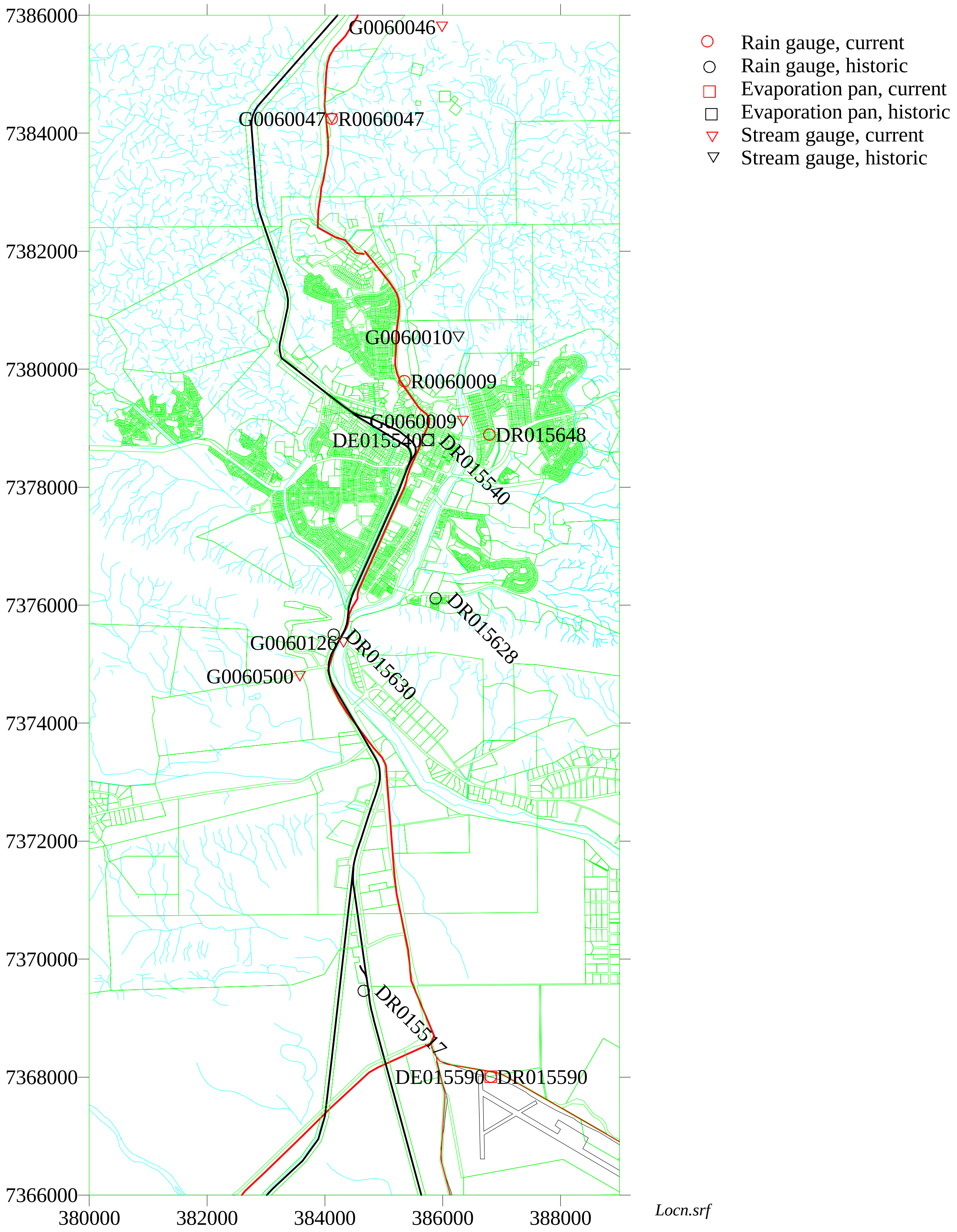


Figure 3 Hydrographic stations around Alice Springs

Table 1 Hydrographic Stations

Station	Name	East	North	Record		Type
				Start	Finish	
DE015540	Alice Springs P O	384763	7377583			Evaporation Pan
DE015590	ALICE SPRINGS AIRPORT - Met Office	386820	738020	01/01/1967	Current	Evaporation Pan
DR015517	TEMPLE BAR	384658	7369462	31/12/1954	31/12/1970	Rain Gauge
DR015540	ALICE SPRINGS P.O.	384599	7376843	30/06/1873	31/05/1987	Rain Gauge
DR015590	ALICE SPRINGS AIRPORT - Met Office	386820	738020	1/10/1941	Current	Rain Gauge
DR015628	Alice Springs Golf Club	385879	7376116	31/07/1990	Current	Rain Gauge
DR015630	HEAVITREE GAP	384150	7375500	31/12/1889	30/11/1911	Rain Gauge
DR015648	Alice Springs Eastside	386792	7378891	31/12/1981	Current	Rain Gauge
R0060047	Charles River At Big Dipper	384119	7384245	14/10/1958	28/02/1979	Rain Gauge
R0060009	Todd River Yard behind Nth Stuart Hwy NRD Office.	385350	7379797	11/03/1980	Current	Rain Gauge, now moved from the site shown
G0060009	Todd River at Anzac Oval	386342	7379120	01/08/1959	Current	Stream Gauge and automatic rain gauge
G0060010	TODD RIVER AT DAMSITE	386269	7380547	15/05/1967	26/05/1972	Stream Gauge
G0060126	Todd River at Heavitree Gap	384317	7375366	02/08/1959	Current	Stream Gauge
G0060500	Alice Springs Sewage Ponds at Flume	383575	7374794	07/06/1977	Current	Stream Gauge
G0060046	Todd River at Wigley Gorge	385988	7385801	21/06/1972	Current	Stream Gauge and automatic rain gauge
G0060047	Charles River at Big Dipper	384119	7384245	13/07/1958	08/01/1987	Stream Gauge and automatic rain gauge

Table 2 Estimated Annual flows

Station No	Name	Period of record	Estimated average ML/year, from gaugings in HYDSYS	Estimated average annual flow based on catchment area ML/year
G0060046	Wigley	1962-2001	12 000	**12000**
G0060009	Anzac	1972-2002	15 000	**15000**
G0060126	Heavitree	1973-2001	31 000	**16800**

The estimates for Anzac and Wigley are reasonably consistent, considering that the discharge of the Charles River should be added. The estimate for Heavitree Gap is far too high. The estimate based on catchment area, in the far right column of Table 2 is closer. An attempt was made to compare individual flows and flows in years (Figure

4), but no consistent relationship could be obtained. The degree of scatter shows that there are serious problems with the data.
The data for G0060126 needs to be analysed by a surface water professional.
It would be useful if old data on ticker tape was digitised.

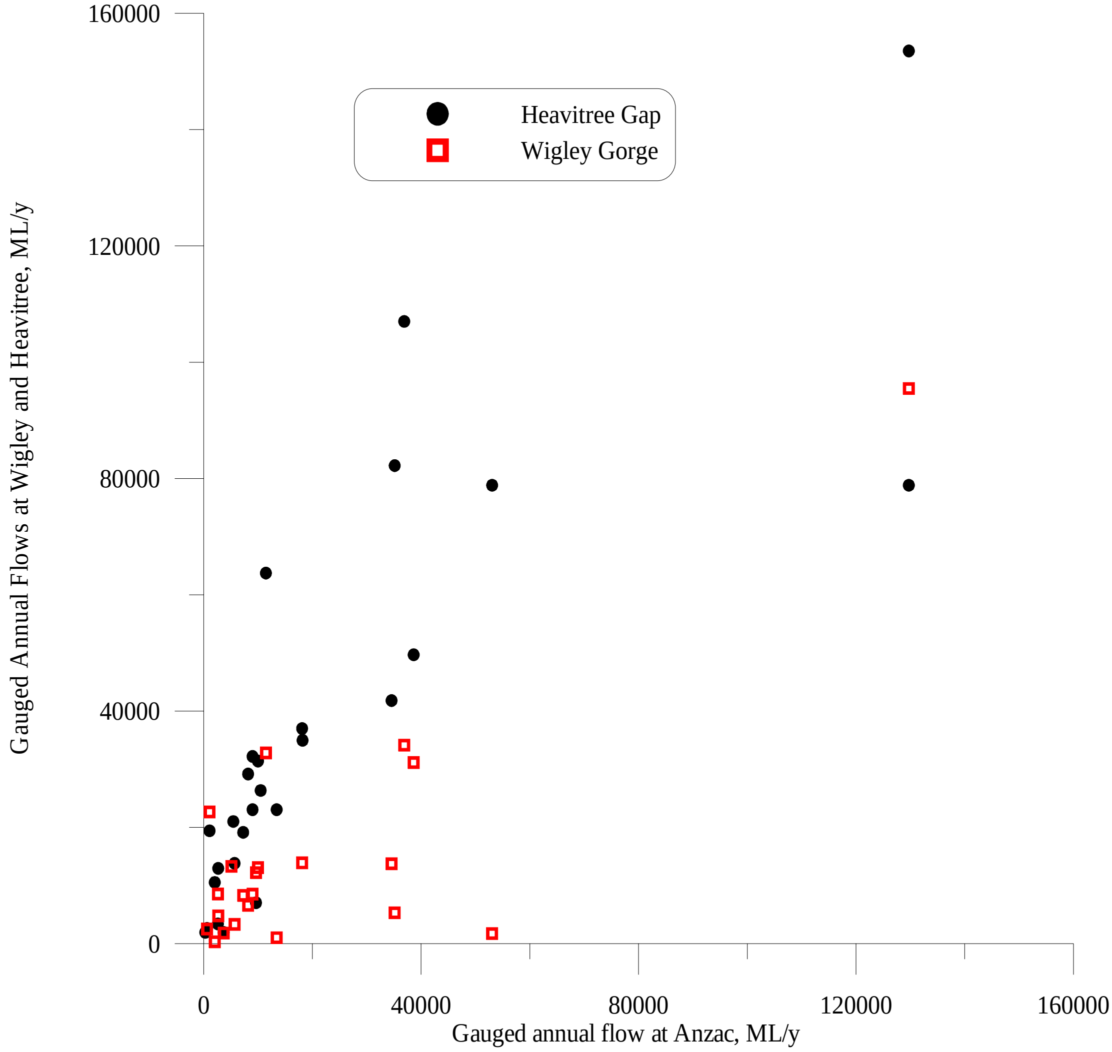


Figure 4 Comparison of annual flows at Heavitree and Wigley with Anzac, using data in HYDSYS from 1972 to 2001

All the stations have some periods of poor record due to malfunctioning recorders. The data needs to be analysed and in-filled by a surface water hydrologist. In particular the rating curve for Heavitree Gap needs to be revised.

It was recognised by Quinlan and Woolley (1969) and others that the critical parameter for estimating the safe yield is the probable maximum time between flows. Figure 5 shows estimated probability of times between flows. This is similar to Figure 6 of Quinlan and Woolley (1969), and shows the same upward inflection at about 200 days. The inflection appears to be a reflection of the strong seasonality of flows, that is flows are unlikely from May to October. The graph suggests that the 630 day period of no flow that ended 1/12/1980 was exceptional, and this could be taken as an effective upper limit.
A reasonable estimate is that the Todd's average annual flow is 15000 ML/year.
Details of salt and chloride flux at the gauging stations are shown in Appendix A.

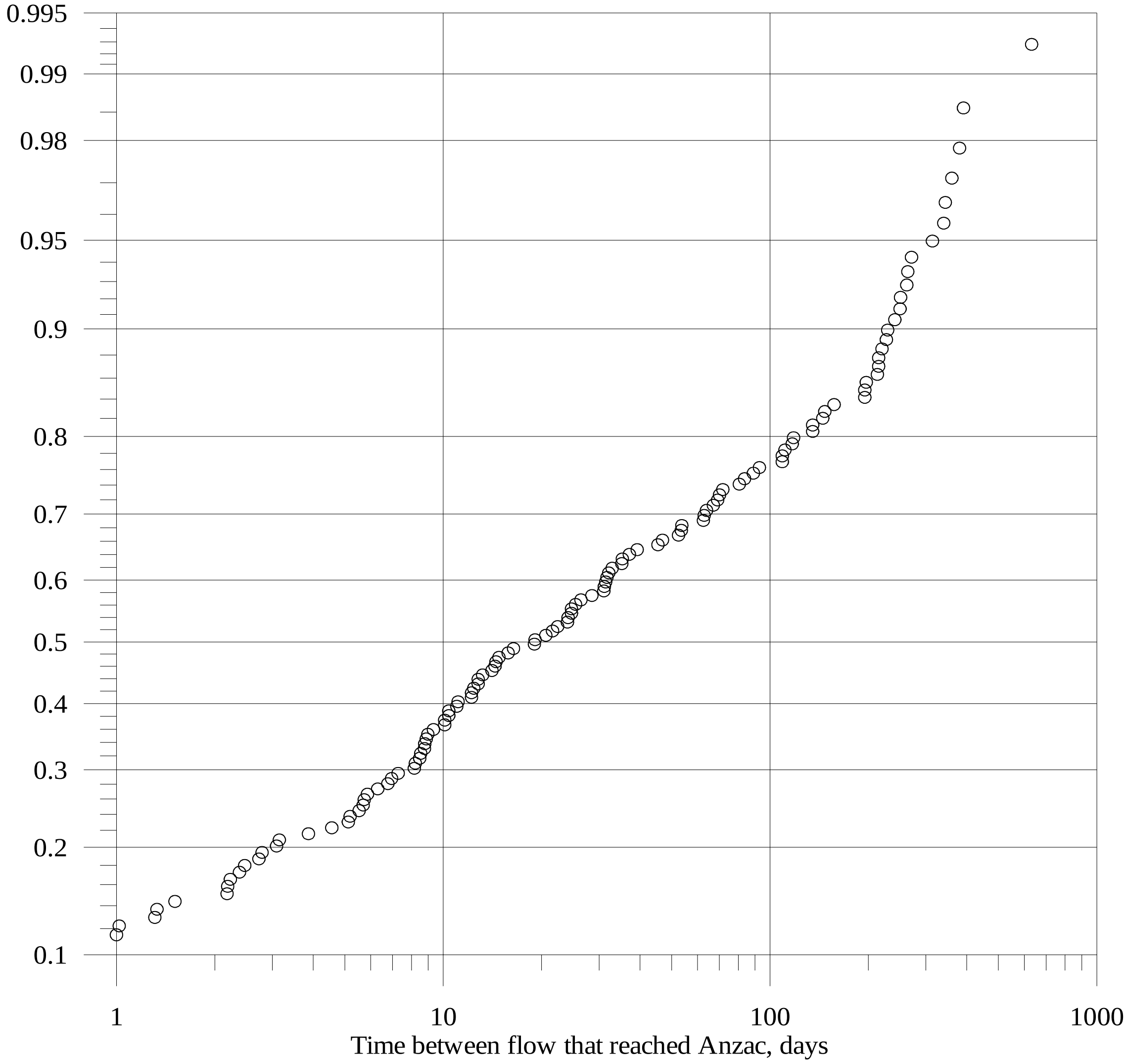


Figure 5 Log-probability of time between flows at Anzac. Data extracted from HYDSYS from 1973 to 2002.

5 Hydrogeology

5.1 Previous investigations

The Alice Springs Town Basin has been studied for over 50 years. This report is an attempt to review previous reports and data.

Previous reports of the Town Basin fall into three groups:

- Reports of the former Bureau of Mineral Resources. These are listed in Table 3 .
- Reports of the former Water Resources Branch. These are listed in Table 4 .
- Reports of hydrocarbon contaminant investigations by various consultants. These are listed in Table 5 .

Table 3 Reports of the former BMR

Record No	Title	Author(s)
1957/020	Preliminary Report on Geophysical Investigations A+D of Underground Water, Alice Springs, Northern Territory, 1956.	D.F.Dyson. [town basin]
1957/089	Final report on the Geophysical Investigations of Underground Water Alice Springs NT 1956	DF Dyson, WA Wiebenga
1962/075	The Occurrence of Groundwater in the Alice Springs Town Basin.	T. Quinlan & D.R.Woolley.
1962/075A	Test drilling at Bent Tree Well Alice Springs	T Quinlan, D Woolley
1963/147	Completion report on bores 62/9 Alice Springs only Town Basin	T Quinlan, D Woolley
1967/017	The Alice Springs Town Basin a Case History	T. Quinlan
1967/069	Criteria for the design and evaluation of mathematical models for the Alice Springs town basin	T Quinlan
Bulletin 89	Geology and Hydrology, Alice Springs Town and Inner Farm Basins, Northern Territory	T Quinlan, D Woolley

Bulletin 89 summarises all previous geological investigations in the Town Basin, and remains the most useful account of the geology. One major problem with all the BMR publications is that bores are referred to by project numbers and local names, not the Registered Numbers.
The map of the Town Basin sediments presented in this report is still the best available. Only in a few areas such as the Railway Yards where there have been recent investigations near the fringe of the basin is there additional data.

Table 4 Reports of the former Water Resources Branch

(including reports of the former BMR and Commonwealth Works held in the WRB system)

Report No.	Date	Title	Author	Type
01/54 A	MAR.54	Geological Investigations of Underground Water Resources at Alice Springs. [town basin] >Resident Geologist Office, Darwin	H.B.Owen	
04/58 A	DEC.58	Report on Engineering Investigations of the Water Resources of Alice Springs during 1956/57	H.Wilson. [Town Basin]	
05/58 A	DEC.58	Alice Springs Water Supply: Report on Water Resources (includes corrections to 05/58) [Town Basin]		
01/59 A	OCT.59	Alice Springs Town Water Supply 1958/59	H.Wilson. [Town Basin]	
05/58 A	DEC.58	Alice Springs Water Supply: Report on Water Resources (includes corrections to 05/58) [Town Basin]		
01/60 A	JAN.60	Alice Springs Water Supply Interim Appreciation	R.N.Eden, Director of WRB	
02/60 A	1960	Test Drilling at Bent Tree Well, Alice Springs.	T. Quinlan, D. Woolley. >Resident Geologist Office	C

Table 4 continued

Report No.	Date	Title	Author	Type
09/62 A	1962	Estimation of Safe Yield from Alice Springs Groundwater Basin.	C.F. Forbes	
31/63 A	1963	Bore completion - Alice Springs Town Basin	Quinlan, T Woolley, D [62/9]	C
02/64 A	APR.64	Pumping for the Alice Springs Water Supply: Technical Report.	H.F. Eggington [Town Basin]	
03/64 A	APR.64	Proposal for Artificial Improvement of Recharge to the Alice Springs Town Basin.	H.F. Eggington	
08/64 A	APR.64	Preliminary Examination 16 Mile Creek Diversion Proposal, Alice Springs. [Town Basin]	P. Augustine, H.F. Eggington	
10/64 A	MAR.64	Investigation of Alice Springs Water Supply	.C. Corbett. [Town Basin]	
02/65 A	NOV.65	Alice Springs Town Basin. Groundwater Storage Characteristics	Eggington. [Town Basin]	
09/65 A	NOV.65	Todd River Recharge Dam Project. WRB [Town Basin] (c) Groundwater Storage Characteristics Alice Springs Town Basin.. (e) Geological Report: Extract of Preliminary Investigation (f-1)Investigations in Central Australia, Survey of Todd River Catchment. Soil Conservation Service of N.S.W. (f-2) Proposed Todd River Recharge Dam Report by Agricultural Branch.	H.F. Eggington. WRB T.R. I.Faulks. Lawler	
10/65 A	JAN.66	Todd River Recharge Dam Project. WRB (b) Todd River Dam Yield and Flood Studies. Investigation By Hydrographic Section.	P.Purich	
11/65 A	1965	Todd River Recharge Dam Project. (d) Investigations by Planning Section.	I.Watson	
25/65 A	1965	Summary of knowledge relative to Town Basin and Alice Springs water supply	Eggington, HF	
05/66 A	JUL.66	Alice Springs Town Water Supply 1960-1966 Useful Data.	R.C.Hamilton. [Town Basin]	
05/67 A	JUN.67	Alice Springs Groundwater Basin 1967 [Town Basin	G.Ride.	
11/67 A	JUL.67	Technical Report: Alice Springs Town Basin: The Water Level Record.	R.C.Hamilton. [Town Basin]	
09/68 A	JUL.68	Infiltration Measurement Tests, Alice Springs Area, 1968.	C.J.Braybrook. [Town Basin]	
15/68 A	1968	Groundwater Storage in the Alice Springs Town & Inner Farm Basins 1957-68.	G.Ride. [Town Basin]	
17/68 A	1968	Readings for Artificial Recharge Experiment 1967	anon [Town Basin]	

Table 4 continued

Report No.	Date	Title	Author	Type
30/69 A	1969	Alice Springs Town Basin: Criteria for the design and evaluation of mathematical models	Quinlan, T	
09/76 A	OCT.76	Alice Springs Town Basin: Observation Bores 1976 Includes Photographic Record)	B.C.O'Sullivan.	
11/76 A	APR.76	Proposal to Utilise Town Basin Water to Irrigate Alice Springs Golf Course.	A.D.Macqueen.	
16/76 A	SEP.76	Alice Springs Town Area: Management of Water Resources. [Town Basin]	A.D.Macqueen. R27: Issued report R28: Calcs.	
27/84 A	AUG.84	Completion Report RN 13625, Sandspear System in Todd River for Conservation Commission.	B.G.Stevens. [Town Basin]	C
35/85 A	MAR.85	Alice Springs Town Area: [Town Basin] Groundwater Investigation for Conservation Commission.	B.G.Stevens	
36/85 A	MAY.85	Bore Completion Report - RN 14196, Todd River Reserve, Alice Springs.	B.G.Stevens.	C
37/85 A	JUN.85	Alice Springs Town Basin, Preliminary Ground Water Management Report.(Stage 1 - Project 2008)	D.B.C.Paige [Town Basin]	
38/85 A	SEP.85	Bore Completion Report - RN 14407, Golf Course Irrigation Supply, Alice Springs. [Town Basin] (Project 3075)	P.S.McDonald.	C
38/86 A	FEB.86	Bore Completion report - RN 14417, Spear Point System Replacement, Alice Springs. [Town Basin]	B.G.Stevens	C
39/86 A	MAY.86	Alice Springs Town Council Production Bore Replacements, 1986 Program. [Town Basin]	B.G.Stevens	C
31/88	Nov. 88	Hydrology of the Todd River flood of March 1988	F.T.H. Barlow	
05/90 A	JAN.90	Alice Springs Town and Farm Basins, Groundwater Quality Sampling 1989. [town basin]	D.Evans Dec 1989.	
14/90 A	MAR.90	Groundwater Investigation at Alice Springs Telegraph Station Historical Reserve [Town Basin] Interim Report.	A. Baker. Mar.1990.	
55/90 A	OCT.91	Alice Springs Town Basin, Construction of Irrigation Bores.	I.Matthews, E.Rooke. Sept.1991	C
82/90 A	OCT.90	Augmentation of Alice Springs Water Supply: Town Basin Groundwater Use and Reclaimed Sewage Effluent Use.	Acer Vaughan for PAWA.	
46/91 A	DEC.92	Alice Springs Town Basin: Test Pumping of RN 15753, Incorporating a Case Study of Saline Contamination.	E.Rooke June 1992	P

Table 4 continued

Report No.	Date	Title	Author	Type
09/92 A	DEC.92	Alice Springs Town Basin: Water and Salt Balance Studies.	K.Berry August 1992	
13/92 A	AUG.92	The Alice Springs Town Basin (A Paper for the AWWA Conference: Living with Salinity) Aug.1992	P.McDonald.	
14/92 A	APR.92	Alice Springs Town Basin: Salinity and Water Management Review.	Dr.R.Evans. >Rural Water Commission of Victoria for PAWA	
61/93 A	OCT.93	Power and Water Authority Augmentation of Alice Springs Water Supply:- Report on Potential for Extended use of Town Basin Ground Water for Irrigation. January 1993	Acer Vaughan Consulting Engineers	
03/94 A	MAY.94	Alice Springs Town Basin Bore Completion Report RN 16355 - 16358.	I. Matthews. May 1994	C
09/94 A	OCT.94	Bore Completion Report RN 15904 St. Philips College Alice Springs Town Basin	I. Matthews	C
14/94 A		PRESERVED FOR: Alice Springs Town Basin Monitoring Network		
01/97 A	JAN.97	Alice Springs Town Basin Monitoring Review 1995-1996.	D. Evans. January 1997.	M
43/97 A	MAR.98	Alice Springs Town Basin Monitoring Review 1996-1997.	D. Evans. March 1998	M
28/98 A	May 1999	Alice Springs Town Basin Monitoring Review 1997-1998.	D. Evans	M

C is bore completion report
M is monitoring review
P is pump test report

Table 5 Consultants reports on contaminated sites

Site	Report Title	Consultant	Date
Shell Depot	Contamination and Risk Assessment	Dames and Moore	July 1997
Shell Depot	Identification and Recovery of Free Product Plume	Shell Co. of Australia	September 1997
Shell Depot	Additional Environmental Site Assessment	Fluor Daniel GTI	October 1997
Shell Depot	Further Environmental Site Assessment	Fluor Daniel GTI	January 1998
Shell Depot	Further Environmental Site Assessment	Fluor Daniel GTI	May 1998
Shell Depot	Risk Assessment	Fluor Daniel GTI	January 1999
Shell Depot	Vegetation Survey of the area surrounding the Shell depot	Clouston	January 1999
Shell Depot	Groundwater monitoring event	IT Environmental	May 1999

Table 5 Continued

Site	Report Title	Consultant	Date
Shell Depot	Environmental Site Management Plan	Shell Co. of Australia	October 1999
Shell Depot	Hydrogeological Information Associated with Shell Alice Springs Depot	Golder Associates	August 2000
Shell Depot	Hydrogeological Information Associated with Shell Alice Springs Depot	Golder Associates	November 2000
Shell Depot	Hydrogeological Information Associated with Shell Alice Springs Depot	Golder Associates	December 2000
Shell Depot	Additional Groundwater Investigation Report	IT Environmental	December 2000
Shell Depot	Additional Groundwater Investigation Report	IT Environmental	October 2001
Shell Depot	Audit Review of Onsite and Offsite Groundwater Contamination	Golder Associates	October 2001
Shell Depot	Groundwater Monitoring Report	IT Environmental	May 2002
Shell Depot	Groundwater Monitoring Report	IT Environmental	May 2003
BP Depot	Environmental Site Assessment	OTEK Australia	March 1998
BP Depot	Extent Assessment	OTEK Australia	August 1998
BP Depot	Health Risk Assessment	OTEK Australia	January 1999
BP Depot	Remedial Action Plan	BP Australia	June 1999
BP Depot	Extent Assessment	OTEK Australia	August 1999
BP Depot	Extent Assessment	OTEK Australia	April 2000
BP Depot	Remediation Monitoring Report	OTEK Australia	May 2000
BP Depot	Monitoring Report No. 2	OTEK Australia	October 2000
BP Depot	Monitoring Report No. 3	OTEK Australia	February 2001
BP Depot	Extent Assessment	OTEK Australia	Sept 2001
BP Depot	Groundwater Monitoring and Extent Assessment Report	OTEK Australia	January 2002
BP Depot	Monitoring Report	OTEK Australia	August 2002
BP Depot	Monitoring Report	OTEK Australia	April 2003
BP Depot	Monitoring Report	OTEK Australia	June 2003
Railway Yards	Groundwater Flow and Solute Transport Model	URS Australia	April 1998

Table 5 continued

Site	Report Title	Consultant	Date
Railway Yards	Human Health and Environmental Risk Assessment	URS Australia	April 1998
Railway Yards	Groundwater Monitoring Event	URS Australia	September 1999
Railway Yards	Report for a Groundwater Monitoring Event	URS Australia	September 1999
Railway Yards	Recalibration of the Alice Springs Railyard Contaminant Fate and Transport Model	URS Australia	December 2000
Railway Yards	Groundwater Monitoring Event	URS Australia	April 2001
Shell Todd	Preliminary Investigation and Environmental Site Assessment Report	IT Environmental	December 2001
Shell Todd	Phase 2 Environmental Site Assessment by IT Environmental	IT Environmental	April 2002
Shell Todd	Phase 3 Environmental Site Assessment by IT Environmental	IT Environmental	April 2002
Shell Todd	Update Soil Validation Report	IT Environmental	August 2002
Shell Todd	Soil Validation Report	IT Environmental	September 2002
Shell Todd	Post Remediation Environmental Site Assessment	IT Environmental	November 2002
Shell Todd	Groundwater Monitoring Report	IT Environmental	April 2003

5.2 Aquifers

5.2.1 Alluvial aquifers

These were described by Quinlan and Woolley (1969), who identified five aquifers. These were named the 'wedge', 1810, 1820, 1830, 1840 and 1850 aquifers for their elevation in feet.

The following description is summarised from Quinlan and Woolley (1969), and would have been based on examination of samples from many cable-tool drilled bores.

"The fluviatile sediments consist of a mixture of gravel, sand, silt, and clay, and can be divided into four main lithological types:

1. Brown sand.
2. Brown and grey clayey sand
3. Brown and grey silt and clay
4. Regolith and colluvium

Brown sand: This has a wide range in grainsize. Quartz is predominant, but some of the beds contain sufficient feldspar grains to warrant the use of the term arkose. Fragments of gneiss and schist, and aggregates of quartz, are common; they range from sand to boulder size. The silt fraction consists mainly of quartz and mica. The sieve analyses of samples from any one bore may show differences in the degree of sorting. This is probably because the sediments are thinly bedded (from 150 to 300 mm thick)."

Test drilling has shown that the beds of sand are long, narrow bodies with a lenticular cross-section. The lenses are from 2 to 25 feet thick, and they anastomose both vertically and horizontally through the body of alluvium.

This type of sediment forms about 15 per cent of the total volume of the saturated alluvium in the Town Basin.

Brown and Grey Clayey Sand: The brown and grey clayey sand contains the same minerals as the brown sand, but much more matrix, and in places the proportion of silt and clay exceeds that of sand.

Brown and Grey Silty Clay: Probably 80 percent of the sediment in the basin is silty clay. It consists of blue or grey silty clay, very thinly interbedded or laminated with brown clayey silt. Black carbonaceous laminae a common, and it may contain variable but appreciable quantities of very fine to medium-sized sand. The clay content is estimated to range from 10 to 40 percent.

Regolith and Colluvium: The regolith overlying the Arunta Complex is a stiff blue sandy clay, with cobles and boulders of both weathered and relatively fresh metamorphic and igneous rocks.

From extensive grain-size analyses Quinlan and Woolley (1969) found that the sediments in the southern end of the basin are more poorly sorted than in the northern end.

5.2.2 Basement aquifers

The metamorphic rocks under the Town Basin have very low permeability and can generally be ignored. A few bores in areas of thin sediments have obtained supplies from basement rocks, but their contribution to the hydrology of the basin is negligible.

5.2.3 Aquifers outside the limits of the alluvial basin

Most of the urbanised area lies outside the Town Basin. Most of this is over weathered bedrock, which would not be considered an aquifer for most purposes, but it is important in that it contains a large store of salt, which may have been mobilised by urbanisation in some cases. Groundwater of up to about 20000 mg/L is known in these rocks

Little data is available for the hydraulic properties of the weathered bedrock aquifers. Permeabilities inferred from a few tests and estimated yields are shown in Appendix I.

There are also a few minor alluvial aquifers associated with minor tributaries to the Todd.

Springs such as that at Morris Soak flow for a time after heavy rain. These appear to be from shallow fracture systems, possibly fed by ephemeral soil aquifers.

5.3 Water Table

5.3.1 Groundwater Monitoring

Some water level measurements were made in 1938-9, and the Army conducted measurements 1941-4. These early measurements have not been incorporated into the data-base. The earliest water level hydrographs in the DIPE database commence in 1952. Over the years water levels have been monitored in a total of 74 bores. Currently 38 are being monitored. Two of the bores monitored have measurements going back to 1952 and six are pre-1960.

Wilson (1958) presents graphs of short hydrographs for numerous bores. Much of this data appears to have been lost. The graphs refer to bores bore by the lot numbers at that time, and it would be difficult to match these with RN s. These records contain information on lag times that is not available from later less frequent monitoring.

In addition up to 10 years of water level data for individual bores are stored in the bore folders and have not been entered into the HYDSYS database.

Most hydrographs have a gap from about early 1972 when the Town Basin was perceived to be of no further importance until mid 1975 when problems with rising water levels were apparent. As a result the large rise that occurred in the very wet year of 1974 is poorly documented. A summary of monitoring bore data is shown in Appendix B. Locations of all monitoring bores are shown in Figure 6 .

There is little data available for the fringes of the basin. Power Water have a large amount of videos of sewers, in some of which groundwater can be seen to be entering the sewers, but it has not yet been possible to get this data in a useful form.

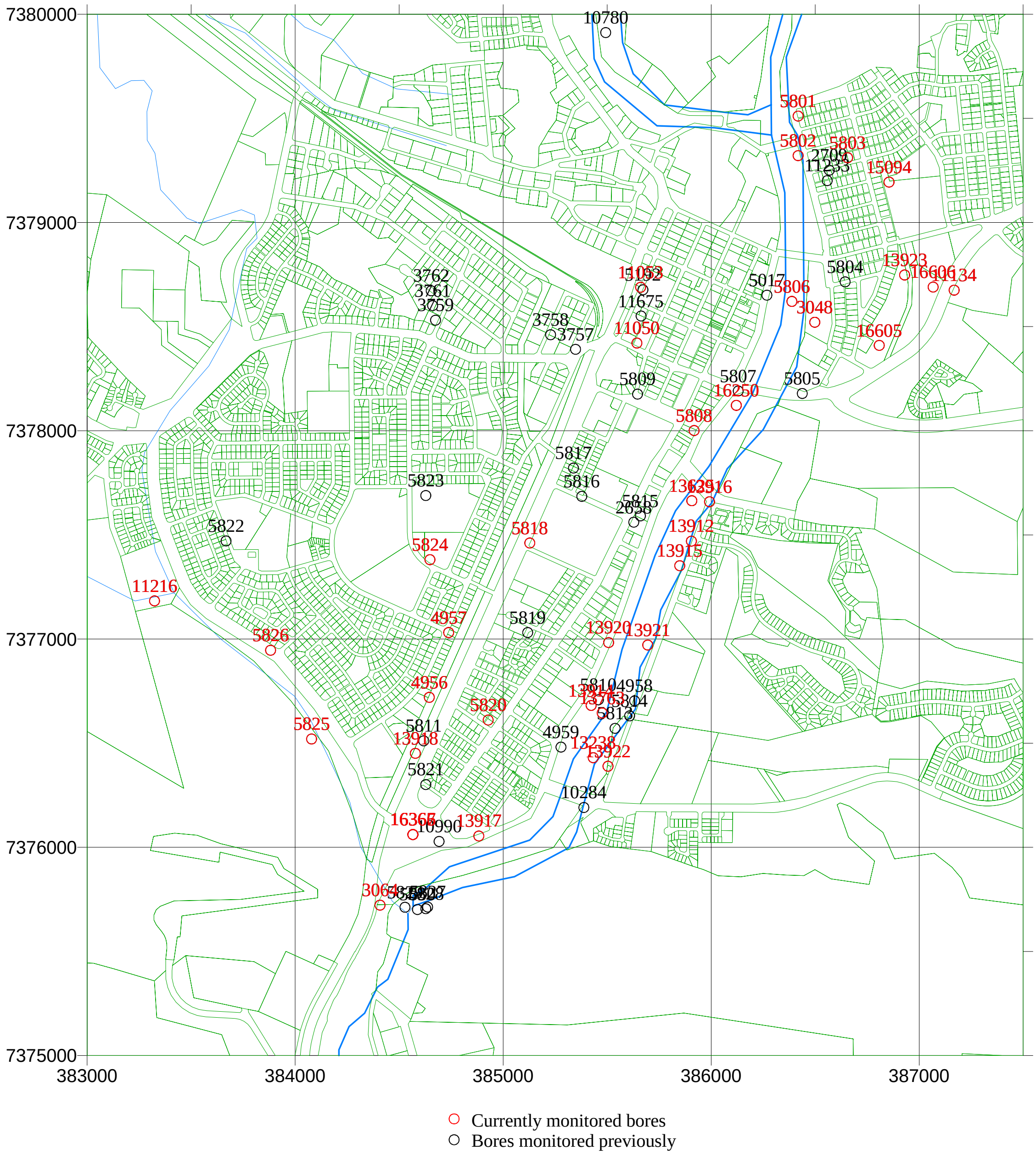


Figure 6 Water Level Monitoring Bores

5.3.2 History of the water table

Figure 7 shows the history of water levels in the Town Basin. The first section of the hydrograph in the early 50's represents a period of moderate withdrawal under more or less 'normal' rainfall. In the 1950's and early 1960's drawdowns accelerated as production increased with a growing population (Figure 8). In the mid 60's water levels began to rise in response to the phasing out of pumping from the Town Basin (Figure 9) in favour of the Mereenie Sandstone aquifer at Roe Creek. There was a dramatic rise following the very wet year of 1974 and then fluctuations with seasonal conditions.

In total water levels have fluctuated by about 9 m.

Water levels have been high from 1975 onwards. The large recharge event of 1974 was in a period of rapid increase in population and water consumption. It appears that run-off from roofs and paved areas and possibly leachate from heavily irrigated grassed areas, have combined to keep water tables high ever since. Leaking sewers and water reticulation have also been suggested as sources of extra recharge, but there is little hard evidence for this.

Rates of loss from storage in periods of no recharge were examined in Appendix G. It was found that in periods of no recharge losses from the Town Basin not due to pumping and the difference between inflow and outflow were proportional to evapotranspiration. Natural losses from the basin in periods of no recharge are estimated as an average of 173 ML/year, corresponding to a rate of decline of about 0.3 m/year.

Figure 10 and Figure 11 and show approximate water levels below surface at about the highest and lowest points in the period of record.

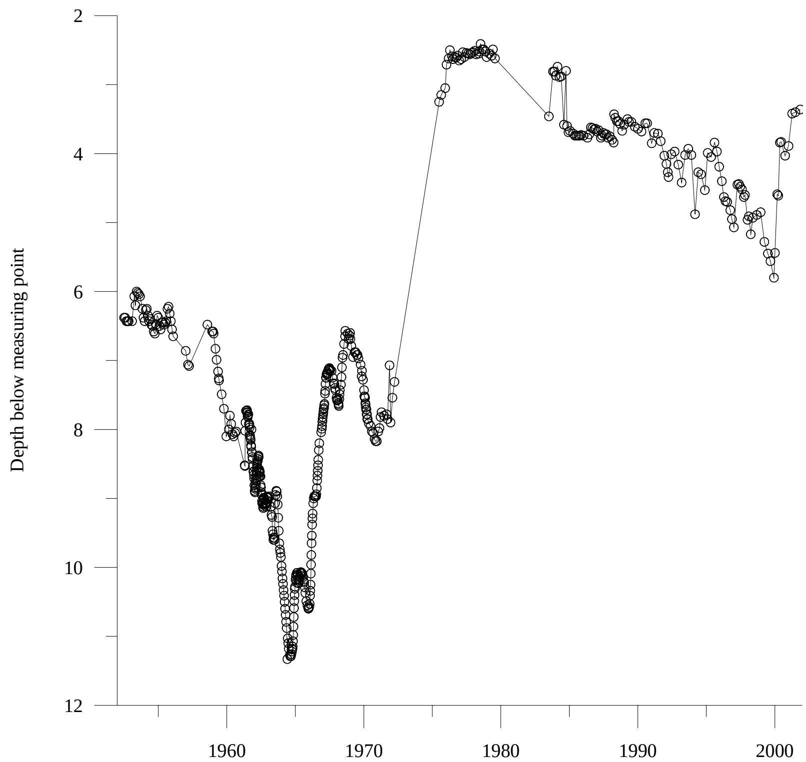


Figure 7 Hydrograph of RN 5825

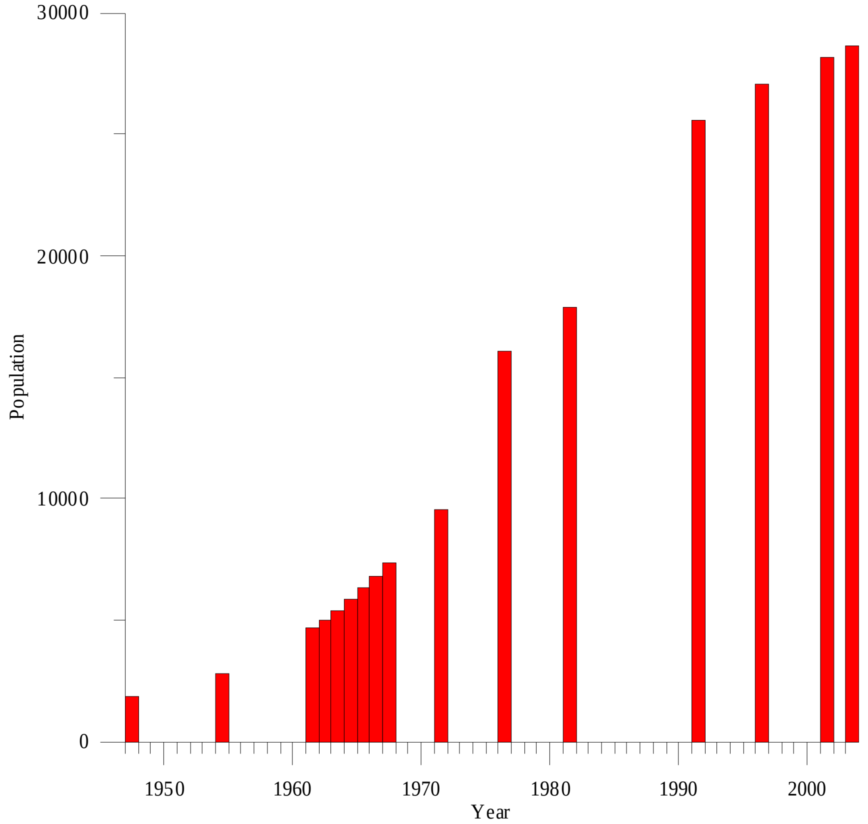


Figure 8 Population of Alice Springs, after Forbes (1962), SKM (2003)

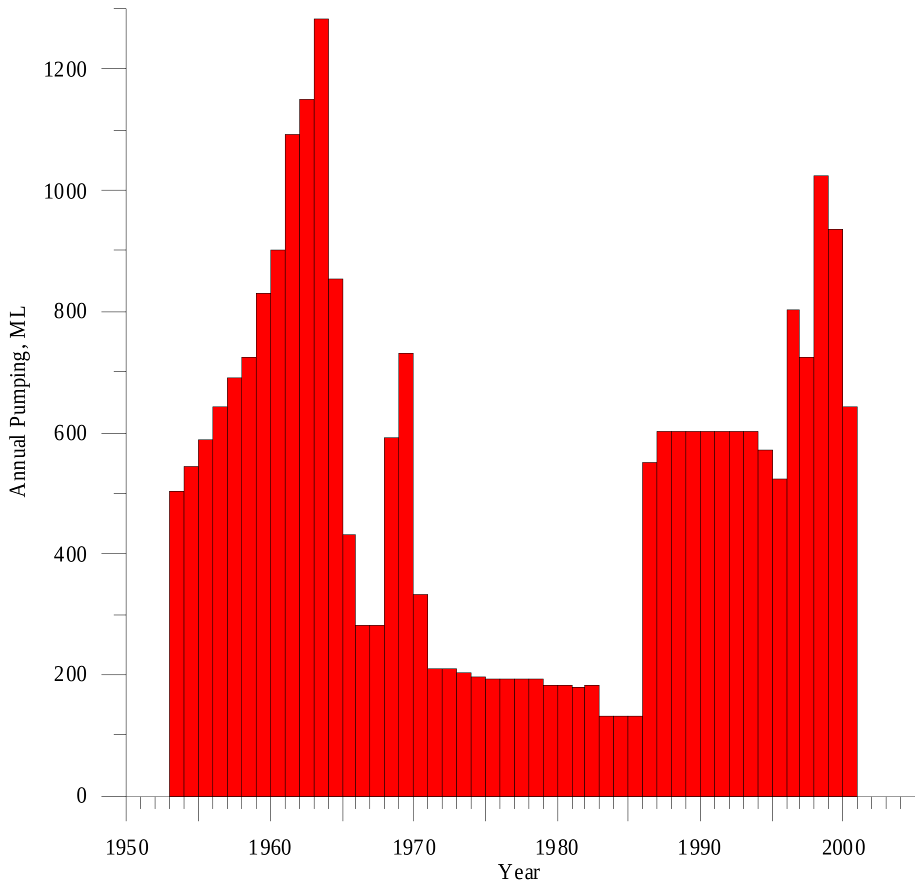


Figure 9 Pumping from the Town Basin

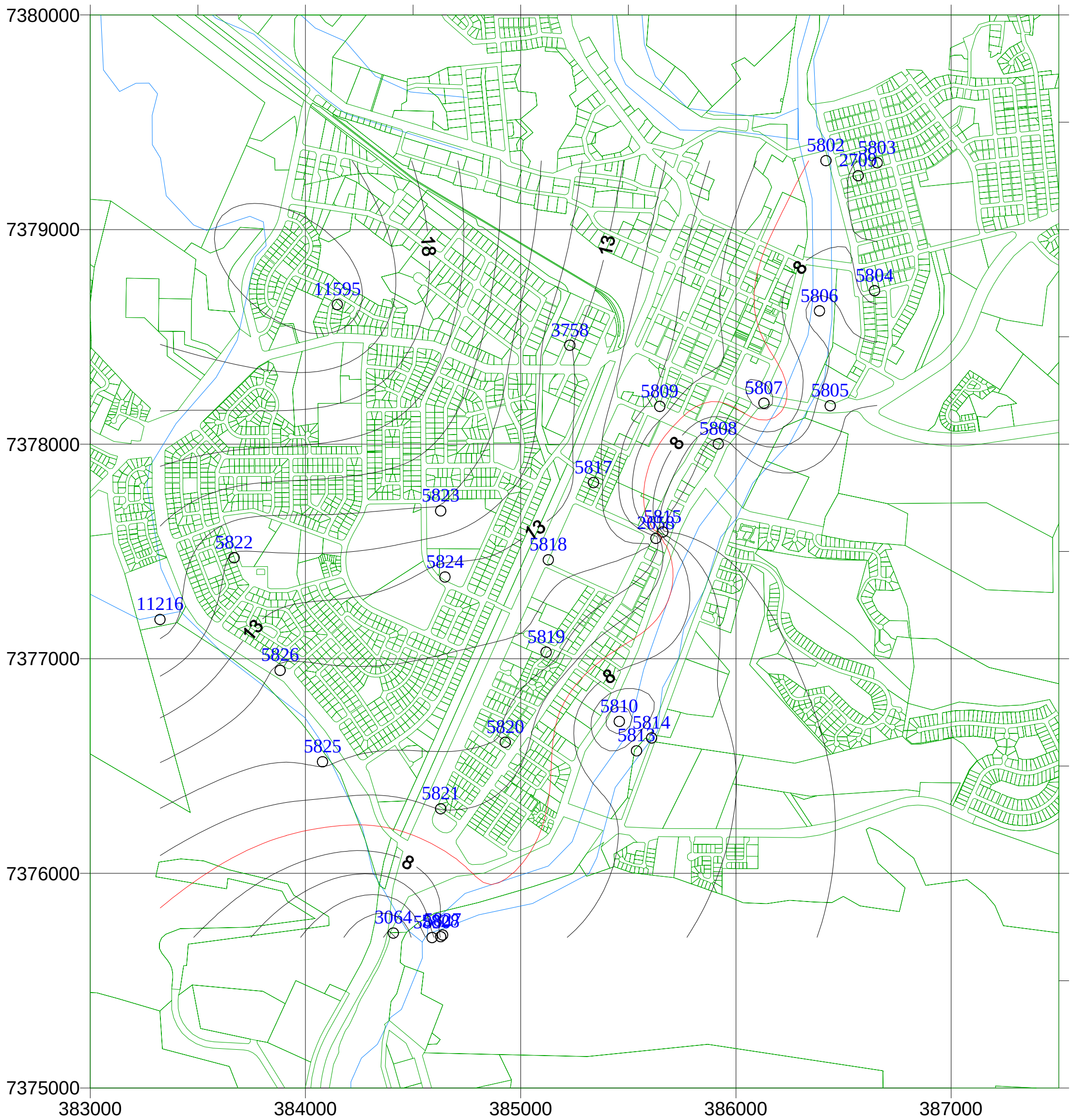


Figure 10 Water level below surface in m, 23/10/64

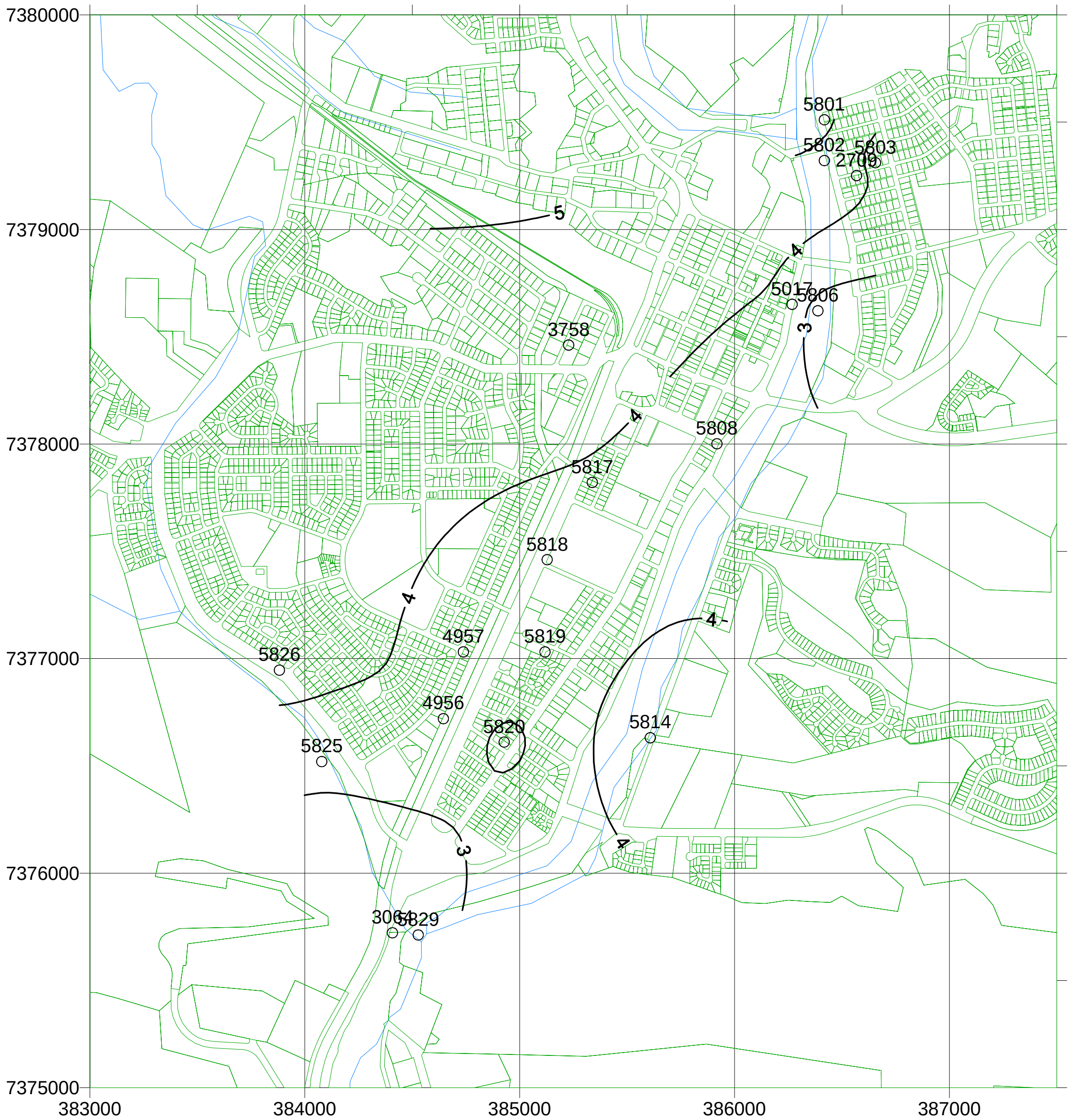


Figure 11 Water level below surface in m, 2/07/75

5.3.3 Perched water tables

There is no known evidence, either documentary or anecdotal for the existence of perched water tables.

5.4 Water Quality

5.4.1 Major ions

The HYDSYS database contains 922 analyses for the Town Basin. These are tabulated in Appendix C.

Quinlan and Woolley (1969) noted that 860 analyses were done between the years 1954 to 1964. Similarly Quinlan and Woolley (1969) state that 1292 conductivity measurements were made on samples taken weekly at the production bores.

Most of this data is not in the DIPE HYDSYS database. While this report was in progress filing cabinets with old analysis files were found. Much of this missing data is in these cabinets. Collating and entering this data will be a large task and not likely to be completed for some years. Graphical representations of some of these missing analyses are in Wilson (1958). Figure 12 to Figure 16 show Surfer plots of TDS values for different periods. Although plots are influenced by single samples on the fringes the overall contraction of the area of better quality water in the Southern Zone is clear.

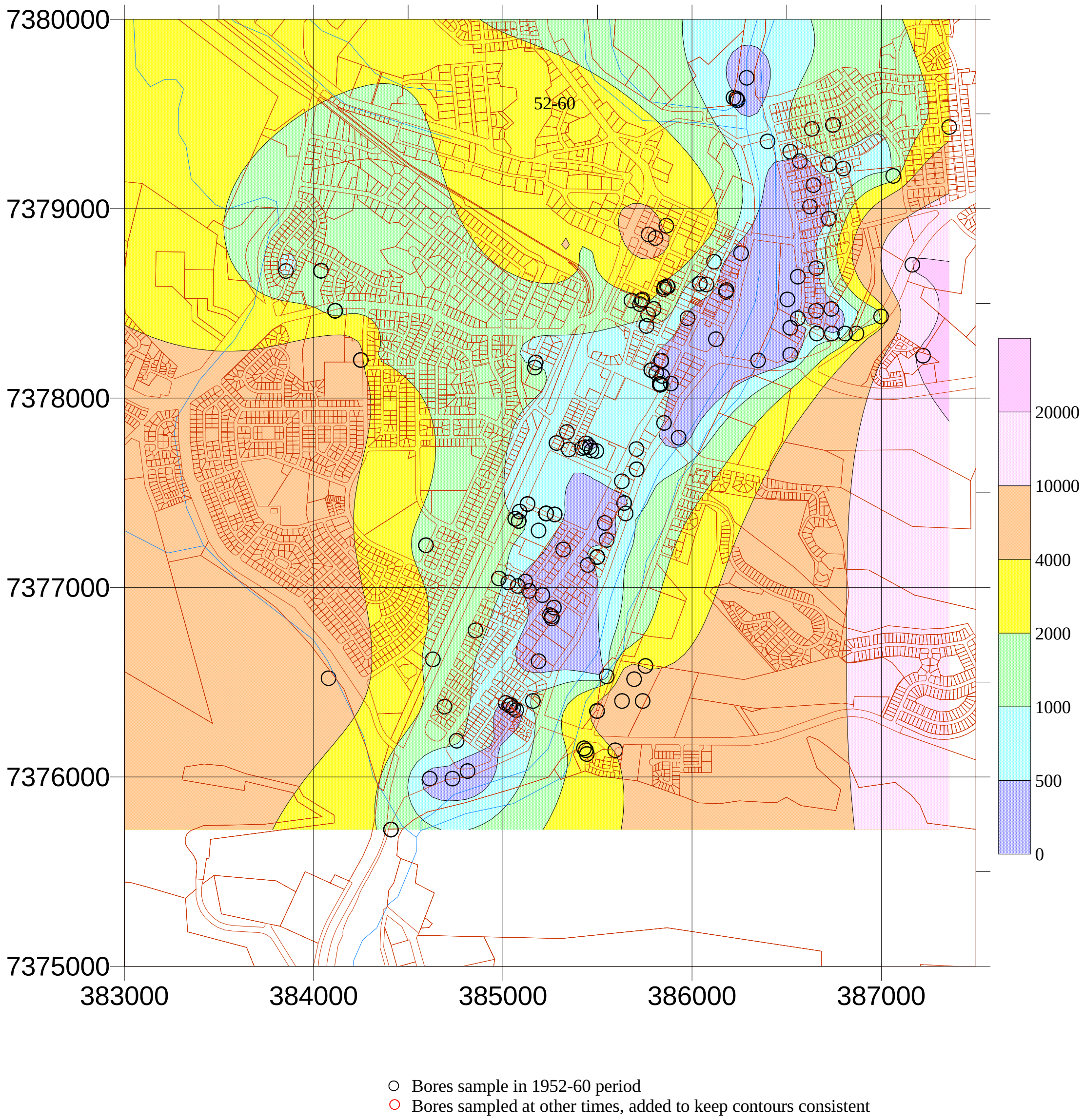
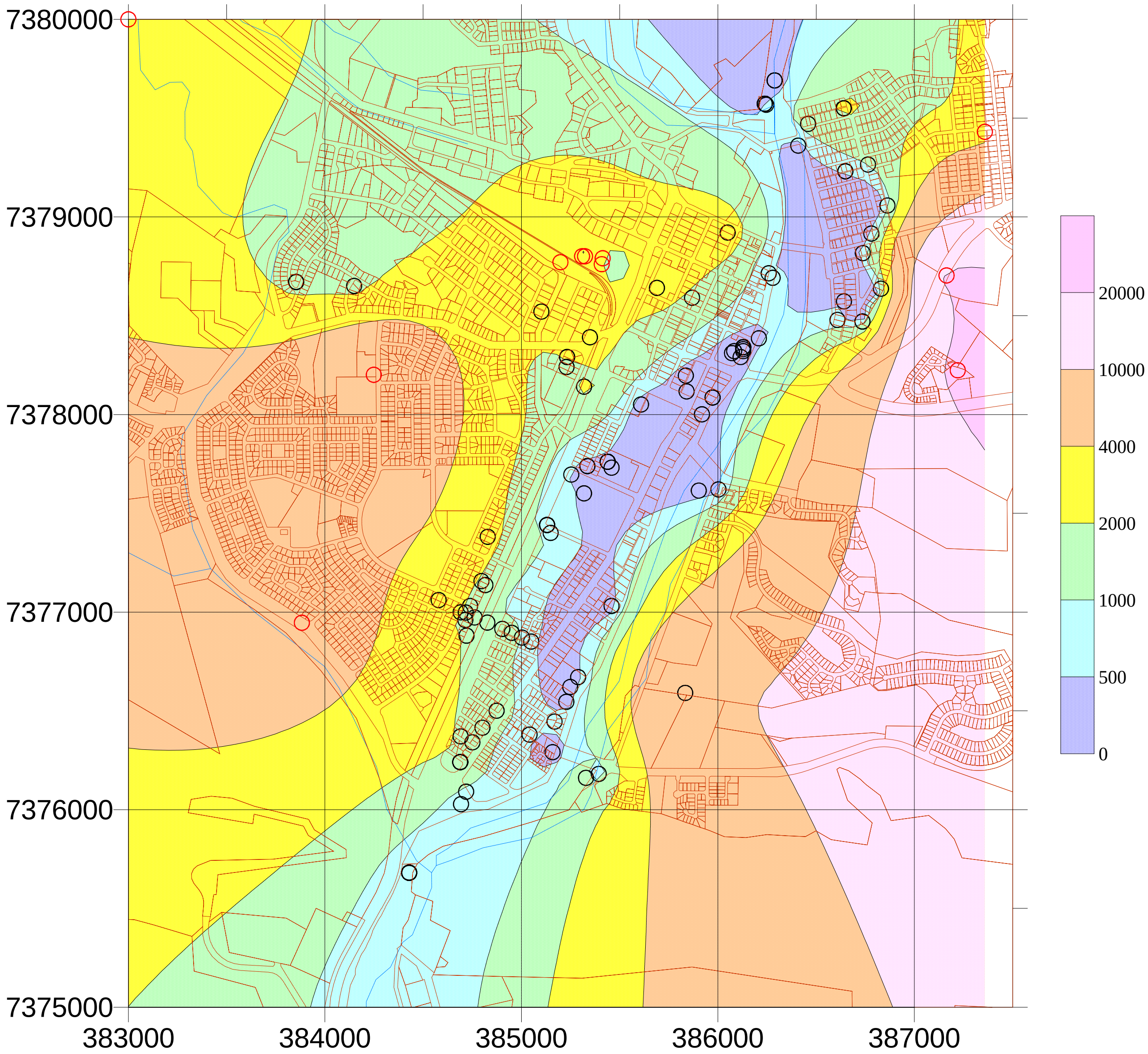


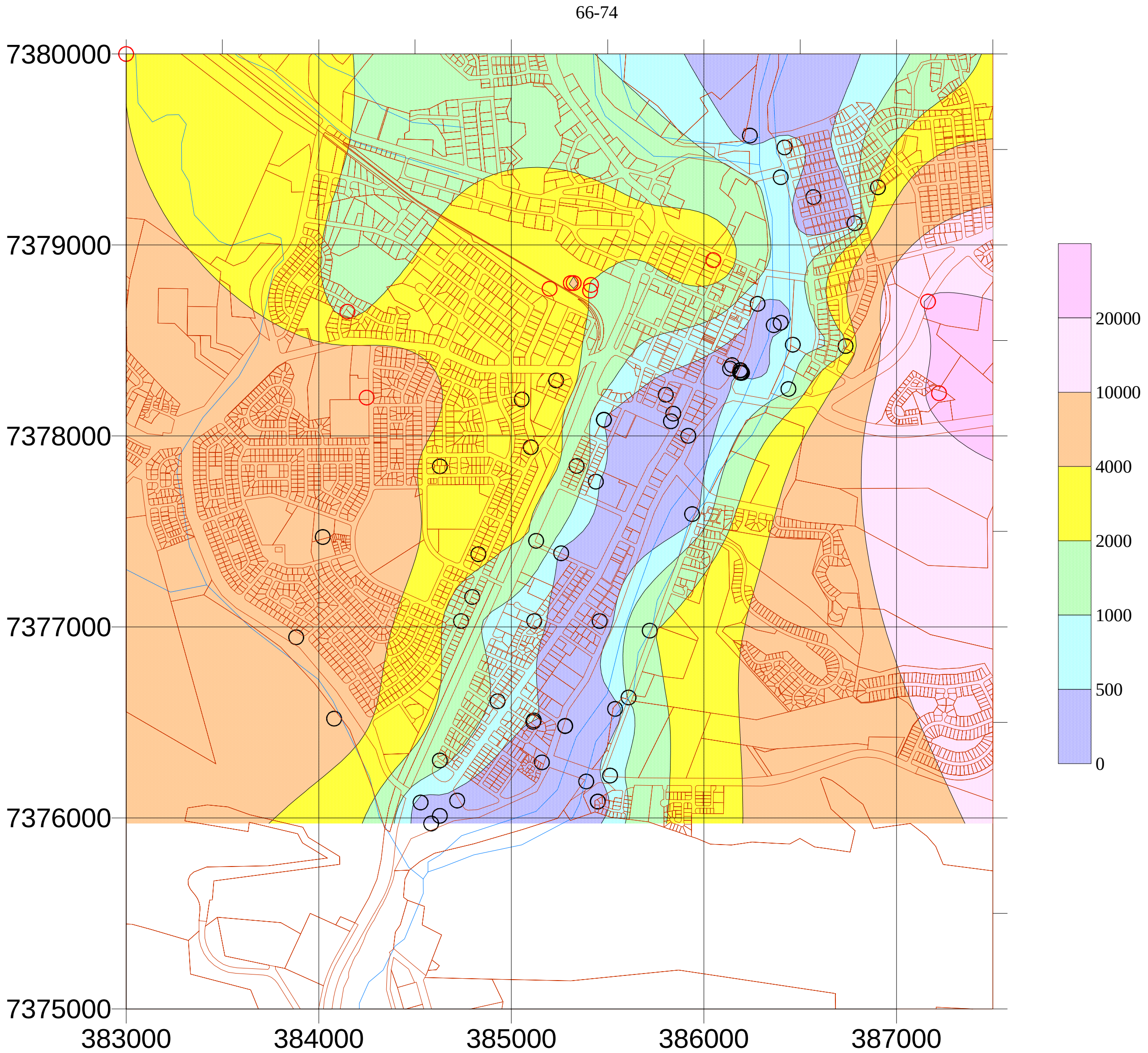
Figure 12 TDS, based on values for 1952 to 1960

61-65



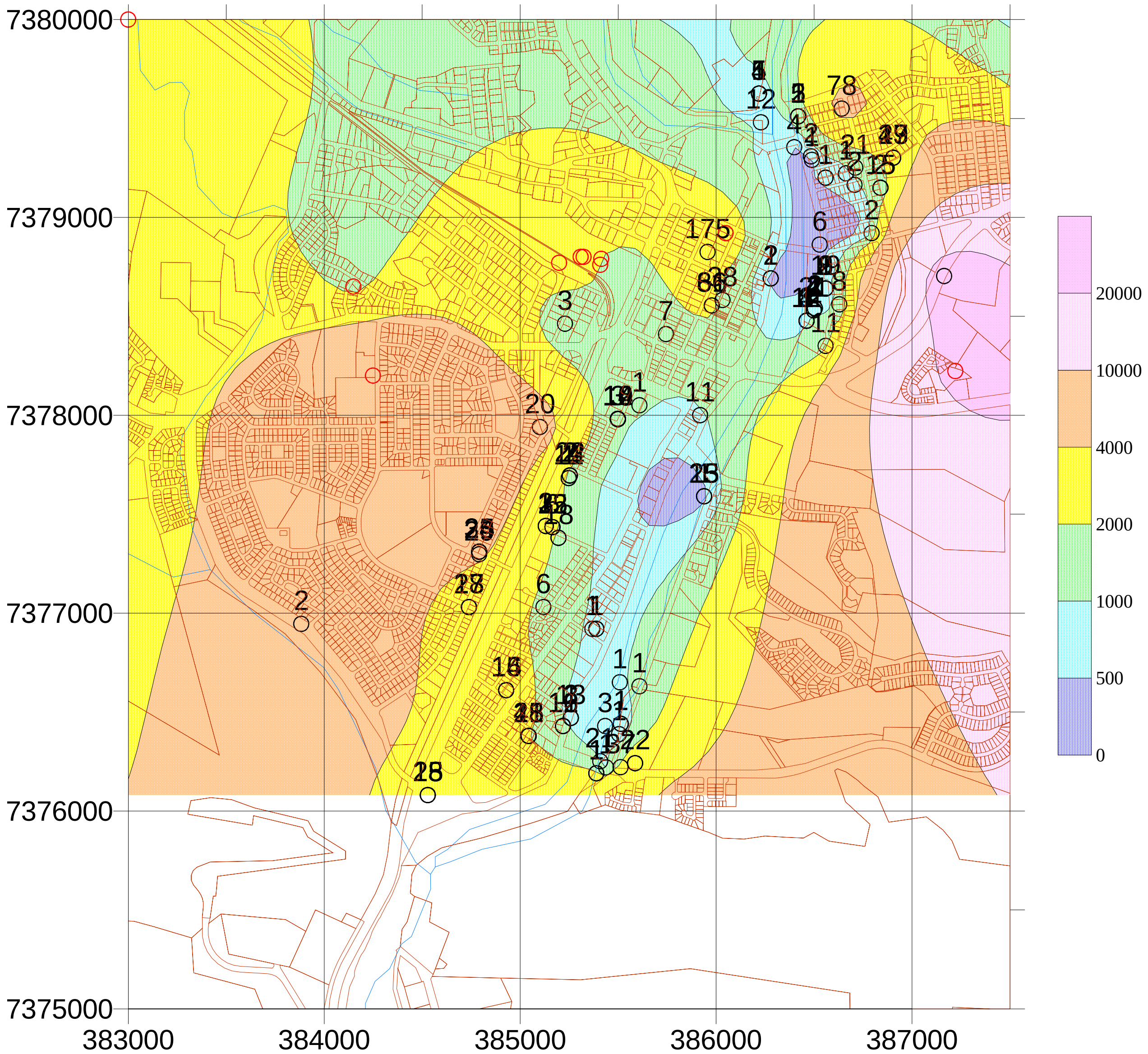
○ Bores sample in 1952-60 period
○ Bores sampled at other times, added to keep contours consistent

Figure 13 TDS for 1961 to 1965



○ Bores sample in 1952-60 period
○ Bores sampled at other times, added to keep contours consistent

Figure 14 TDS for 1966 to 1974



○ Bores sample in 1952-60 period
○ Bores sampled at other times, added to keep contours consistent

Figure 15 TDS 1975 to 1983

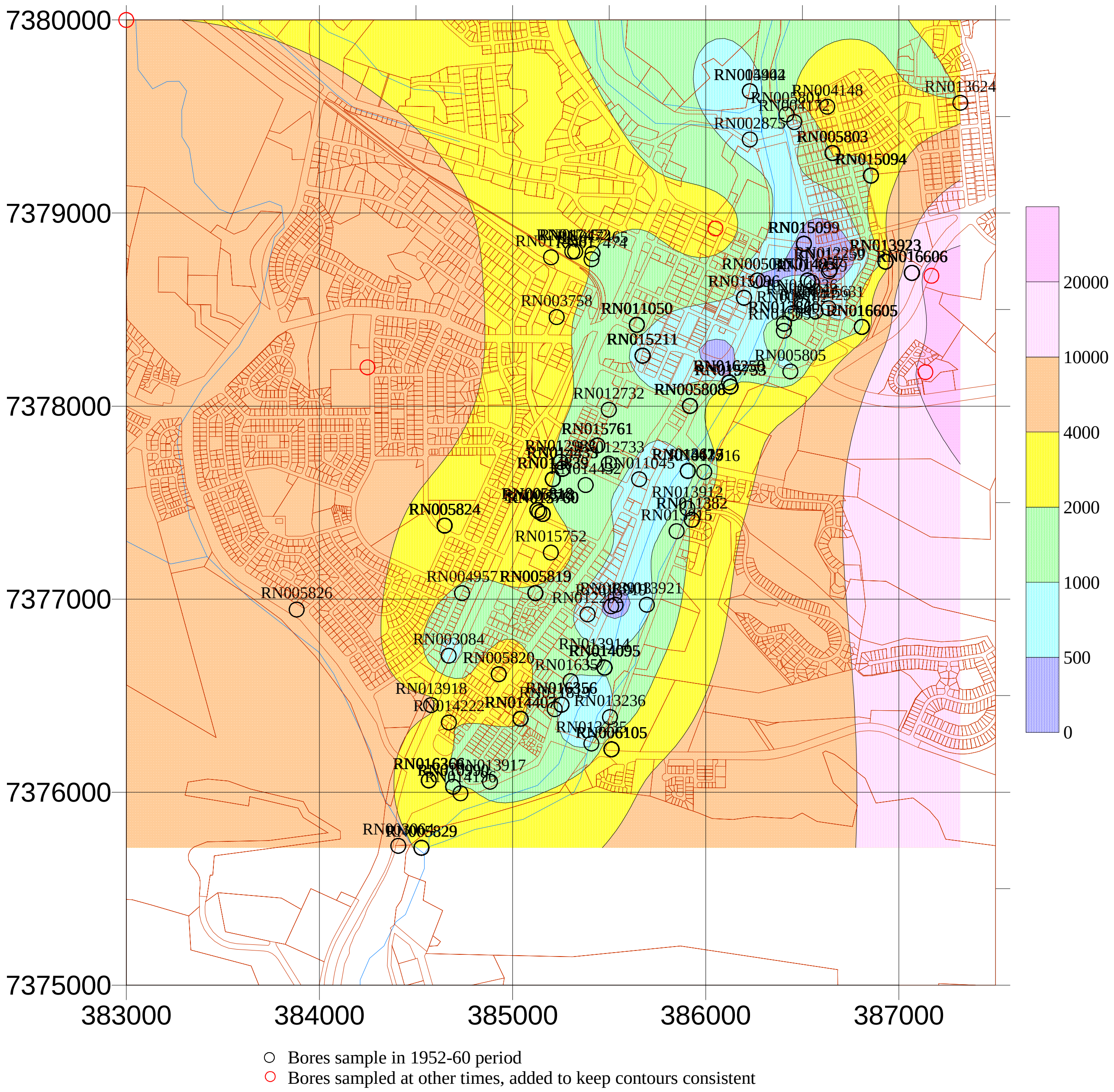


Figure 16 TDS 1984 to 2000

Figure 17 shows a Durov plot of all suitable analyses in the Town Basin. The anions cluster on a line between the bi-carbonate corner and about 30% sulphate, 70% chloride.

The cations are clustered on a line between about 60 % calcium, 40% magnesium and the sodium corner.

Analyses from the Todd at the Anzac gauge have been included. It can be seen that while the anion plot is similar, the cation plots of the low salinity water at high flows are significantly lower in magnesium.

5.4.1.1 Fluoride

Figure 18 shows the distribution of fluoride values in the area. Very high values occur in the saline waters in the metamorphic rocks around the edge of the town basin. This is related in part to the low calcium contents of these waters. Figure 19 shows a plot of calcium and fluoride. It can be seen that most of the analyses lie below the line of calcium fluoride saturation as calculated from Aylward and Findlay (1965), with a few samples above. This may be a result of super-saturation, or of errors in the published value, as very low solubility products are difficult to determine.

Fluorides above drinking water guidelines do not occur in water where the TDS is acceptable for potable water. Some of the marginal waters on the eastern side of the basin are unsuitable for stock because of high fluoride.

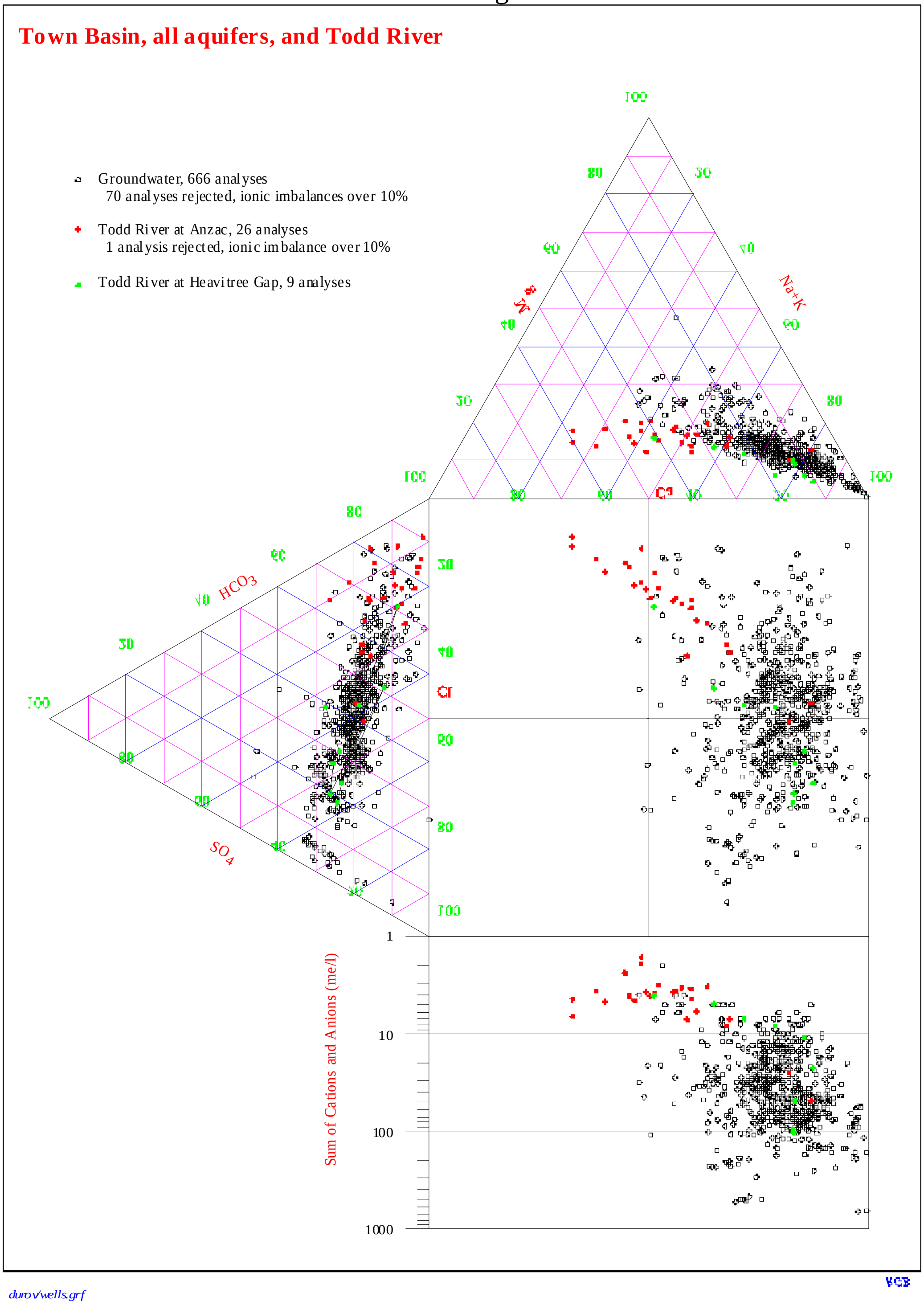


Figure 17 Durov plot for the Town Basin

Fluoride

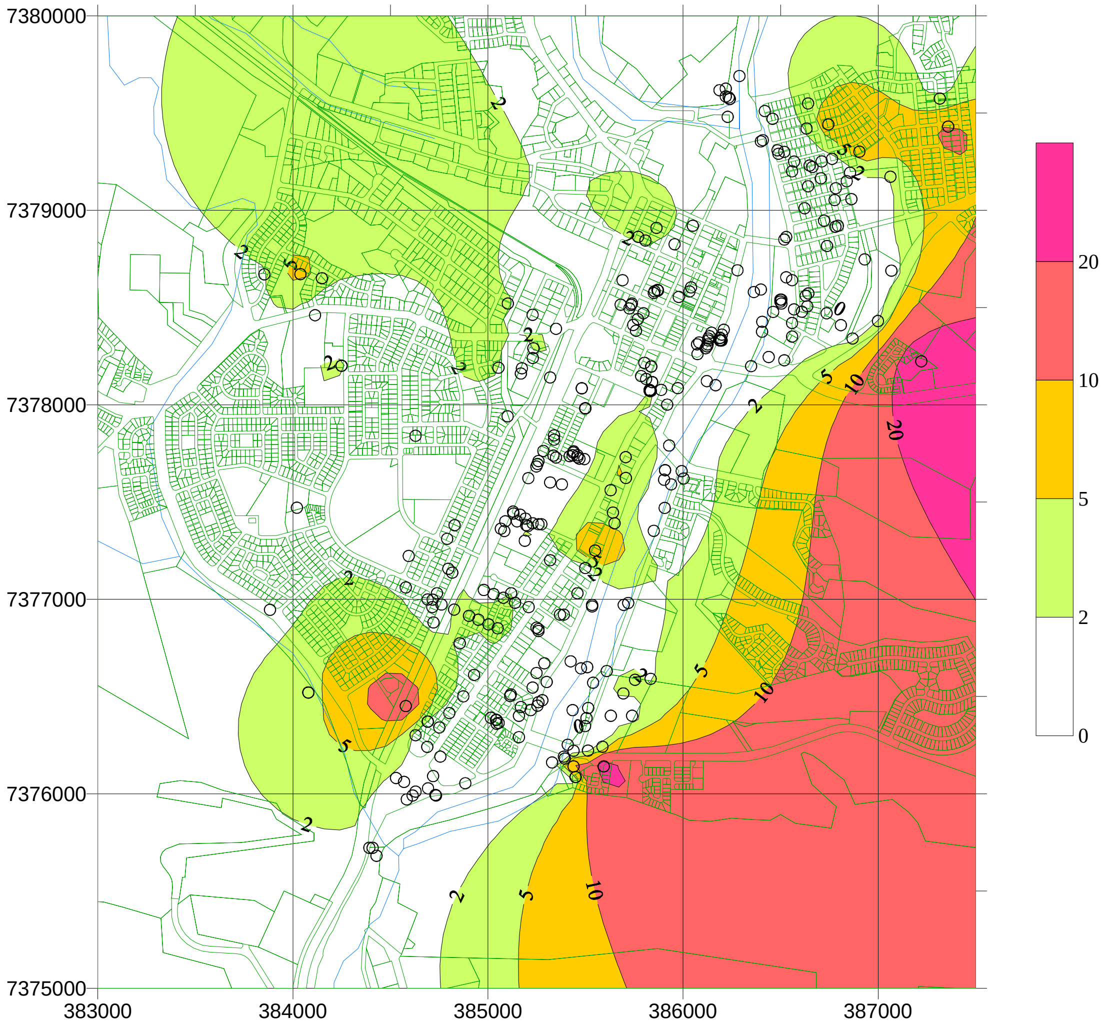


Figure 18 Fluoride distribution, using last available analysis for each bore

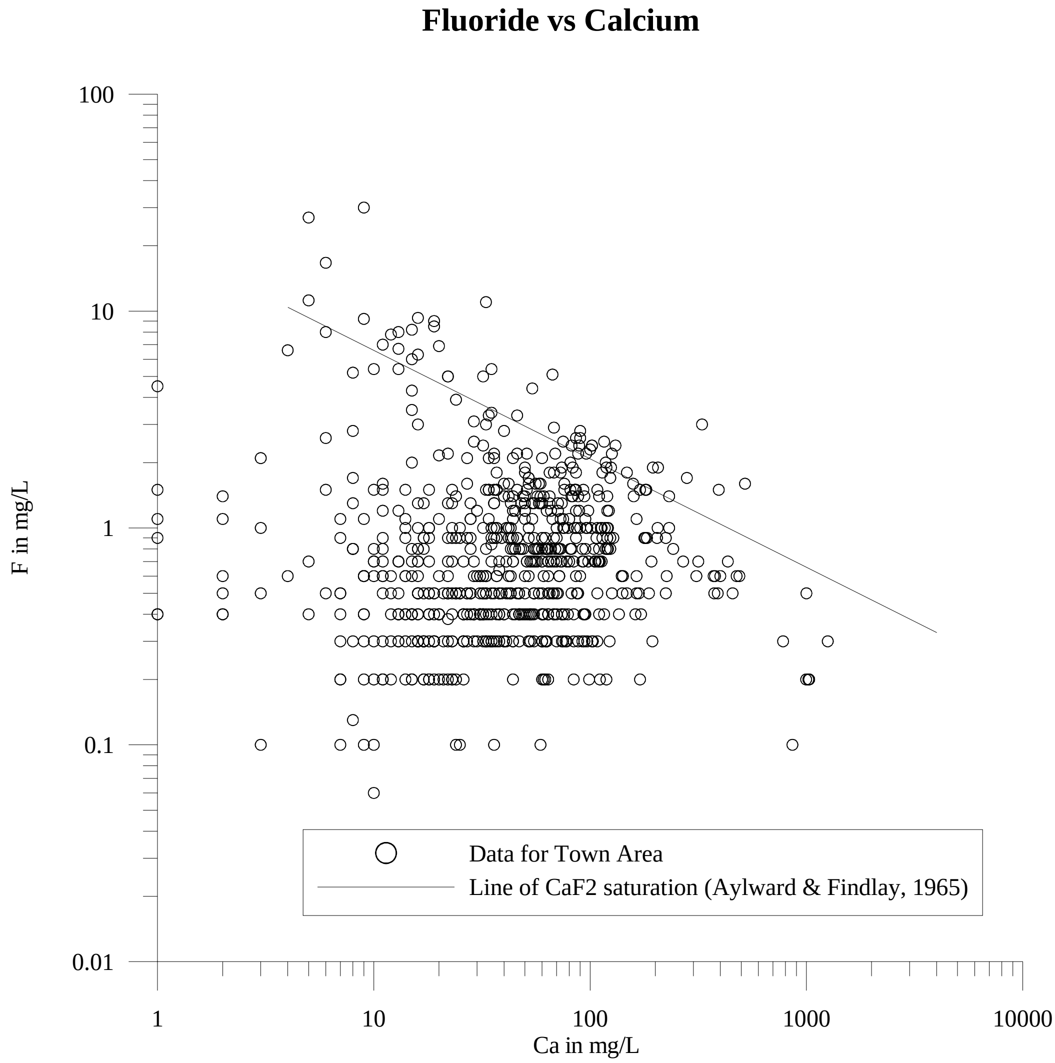


Figure 19 Fluoride versus calcium, Town Area

5.4.1.2 Nitrate

High nitrates are widespread in Central Australia, however nitrate in the Town Basin is generally low (Figure 20). The very high nitrate in the north east corner is a single analysis from a shallow well that was probably badly polluted. Figure 23 shows the relation between nitrate and chloride. It can be seen that there is a small population of waters with high nitrate and low chloride. The nitrate could not have been derived by evaporative concentration of river water, and is either a result of pollution, or possibly direct infiltration of nitrate rich waters. The very high chloride waters have low nitrate.

5.4.1.3 Potassium and Sodium

Figure 21 shows the relationship of potassium and sodium concentrations. For the Todd at the Anzac and Heavitree gauging stations there is a clear power relationship. The groundwater samples are far more scattered, but show a very similar power relationship. The reason for this is not known.

Nitrate

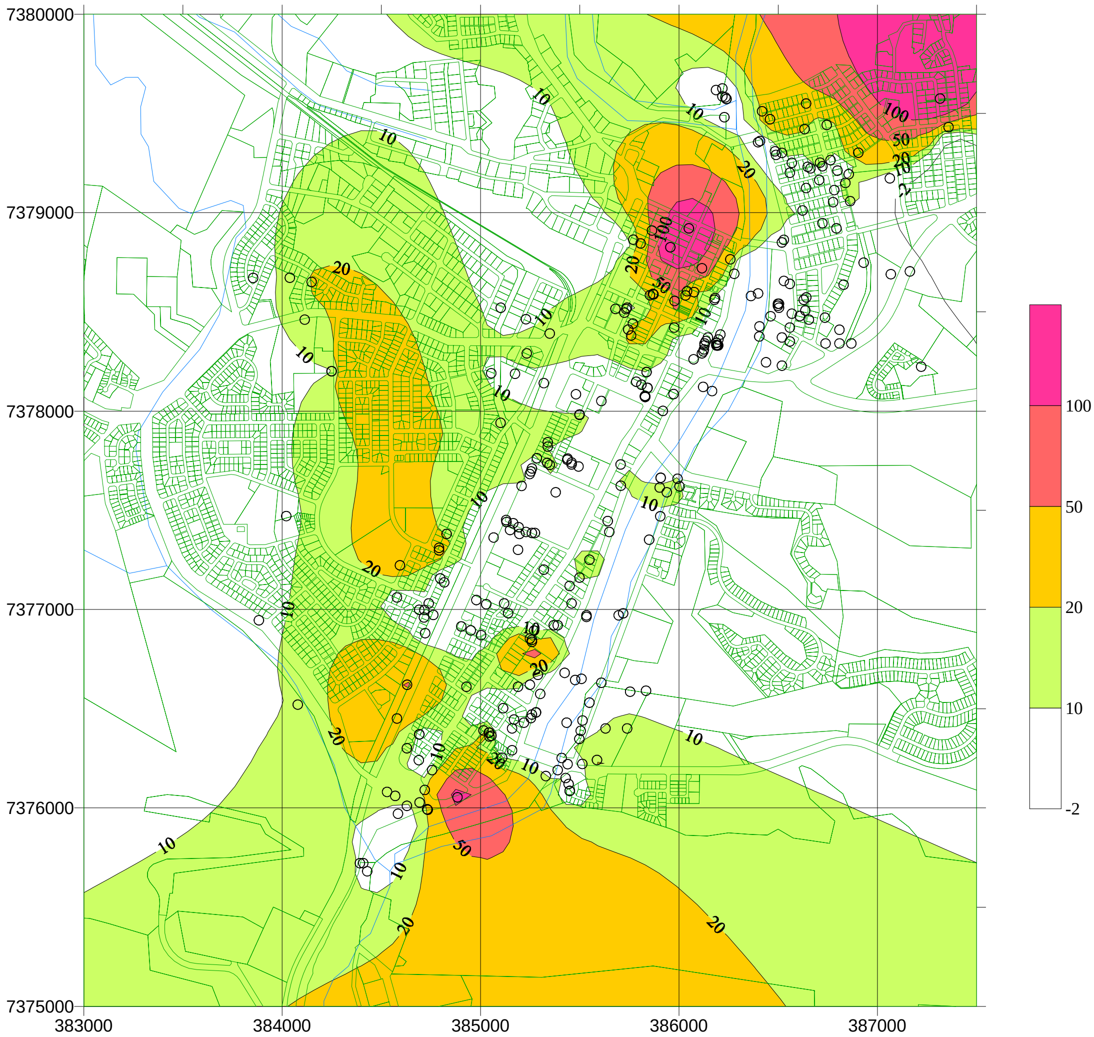


Figure 20 Nitrate in the town area.

5.4.2 Hydrocarbons

Alice Springs has been a major transport hub for over 60 years, and large volumes of petroleum products have been handled in it. Within the Town Area there are a number of fuel storages and service stations, all of which are potential sources of pollution. Figure 22 shows present and some past hydrocarbon storages. This list is not complete, and there are probably other service stations that have operated at times. Also shown are known hydrocarbon plumes.

Investigations into hydrocarbons fall into two groups:

- From 1990 to 1992 the then Water Resources Branch collected samples from some existing bores for sampling for total organic carbon.
- Since 1998 there have been several investigations where test bores have been drilled specifically to investigate known or suspected hydrocarbon spills. For this work hydrocarbons have been reported in groups according to the carbon chain length.

Potassium vs Sodium

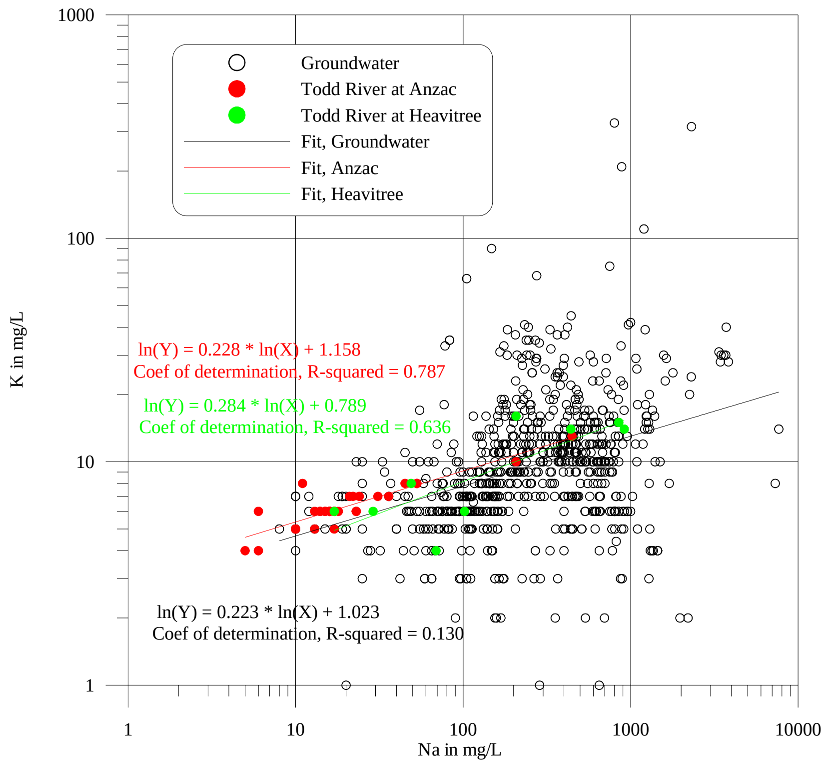


Figure 21 Potassium versus Sodium

Hydrocarbon pollution is discussed in more detail in Appendix C. No relevant analyses exist in the HYDSYS database, but analytical results were extracted from the data files and from consultants' reports. Summarised information on hydrocarbon plumes is shown in Table 6 . Locations are in Figure 22 .

Table 6 Known hydrocarbon plumes in the Town Basin

Plume	East	North	Date first found	Length m	Width m
Railway Yards Plume 1	385190	7378640	1997	20	20
Railway Yards Plume 2	385250	7378600	1997	80	25
BP depot	385780	7379107	1998	80	40
Shell Todd	386204	7378863	2001	20	10
Shell depot	385353	7379064	1998	250	80
Wills Terrace storm drain outfall	386328	7378811	1998	?	?
Tuncks Road drain outfall	385973	7377644	1990	?	?

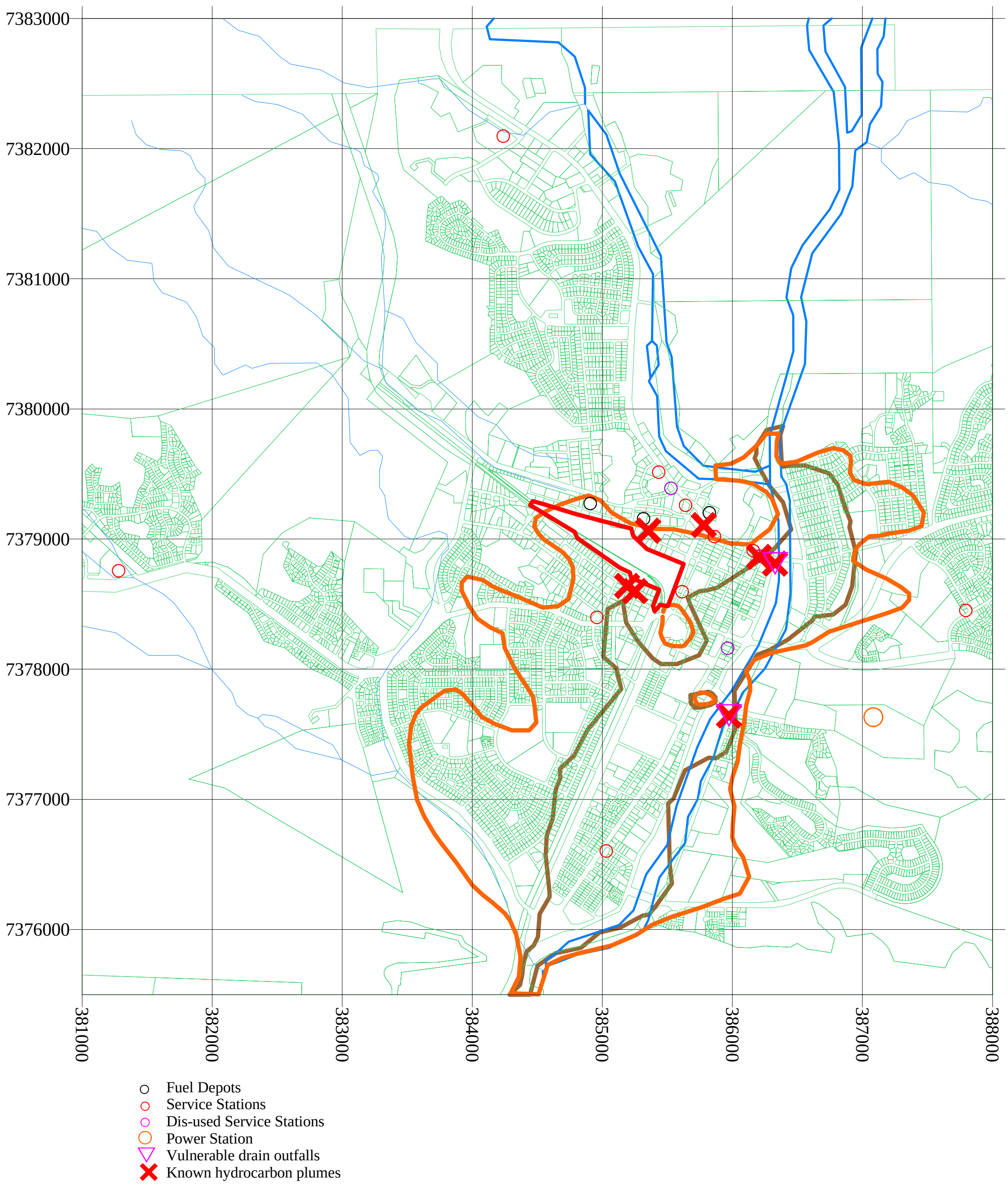


Figure 22 Hydrocarbon storages and plumes

5.4.3 Other Pollutants

Also buried in a folder were results for insecticides in 1993 (Appendix C). These show that levels of dieldrin in RN 14433 at Traeger Park were high enough to be of concern.

5.4.4 Bacterial

The HYDSYS database has 37 bacteriological tests for the town basin, all for the period 1976 to 1993. Wilson (1958) details extensive bacteriological testing which has not been entered into the HYDSYS database. Likewise more recent tests have not been entered into the database. Paper copies of these are being sought for future assessments.

Appendix C shows all bacteriological tests in HYDSYS. Coliforms have been detected in 13 of 31 samples tested, a high detection rate. Further study would be needed to determine what the sources of contamination were for particular bores. Faecal coliforms have been detected in 6 of 36 samples tested. The two very high faecal coliform counts came from RN 6518.
It is clear that the Town Basin could not now be used for potable town supply without disinfection.

5.4.5 Viral

No viral testing in the basin is known, and it is very unlikely that any has been carried out.

5.4.6 Radionucleides

During the period of atmospheric nuclear weapons testing regular checks were made of the radioactivity of Alice Springs water supply, as for many other Australian towns. No records of analyses for uranium, radium, or for gross alpha or beta activity could be found in the HYDSYS database. Two determinations of gross alpha and beta activity in 1985 were found in a data file and are shown in Appendix C. Levels are well below those of concern.

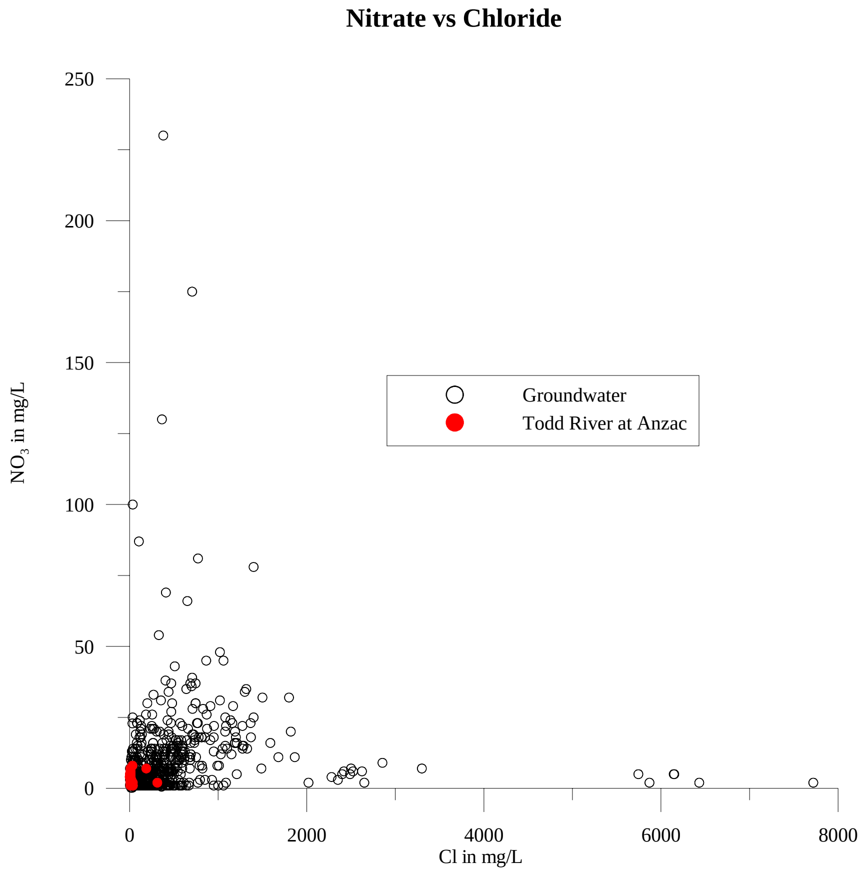


Figure 23 Nitrate versus Chloride

5.4.7 Stable isotopes

Berry (1992) shows ^{18}O and ^{2}H compositions for samples from the Town Basin. No ^{18}O or ^{2}H data for the Town Basin could be found in HYDSYS, and the figures that

Berry's graph (Figure 24) is based on could not be found in the bore folders, data or correspondence files.
The ^{18}O ^{2}H values in Berry (1992) plot close to and below the local meteoric water line. Berry notes that this could be explained either by evaporation prior to recharge or by the fact the groundwater isotope composition is similar to that of rainfall in the wetter months.

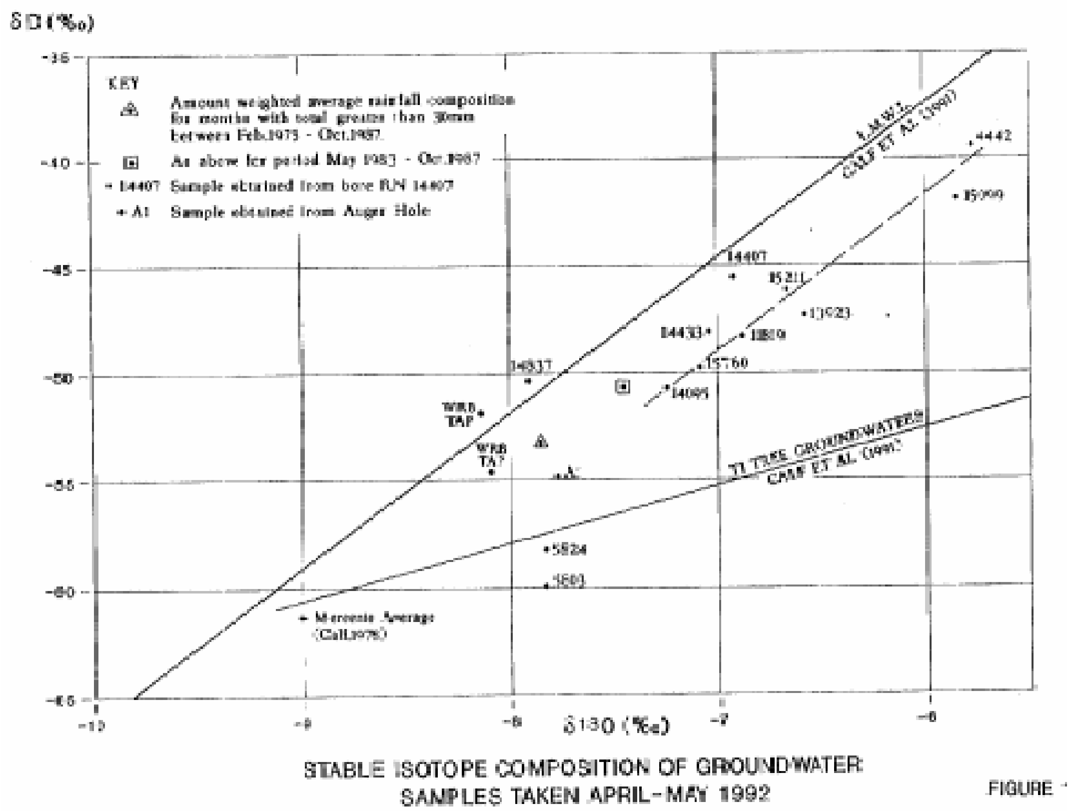


Figure 24 Oxygen 18 Deuterium plot, from Berry(1992)

Two bores RN 5803 and 5824 have anomalous stable isotope contents. Berry suggested that this might be because they are effectively leachate from Town Water Supply irrigation. However the fluoride contents tend to disprove this.

5.4.8 Salt and Chloride Balance

Berry (1992) attempted a salt balance for the Town Basin for the period March 1991 to March 1992. The conclusion was that salt inputs almost balance outputs over this period. This report did not consider the wider town area, and did not include surface water flows.
SKM (2001), present salt balances for the Town Basin for the years 1999 and 2000.
As part of the current study a chloride balance was attempted for the entire town area. Chloride was studied because it is a conservative ion. "Salt" includes the bicarbonates in the water imported from Roe Creek, much of which precipitates in soils as calcium carbonate.

Inputs to the town area are as follows:

Inflow in Todd at Anzac, (Appendix A)	110 T/y	Fair estimate
Inflow of water from Roe Creek borefield, 10 GL at 75 mg/L Cl	750 T/y	Good estimate
Natural inflow	2 T/y	Taken from Berry (1992). Adjusted to chloride.
Swimming Pool salt	150 T/y	
TOTAL to nearest 00	1 000 T/y	

Outputs are as follows:

Outflow in Todd at Heavitree (Appendix A)	1000 T/y	Based on only 7 points. This estimate is suspect because of major problems with the rating curve.(1)
Outflow in sewers	600 T/y	Rough estimate. Chloride has not been determined in sewage and has been estimated from limited and variable conductivity data.
Groundwater outflow	50 T/y	Present outflow (see 5.8.2) by a TDS of 4000 mg/L, converted to chloride
TOTAL	1650 T/y	

(1) There is no reason to doubt the chloride values, which were determined in the usual way. The corresponding gauge heights were taken from the recorder data and may have some error. All samples were taken on the recession leg of the hydrograph, which would introduce some error.

The component with the largest uncertainty is the chloride flux at Heavitree Gap. Only seven chloride-discharge values are available. The chloride flux through Heavitree Gap is in the range 2000 to 4000 T/y of chloride that is 6000 to 12000 T/y of salt.

It appears there is a large salt imbalance in the system. While this figure implies a salt loss of 300 T/ km^2 (or 300 g/m^2) over the entire urbanised area, it is within the range of values (177 to 623 g/m^2) tabulated by Hatton et. al (2002) for catchments in Western Australia.

Bradshaw Drain and the drain along Telegraph Terrace both receive groundwater discharge when the water table is high. This water would be saline and would add to the salt flux at Heavitree Gap.

It would be very useful to have estimates of the historic salt flux and changes. Unfortunately because of the total lack of any analyses or conductivity measurements before 1981 and the very restricted number of analyses since it is not possible to examine the changes over time.

5.4.9 Trends in Salinity

SKM (2001) concluded that salinity in the Town Basin is generally decreasing. Salinity trends for production bores (Appendix E) show that there are significant decreases in some bores, but not all. The two bores with increasing salinity are both

east of the Todd close to the saline margins of the basin, and it appears that saline water from the margins is moving to these bores. Figure 25 shows the distribution of bores with increasing salinity trends.
For the other production bores the reduction in salinity is presumably a result of pumping an increased proportion of Todd River recharge water with time.

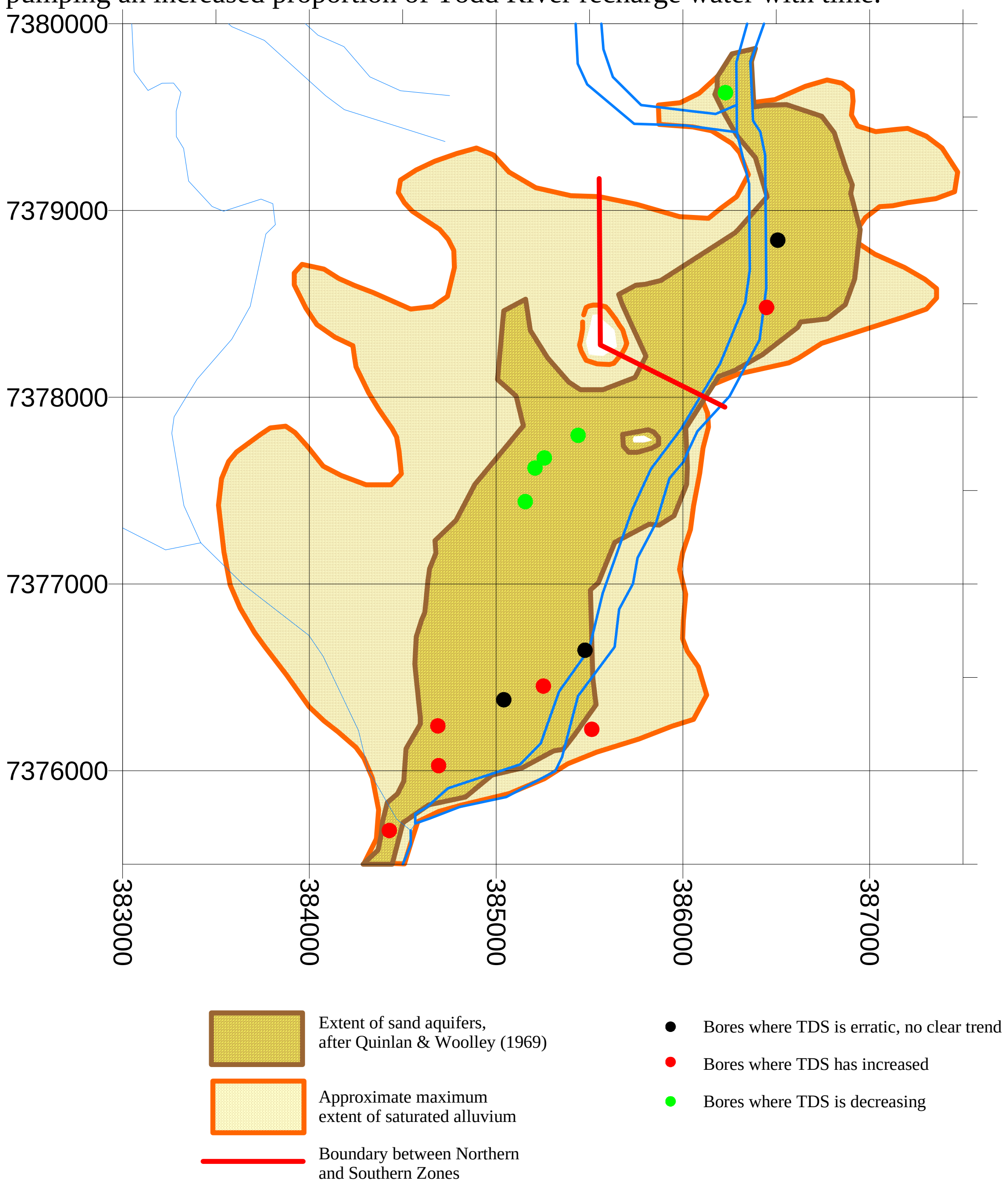


Figure 25 Salinity trends in production bores

5.4.10 Salt storage

Berry (1992) estimated 47 000 T of salt (say 15 000 T of chloride) in the Town Basin. This was based on results of 11 auger holes. Estimated salt stored above the water table ranged from 3.5 to 21 kg/m^2 with an average of 11.5 kg/m^2, that is 11 500 T/km^2. This estimate refers only to the approximately 4 km^2 of the Town Basin with significant aquifers, and not to the low transmissivity parts of the basin and urbanised areas over weathered metamorphic rocks. Salt storage in the weathered rock areas

around the Town Basin is likely to be higher than this. Berry's estimate excludes the substantial areas of the town over weathered bedrock, which may have a larger salt storage. Tickell (1994) quotes salt storage for the southern region of up to 790 kg/m^2. Average salt storage could be in the range 10 to 100 kg/m^2, that is 200 000 T to 2 000 000 T over 20 km^2 of urban area.
This salt can be mobilised by heavy irrigation of gardens, and possibly by increased recharge as a result of urbanisation as discussed in 5.7.1.3

5.5 Hydraulic characteristics

5.5.1 Aquifers

Table 7 shows summarised test pumping data for the Town Basin. Transmissivities range from 1 500 to 30 m^2/d. Little testing has been done in the marginal parts of the basin where transmissivities are lower.
In the northern zone transmissivities range from about 50 to 100 m^2/d.
In the southern zone there is a large area where transmissivities are from 500 to 1 500 m^2/d (Figure 26).
Quinlan and Woolley (1969), p.51, concluded that the representative aquifer parameters were;

Hydraulic conductivity	45 m/d	(150 ft/day)
Transmissivity	450 m^2/d	(30000 gal/day/ft)
Specific yield	0.07	

The estimate of transmissivity appears to apply to the central part of the Southern Zone.
Berry (1992) calibrated a model with hydraulic conductivity ranging from 1 and 2 in the marginal areas of the basin to 160 m/d. Transmissivity of over 500 m^2/d are generally restricted to part of the Southern Zone (Figure 26).
Berry's (1992) model used S values ranging from 0.003 in the marginal areas of the basin to 0.26 in the more highly permeable sands. The parameters used in the model are shown in Appendix F.
The average over the cells with non-zero permeability is about 0.09. For water balance studies in Appendix G a specific yield of 0.07 was applied to the whole basin with satisfactory results.

An attempt was made to estimate hydraulic conductivities in the marginal zones of the aquifer (Appendix I). The weathered bedrock was found to have a hydraulic conductivity of up to 6 m/d, but generally less than 1. The adjoining bedrock aquifers have no significant effect on the water balance, but because of high salinity may have an effect on the salt balance.

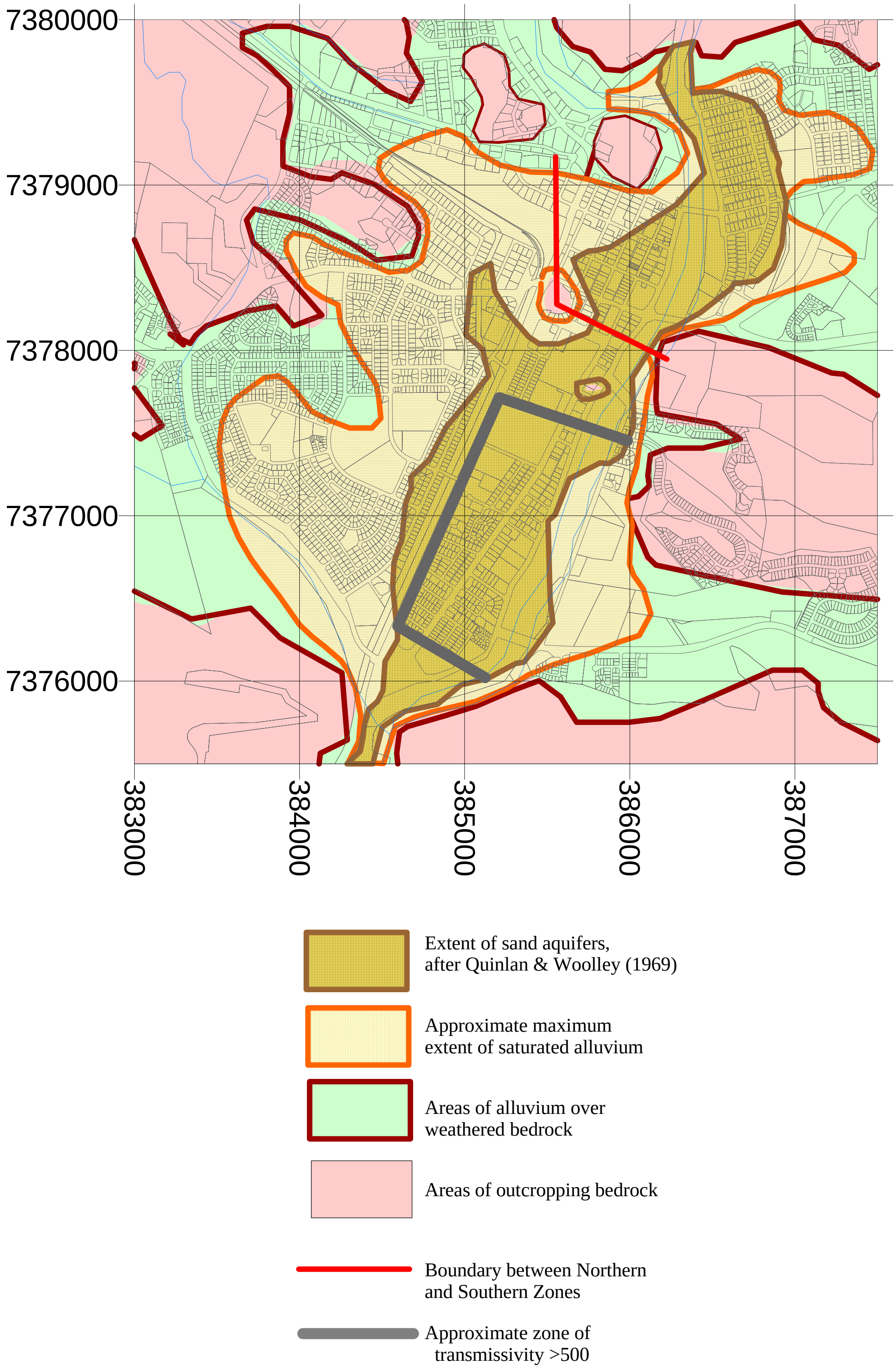


Figure 26 Zones in Town Basin

Table 7 Summarised test pumping data, after Berry (1992)

RN	Depth m	Pump test date	Rate m^3/d	Screen depth m	Jacob drawdown T m^2/d	Jacob rec T m^2/d
RN006518	16.2	17/07/1974	431	8-16	132	
RN006518	16.2	17/11/1983	877	8-16	115	
RN006782	19.2	28/09/1978	605	12.5-19	130	
RN011149	14.0	03/03/1981	346	6-11	70	
RN011382	18.0	10/08/1976	442	12-18	530	
RN011817	18.0	21/09/1978	346	7-8, 8-13	58	
RN011820	15.5	13/09/1978	696	9.5-10.5, 14-15	821	
RN011836		01/05/1986	225	10-11	38	
RN012473	20.0	15/07/1980	48	14-19	1.6	1.6
RN012651	18.0	11/12/1980	896	12-13, 16-17	263	
RN013919	13.0	19/03/1984	306	8-10.6	37	55
RN014095	7.6	08/09/1998	1391	2.5-5.5	1500	1600
RN014196	20.0	22/03/1985	1211	17-20	131	188
RN014222	18.0	04/06/1985	1058	11-14	1490	1290
RN014407	18.7	29/08/1985	1728	11-13, 17-18	790	1340
RN014417	11.0	03/02/1986	697	5-8		
RN014429	16.5	17/03/1986	523	7-8, 13-15	169	383
RN014433	18.0	24/04/1986	1631	13-15	1200	855
RN014837	16.4	20/05/1986	475	13-15	79	
RN014839	19.0	29/04/1986	1730	11-13	513	
RN015096	20.5	20/04/1988	399	12-14, 18-20	108	
RN015099	21.4	22/07/1986	523	18-20	59	
RN015211	18.1	22/07/1988	346	15-17	62	
RN015760	14.0	20/10/1990	2592	11-13	1725	1900
RN015761	21.9	05/02/1991	1730	9-18	745	1150
RN015762	22.8	27/02/1991	518	14-16	225	

5.6 Groundwater movement

5.6.1 Trends (directions)

The Town Basin is a dynamic system and flow directions change with time.
The dominant direction of flow in the basin is southwards toward Heavitree Gap along the axis of the basin, that is generally parallel to the Todd River.
There is a lack of monitoring bores around the edge of the basin, but the limited potentiometric data available and the distribution of TDS indicate that there is flow from the weathered rock areas and the silty aquifers into the more highly transmissive sand aquifers of the basin. This probably has a negligible effect on the water balance, but a significant effect on the salt balance. This can be seen on the eastern edge of the basin where highly permeable aquifers abut the low transmissivity bedrock

Superimposed on this is the intermittent recharge from the Todd River.

5.6.2 Flow models

Macqueen (1976) developed a simple model based on a water balance equation.
Berry (1992) described a numerical model of the Town Basin that was developed. The results are reported and the parameters used recorded, but the digital data files used for the model have been lost.
Macqueen and Berry's results are discussed in Section 6.3.1.

5.7 Recharge

5.7.1 Mechanisms

The following processes have been recognised:

- River recharge
- Underflow
- Direct infiltration
- Local recharge, mostly locally generated run-off.

5.7.1.1 River flows

This has long been known to be the dominant recharge process in the Town Basin (Quinlan and Woolley 1969, Macqueen 1976).

5.7.1.2 Underflow

Berry (1992) estimated this as 15 ML/year.
SKM (2001) estimated 67 ML/year in 1999 and 62 ML/year in 2000. The basis for these figures is not known. This result is questionable and depends on an artificial northern boundary of the basin.
With a sustainable yield of over 1000 ML/year the difference between inflow and outflow represents some 2 to 3 %, that is less than the errors in metering the pumped discharge.
An attempt was made (Appendix H) to quantify the variability of the inflow, but the influence of pumping on observation bores is too great for sensible answers. However inflow is such a small portion of the overall water balance that variation can be ignored.

5.7.1.3 Direct infiltration (diffuse recharge) and local recharge

Quinlan and Woolley (1969) considered that all recharge was from flood waters of the Todd, and by implication that direct infiltration was negligible.

Macqueen (1976) assumed that direct recharge was less than 100 ML/year.

Berry (1992) assumed a rate of 58 mm/a (418 ML/year) for his 1963-4 calibration and a range of 58 to 131 mm/a (418 ML/year to 943 ML/year) in 1991-2. These figures include irrigation leaching and water main leakage minus leakage to sewers.

SKM (2001) stated that 2% of rainfall infiltrates to the aquifer, and from this 24 ML/year in 1999 and 79 ML/year in 2000.

In Appendix D diffuse recharge for high rainfall periods was calculated as follows:
March 1972 to July 1975 120 mm

January 2000 to June 2000   80 mm.

SKM's (2001) estimate is doubtful. Diffuse recharge appears to occur in the rare periods of heavy rainfall. It has been increased by changes due to urbanisation, such as:

- The establishment of heavily irrigated grass areas and landscaped gardens, especially if cultivated.
- Concentration of run-off from paved areas and roofs.
- Leakage from water reticulation and sewers.
- The construction of trenches for sewerage and water reticulation produces zones with permeability much higher than the surrounding undisturbed rock (Sharp & Krothe, 2002). This can lead to higher vertical permeability and hence higher diffuse recharge. This has been suggested as a mechanism for contaminating the alluvial aquifer with highly saline water from weathered bedrock, but calculations presented by Rooke (1992) show that it is unlikely to be significant.

Diffuse recharge is difficult to relate to rainfall, as periods of sufficiently high rainfall are rare, and always coincide with major river recharge.

5.7.1.4 Local Recharge

This component has not been described in previous studies. It was identified in water balance studies for monitoring periods with no river flow (Appendix G).

Significant recharge was identified in periods with rain and no river flow at the Anzac gauge. This recharge is described by equations

$R = 2.24\ (F-10),\ \ F>10$
$R=0,\ \ F \leq 10$
Where R is recharge in ML in periods of no river flow.
F is rainfall in mm.

Most of this recharge is from storm drains that discharge into the Todd, and is not diffuse recharge (Appendix G).
This local recharge appears to average about 200 ML/year (Appendix G). This estimate relates to the state of development of the town from 1996 to 2000. It would not have applied prior to the construction of the present system of storm drains.

5.7.1.5 Recharge from sewers and water pipes

PWC are not able to account for 2000 ML/year pumped into the town area. Much of this may be due to problems with meters, but if say one quarter of it is leakage this would represent a large increase in recharge to the Town Basin. Sharp and Krothe (2002) presented data showing that leakage from water mains ranges from 8 to 50%. The study in Appendix G did not identify any constant recharge component. Either recharge from this source is almost exactly balanced by outflow to sewers or, more likely, it is insignificant. This does not necessarily mean that leakage is not occurring. Most of the town has well established trees and shrubs that could easily evapotranspire water from a leak.
However the water balance studies of periods with no river flow suggest that the net effect is insignificant (Appendix G).

5.7.2 Major recharge zones

Water quality maps indicate that recharge from the Todd mainly occurs:

Upstream from the Will Terrace causeway in the Northern Zone.
Downstream of the Tuncks Road causeway.
To a lesser extent downstream of the Casino causeway.

The area downstream of the Tuncks Road causeway corresponds to where the Todd crosses an area of relatively thick permeable aquifer.

5.8 Discharge through Heavitree Gap

5.8.1 Hydraulic gradients

Although an array of bores was drilled at Heavitree Gap in 1957 only one (RN 3064) has been monitored since. There is therefore no direct record of hydraulic gradients in the gap, and gradient had to be inferred from the head difference between RN 3064 and RN 3667 on the downstream side in the Inner Farm Basin (Appendix H).

5.8.2 Outflow

Wilson (1958) estimated outflow to be 130 ML/year. There were some errors in his assumptions (see Macqueen (1976)) and this figure was revised to 100 ML/year. The hydrograph in Appendix H shows that the average head difference across Heavitree Gap since about 1973 is about 40% of that in the earlier monitored period, a result of the large decline in pumping in the Inner Farm area. There has been a substantial reduction in average outflow. Calculations in Appendix H show that since 1975 outflow has ranged from 40 to 90 ML/year, averaging 80 ML/year.

The low permeability of the aquifer in Heavitree Gap relevant to that upstream is counter-intuitive. The following explanation is offered for it.

- The aquifers in the Town Basin were deposited in the Quaternary.
- Palaeoflood studies (Patton et al. 1993) have indicated that very large floods occurred in the Todd catchment at about 700 and 1 500 y B.P..
- Such a large flood would have scoured out the unconsolidated material to bedrock, leaving a deep waterhole in the gap.
- This waterhole was slowly filled with silty sand by small flow events.
- Some later scouring by smaller floods partly removed some of the clay layers and deposited more permeable sand in the upper part of the section.

Hydrographs and results are in Appendix H. Since 1975 outflow has ranged from about 40 to 90 ML/year with an average of 77 ML/year. Since a number of assumptions have had to be made this estimate is probably only accurate to $\pm$ 20%. Previously one of the constraints on management of the Town Basin was the need to maintain outflow to the Inner Farm. The quality of the outflow is now so poor (see section below), that this is no longer an issue and it would benefit the Inner Farm basin if pumping in the Town Basin stopped outflow.

5.8.3 Water quality

Unfortunately water sampling at the gap has been inconsistent, there are no bores with data over a long period, and no samples were taken between 1965 and 1989. Chloride

contents over time are shown in Figure 27 , and Figure 28 shows bore locations. It can be seen that there are significant differences between bores that are close.
RN 3064 is only 14 m from RN 3071, hence their water chemistry should be similar. With this assumption chloride content of the water discharging from the Town Basin has increased by a factor of 3 between 1957 and the present.
Chinaman Creek (or Bradshaw Drain) receives groundwater discharge and flows into the Todd just above Heavitree Gap. Water analyses for it are shown in Appendix A. The highest TDS and chloride values measured in it are about 5000 mg/L and 1 500 mg/L respectively, slightly higher than in RN 3064. No flow figures are available for Chinaman Creek, but base-flow would be small and the overall contribution minor.

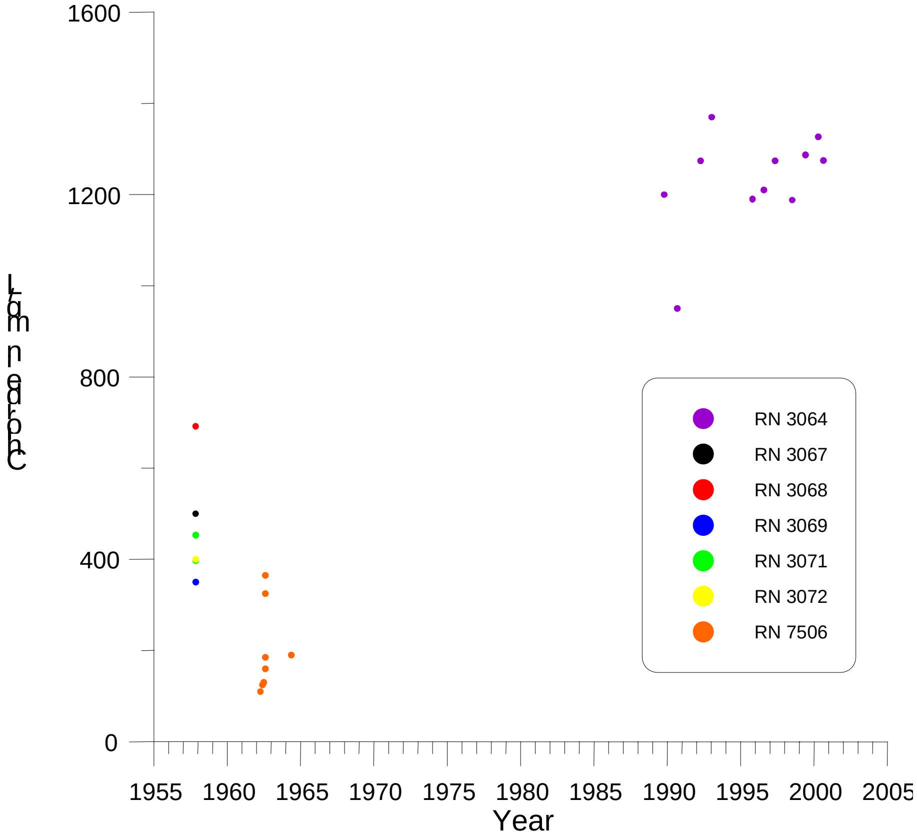


Figure 27 Chloride in groundwater at Heavitree Gap

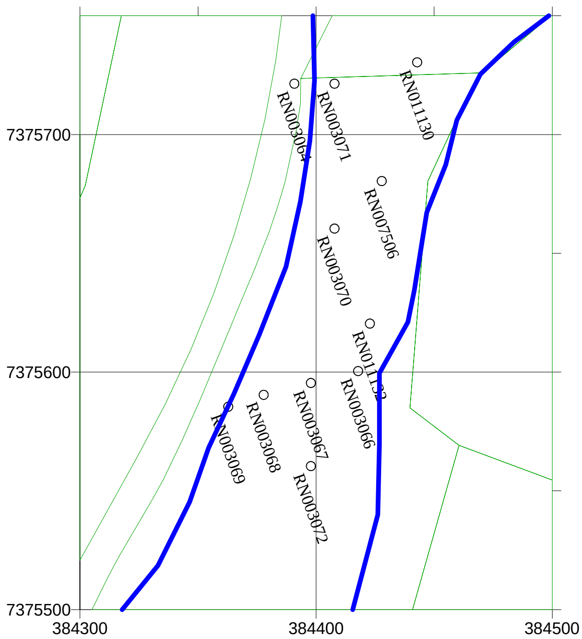


Figure 28 Bores in Heavitree Gap

5.9 Discharge across the basin

5.9.1 Flow out of Northern Zone

Wilson (1958) estimated discharge from the Northern Zone as 5600 gallons per hour, that is about 220 ML/year. In the current study it was estimated as follows:

Transmissivity, m^2/d	200
Head difference, m	0.5
Length, m	190
Width of flow, m	600
Estimated outflow, ML/year	115

Pumping the Northern Zone at capacity will largely eliminate this outflow. Detailed modelling would be needed to determine the effects of this.

5.10 Evapotranspiration

SKM (2001) designated evapotranspiration as zero, but also stated that the River Red Gums are groundwater dependent.
Evapotranspiration was estimated from water balances, using data from 1996 to 2002, in Appendix G as
$E = 0.0687\ V$
Where E is evapotranspiration in ML for any period.
V is measured pan evaporation at Alice Springs Airport in mm for the same period.

Since average annual V is 2374 mm/year, average E is 163 ML/year, that is it is four times larger than the discharge through Heavitree Gap. This is about 40 ML/year/km of the Todd. Evapotranspiration is probably also sensitive to water level, but this was not investigated.

5.11 Volume of water in storage

5.11.1 Extractable volumes by quality and zone

Estimated extractable volumes are listed in Table 8 . Figure 29 shows the relation between TDS and extractable volume for the Southern Zone. These were derived using Surfer to estimate volumes of saturated aquifer, and assuming a specific yield of 0.07, and porosity of 0.2. It is essential to distinguish between the meaning of these numbers. The specific yield is the volume released by draining a unit volume of aquifer. Most of the water in the aquifer is held by capillary tension and is not released by gravity drainage. However for calculating the volume of water of low salinity that may be displaced by lateral flow of more saline water the total porosity of about 0.2 may be applicable.

For the Northern Zone the estimate is quite straightforward, as the volume of water of under 1000 mg/L in storage exceeds the volume that could be released by gravity drainage.

Table 8 Extractable volumes in zones

Salinity	Northern Zone				Southern Zone, >5L/s (1)	
	Area km^2	Volume ML	<5 L/s	>5 L/s	Area km^2	Volume ML
Total working storage (2)	1.9	440	120	320(3)	5.8	2100
All <500 mg/L	0(4)	0	0	0	0	0
All<800 mg/L	0.26	260-440	120	320	0.04	70
All<1000 mg/L	0.72	440	(5)		0.16	200
All<1500 mg/L			(5)		0.69	1000
All<2000 mg/L			(5)		1.1	1700
> 2000 mg/L			(5)		4.7	400(6)

(1) There are areas of aquifer with yields under 5 L/s, but all the available resource could be extracted from areas where bore yields are > 5L/s.
(2) This has been determined by estimating the difference in stored volume between the 08/2002 potentiometric surface and the 10/1964 potentiometric surface.
(3) The only known area where bores yielding above 5L/s can be constructed is around RN 6823 in Colacag Park.
(4) There is some water in this zone under 500 mg/L, but experience is that it could not be extracted in significant quantities.
(5) There is water of these salinities in the Northern Zone, but all the available storage could be extracted by pumping only the better quality water.
(6) This is based on the total storage less what could be extracted at better quality. The volume of stored saline water is far larger than this, and it could be beneficial to remove some of it to induce recharge of better water.

To summarise:
All the 440 ML of storage available in the Northern Zone could be pumped at under 1000 mg/L and most at 800 mg/L. Bore yields are generally less than 5 L/s, except for some bores around Colacag Park.
In the Southern Zone only a trivial amount of water less than 1000 mg/L could be extracted. In the long term water quality depends on the fate of the salt in the water pumped.

If salt leaches back to the water table in the zone of pumping salinity will continue to deteriorate.

If salt does not return to the aquifer the induced recharge from the Todd will steadily lower the salinity. This could be achieved by;

exporting water is or to another part of the basin.

exporting water out of the basin.

storing salt in the unsaturated zone.

The latter would be difficult to achieve in the Town Basin because of the shallow water tables and the permeable basin sediments.

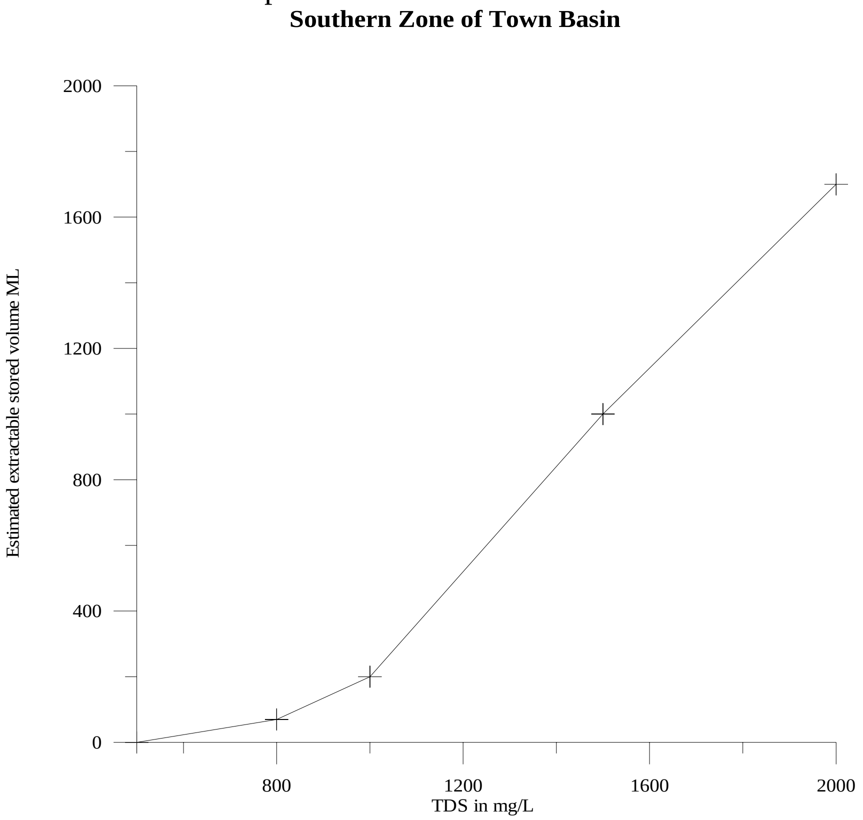


Figure 29 Extractable stored volume in the Southern Zone against TDS.

6 Water Extraction

The locations of production bores are shown in Figure 30 . Graphs of TDS against time are in Appendix E. Table 9 gives details of those now in use. The locations of historic production bores used for town water supply in the past have also been shown. Some difficulty was experienced in relating the bore names or numbers used by Quinlan and Woolley (1969) and Wilson (1958) to registered numbers, and two of the bores could not be identified in the DIPE system at all. Production bores were drilled for the Commonwealth Department of Works, with technical advice being given by the Resident Geologist of the BMR. Many of these bores were not registered in the Water Resources system until years after they had been drilled, and only a small number of analyses were filed in the bore folders. Summaries of the historic production bores are in Table 10 . Quinlan and Woolley (1969) note that some bores suffered from aquifer collapse as water levels fell, and six replacement bores had to be drilled after 1959. G. Ride (pers. comm.) provided the following information.

> “The (post 1959) drilling was designed to spread the bores and replace wells with bores. Also there was a problem in the Inner Farm area when one of the town supply bores de-watered one of the shallow aquifers.”

Some of the historic bores clearly show the degradation of water quality in the aquifer. Few of them could now be used for potable water supply. By pumping saline water it may be possible to restore Available data on the changes in salinity of production bores is in Table 11 .

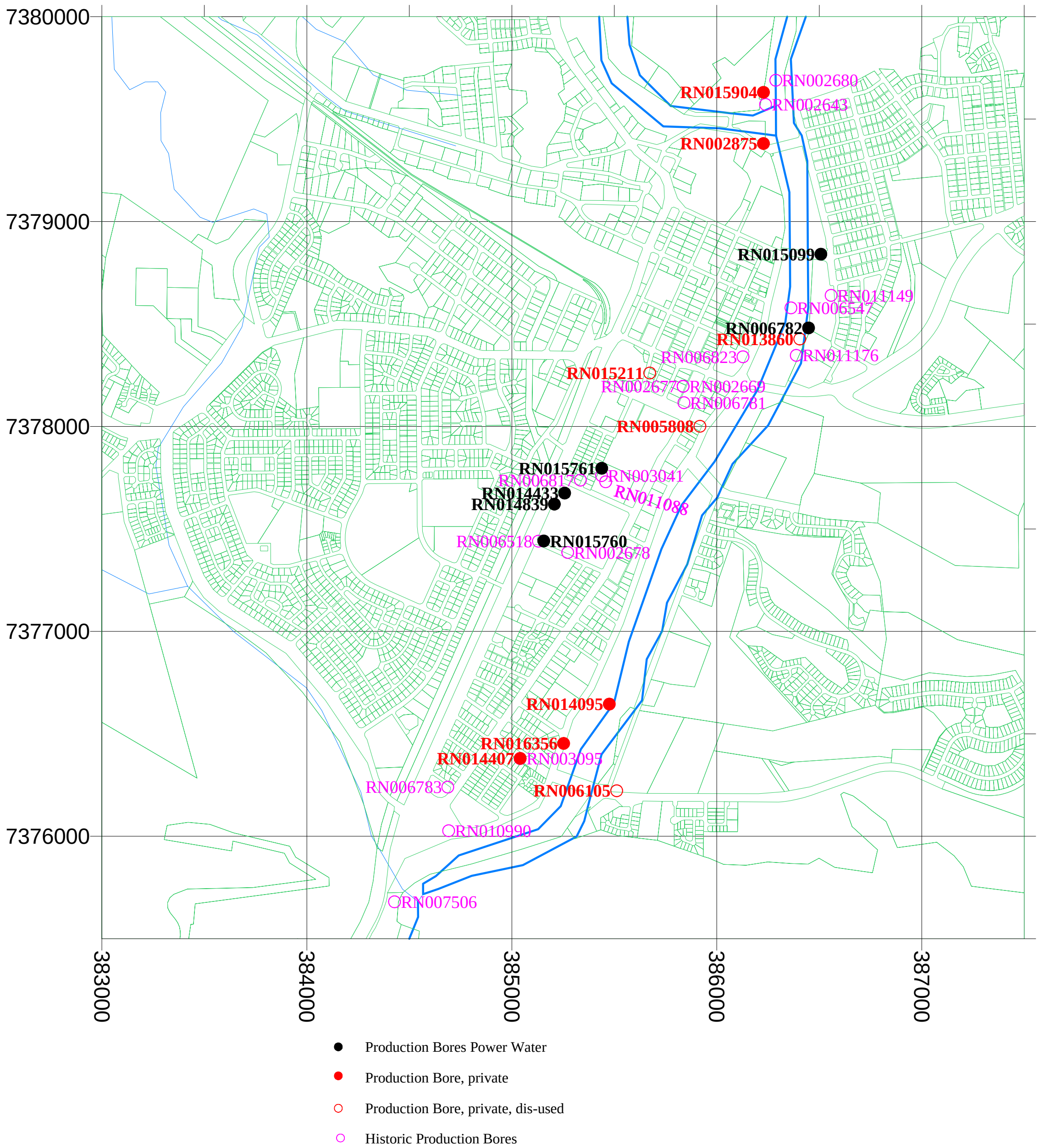


Figure 30 Location of Production bores (See Tables 7 & 8 for bore names)

Table 9 Capacity, Extraction and Salinity Summary of Town Basin Production Bores, after SKM (2001)

Bore ID	Ownership	Zone (1)	Current Equipped Capacity (L/s)	Current Effective Capacity (L/s) (2)	Groundwater Extraction Volume (ML/a)					Latest Salinity Reading (mg/L TDS)
					1999	2000	2001	2002	2003	
RN015761	PWC - Traeger	S	8.4	7	63	48	52	(5)	(5)	990
RN014433	PWC - Hockey	S	10	10	139	105	119	(5)	(5)	1200
RN015099	PWC - Sturt	N	4	3	25	15	85	(5)	(5)	350
RN014839	PWC - CAFL	S	10	10	119	102	119	(5)	(5)	1600
RN006782	PWC - Pacific	N	2.8	2.8	32	2	7	(5)	(5)	1400
RN015760	PWC - Baseball	S	7.8	7	54	72	79	(5)	(5)	1800
RN014095	Private - Golf Course	S	15.01	9	78	29	39	79	(5)	910
RN014407	Private - Golf Course	S	15.01	9	285	197	137	26[4]	(5)	
RN016356	Private - Golf Course	S	15.01	9	74	36	67	99	(5)	
RN015904	Private - St Philips	N	3.01	1.8	23	19	11	16	(5)	
RN002875	Private - Det 421	N	2.01	1.2	7	5	0	0	(5)	
RN006105	Private - Casino	S	1.51	0.91	37	15	0[3]	0	0	
Total			**94.6**	**70.7**	**936**	**642**	**715**			-

(1) Zone, N=northern, S=southern
(2) Effective capacity is an attempt to account for the effects of long term drawdown and interference from other pumped bores.
(3) Bore no longer used
(4) Meter reading suspect
(5) Data not available, due to a badly managed change in recording practise.

Graphs of TDS against time are in Appendix E.

Table 10 Historic production bores

RN	Name	Easting	Northing	Depth	Date Drilled	Date on line (Hamilton 1966)	Comments
RN002643	Todd River Bore.	386238	7379572	12.2	01/01/1960	1-Jun-60	
RN002669	Town Well.	385836	7378196		1939	pre 1959	This is assumed to be Town Well 2. DIPE records for this well are very sparse. During the course of this study a number of analyses not in the DIPE system were found.
RN002677	No.1 Town Well.	385836	7378196		1939	pre 1959	DIPE records for this well is very sparse. During the course of this study a number of analyses not in the DIPE system were found.
RN002678	No.1 Army Well.	385273	7377385	56	1943		
RN002680	No.3 Well Todd River	386288	7379690	0.0	?	pre 1959	
RN003041	Bent Tree Well 59/12	385438	7377760	21.6	01/01/1957	pre 1959	This bore was drilled in the bottom of Bent Tree Well.
RN003095	No110.	385041	7376379	18.6	08/02/1958	pre 1959	
RN006518	No.2 Army Well	385130	7377440	16.2	1943	pre 1959	
RN006547	62/9	386362	7378579	15.4	01/01/1962	13-Dec-63	
RN006781	Town Bore 60/19	385840	7378116	19.6	01/01/1960	1-Dec-60	Replaced RN2669
RN006783	61/33	384688	7376240	16.9	01/01/1961	22-Dec-61	
RN006817	Bent Tree Well No 1 60/14	385335	7377738	18.3	02/06/1960	1-Aug-60	Partly confused with RN 3041
RN006823	Colacag Park, 61/24	386128	7378340	21.3	01/06/1961	1-Feb-62	Hamilton (1966) has confused this with 60/30 RN 4498. The bore folder and Quinlan and Woolley (1969, p.28) show this is an error. By 1975 this bore had been filled in
RN007506	Works No 59 or Heavitree Gap	384428	7375680	17.1	03/10/1957	pre 1959	
RN010990	59/11 Bore 216	384692	7376027	14.6	01/01/1959	1-Jan-60	?
RN011088	Bent Tree No.2 61/42	385458	7377730	19.1	28/09/1961	19-Dec-61	Not entered into DIPE database until 1975. Six old analyses not in database were found
RN011149	Works No86.	386558	7378640	14	26/11/1957	pre 1959	
RN011176	Works No27.	386388	7378347	16.5	21/06/1957		Not entered into DIPE database until 1975.
	Works No21				1958	pre 1959	Mentioned in Quinlan and Woolley (1969) and shown in Wilson (1958), Fig. 7, but could not be found in DIPE database
	Works No28				1958	pre 1959	Included in Wilson(1958)

Table 11 Historic production bores, changes in TDS

RN	TDS 1950's	Comments	TDS Present (1)	Comments
RN002643	300	No trend apparent		TDS in this area is still under 400 mg/L.
RN002669	<500	Both the limited data in HYDSYS and Wilson (1958) indicate a slight decline.		TDS in this area would now be about 1000 mg/L.
RN002677	<500	Both the limited data in HYDSYS and Wilson (1958) Plate 22 indicate a slight decline.		TDS in this area would now be about 2000 mg/L.
RN002678	500	Data in Wilson (1958) Plate 23indicate a slight decline 1954 to 1957.		TDS in this area would now be about 2000 mg/L.
RN003041	600	Erratic variation, possibly partly due to samples from several bores being attributed to this bore.		TDS in this area would now be about 1500 mg/L.
RN003095	600	No trend apparent	3000	The replacement bore (RN 14407) is showing a trend of declining TDS.
RN006518	700	Data in Wilson (1958) indicate a slight decline 1954 to 1957.	2000	Has shown a general decline since 1983
RN007506	700	No trend apparent in production Measurements taken during the pump test in 1959 show a distinct upward trend.		TDS in RN 3064 55 m away is now about 4000 mg/L.
RN011149	500	No historic data found	900	TDS has shown a decline since 1975
RN011176		No historic data found		
RN10990	700		2600	Replacement RN 14196 does not appear to have been used.

(1) See Appendix E for salinity trends

6.1.1 Agricultural use

Agricultural use in the Town Basin continued up to the 1960's (G. Ride pers. comm.). During this period there may have been heavy use of pesticides, and these former agricultural areas are potentially areas of groundwater contamination. An historical search to identify these areas would be useful.

6.1.2 Public use

The town basin was used for public water supply, beginning with the construction of the Town Wells in 1939 and peaking in 1964 when the use of the basin was phased out with the development of Roe Creek borefield. Total annual pumpage is shown in Figure 9 . After 1970 there was only limited private pumping.
In 1976 pumping from the Town Basin for irrigating recreation areas instead of Roe Creek water was proposed, but this did not happen until 1986.

6.1.3 Current usage

Extraction rates for 1999 to 2001 are shown in Table 9 . Figures for 2002 and 2003 are incomplete.

6.2 Bores & wells

6.2.1 Bore hydraulics

The relationship between drawdown in production bores and screen length and aperture was investigated in Appendix I. The following conclusions were drawn:

- Screen length was not significant, that is sufficient screen length has been used in all cases. Generally 2 m of screen is adequate.
- Screen aperture was strongly related to well-efficiency, though this may largely be due to the fact that larger apertures can be used in coarser more transmissive aquifers. There are a number of bores with 2 mm aperture screens that are not particularly efficient.
- Both the linear and non-linear head losses, were very strongly correlated with transmissivity, that is good bores are in good aquifers.
- The relationship with transmissivity provides a benchmark for assessing the standard of completion of individual bores.

6.2.2 Design and construction of production bores

Over the years various approaches have been used for the design of production bores. Quinlan and Woolley (1969) noted that there had been problems with the collapse of aquifers and recommended the following method:

> "Place screens with oversize slot openings (which will pass up to 80 % of the aquifer) against the full thickness of a bed of sand with a minimum of disturbance, even though part of it is of very low permeability.
> Some disturbance of the alluvium and increases in well loss will occur during development. This can be kept to a minimum if the bore is developed by pumping and backwashing with an axial flow turbine pump. Surging to remove clay and silt from aquifers can be disastrous, particularly if screen openings are less than 1 mm."

McDonald (1985) described a method of rotary drilling using polymer mud, reaming to 430 mm and installing 350 mm ID casing and in-line screens. Little development was required to produce a sand free discharge.

Similar methods were used for the construction of further bores (Stevens 1985 and 1986). Stevens (1986) states that "Most of the bores which have failed are constructed of perforated 150 mm casing, with or without a gravel pack." He further cites the performance of RN 14433 and RN 14839 as evidence of the success of the method. In Appendix I the performance of these large diameter bores was compared with that of four 150 mm diameter screened bores for which data was available. The large diameter bores did not seem to have noticeably better performance.

D. Miller (pers. comm.) considers that bores in the river bed can be constructed by jetting in oversize temporary casing, installing the permanent casing and screen, and then withdrawing the temporary casing, allowing a natural pack to form around the screen.

The key factor in constructing a high-yielding bore is selection of an area of high transmissivity aquifer.

6.2.3 Efficiency of existing production bores

In Appendix I it was shown that there is a strong relation between aquifer transmissivity and the parameters that describe drawdown in a bores. Individual bores deviate significantly from this line, and this is assumed to be an indicator of the standard of the bore completion. Table 12 shows PWC bores with;

observed drawdowns in pumping test

ratio of the above to “average drawdown” for the transmissivity

estimated reduction in drawdown if completion were the best possible for the transmissivity.

The latter has been taken to be 0.6 of the average production bores.

It can be seen that while improvements may be possible they are marginal and do not justify the construction of a new bore.

Table 12 Production bores with possible reduction in drawdown with improved completion

RN	Name	Estimated drawdown from test data at equipped rate	Ratio of observed drawdown to estimated drawdown from line of best fit	Estimated reduction in drawdown if completion was improved to the best, m
RN006782	Alice Pacific Prod.	1.75	1.06	0.76
RN014095	Golf Club Production	0.92	0.56	0
RN014407	For Alice Springs Golf Club	2.00	0.65	0.14
RN014433	Traeger Pk.	1.75	1.64	1.11
RN015760	Traeger Park.	0.57	1.12	0.26
RN015761	Traeger Park School	1.14	1.59	0.71
RN016356	Site No2 A/S Golf Club	9.92	0.84	2.87

6.2.4 Optimum siting of production bores

From the above it is clear that production bores should be located in areas of high transmissivity aquifer. The salinity trends in production bores (Section 5.4.8) show that bores sited near the saline eastern edge of the basin are likely to have increasing salinity.

Simple modelling should be used to determine the optimum location of production bores in relation to other bores.

6.3 Sustainability (safe yield)

6.3.1 Previous work

Forbes (1962) estimated a safe yield of 680 ML/year. This was made up of 545 ML/year pumping from the basin estimated from the graph in Figure 31 , and 130 ML/year outflow through Heavitree Gap. This was based on observations of draft and water level decline for the years 1957 to 1961, a period of drought and is very conservative.

Quinlan and Woolley (1969) estimated a safe yield of about 700 ML/year. Quinlan and Woolley (1969) also suggested that the yield of the basin could be maximised by pumping at 90 ML per month for two months after recharge, and then reducing the rate by 15 ML per month for each month without recharge. As stated withdrawal would be 0 in the eighth month, and only 400 ML would have been extracted.

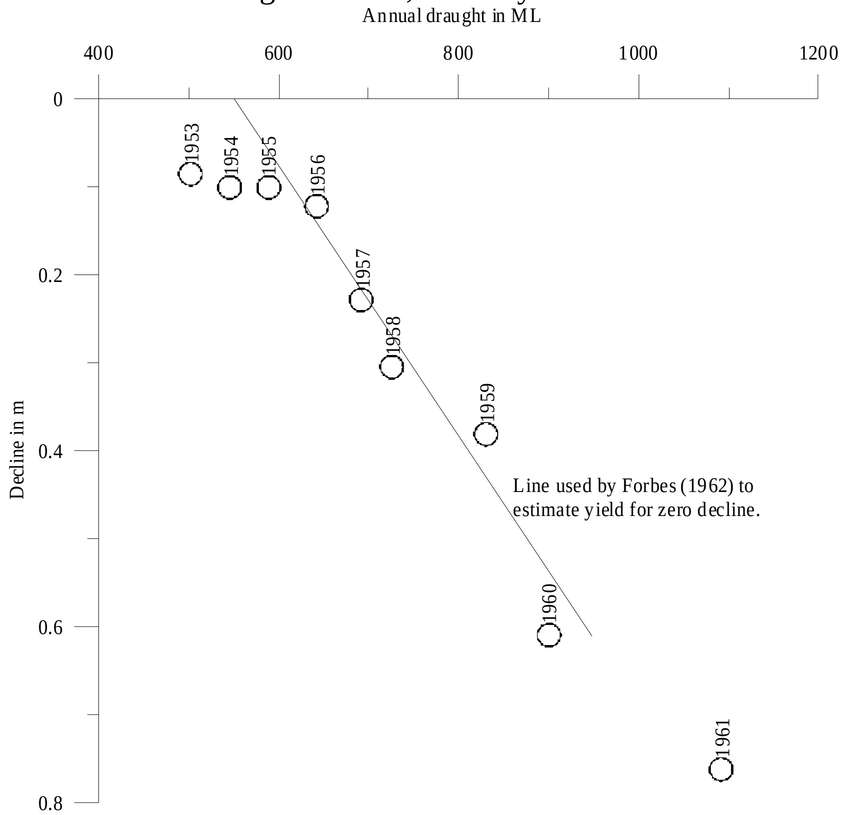


Figure 31 Water level decline versus draft, 1953 to 1961, after Forbes (1962)

Macqueen (1976) estimated the safe yield of the basin to be 660 ML/year, 300 ML/year from the Northern Zone and 360 ML/year from the Southern Zone. Macqueen's model related groundwater recharge to water level below the Todd. Pumping at average rates more than this has left water levels at above desirable levels. SKM (2001) estimated median annual recharge as 840 ML/year. SKM's calculations assume that recharge is independent of water level, which is doubtful.
SKM (2001) have also attempted estimates of the time that it would take for water levels to reach the minimum allowable of 8 m below the river bank. These are in Table 13 .

Table 13 Extraction rate against time to minimum, after SKM (2001) Figure 5-2.

Extraction rate ML/year	Estimated years for water level to reach the minimum, assuming annual recharge of 840 ML/year.
1 650	4
1 500	5
1 250	8
1 000	21

From the above it would be reasonable to raise extraction rates to the range 1000 to 1250 ML/year. This would appear to make good use of the resource, lower nuisance water tables with a reasonable usage rate of production bores.
SKM (2001) did not divide extraction between zones. Extraction from the Northern Zone should be 350 ML/year, and the balance from the Southern Zone.

6.3.2 Current estimates (good, fair, poor & saline chemical quality)

Best current estimates are as above, that is 350 ML/year for the Northern Zone and 700 to 900 ML/year from the Southern Zone.
Stored volumes against TDS are shown in Table 8 and Figure 33 .

6.3.3 Current licensed extraction

Present licenses are shown in Table 14 .

Table 14 Current licenses in the Town Basin

Licence Holder	Licence Number	Annual Vol, ML	Actual Extraction 1999 ML	Actual Extraction 2000 ML	Actual Extraction 2001 ML	Actual Extraction 2002 ML	Expiry Date
St Philips College	511	4.50	23	19	11	16	01/03/2011
H. J. White	516	0.20					01/03/2011
C Carter	517	0.65					01/03/2011
Lasseters Casino	519	27.00	37	15	0	0	01/03/2011
F.W. Fitzgerald	536	0.70					01/03/2011
Golf Course	501, 502, 503	450	437	262	243	204	
PWC	523	600.00	432	344	461	?	01/03/2011
Total		1083.05	936	642	755	?	

Table 15 shows annual extraction by PWC/PAWA over 6 years. It can be seen that only about 65% of their allocation has been used.

Table 15 Annual usage by PWC/PAWA

Water Year ending	Annual extraction ML
97	387
98	388
99	424
00	402
01	381
02	365
Average	391

6.4 Water Quality Pollution (Salinisation)

The most dramatic change in the basin is the massive increase in salinity that occurred at about the same time as the large recharge event in 1974.
Figure 32 shows the relation between stored volume and salt. Note that the stored volume referred to is the total pore volume, assumed to be 0.2 of aquifer volume, **not** the extractable storage which is assumed to be 0.07 of aquifer volume. Hence when 1 m^3 of aquifer is drained about 65% of the salt may remain in pore water in the unsaturated zone. Hence the relation between stored salt below the water table and stored water volume is something of a truism. The graph cannot be taken too literally, as the salinity used has had to be compiled from samples taken over a period of years. The relationship between stored volume and mean TDS (Figure 33) is more significant, though this is partly a consequence of the more saline water being in the

areas of thinner aquifer near the basin margin. A rise in water level will cause a proportionately larger increase in stored volume in these saline areas.
There are three possible mechanisms that could have caused the large increase:

- As noted above gravity drainage of a portion of aquifer may leave about 65% of the water behind in the unsaturated zone. If this is within the root zone, most of the water could be removed by evapotranspiration, with the salt remaining in place. If the aquifer was then saturated again with water of the same quality as before the salinity will be about 65% higher. In 1975 water levels had risen to within 4 or 5 m of the surface over most of the Town Basin (Figure 11). This is well within the root zone, so this mechanism is possible.
- The extreme rainfall caused unusual diffuse recharge, leaching salt normally immobile in the unsaturated zone to the water table.
- Irrigation could have leached salt down to the where it was dissolved by the rising water table.

These mechanisms are not exclusive, and it is likely that all of them have operated to some extent.
Beyond this it is hard to draw firm conclusions about the relation between salt storage and water level. Selected hydrographs in Appendix H show that while TDS levels generally declined after 1976 TDS in some bores (e.g. RN 4957) had begun to increase again in the 1990's. This predates the large rainfall event in 2000.

The variety of TDS trends displayed by bores in Appendix H suggests that a number of mechanisms are at work.

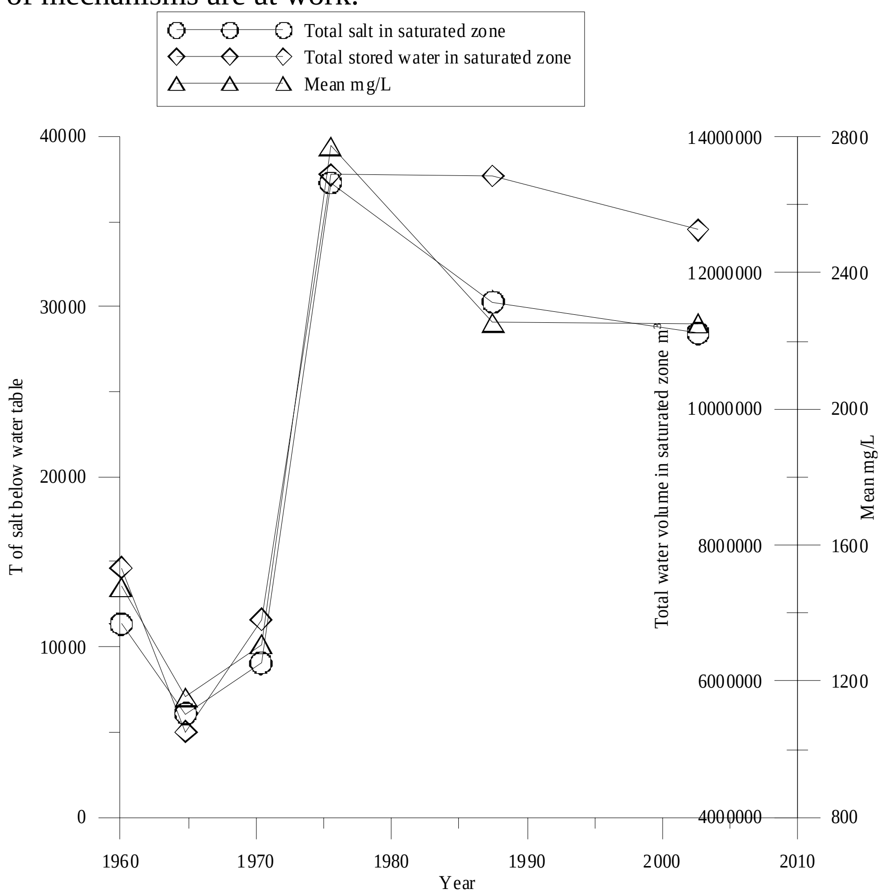


Figure 32 Relation between salt storage and stored volume

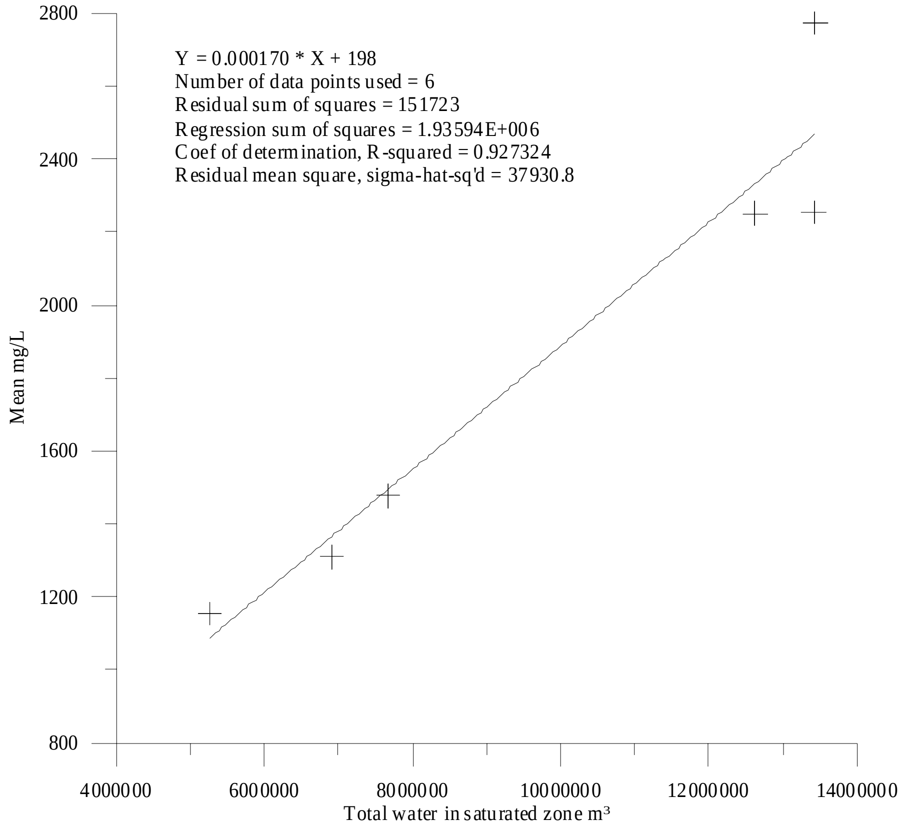


Figure 33 Relation between stored volume and mean TDS in basin sediments

6.4.1 Northern Zone

There seems to be little evidence of groundwater salinisation in this area. One production bore (RN 6782) has showed increasing salinity, probably because of its location near the saline eastern margin of the basin. Soil salinisation is occurring in the heavily irrigated Ross Park marginal to the aquifer.

6.4.2 Braitling

This area lies outside the Town Basin in the valley of the Charles River. The hydrogeology of this area is poorly known. Seventeen bores are recorded as having been drilled in it. Some of these are old and poorly documented.

Most bores have been dry, but a few have yielded small supplies from fractured Alice Springs Granite. Salinities range from about 400 mg/L near the Charles River to 4000 mg/L.

There is no current extraction and historic extraction in this area would have been small. RN 5714 was formerly licensed for 0.5 ML/year, but this seems to have lapsed.

The Quaternary alluvium is generally about 6 m thick, up to a possible maximum of 15 m. It is mostly above water table, or has only thin ephemeral aquifers. Fresh rock is at fairly shallow depth on the eastern side near the Charles River, but to the west the regolith is about 15 m thick.

One bore (RN 10780) was monitored on the fringe of the area from 1975 to 1980. This shows the decay of the recharge mound following the summer of 1976, but is too short to show the full range of water levels. There has been no chemical monitoring in the area, and the changes due to urbanisation cannot be quantified.

RN 5713 had a water level of 14.9 m in 1961 and 4.5 m in 1975. By 1975 this area was partly urbanised. This large change is interesting in view of the fact that there has been no significant extraction in this area.
Irrigation leaching from the Braitling Oval, numerous private gardens and the usual leaking distribution systems must all have contributed to increased recharge and raised water tables.

By analogy with the Town Basin direct recharge is likely to be in the range of 10 to 20 mm per year. Assuming an area of 2 km^2, outflow from Braitling is around 20 to 40 ML/year. Some of this may be down the present channel of the Charles River, but most probably moves south through the former channel of the Charles to the west of Teppa Hill. Quinlan and Woolley (1969) indicate branches of the 1820, 1830 and 1840 aquifers that appear to come from this direction. Salt export would be in the range 40 to 200 T/y.

No evidence of salinisation is known from this area.

6.4.3 Golf Course

The hydrogeology of this area is poorly documented. Bores drilled in this area encountered saline water, which in some cases was not tested. Salinities of up to 9700 mg/L are known, from the marginal Town Basin sediments. The weathered bedrock to the east probably has water with salinity in the range 10 000 to 20 000 mg/L. Within the golf course some shallow piezometers (not entered as bores in the HYDSYS database) have been installed. Water levels under the greens range from 0.8 m to 0.2 m. The irrigation of greens over low permeability weathered rock and sediments has caused water tables to rise.

6.4.4 Heavitree Gap Area

This area is the extreme southern part of the Southern Zone and the Figure 34 shows salinity trends in the Heavitree Gap Area. Locations for the bores are in Figure 35 . In the area near Heavitree Gap there has been an increase in salinity. However RN 3084 which is further upstream and in the sand aquifer has shown no significant change. Historically this area always showed considerable fluctuations in salinity, depending in part on flows on the Todd (see graphs for RN 7506, Appendix E).

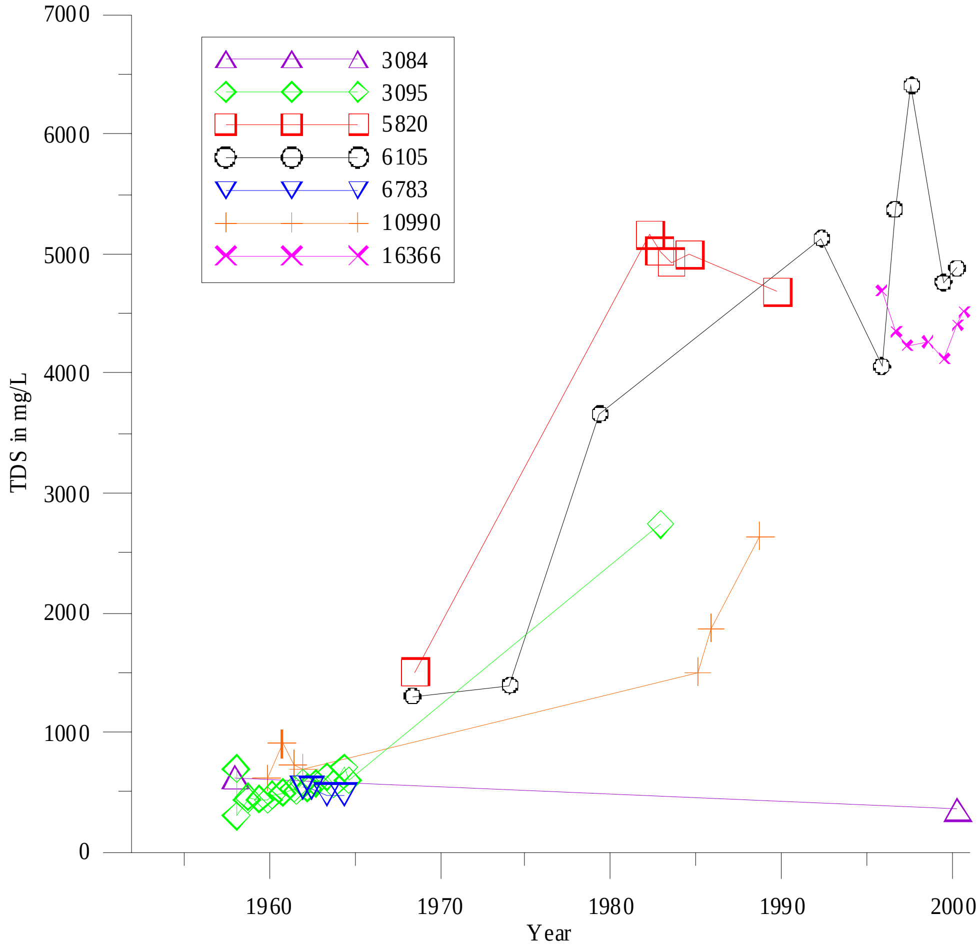


Figure 34 Salinity trends in the Heavitree Gap Area

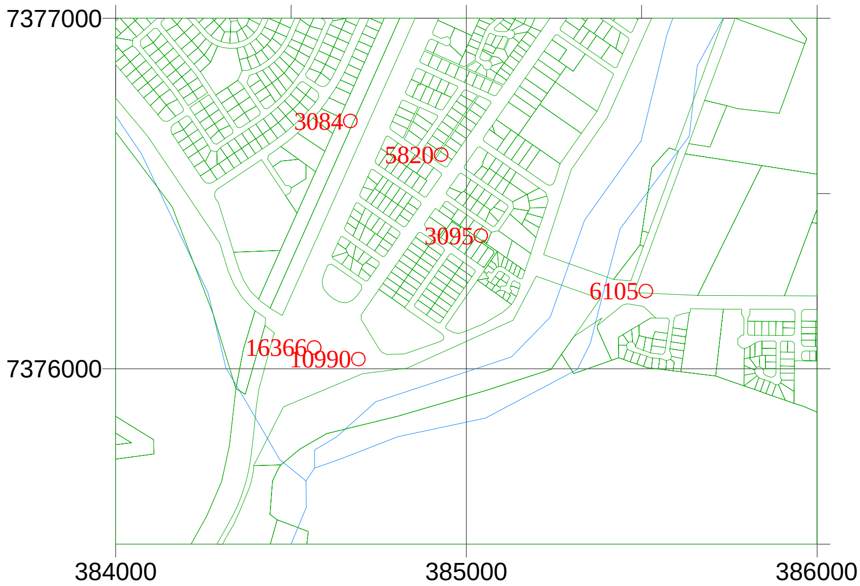


Figure 35 Locations for Figure 34

6.4.4.1 Proposed rehabilitation of the Heavitree Gap Area

Pumping the saline water out of this part of the aquifer to restore it as a useful resource has been proposed (G. Ride pers. comm.).
Taking the boundaries shown in Figure 36 the volume of saturated sediments and water stored are shown in Table 16.
RN 14196 has a recommended pumping rate of 9 L/s.
There is no data recorded for RN 10990. RN 7506 has data for an extended pumping test, but no measurements for the bore itself.

Table 16, estimated volumes of saline water in the Heavitree Gap area

	Volume of saturated sediment m^3	Estimated volume of saline water ML (1)
All sediments	8 600 000	2 600
Sand aquifer only	5 600 000	1 700

(1) Porosity is assumed to be 0.3

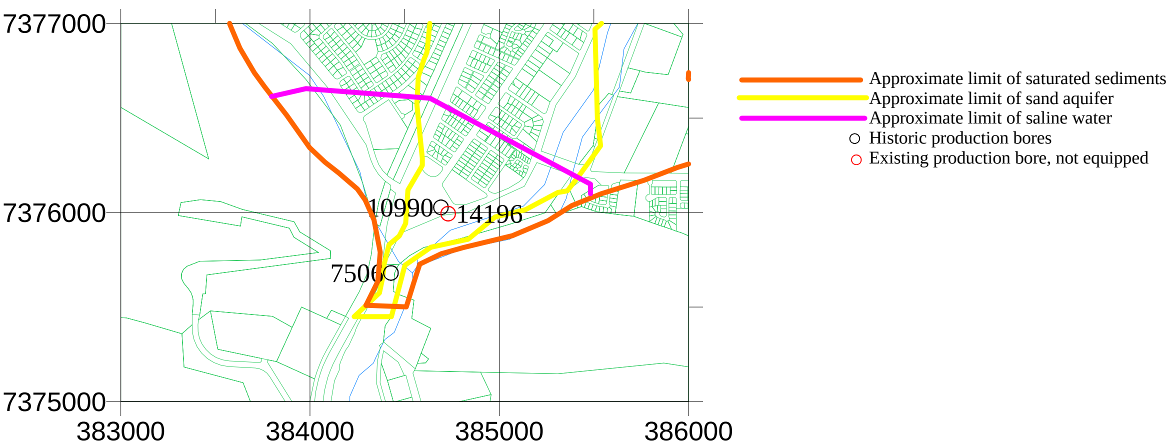


Figure 36 Heavitree Gap Area

By the most optimistic assessment, to flush saline water from the sand aquifer only, at least 6 years of continuous pumping at 9 L/s (280 ML/year) would be needed. In practise it would take longer as saline water from the adjacent lower permeability sediments continued to drain into the sand aquifer, and there would be significant mixing of the fresh and saline water.
Disposal of 280 ML/year of water ranging from 2000 mg/L to 5000 mg/L would be a problem. One possibility would be pumping to ornamental lakes (G. Ride pers. comm.). Annual evaporation is about 3000 mm/year, but minimum monthly evaporation is only 100 mm. Therefore 25 ha of water surface would be needed to dispose of this much water. Alternatively if a field of two or three bores was used to take advantage of the higher evaporation rates in summer only 10 ha of evaporation ponds would be needed.
If the average TDS of the input water was 3000 mg/L after six years of evaporating it in a 1 m deep lake the TDS would be about 50000 mg/L, that is just above that of seawater.

6.4.5 Gillen Zone

There are two long term hydrographs and one long term set of chemical records for this area. These are shown in Figure 37 below. Additional hydrographs are in Appendix H.

The large rise in water levels in the late 1970's is clearly a result of the very wet years at that time. However the continued high water levels seem to indicate a change due to urbanisation. Likewise the continuing upward trend in salinity postdates the rise in water levels and is probably a result of mobilisation of salt from the unsaturated zone following urbanisation.
The western side of Gillen includes areas of shallow crystalline rock. Groundwater discharges at Morris Soak, west of Lovegrove Drive, after good rains. This shows the presence of shallow water tables in the metamorphic rock aquifers. It can be inferred that there is saline water in this area, and that there is a potential for problems if the area is developed. Any developments in this area should be designed so as to minimise additional recharge so as to avoid rising saline water tables.

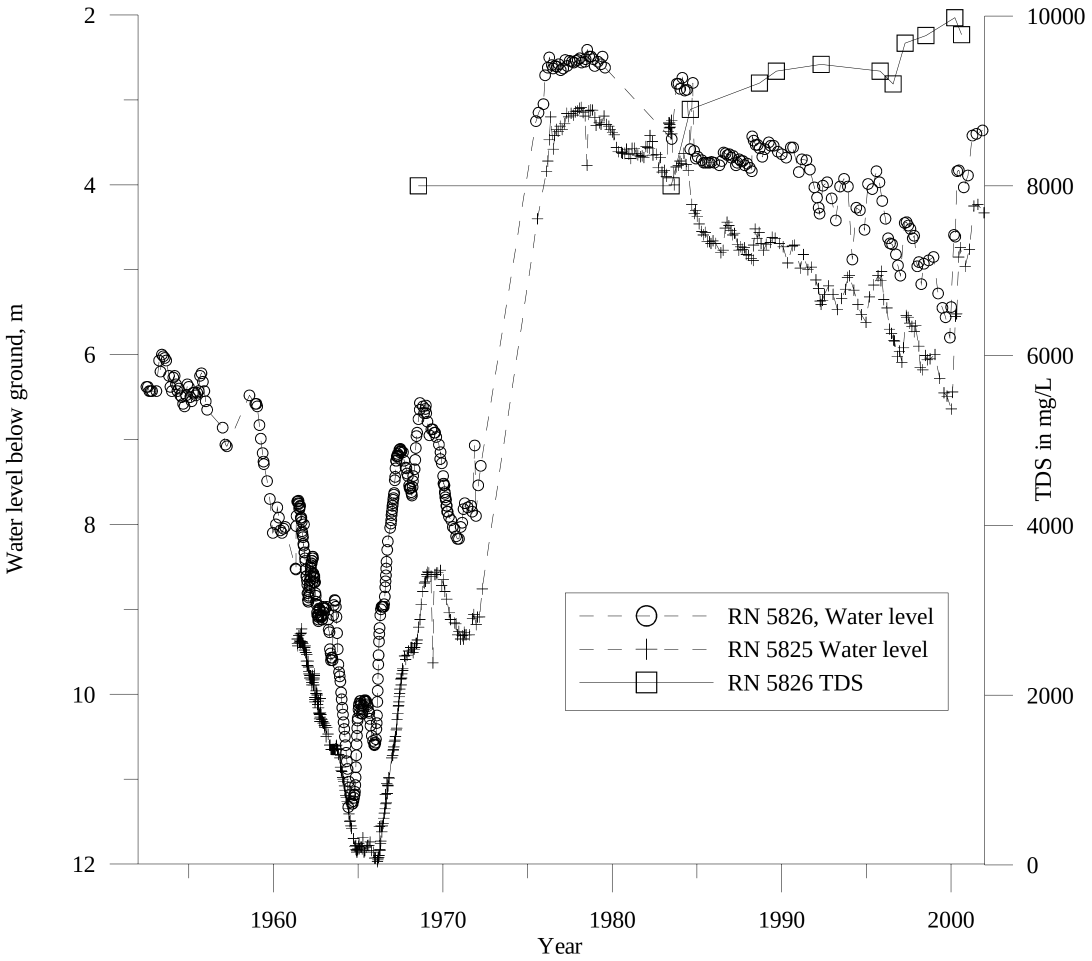


Figure 37 Gillen Zone, hydrographs and salinity trends

6.4.6 Larapinta Zone

Little is known about the hydrogeology of this area. No bores have been drilled in the subdivision, but four bores were drilled in the area to the south of it in 1978 (Figure

38). Details are shown in Table 17 . Two of the bores have very high salinity, the others apparently being freshened by recharge from the creek.
The shallow very saline groundwater must extend under the developed area. Clearly there is a potential for rising saline water tables to cause problems, particularly in response to heavy watering. As in Gillen any developments in this area should be designed so as to minimise additional recharge so as to avoid rising saline water tables.

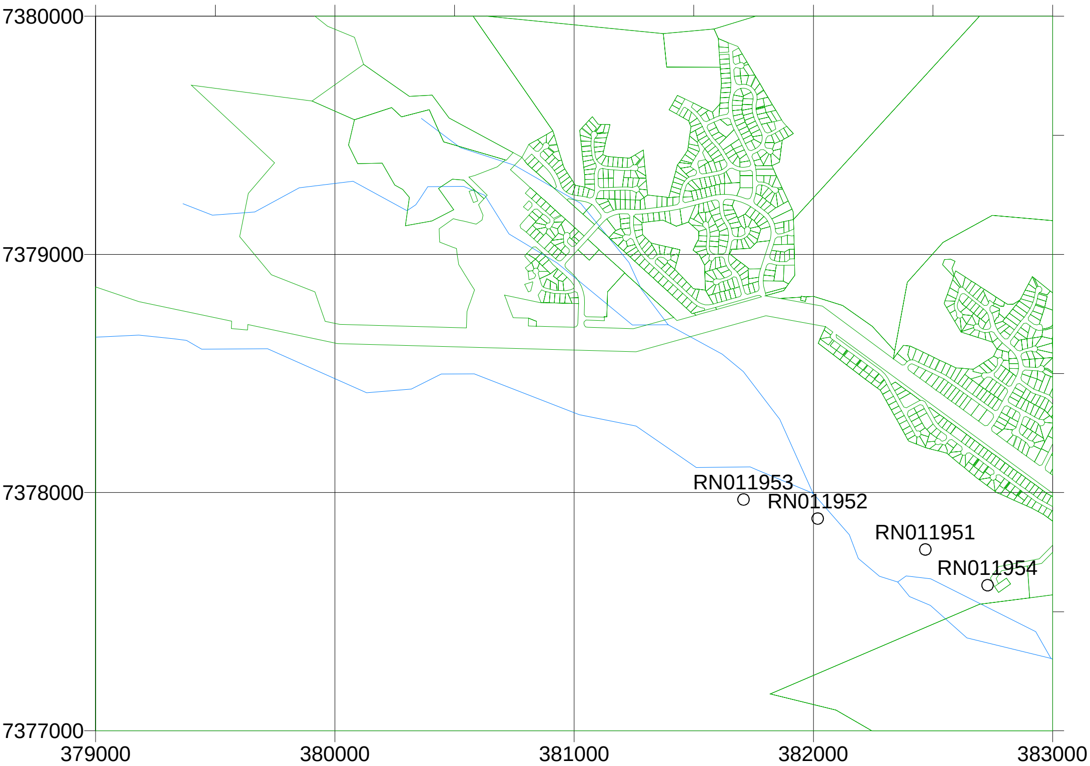


Figure 38 Bores in the Larapinta area

Table 17 Bores in the Larapinta area

RN	Depth m	SWL m (1978)	TDS mg/L	Geology
RN011951	15.0	4.60	29000	0-8 alluvium 8-15 weathered metamorphics
RN011952	7.2	3.50	15500	0-6 alluvium 6-7.2 weathered metamorphics
RN011953	7.8	5.00	3550	0-5.5 alluvium 5.5-7.8 weathered metamorphics
RN011954	7.3	?	1410	0-6 alluvial silt 6-7.3 weathered metamorphics

7 RECOMMENDATIONS FOR MANAGEMENT

7.1 Data Management

Surface water data needs work as stated in Section 4.1.
Production data needs to be entered in the HYDSYS database.
The HYDSYS database contains a great deal of major ion chemical data. However it is a disaster in respect to isotope chemistry, total organic carbon and possibly other minor constituents. Much of this information is in old data files and there needs to be a concerted attempt to get all this information into HYDSYS.

7.2 Data Acquisition

7.2.1 Salt Balance

To understand the salt balance of the Town Basin it is essential to monitor salinity at Heavitree Gap. Moves are in progress to add a conductivity probe to the water level logger at Heavitree Gap.

7.2.2 Sampling for pollutants, insecticides

Power Water are currently regularly testing their production bores for a range of contaminants. This should include some testing for dieldrin which has been detected previously.

7.2.3 Water level monitoring

The existing monitoring grid has evolved historically to monitor the Town Basin. There is a need to extend the monitoring grid to give information on water levels in the areas of weathered rock in the areas fringing the Town Basin. Figure 39 shows the locations of currently monitored and proposed monitoring bores.
Table 18 shows the location of existing bores that could be monitored.
Table 19 shows proposed new monitoring bores to be drilled.
Monitoring bores need only by drilled into the regolith to intersect the water table. A full size water well rig is neither needed nor desirable for this. A light auger or similar rig that can work in limited space would be desirable.

Table 18 Existing bores that could be monitored

RN	Easting	Northing	Depth m	Comments
17494	384346	7379243	11.5	Drilled as part of the railway clean-up, control passed to DIPE.
5714	384698	7381630	101.8	Disused private production bore
5713	385058	7380590	65.2	Disused private production bore

Table 19 Proposed new monitoring bores to be drilled

Easting	Northing	Area	Approximate Depth m
383900	7378100	Araluen	20
384900	7379800	Braitling	20
386000	7376900	Golf Course	5
387500	7376300	Golf Course	15
386700	7377000	Golf Course	5
386300	7376300	Golf Course	5
381200	7379000	Larapinta	15
382500	7378300	Larapinta	10
380000	7378900	Larapinta 4	10
383800	7378900	Morris	15
388500	7376200	Mount John	15
388100	7379600	New Eastside	15
387700	7378100	Sadadeen	10

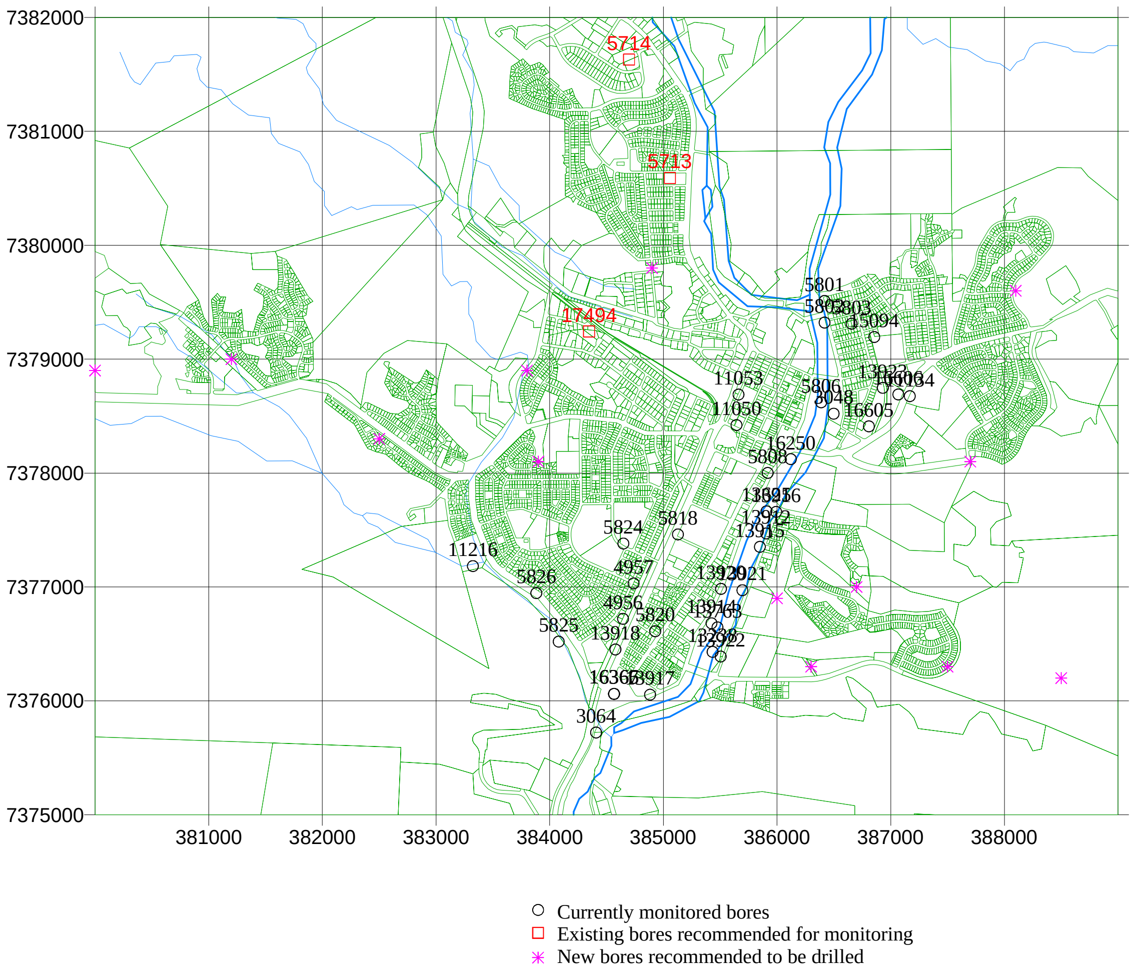


Figure 39 Recommended additional monitoring bores

7.3 Management

The total of licensed allocations for the Town Basin is in the desirable range, but it would be better to increase. The ongoing problem is how to get actual extraction up to the licensed amount.

7.3.1 Northern Zone

Policy should be directed at raising extraction to 350 ML/year. Most of this could be withdrawn at less than 800 mg/L.
PWC will need to abandon RN 6782 and replace it with a bore in a better location.

7.3.2 Southern Zone

Policy should be directed at raising extraction to 900 ML/year. If schemes to remove saline water from parts of the basin, such as that discussed in Figure 31 , are implemented this pumping could be additional to the 900 ML/year for a limited number of years. The major limitation on water use in this area is salinity. Most of this water could be extracted at under 1 500 mg/L, but some will be above this. Some water could be blended with Roe Creek water to produce a mix suitable for irrigation.
With better management of the basin average salinity might be reduced to 1000 mg/L.
It is no longer necessary to maintain an outflow from the Town Basin into the Farm Basin. Reduction of the saline outflow at Heavitree Gap by pumping upstream would be beneficial to the Inner Farm Basin.

7.3.3 General

SKM (2001) recommended a management strategy with five key elements:

1. Extraction of groundwater from the Town Basin aquifer for non-potable purposes, primarily for municipal and domestic irrigation or selected industrial applications.
2. Increasing the level of consumptive use from the Town Basin aquifer, through incentives to existing or new consumers to transfer their demand from Roe Creek water.
3. Reducing discharge from the aquifer by minimising infiltration of groundwater to the sewers.
4. Continuing the program to improve municipal irrigation practices, aiming to minimise the leaching of salts from the unsaturated zone of the soil profile.
5. Work towards maintaining the Town Basin aquifer as a potable water supply by implementing a stringent pollution control and mitigation plan for the aquifer and adjacent weathered bedrock areas.

Points 1 and 2 are valid.
Point 3 is doubtful. Decisions on the benefits of sewer re-lining are a matter for PWC to consider for its own operations. (Note that a program of sewer re-lining was completed while this report was in progress).
Point 4 is important.
Point 5 is correct. The Town Basin should be maintained as potable or near-potable for emergency use. It is a valuable renewable resource of water increasingly cheaper to produce than Roe Creek borefield water.

7.4 Licenses

All license-holders should be required to submit samples from each bore every six months. A conductivity measurement on these would be adequate.

7.5 Modelling

A digital model of the basin is needed to allow better prediction of the effects of siting new bores, and manage extraction in varying climatic conditions. Such a model should incorporate salt transport to try to improve understanding and management of the salinity problems.

7.6 Bore Construction

The method of constructing large diameter bores is successful, but bore performance is little better than properly screened 150 mm bores.
In view of the high-cost of large diameter bores it is recommended that 150 mm screened bores, stabilised with gravel-packs and carefully developed should be used.

7.7 Salinisation

The weathered metamorphic rocks around the fringe of the Town Basin contain highly saline water, usually at relatively shallow depth.
Problems are already evident in Golf Course and some other parts of the town. Care should be taken with future subdivisions that recharge is not increased, and that over irrigation is avoided.

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Northern Territory Government
Department of Infrastructure, Planning and Environment

ALICE SPRINGS TOWN BASIN, REVIEW 2003

Report No.: 42/2003A

VOLUME 2, APPENDICES

R.E. Read,

Natural Resources Division
Alice Springs

December 2003

CONTENTS, VOLUME 2

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APPENDIX A

SALT AND CHLORIDE FLUX IN THE TODD RIVER

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Chemical monitoring

Some water samples have been taken at gauging stations.
Table 3 shows a brief summary of the available data.

Table A-1

Gauging Station	**Wigley Gorge G0060046**	**Anzac G0060009**	**Heavitree G0060126**
Total chemical analyses	3	27	9
Chemical analyses with flow rates	2	23	5
Comments	1 is for very low flow		
Chloride flux, T/yr	Insufficient data	110	5900
Estimated discharge, ML/year (1)	12000	15000	16800

See Table 2 in text.

Chloride Flux

Figure 1 shows plots of chloride content against instantaneous flow for all three stations.
Anzac has the highest number of analyses and a reasonably good relationship can be obtained between flow and chloride.
Only two points are available for Wigley, but they appear to lie on the same line as the Anzac results.
Seven points are available for Heavitree. These clearly plot well above the Anzac results. However three points based on conductivity measurements together with gaugings plot in the same general area.
This data is difficult to reconcile. There is no reason to doubt the chloride values.
The discrepancies may be due to the following:

- All the earlier samples were taken on the falling limb of the hydrograph.
- There was a problem with the rating of the gauging station.

Estimated annual chloride fall is about 0.11 g/m^2, or 0.11 T/km^2. The area of the catchment is 460 km^2, hence chloride fall on the catchment would be about 50 T/yr.
The estimate of 110 T/yr at Anzac is reasonable. The difference could be due to errors in the estimates and possibly to a small salt imbalance resulting from salt in the un-saturated zone being released by grazing.
The estimate of discharge at Heavitree is clearly too high, probably because of inaccuracies in the rating curve have caused overestimation of the discharge, and the estimated chloride flux will also be too high. Assuming that the discharge at Heavitree is 2000 ML/year as that at Anzac, the chloride flux is about 3800 T/yr.
Chemical analyses are only available for the period 1981 to 1993, and the changes due to urbanisation are not visible in the record.

The calculation was repeated for the period 1981 to 1993, and again correcting the discharge to that at Anzac. This gave a chloride flux of 1220 T/yr. It would be expected that the estimate would be lower as most chloride will move in very wet years. It is concluded that annual chloride flux at Heavitree Gap is in the range 1000 to 3000 T/yr, and that salt flux is in the range 3000 to 10 000 T/yr.

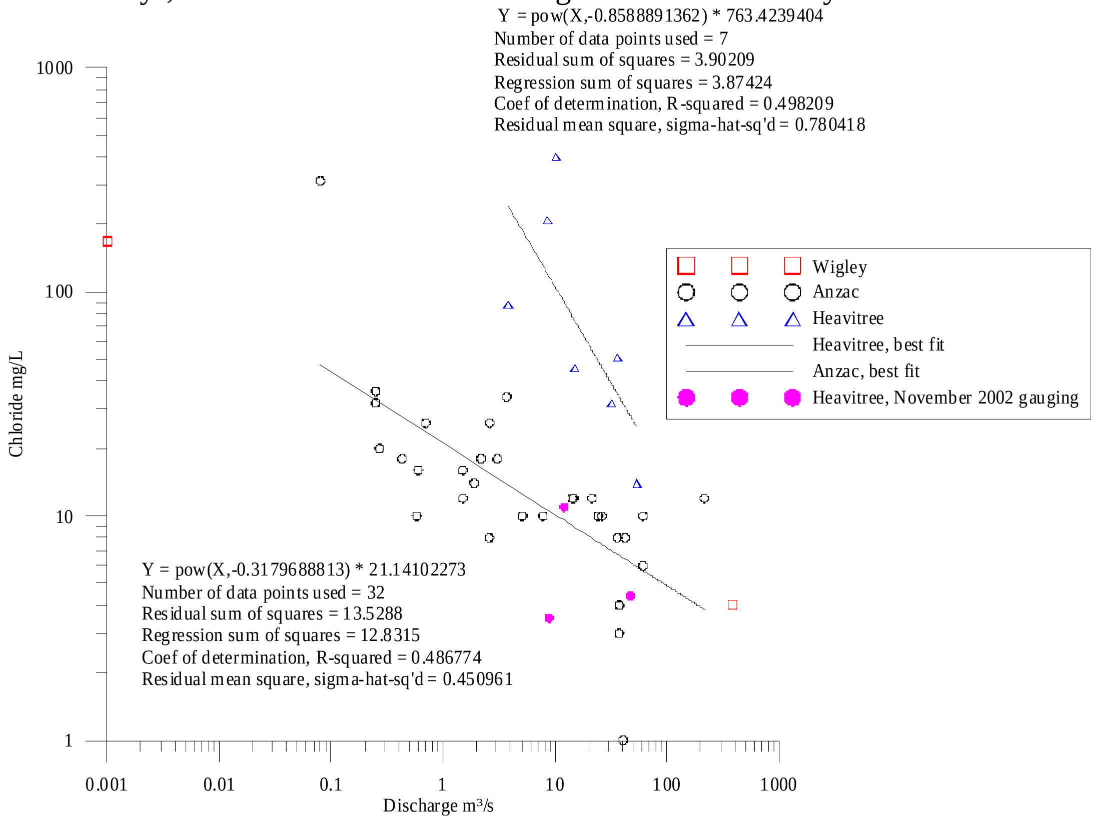

Figure A-1 Chloride versus discharge at gauging stations

Chinaman Creek (Bradshaw Drain)

This is a discharge point from the western side of the Town Basin. It discharges into the Todd, adding to the saline outflow through the Gap.

Table A-2 shows 14 analyses from Chinaman Creek. No flow data is available. TDS values range from about 200 mg/L to about 5000 mg/L. The high values presumably represent groundwater discharge, and the lower ones are for periods when this is being diluted by surface runoff. Figure A-2 shows a Durov Plot for this data and RN 3064 which is in the Todd just below where Chinaman Creek enters it.

Table A-2 Analyses for G0065013 (Chinaman Creek)

DATE	TIME	TDS (mg/L)	Cl (mg/L)	HCO3 (mg/L)	SO_4 (mg/L)	F (mg/L)	Ca - (mg/L)	Mg mg/L	K (mg/L)	Na (mg/L)
11/02/1982	1400	560	160	141	130	0.6	18	6	16	165
11/02/1982	1400	224	44	99	29	0.1	15	4	10	48
17/02/1982	1030	110	16	50	33	0.2	6	3	8	23
17/02/1982	1630	520	150	125	122	0.5	13	6	13	162
23/03/1982	920	210	60	72	35	0.2	8	3	8	63
07/10/1982	1055	4950	1580	869	1150	3.2	123	81	11	1650
01/01/1983	845	2470	800	195	530	1.4	28	2	38	844
01/01/1983	2030	2400	690	744	390	3.5	42	59	88	712
19/04/1983	840	4990	1490	950	1177	3.3	28	40	12	1775
10/01/1984	910	600	178	127	123	0.6	16	7	6	193
10/01/1984	1340	600	190	116	123	0.2	14	7	6	191
10/01/1984	1555	400	113	95	83	0.6	12	5	6	119
11/05/1993	905	115	12	91	11	0.1	17	3	5	19
02/10/1993	1120	87	12	58	11	0.1	11	4	5	11

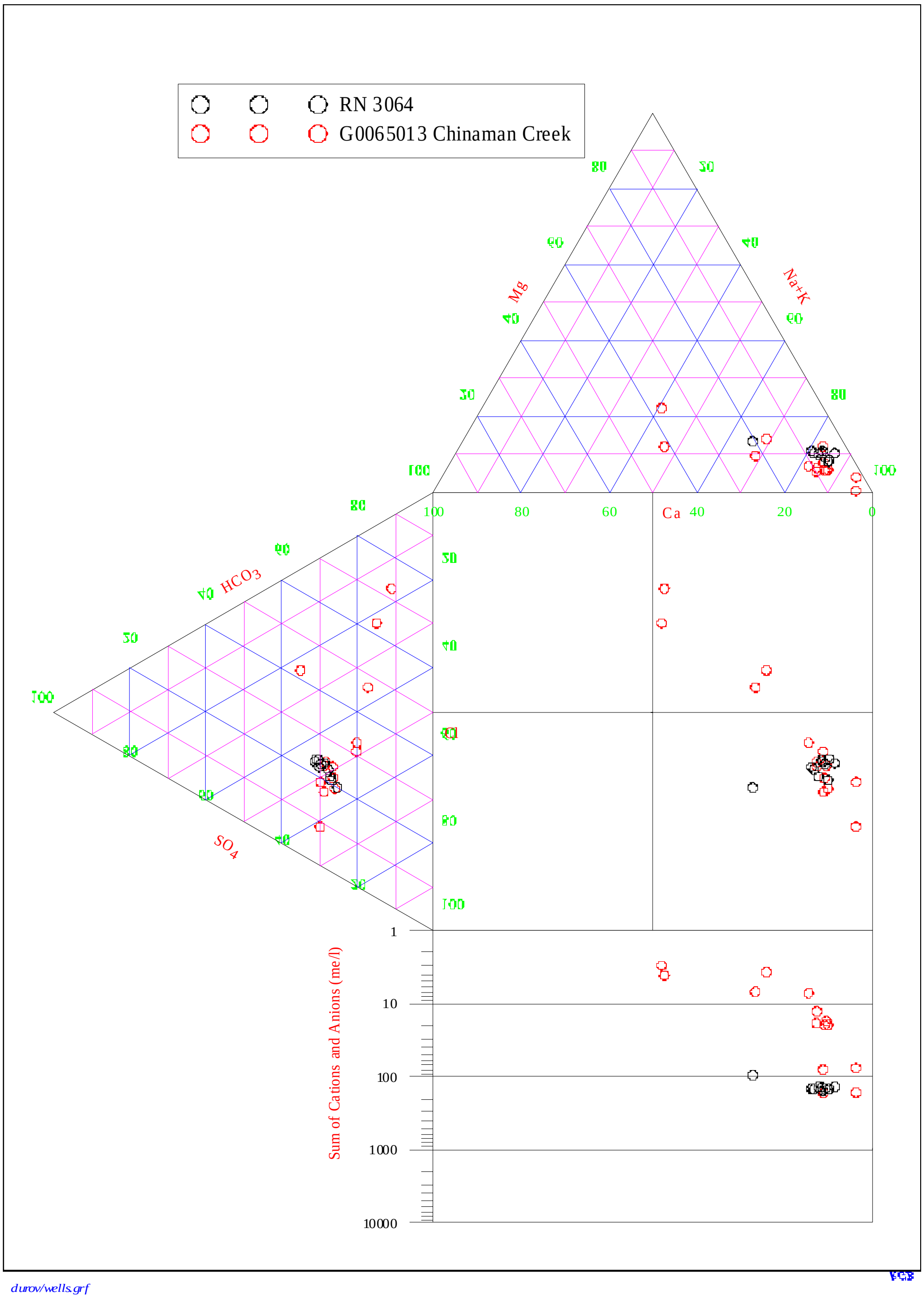
RN 3064
G0065013 Chinaman Creek
Mg
Na+K
Ca
HCO3
SO4
Sum of Cations and Anions (me/l)
durov/wells.grf

Figure 2

APPENDIX B

MONITORING BORES IN THE TOWN BASIN

Table B-2 Monitoring Bores

RN	Name	EAST	NORTH	Depth	First reading	Last reading	
RN002658	No.3 Bore. (Kilgariff)	385628	7377561		26/03/1957	28/03/1967	
RN002709	Robinson's	386568	7379251		18/12/1959	30/03/1989	
RN003048	Botanic Gdns.	386498	7378521	18.0	29/04/1981	13/11/2001	C
RN003064	Heavitree Gap	384408	7375722	17.1	22/07/1959	15/11/2001	C
RN003757	W.R.B. No.1	385348	7378391	18.6	27/04/1962	12/08/1969	
RN003758	George Cres.	385228	7378461	17.7	27/04/1962	07/09/1999	
RN003759	W.R.B.No.3	384675	7378531	16.2	27/04/1962	27/10/1962	
RN003761	W.R.B.No.4	384661	7378601	21.3	17/01/1962	16/12/1962	
RN003762	W.R.B.No.5	384654	7378672	19.5	27/04/1962	19/05/1964	
RN004956	Bloomfield St.	384645	7376720	22.9	16/07/1965	13/11/2001	C
RN004957	Bloomfield St.	384738	7377031	18.9	16/07/1965	13/11/2001	C
RN004958	Town Water Level No.	385632	7376703	16.8	16/07/1965	19/04/1971	
RN004959	Town Water Level No.	385278	7376481	12.8	30/04/1967	28/03/1972	
RN005017	Leichardt Tce.	386268	7378651	14.0	10/09/1965	07/09/1998	
RN005192	Town Water Level 65/	385672	7378677	14.0	17/12/1965	28/03/1972	
RN005713	B=673 Wintersun C/Pk	384672	7380591	65.2	20/08/1967	06/11/1969	
RN005801	Goss Street	386418	7379511	9.8	18/12/1959	14/11/2001	C
RN005802	Sturt Tce.	386418	7379321	18.6	02/06/1962	13/11/2001	C
RN005803	Chewings St.	386656	7379311	11.0	21/04/1961	15/11/2001	C
RN005804	61/26	386644	7378715	19.5	02/09/1962	28/03/1972	
RN005805	Zdena's Well	386438	7378179		09/12/1957	21/07/1967	
RN005806	Todd River	386388	7378621	9.8	04/03/1963	14/11/2001	C
RN005807	60/12	386130	7378191	21.9	03/03/1961	28/02/1980	
RN005808	Memorial Club	385918	7378001	9.1	18/02/1957	13/11/2001	C
RN005809	Army "U" (Melanka)	385646	7378176		16/10/1957	14/10/1970	
RN005810	Smith Well	385458	7376708	5.2	01/09/1956	12/08/1969	
RN005811	65/5	384618	7376511	17.1	30/07/1965	28/03/1972	
RN005813	Picks #9 Bore	385538	7376571	23.2	16/10/1957	13/01/1970	
RN005814	60/31	385608	7376631	10.1	22/04/1961	09/04/1980	
RN005815	60/34	385660	7377591	14.3	16/03/1961	10/11/1982	
RN005816	59/2.Wiltshire St.	385378	7377685	21.0	13/07/1967	19/04/1971	
RN005817	W 60/6 Telegraph Tce	385338	7377821	17.5	21/03/1961	24/11/1994	
RN005818	Traegar Park	385128	7377461	12.9	01/10/1959	13/11/2001	C
RN005819	Allchurch St.	385118	7377031	20.7	01/07/1952	10/11/1997	
RN005820	Gnoilya St.	384928	7376611	14.1	28/05/1962	13/11/2001	C
RN005821	Works 61/34 Gap Area	384628	7376301	16.5	26/05/1962	19/04/1971	
RN005822	Army H.C. Alice Spgs	383668	7377471	27.7	20/02/1961	21/06/1971	
RN005823	Army Ea Gason St.	384628	7377689	19.2	03/03/1961	19/04/1971	
RN005824	Bloomfield St.	384648	7377381	16.3	21/03/1960	13/11/2001	C
RN005825	Bradshaw Drive	384079	7376520		01/07/1952	13/11/2001	C
RN005826	Crann St.	383882	7376946	29.0	22/04/1961	13/11/2001	C
RN005827	59/8 Slaughter House	384637	7375713	19.4	18/12/1959	28/03/1972	
RN005828	59/6 Slaughter House	384628	7375705	19.5	18/12/1959	20/02/1968	
RN005829	Bmr 1. Block 649	384528	7375712	13.3	01/01/1957	07/03/1994	
RN005830	Zb Heavitree Gap	384588	7375701	22.6	18/12/1959	09/12/1969	
RN010284	Gc 1/72. A/Spgs	385388	7376191	13.7	16/07/1982	30/11/1983	
RN010780	Charles River Obs Bo	385493	7379912	6.0	20/08/1975	08/07/1980	
RN010990	South Tce.	384692	7376028	14.6	30/09/1985	15/05/2000	
RN011050	Elkira Motel	385643	7378421	9.0	15/01/1976	14/11/2001	C
RN011053	Govt. Centre	385661	7378689	9.0	15/01/1976	14/11/2001	C

RN011134	Sadadeen	387168	7378675	9.1	13/03/1976	15/11/2001	C
RN011216	Bradshaw Drive	383324	7377183	9.9	01/07/1952	13/11/2001	C
RN011233	J.B.Owen.Well	386558	7379201	9.0	23/10/1952	31/01/1979	
RN011675	Office Yard Bore 77/	385663	7378551	15.7	08/11/1977	04/12/1979	
RN013238	Casino	385433	7376430	12.2	06/01/1984	13/11/2001	C
RN013625	Golf Causeway	385907	7377664	7.0	30/09/1985	13/11/2001	C
RN013763	Todd River	385476	7376645	6.3	30/09/1985	13/11/2001	C
RN013912	Barret Drive	385905	7377470	14.5	21/02/1984	13/11/2001	C
RN013914	Bowling Club	385423	7376681	12.8	19/03/1984	13/11/2001	C
RN013915	Redsands	385849	7377352	10.0	19/03/1984	13/11/2001	C
RN013916	Tunks	385992	7377659	7.0	19/03/1984	13/11/2001	C
RN013917	Gap Motel	384883	7376054	16.0	19/03/1984	13/11/2001	C
RN013918	Railway Line	384578	7376451	17.0	19/03/1984	13/11/2001	C
RN013920	Todd River	385507	7376983	13.0	19/03/1984	13/11/2001	C
RN013921	Sheraton	385695	7376971	9.5	19/03/1984	13/11/2001	C
RN013922	Sheraton	385504	7376389	10.0	21/02/1984	13/11/2001	C
RN013923	Federals	386930	7378748	11.0	19/03/1984	13/11/2001	C
RN015094	Ross Park	386855	7379194	14.4	29/03/1988	13/11/2001	C
RN016250	Stott Bridge	386121	7378122	8.6	10/05/1992	13/11/2001	C
RN016365	West Gap	384566	7376061	14.3	24/11/1994	13/11/2001	C
RN016366	Centre Gap	384566	7376061	11.5	24/11/1994	13/11/2001	C
RN016367	East Gap	384566	7376061	5.8	24/11/1994	13/11/2001	C
RN016605	Coolibah	386808	7378410	10.3	22/02/1996	13/11/2001	C
RN016606	Coolibah	387067	7378690	11.8	07/03/1996	14/11/2001	C

APPENDIX C

CHEMICAL DATA AND CONTAMINATION IN THE TOWN BASIN

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1 Hydrocarbon pollution

1.1 Power Station Drain outfall

This was the earliest investigation of hydrocarbon pollution in the Town Basin. Berry (1992) records that sampling of existing was undertaken to find the extent of contamination. By chance a folder was found with dissolved organic carbon values in it. Results are in Appendix C. A level of 30 mg/L was found in RN 13916 in 1990, but subsequently dissipated. High levels of dissolves organic carbon were found in 1990, but appeared to have dissipated by 1992. In more recent sampling of Town Basin production bores Total Petroleum Hydrocarbons have been below detection limits.

G. Ride (pers. com.) states that on occasions oil had been collected in pits in the creek downstream of the power station.

1.2 BP Depot

Losses of petroleum products in around 1998 led to a drilling investigation that identified up to 0.5 m of phase separated hydrocarbon and a plume of dissolved hydrocarbon that extended some 200 m to the SSE (OTEK 2002).
Hydrocarbons were removed by sparging.
Testing of groundwater samples showed that anaerobic biological attenuation of the plume is occurring.

1.3 Railway Yards

Drilling identified two free phase hydrocarbon plumes of diesel fuel.
The first of these appeared to have reached a steady state. Modelling predicted that dissolved phase hydrocarbons will decline to below the guideline level of 100 μg/L by 2085.
The second is predicted to continue to expand to 2010, and still to be present at above guideline levels in 2085.

1.4 Shell Todd

Small plume of dissolved hydrocarbons, no free phase

1.5 Shell Depot

In May 1997 petrol vapour was noticed in a stormwater drain near the site (Golder Associates 2001). Subsequent investigations showed that a large plume extended south from the site, originating in part from the petrol leak of 1997, but also from earlier leaks, including diesel fuel.
Monitoring over a three year period suggested that the plume has been stabilised by bio-degradation.

Golder Associates (2001) conducted an audit and suggested additional monitoring bores and some remediation work. The monitoring bores have been constructed, but the remediation work has not been done.

Continued monitoring (IT Environmental 2004) suggests that the plume is continuing to expand.

Wills Terrace stormwater outfall

Three monitoring bores were drilled in the Todd River near the Wills Terrace stormwater outfall on behalf of Shell Australia to check for hydrocarbons carried down the drain from the Shell depot. It should be noted that the Shell depot is not the only possible source of this contamination.

Summarised results are shown in Table C-1 . Hydrocarbons have been detected erratically.

Table C-1 Selected data from the Wills Terrace outfall area, after Golder Associates (2001)

Date	**MW31**		**MW32**		**MW33**	
	SWL m (1)	**TRH μg/L (2)**	**SWL m (1)**	**TRH μg/L (2)**	**SWL m (1)**	**TRH μg/L (2)**
9/5/98	0.28	ND	0.284	ND	0.340	610
14/5/99			1.945	412	2.168	
19/6/00	Bore destroyed		0.594	ND	0.405	ND
15/12/00			0.537	200	0.381	ND
20/10/01			1.499	370	1.099	250
28/5/02			0.935	ND	1.055	530
11/11/02			1.270	650	1.562	1240
12/5/03			1.128	410	1.195	#
2/12/03			1.425	#	Dry (3)	

(1) SWL, standing water level

(2) TRH, total recoverable hydrocarbons, the sum of the C_6-C_9, C_{10}-C_{14}, C_{15}-C_{28}, C_{29-36} results.

(3) The bore is described as dry, but the SWL in MW32 clearly shows that water level is above the bottom of the screen. Presumably the bore has sanded up.

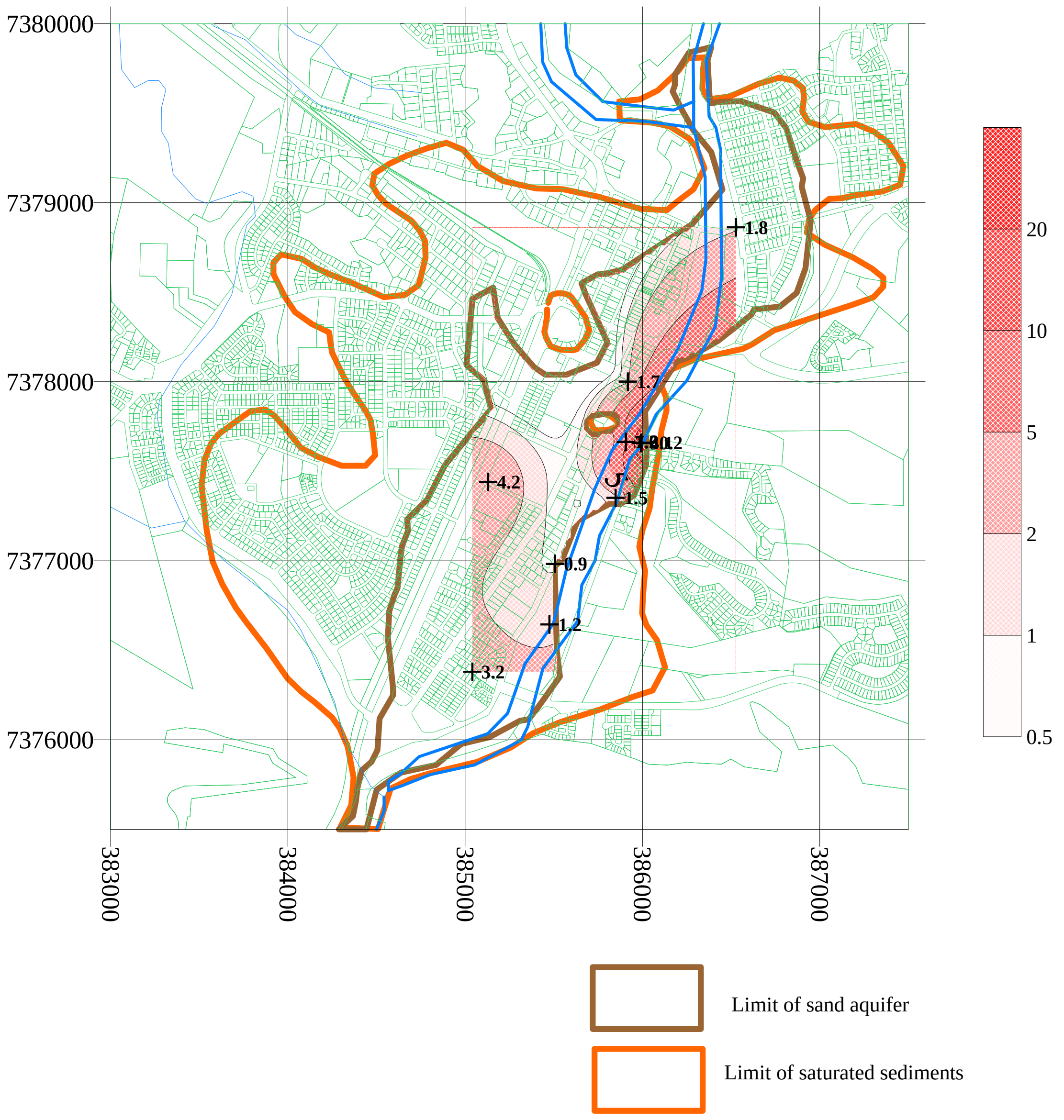

Figure 1 Total Organic Carbon, mg/L, 1990

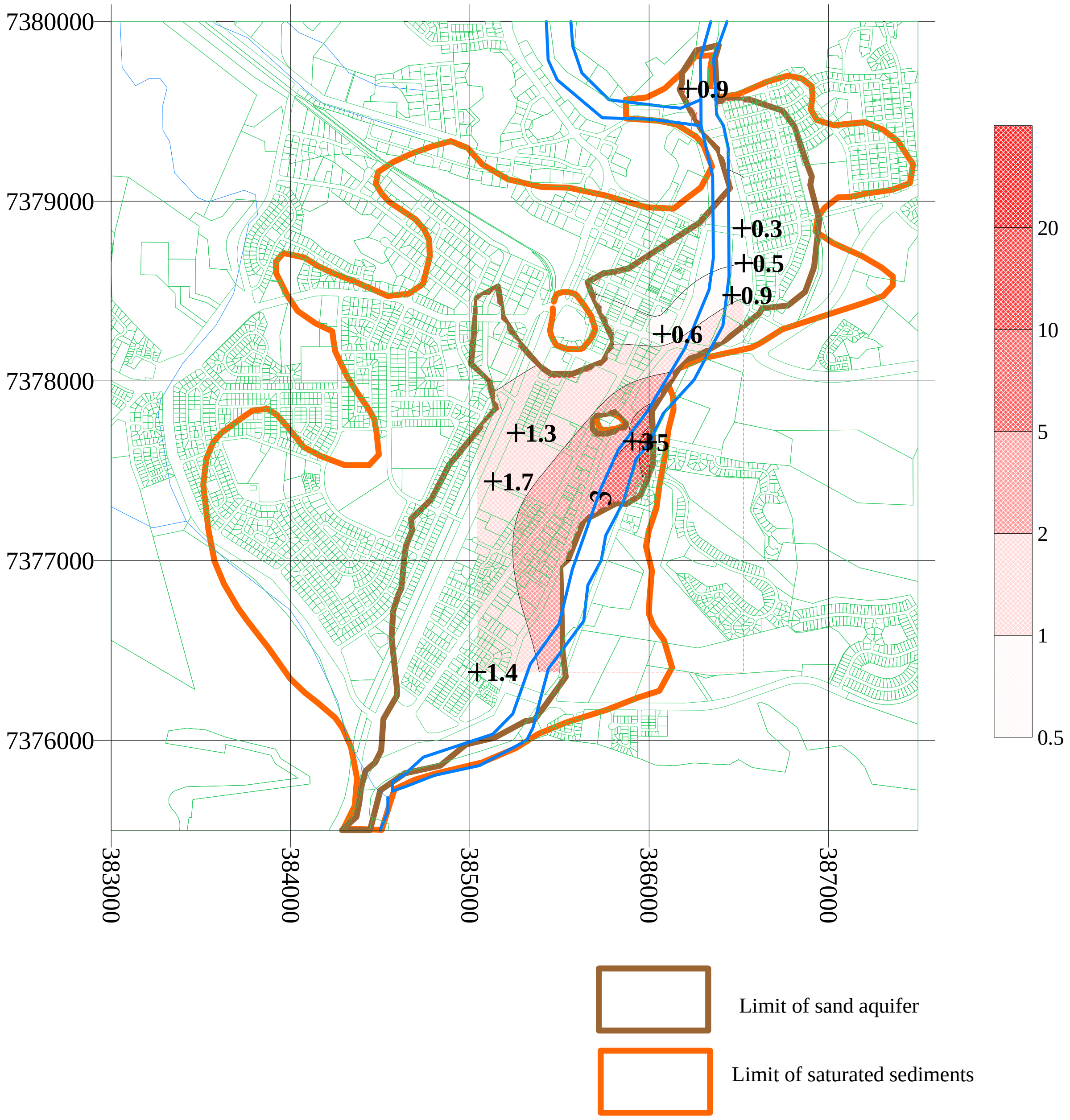

Figure 2 Total Organic Carbon, mg/L, 1992

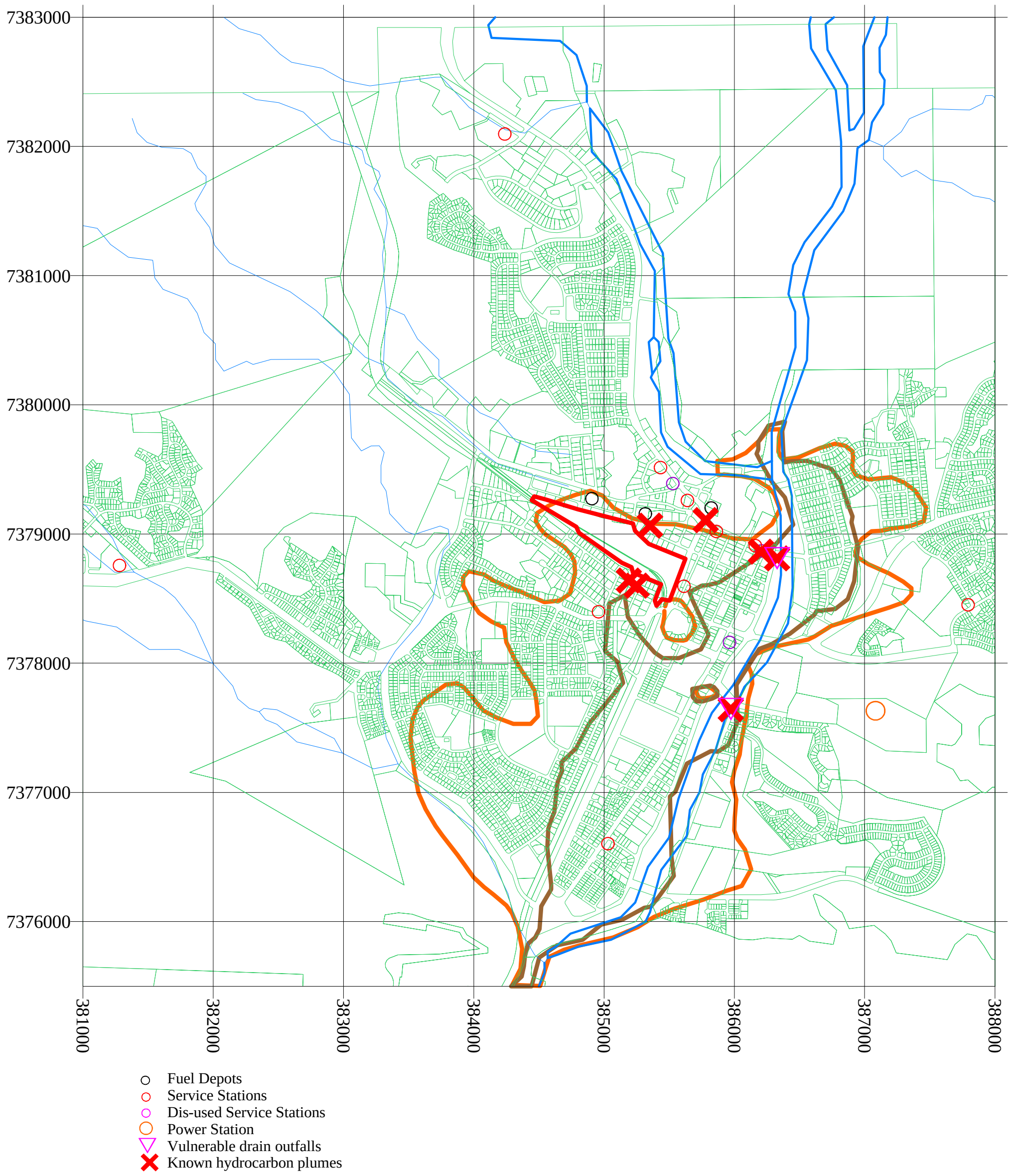

Figure 3 Hydrocarbon storages and plumes

Table C-1 Contamination Assessments (post 1996)

Site	Date	Title of Investigation	Basis for Investigation	Action
Lots 912 and 8607, Alice Springs	1997	Preliminary Site Contamination Assessment of Lots 912 and 8607 in Town of Alice Springs: by Woodward-Clyde in March 1997.	As a preliminary to decommissioning NT government owned land that had been used for motor vehicle workshops	No contamination identified. No action required.
Shell Depot: 47 Stuart Highway, Alice Springs	1997	Contamination and Risk Assessment. Shell Depot, Alice Springs: by Dames & Moore, July 1997.	Following a report of petrol fumes in the Wills Terrace storm drain	An environmental audit of the site is currently being undertaken to examine whether the current approach to self remediation, is sufficient.
		Identification and Recovery of Free Product Plume: by the Shell Company of Australia in September, 1997.		
		Additional Environmental Site Assessment: Fluor Daniel GTI, October 1997.		
		Further Environmental Site Assessment: Fluor Daniel GTI, January 1998.		
		Further Environmental Site Assessment: Fluor Daniel GTI, May 1998.		
		Risk Assessment: Fluor Daniel GTI, January 1999.		
		Vegetation Survey of the Area Surrounding the Shell Alice Springs Depot: Clouston, January 1999.		
		Groundwater Monitoring Event: IT Environmental, May 1999.		
		Environmental Site Management Plan: Shell Company of Australia, October 1999.		
		Hydrogeological Information Associated with Shell Alice Springs Depot: Golder Associates Pty Ltd, December 2000.		
Australian Fuel Distributors Depot: Whittaker Street, Alice Springs	1998	Environmental Site Assessment: Otek Australia Pty Ltd, March 1998.	Following the reporting of an underground leak of petrol and some diesel fuel by BP Australia Ltd from the Australian Fuel Distributors Depot in Whittaker Street, Alice Springs.	The site is being actively remediated by vapour enhanced recovery methods.
		Extent Assessment: Otek Australia Pty Ltd, August 1998.		
		Health Risk Assessment Report: Otek Australia Pty Ltd, January 1999.		
		Remedial Action Plan: BP Australia Ltd, June 1999.		
		Extent Assessment: Otek Australia Pty Ltd, August 1999.		
		Extent Assessment: Otek Australia Pty Ltd, April 2000.		
		Remediation Monitoring Report: Otek Australia Pty Ltd, May 2000.		
		Monitoring Report No.2: Otek Australia Pty Ltd, October 2000.		

Site	Date	Title of Investigation	Basis for Investigation	Action
Alice Springs Railyards	1997	A report in the form of a letter to the Regional Manager, LP&E from Woodward Clyde, November 1997.	Following the change of ownership of the railway yards in Alice Springs	Self-remediation of a small plume which is not expected to migrate off-site. Monitoring is on-going.
		Groundwater Flow and Solute Transport Model - Alice Springs Railyard: Woodward - Clyde, April 1998.		
		Human Health and Environmental Risk Assessment – Alice Springs Railyards: Woodward-Clyde, April 1998.		
		Phase 2 Environmental Site Assessments of Lots 1 to 23 and a letter about a lead investigation in the Alice Springs Railyard: Woodward-Clyde, September 1998.		
		Groundwater Monitoring Event, September 1999, Alice Springs Railyard, Alice Springs, N.T: Woodward-Clyde, February 2000.		
Former Co-ord Transport Depot: Stuart Highway, Alice Springs	2000	Additional Investigations Former Co-ord Transport Depot, Stuart Highway, Alice Springs: PPK Environment & Infrastructure Pty Ltd, November 2000.	Following the reporting of an underground leak of diesel fuel by Ascot Haulage (NT) Pty Ltd from the former Co-ord Transport Depot on the North Stuart Highway in Alice Springs.	The contaminated soils are being farmed to remove hydrocarbons. Groundwater monitoring is on-going.
Ampol: North Stuart Hwy Service Station	1997	Tank testing - no known impacts	Following a report of contamination of a storm drain downstream.	No action required.
BP Service Station: Smith Street	1998	Drilling in forecourt - no known impacts	Routine check.	No action required.

Table C-2 Chemical analyses in the Town Basin

Bore	Date	TDS	Cl	HCO3	SO4	Na	K	Ca	Mg	NO3	F	Fe
RN000610	12/12/1961	670	70	359	90			70	32			
RN001797	25/09/1961	1695								12	1.6	
RN001798	09/09/1963	2320	640	500	433	600	8	81	55	1	2	
RN001907	08/01/1960	284	15	164	21	59	3	3	9	10	0.1	
RN001909	01/08/1978	330	72	171	36	95	6	15	8	7	0.4	0.1
RN001909	24/06/1981	370	100	189	39	106	7	18	9	1	0.4	0.1
RN001909	24/09/1981	380	96	83	44	109	9	19	9	6	0.3	0.2
RN001910	06/07/1964	469	80	205	35	104	6	20	11	7	0.6	

RN001910	12/08/1976	1660	428	668	280	490	13	80	41	24	0.7	0.4
RN001910	31/07/1978	2270	594	918	385	670	12	112	61	22	1	1.8
RN001910	24/06/1981	1700	390	559	275	432	17	68	38	7	1.8	0.1
RN001910	28/07/1982	1580	412	598	315	480	16	76	42	2	1.6	0.6
RN001918	17/10/1955	561	75	242	69	137	16	8	13		0.8	
RN001918	20/08/1956	684	110	280	40	172	6	19	16	7	0.4	
RN001919	18/01/1978	640	149	305	76	129	13	53	27	1	0.3	0.4
RN001926	13/05/1953	4746	2041	134	894	884	209	393	181		1.5	
RN001926	28/05/1956	5646	1589	771	1239	1700	8	19	35	16	0.3	
RN001956	12/05/1960	192	5	122	13	25	8	10	9		0.2	
RN002270	11/10/1957	183	20	100	16	30		10	7		0.8	
RN002511	02/05/1961	525								1	0.4	
RN002598	13/06/1952	574	177									
RN002598	03/10/1957	1287	225	507	128	367	3	16	16	10	3	
RN002599	01/10/1953	1460	231	476	309	245	40	96	52		2.2	
RN002599	20/08/1956	2364	745	407	499	440	5	110	128	30	0.7	
RN002603	25/03/1952	520	142									
RN002618	21/11/1956	425	70	149	48	95	7	15	14	1		
RN002619	28/08/1956	165	30	75	4	37	8	2	5	3	1.4	1
RN002621	09/09/1954	4038	852	1252	584	1308		5	10		27	
RN002635	04/04/1955	949	230	312	135	210	30	14	18		0.2	
RN002635	20/08/1956	599	100	220	93	130	12	25	9	10	0.1	1
RN002635	15/05/1957	158	20	98		15	5		9	11		
RN002637	17/08/1955	902	115	417	100	193	8	29	15	24		
RN002640	17/12/1956	389	50	176	15	100	6		13	10		
RN002641	07/09/1956	318	40	166	3	45	11	17	14			
RN002643	12/10/1953	275	25	165	10	30		24	14		0.2	
RN002643	27/09/1962	286	20	164	22	60	5	9	5		0.6	
RN002643	14/10/1963	312	15	180	30	66	6	6	8		0.5	
RN002643	13/08/1964	245	16	157		49	6	7	6	3	0.5	
RN002643	30/10/1968	320	42	107	15	80	6	15	7	3	0.4	0.1
RN002643	30/10/1968	320	42	107	15	80	6	15	7	3	0.4	0.1

RN002643	16/12/1968	260	56	101	27	85	6	16	8	1	0.3	0.1
RN002643	04/11/1969	330	40	124	27	75	6	26	7	1	0.3	0.7
RN002645	20/08/1956	327	45	146	63	40	5	12	7	9		1
RN002646	07/09/1954	2538	452	885	335	750	75		6		11.2	
RN002648	20/06/1955	3074	930	384	753	810	6	116	60	3	2.5	
RN002649	17/09/1956	227	35	122		40	5	10	7	8		0.5
RN002654	16/02/1956	1452	345	481	210	351	8	18	32	6	1.5	
RN002657	16/02/1956	1723	375	627	193	453	10	10	40	13	1.5	
RN002658	06/09/1954	755	50	343	63	225	3	1	5		4.5	
RN002660	13/04/1953	8614	3266	427	1821	2308	316	329	148		3	
RN002661	20/08/1956	277	35	146	11	46	6	14	8	10		1
RN002662	12/04/1955	1592	195	922	38	275	68	51	41		2.2	
RN002663	21/10/1954	334	25	202	11	55	17	15	8		0.7	
RN002663	20/08/1956	302	40	165		59	3	20	4	0.6	1.1	
RN002669	20/08/1956	382	70	176	24	75	6	9	12	10		
RN002669	13/08/1964	290	30	168	6	47	6	18	9		0.4	
RN002670	20/08/1956	717	115	281	112	155	2	18	24		0.7	
RN002670	18/11/1959	773	80	356	101	155	3	34	26	16	1.5	
RN002670	01/07/1960	792	90	353	112	155	3	37	25	15	1.5	
RN002670	30/04/1962	1462	255	463	288	270	4	102	32	26	2.4	
RN002670	01/05/1962	1481	250	493	286	270	4	102	52	22	2.4	
RN002670	12/06/1964	791	105	351	103	164	3	34	24	5	1.5	
RN002672	20/08/1956	7837	2855	373	1965	2250	20	86	277	9	2.6	1
RN002673	20/08/1956	2364	745	407	499	440	5	110	128	30	0.7	
RN002674	13/09/1955	1523	366	705		355	2	5			11.2	
RN002674	20/08/1956	2054	395	692	235	650	1	11	7	13	7	1
RN002675	04/12/1956	2092	345	727	291	625	10	4	7		6.6	
RN002675	04/11/1957	2002	297	720	230	650	4	6	10	5	8	
RN002676	21/11/1956	323	40	166	13	55	10	10	14	2		1
RN002676	21/05/1963	268	25	149	19	47	7	47	9	1	0.3	
RN002676	15/10/1963	265	22	141	22	50	10	7	9	4	0.4	
RN002676	14/04/1966	1311	350	339	194	270	35	84	34	5	0.2	

RN002677	12/10/1953	459	70	213	40	91		20	16		0.4	
RN002677	15/09/1954	444	60	220	26	83	35	10	10			
RN002677	10/11/1955	444	60	220	26	83	35	10	10			
RN002677	15/02/1956	307	40	178		58	8	8	12	3	0.13	
RN002677	17/09/1956	227	35	122		40	5	10	7	8		0.5
RN002678	15/09/1954	627	85	277	61	105	66	22	10		0.9	
RN002678	15/02/1956	461	75	242		113	5	12	11	3		
RN002680	15/09/1954	196	15	128		23	10	11	8		0.2	
RN002680	02/06/1963	165	18	82	19	19	5	14	7		0.6	
RN002680	03/07/1964	200	5	127		17						
RN002681	14/04/1970	1470	440	508	212	312	12	120	68	19	0.9	0.6
RN002683	15/02/1956	511	80	244	30	113	6	9	14	3	0.4	
RN002684	17/08/1955	1264	290	412	202	290	7	35	27		0.84	
RN002699	28/05/1954	891	60	445	85	184	39	22	8		2.2	
RN002699	01/08/1956	680	55	388		173	3	13	7	11	5.4	1
RN002707	03/04/1957	1759	325	669	194	475	9	38	25		0.64	
RN002707	13/02/1958	1779	290	720	206	468	9	46	28	11	1.5	
RN002709	20/10/1958	209	10	137	6	25	3	16	11	1	0.3	
RN002709	17/07/1968	146	12	56	7	10	7	18	5	1	0.5	0.1
RN002710	20/08/1956	5927	1865	642	1325	1970	2	15	64	11	4.3	1
RN002796	14/12/1967	3549	1020	592	340	1200	110	22	78	48	5	7.6
RN002798	11/09/1964	740	125	302	78	168	9	27	17	7	0.4	
RN002799	11/04/1962	274	45	170	24			15	9			
RN002799	11/04/1979	1140	311	445	210	343	13	56	29	1		6.3
RN002875	22/09/1981	1040	240	494	184	256	14	82	35	12	0.5	0.8
RN002875	09/11/1994	706	150	376	128	195	9	47	19	4	0.5	0.1
RN003041	04/10/1960	532	54	211	33	103	5	12	6	7	0.5	
RN003041	02/01/1962	454	60	211	39	108	5	13	7	10	0.5	
RN003041	09/04/1962	459	65	206	40	110	5	14	8	10	0.6	
RN003041	19/05/1963	496	90	222	49	96	7	16	10	5	0.5	
RN003041	13/08/1964	709	130	293	54	160	9	13	28	22	0.3	
RN003041	30/10/1968	550	108	135	61	150	7	27	13	1	0.5	0.1

RN003041	04/11/1968	550	112	137	55	155	7	31	13	12	0.4	1.1
RN003041	16/12/1968	570	112	142	68	160	7	32	13	1	0.6	0.1
RN003048	03/04/1957	474	70	232	10	94	10	22	12	19		
RN003048	10/04/1992	645	140	308	102	173	12	32	17	12	0.4	4.9
RN003048	26/10/1995	357	51	256	56	96	8	23	11	4	0.3	3.4
RN003048	01/08/1996	483	84	305	76	137	11	25	15	1	0.5	2.5
RN003048	30/04/1997	393	66	257	65	93	8	28	13	1	0.4	3.3
RN003048	08/07/1998	387	73	246	76	95	7	26	13	1	0.2	3.2
RN003048	15/08/2000	539	104	283	81	129	10	29	16	2	0.4	3.1
RN003051	14/11/1967	339	16	121	20	60	8.4	24	25	6.6	0.1	0.1
RN003064	12/10/1989	3535	1200	667	746	895				18		
RN003064	04/09/1990	2865	950	581	597	702	8	192	76	13	0.7	0.1
RN003064	07/04/1992	4030	1274	906	922	1291	8	100	83	22	2.3	1
RN003064	11/01/1993											
RN003064	11/01/1993	4390	1370	924	971	1450	4	89	73	18	2.4	0.2
RN003064	24/10/1995	4360	1190	1050	1100	1450	4	82	76	16	2.4	0.5
RN003064	30/07/1996	4080	1210	1030	1000	1310	4	46	83	16	3.3	0.1
RN003064	08/05/1997	5210	1274	1083	1180	1450	4	90	100	15	2.6	
RN003064	09/07/1998	4150	1188	1043	1064	1286	3	86	84	16	1.8	0.6
RN003064	02/06/1999	4190	1287	1074	1100	1365	4	88	78	15	2.2	0.1
RN003064	13/04/2000	4411	1327	1043	1010	1340	4	118	90	14	2	0.1
RN003064	24/08/2000	4330	1275	1012	1094	1303	5	119	93	14	1.9	0.2
RN003065	19/03/1956	1064	130	342	292	117	8	120	54		0.9	
RN003071	06/11/1957	1686	397	415	313	465	7	60	27		2.1	
RN003071	06/11/1957	1616	453	244	320	430	9	74	30	2	1.9	
RN003074	02/12/1957	1159	200	398	214	305	7	17	16	1	1.3	
RN003077	20/07/1965	199	15	109	16	32	4	10	8	5	0.3	
RN003077	15/07/1968	131	8	46	2	13	5	15	4		0.4	1.6
RN003078	18/12/1957	168	5	171	26	36	7	14	9			
RN003079	18/12/1957	358	28	210	21	70	8	12	9			
RN003081	18/12/1957	507	78	224	48	130	7	6	7	6	1.5	
RN003082	17/01/1958	485	40	259	44	105	7	18	10	2	0.2	

RN003083	17/01/1958	1403	350	463	149	395	5	24	19	2	0.9	
RN003084	17/01/1958	621	100	239	86	175	3	8	9		1.7	
RN003084	25/03/2000	353	57	205.9	48	74	7.3	26	13	1	0.3	0.1
RN003085	17/01/1958	681	95	322	88	152	6	35	13		5.4	
RN003086	22/01/1958	380	50	195	22	98	4		9	1	1	
RN003087	22/01/1958	456	15	307	10	105	3		16		0.4	
RN003088	22/01/1958	681	112	291	68	155	11	26	15	3	0.4	
RN003089	29/01/1958	806	150	247	65	178	16	30	20			
RN003090	29/01/1958	439	35	244	34	100	9	6	7	4		
RN003091	29/01/1958	650	105	283	60	170	10	8	10	4		
RN003092	29/01/1958	2461	795	400	406	770	20	45	22	3	0.8	
RN003094	29/01/1958	22374	5745	4780	3550	7670	14	9	19	5	30	
RN003095	29/01/1958	693	125	293	57	152	14	25	18	9		
RN003095	10/02/1958	302	15	181	17	68	4	10	5	2		
RN003095	02/01/1962	576	95	227	74	124	6	29	12	8	0.7	
RN003095	09/04/1962	532	80	220	67	110	5	31	12	6	0.6	
RN003095	09/05/1962			219	90							
RN003095	30/05/1962		85	211								
RN003095	28/06/1962		80	226								
RN003095	19/05/1963	628	115	242	80	139	5	33	13		0.6	
RN003095	17/05/1964	701	110	277	98	151	8	36	16	4	0.5	
RN003095	13/08/1964	597	115	236	67	112	7	40	18	2	0.4	
RN003095	17/11/1982	2740	830	708	500	716	29	168	62	28	0.5	0.5
RN003330	07/09/1956	2872	185	1427	72	890	3		5	2	12	
RN003424	01/02/1956	1856	360	346	637	352	7	108	45	0.6	0.5	
RN003424	19/03/1956	1648	365	207	570	337	9	101	40	0.7	1	
RN003757	23/11/1961	2518								21	1.8	
RN003758	15/07/1983	910	420	260	1	329	19	11	12	3	0.2	
RN003758	08/08/1984		1060	60	164	477	11	178	53	1	0.9	
RN003758	19/09/1989	1055	460									
RN003758	15/04/1992	3120	1300	70	380	556	14	204	83	34	0.9	
RN003758	12/01/1993											

RN003758	12/01/1993	2280	1000	67	338	503	15	187	51	1	0.5	
RN003759	28/11/1961	1947								8	2.2	
RN004146	26/11/1963	467	60	244	28	88	12	19	15	1		
RN004147	03/03/1978	840	213	403	140	201	16	62	35	2	0.3	0.5
RN004148	28/11/1963	2244	550	605	331	640	10	33	32	3	3	
RN004148	24/07/1964	2566	610	726	374	780	9	34	28	2	3.3	
RN004148	09/12/1983	4950	1400	1122	1100	1635	29	75	75	78	2.5	0.1
RN004148	02/12/1991	3230	706	1281	586	1185	12	29	26	39	3.1	0.3
RN004162	12/02/1964	337	45	172	22	48	6	23	15	6	0.4	
RN004172	30/07/1964	1357	270	444	187	285	34	68	36	33	0.4	
RN004172	11/09/1989	515	92									
RN004174	27/08/1956	1526	300	581	144	434	10	5	28	5	0.4	1
RN004174	28/08/1956	2342	470	749	272	650	12	44	35	37	1.4	1
RN004174	27/12/1963	1820	280	779	169	405	15	79	49		1	
RN004178	22/01/1964	2770								176	1.2	
RN004442	02/02/1978	680	119	372	100	164	9	44	21	1	0.3	0.1
RN004442	22/09/1980	960	216	445	144	230	12	64	31	5	0.4	4.9
RN004442	29/07/1983	900	200	436	144	230	13	64	31	4	0.2	0.4
RN004442	29/07/1983	900	210	435	143	233	17	64	30	5	0.4	
RN004442	10/07/1984	870	200	387	124	216	9	55	28	2	0.3	0.7
RN004442	28/09/1989	635	173									
RN004442	12/03/1992	495	98	255	75	129	8	29	13	1	0.4	0.1
RN004442	23/09/1992											
RN004442	23/09/1992	550	107	278	84	143	8	33	15	1	0.3	0.2
RN004442	11/11/1992											
RN004442	11/11/1992	524	112	280	80	144	8	33	14	1	0.4	0.2
RN004442	12/12/1992											
RN004442	14/12/1992	491	98	270	79	137	8	29	13	1	0.4	0.1
RN004442	08/11/1994	563	108	305	86	145	8	34	15	2	0.4	0.1
RN004498	13/08/1964	503	85	221	44	118	6	16	10	2	0.5	
RN004505	27/09/1964	606	85	266	57	142	9	13	11	23	0.4	
RN004505	30/09/1964	607	100	262	61	140	6	22	12	4	0.5	

RN004540	15/04/1964	2589	685	528	540	660	6	90	67	10	2.8	
RN004540	28/07/1964	555	60	256	72	80	9	52	16	10	0.4	
RN004540	12/07/1972	2700	953	512	440	800	11	68	76	22	2.9	0.1
RN004653	05/07/1964	400	60	150	39	62	10	26	9			
RN004656	07/07/1978											
RN004656	07/07/1978	500	124	268	65	158	8	26	12	2	0.4	0.8
RN004956	08/07/1965	2019	460	519	367	570	7	30	61	4	1.2	
RN004956	20/07/1968	1346	345	194	256	450	5	50	17	2	1.4	0.2
RN004957	12/07/1965	1990	500	519	322	560	9	48	26	5	1.3	
RN004957	20/07/1968	1239	295	231	205	405	5	40	15		1.4	0.3
RN004957	08/04/1982	2830	850	675	650	850	10	110	55	18	1.4	
RN004957	04/11/1982	2780	760	764	570	792	16	108	52	23	1.5	4.6
RN004957	12/07/1983	2410	650	705	499	748	15	86	42	17	1.5	25
RN004957	08/08/1984	2430	690	737	515	801	6	89	41	16	1.2	0.5
RN004957	19/09/1989	2235	560									
RN004957	14/04/1992	2080	520	777	399	625	6	73	44	17	1.1	5.7
RN004957	24/10/1995	1540	333	714	310	512	5	44	24	7	1.2	1.1
RN004957	30/07/1996	1620	369	707	310	537	6	45	35	8	0.8	0.6
RN004957	14/04/1997	1507	328	704	300	534	6	36	24	7	1.5	0.27
RN004957	09/07/1998	1773	398	766	325	614	5	52	27	11	1	0.2
RN004957	23/06/1999	1896	455	816	410	615	6	59	31	15	1.3	0.1
RN004957	22/03/2000	1966	417	829	362	608	6	58	32	17	1.3	0.1
RN004957	18/08/2000	1865	413	817	445	593	6	57	30	14	1.4	0.1
RN004958	21/07/1968	1925	575	254	430	650	6	85	39	2	1	1
RN004959	06/07/1968	120	8	40	14	12	6	23	6		0.5	5.5
RN004959	14/07/1968	124	12	43	11	10	5	15	5	1	0.6	1
RN005017	21/07/1965	887	220	219	158	200	10	53	19	7	0.7	
RN005017	06/07/1968	463	40	172	70	140	4	30	11		0.6	0.5
RN005017	09/04/1982	350	60	220	39	110	4	14	7	2	0.9	2.9
RN005017	05/11/1982	340	54	223	23	104	7	14	7	1	1	2.2
RN005017	13/07/1983	350	66	227	38	112	5	17	7	2	0.8	0.7
RN005017	05/07/1984	370	64	239	40	111	3	16	8	1	0.7	

RN005017	11/10/1989	390	66									
RN005040	06/10/1965	1060	295	287	128	250	13	54	26	6	1.1	
RN005041	11/10/1965	665	190	189	87	82	6	76	33	2	0.4	
RN005801	15/07/1968	663	128	167	102	230	6	17	10		0.9	10
RN005801	12/05/1982	1230	250	634	230	406	12	36	25	1	1.3	
RN005801	07/12/1982	1750	370	834	320	564	17	42	40	2	1.4	26
RN005801	01/06/1983	1520	300	714	281	468	19	42	31	5	1.6	4.1
RN005801	11/08/1984	1980	440	912	338	644	10	49	43	20	1.4	
RN005802	04/10/1960	551	88	223	64	130	8	22	10	5	0.6	
RN005802	16/07/1968	223	18	85	17	60	4	7	2	1	0.1	0.1
RN005802	30/10/1968	1040	265	233	128	300	10	51	23	16	0.7	0.1
RN005802	04/11/1968	940	238	190	131	300	11	24	23	13	0.5	4.4
RN005802	16/12/1968	1020	210	229	132	300	11	55	24	13	0.5	0.1
RN005802	16/10/1969	880	200	459	110	257	12	38	20	2	0.4	0.1
RN005802	23/09/1981	490	120	256	60	155	10	21	10	4	0.5	9.4
RN005803	16/07/1968	2073	525	462	380	750	6	19	12	17	9	0.1
RN005803	12/05/1982	2450	470	1321	365	898	12	16	16	27	9.3	4.2
RN005803	07/12/1982	2910	510	1373	530	1070	12	19	17	43	8.5	3
RN005803	01/06/1983	2200	384	1254	339	840	15	13	13	19	6.7	5.4
RN005803	09/08/1984	2110	340	1198	316	779	4	9	10	20	9.2	
RN005803	08/09/1989	2240	412									
RN005803	14/04/1992	2420	570	1042	378	896	6	13	13	23	8	0.1
RN005803	25/10/1995	2530	532	1220	460	957	6	15	16	15	6	0.2
RN005803	01/08/1996	2520	582	1180	440	919	6	16	17	17	6.3	
RN005803	30/04/1997	2542	490	1337	442	960	6	20	20	15	6.9	0.2
RN005803	08/07/1998	2568	545	1308	498	909	5	22	18	16	5	0.3
RN005803	24/03/2000	2148	354	1219	345	820	4.4	12	12	31	7.8	0.1
RN005803	15/08/2000	2876	440	1276	401	884	5	15	14	34	8.2	0.14
RN005804	21/09/1966	292	38	83	14	160	5	2	16	14	0.5	0.72
RN005805	30/10/1968	1040	265	233	128	300	10	51	23	16	0.7	0.1
RN005805	04/11/1968	940	238	190	131	300	11	24	23	13	0.5	4.4
RN005805	30/07/1969	880	200	459	110	257	12	38	20	2	0.4	0.1

RN005805	10/07/1984	840	184	444	116	224	29	44	22	3	0.2	0.1
RN005806	30/07/1969	320	46	200	36	75	6	16	8	1	0.3	0.1
RN005806	01/08/1969	320	46	200	36	75	6	16	8	1	0.3	0.1
RN005807	09/07/1968	405	80	106	54	150	4	23	5	1	0.9	4.1
RN005808	05/07/1964	250	20	141		43						
RN005808	10/07/1968	126	14	49	2	20	5	17	5		0.5	0.2
RN005808	02/06/1983	950	300	305	102	233	41	63	27	11	0.3	0.1
RN005808	24/05/1989	1470	461	422	247	380	22	92	35	2	0.3	0.1
RN005808	02/10/1989	760	194									
RN005808	05/05/1992	1860	560	556	373	474	21	111	51	1	0.2	1.7
RN005808	10/11/1994	487	107	244	77	162	6	11	4	1	0.5	1.1
RN005808	27/11/1995	570	126	288	98	187	8	16	7	1	0.4	0.6
RN005808	29/07/1996	487	104	252	80	164	7	13	7	1	0.7	0.1
RN005808	30/07/1996	487	104	252	80	164	7	13	7	1	0.7	0.1
RN005809	18/07/1968	295	32	81	30	65	7	16	6		0.4	5.5
RN005810	23/02/1962	247	15	122	28	40	7	16	8	10	0.5	
RN005810	17/07/1968	108	10	37	9	20	5	10	3	1	0.1	1
RN005811	19/07/1968	464	72	118	74	80	6	47	12	1	0.5	0.1
RN005813	10/07/1968	239	20	106	17	44	4	32	7		0.4	5
RN005814	05/01/1966	1083								2	1.4	
RN005814	12/05/1982	1230	250	634	230	406	12	36	25	1	1.3	
RN005815	10/07/1968	281	32	123	2	55	6	28	10	13	0.8	5
RN005815	24/09/1981	330	40	289	15	70	12	33	17	13	0.5	14.8
RN005815	12/05/1982	770	180	298	186	196	16	50	22	1	0.5	
RN005815	03/11/1982	320	34	257	16	67	10	35	12	25	0.9	3.6
RN005817	17/02/1960	560	65	279	41	131	7	16	10	10	0.8	
RN005818	16/07/1968	1869	515	266	410	240	8	159	70	1	1.4	0.2
RN005818	17/04/1997	2215	578	920	414	695	10	65	50	1	1.8	0.8
RN005818	08/07/1998	2273	594	960	439	701	9	67	54	1	1.1	0.4
RN005818	02/06/1999	2128	495	919	396	670	9	61	43	1	1.4	0.1
RN005818	22/03/2000	2178	491	951	375	670	9	65	45	1	1.4	0.3
RN005818	21/08/2000	3558	1088	1127	657	955	13	120	104	2	1.2	0.1

RN005819	07/09/1956	321	25	98	15	97	3		10		0.7	0.7
RN005819	17/07/1968	678	118	222	52	205	5	32	16.5	3	1	3.5
RN005819	12/07/1983	1760	430	731	269	574	9	68	32	6	0.9	3.1
RN005819	08/08/1984	1860	470	749	314	593	12	72	32	6	0.8	1
RN005819	11/10/1989	1355	272									
RN005819	10/04/1992	1245	265	620	187	400	6	35	19	11	1	
RN005819	26/10/1995	1440	342	682	240	473	7	42	29	2	1	0.6
RN005819	06/08/1996	1341	354	596	225	423	7	28	24	2	1.1	1.9
RN005819	06/08/1996	1340	354	596	230	423	7	28	24	2	1.1	1.9
RN005819	17/04/1997	1319	294	642	240	398	7	28	26	2	1.3	0.9
RN005820	18/07/1968	912	194	206	171	265	3	50	15	1	1.8	5.4
RN005820	08/04/1982	3130	1190	480	560	810	13	205	90	16	1	
RN005820	06/11/1982	3090	1080	586	540	756	15	224	84	15	0.9	21
RN005820	12/07/1983	3150	1050	651	580	760	12	232	90	14	1	5
RN005820	09/08/1984	3200	1030	663	607	805	5	226	83	12	0.6	
RN005820	19/09/1989	2900	892									
RN005821	18/07/1968	1200	250	194	276	330	4	62	17	14	0.9	0.1
RN005822	18/07/1968	8539	3300	221	2080	2300	24	520	320	7	1.6	0.3
RN005823	19/07/1968	2651	960	79	500	480	7	195	142		1.9	0.2
RN005824	08/07/1965	2472	680	469	509	660	7	86	53	7	1.2	
RN005824	19/07/1968	2352	840	126	535	650	7	114	65		1.8	4.7
RN005824	15/04/1992	2560	710	752	537	750	9	83	60	28	1.9	13
RN005824	25/10/1995	2000	485	794	440	672	8	50	37	14	1.9	14
RN005824	30/07/1996	1440	238	854	220	501	8	24	28	14	3.9	3
RN005824	06/05/1997	1608	328	809	356	545	10	35	27	9	3.4	12.7
RN005824	09/07/1998	1923	416	944	370	637	8	36	31	13	2.1	4
RN005824	12/04/2000	2092	470	909	452	671	10	51	37	13	1.5	0.3
RN005824	24/08/2000	2030	470	888	416	654	9	52	37	14	1.7	13.6
RN005825	20/07/1968	5637	1800	636	1390	2200	2	15	50		3.5	0.1
RN005826	20/07/1968	6030	2320	131	1415	1300	14	280	290		1.7	5.5
RN005826	24/06/1983	5820	2020	390	1425	1220	39	316	285	2	0.7	0.4
RN005826	10/08/1984	6230	2280	373	1500	1266	14	378	318	4	0.6	

RN005826	08/09/1988	6200	2352	350	1520	1240	16	389	320	3	0.5	5.5
RN005826	08/09/1989	6585	2425									
RN005826	02/05/1992	6305	2400	381	1569	1229	18	372	344	5	0.6	0.5
RN005826	26/10/1995	6590	2420	355	1700	1280	15	375	357	6	0.5	1.3
RN005826	01/08/1996	6490	2650	356	1700	1390	16	400	353	2	0.6	4.9
RN005826	17/04/1997	6856	2489	387	1815	1295	20	310	360	5	0.6	1.33
RN005826	09/07/1998	6950	2624	389	1915	1240	15	456	398	6	0.5	0.7
RN005826	23/03/2000	7290	2523	386	1810	1350	17	476	402	6	0.6	0.5
RN005826	15/08/2000	7400	2500	389	1830	1252	16	490	386	7	0.6	0.1
RN005827	05/07/1964	850	180	328	133							
RN005827	14/11/1967	350	32	72	20	125	9	7	10	5.6	0.2	1.4
RN005827	14/11/1967	365	32	66	20	115	6.6	8	4	22.9	0.8	0.9
RN005827	16/07/1968	375	112	66	34	105	3	16	4	18	1	0.1
RN005828	13/07/1968	498	94	116	76	140	5	30	7	10	0.3	2.2
RN005829	06/07/1968	278	24	93	24	90	2	8	2		2.8	
RN005829	07/04/1982	3530	1080	685	870	1090	10	125	70	25	1.9	5
RN005829	04/11/1982	3630	1160	695	780	1100	18	148	77	23	1.8	1.6
RN005829	14/07/1983	3110	950	622	694	914	17	124	63	18	1.7	8.2
RN005829	05/07/1984	3810	1190	676	845	1026	7	180	94	20	0.9	4.4
RN005829	19/09/1989	3505	1164									
RN005829	04/09/1990	3435	1079	715	824	1000	6	164	78	20	1.1	0.1
RN005829	07/04/1992	2540	660	820	495	733	21	85	57	21	1.5	7
RN005830	14/07/1968	85	10	26	17	10	7	9	4	1	0.1	5.9
RN005966	14/06/1967	324	8	74	10	70	6	3	10	1	0.5	1
RN005968	17/06/1967	308	10	73	10	80	7	2	12		0.4	0.1
RN005968	17/06/1967	332	10	73	10	170	6	2	11	1	0.4	1
RN005970	18/08/1967	167	4	54	2	34	9	1	13	3	0.4	
RN005970	18/08/1967	174	4	57	2	33	10	1	12	7	0.4	1
RN005972	04/07/1967	359	6	72	2	65	4	1	6		0.9	
RN005974	18/08/1967	302	10	96	30	75	8	2	17	1	1.1	
RN005975	08/08/1967	464	20	124	40	125	9	3	10	0.3	2.1	
RN005976	26/06/1967	303	20	74	30	100	7	2	11	1	0.6	1

RN005977	24/06/1967	677	30	146	170	210	9	10	20	0.2	0.7	0.7
RN005993	23/06/1967	186	6	70	20	90	6	1	2	1.5	1.1	
RN005995	22/06/1967	328	16	79	50	130	6	1	6	0.2	1.5	
RN005997	28/06/1967	449	28	111	50	165	8	5	16	1	0.7	3.5
RN005998	20/06/1967	437	24	111	40	150	7	4	9		0.6	0.1
RN006057	19/09/1966	330								7	0.7	
RN006059	15/12/1960	299								7	0.8	
RN006060	21/12/1960	280								3	0.5	
RN006061	16/12/1962	295								3	0.8	
RN006062	01/10/1962		45	193	37	80						
RN006104	11/06/1979		1230	521								
RN006104	13/06/1979	3340	1089	500	646	491	28	433	140	22	0.7	0.3
RN006105	22/05/1968	853	244	133	194	200	15	55	40	4.9	0.8	0.2
RN006105	31/01/1974	800	250	241	136	210	9	41	25	1	0.7	1.4
RN006105	02/05/1979	2230	745	461	415	476	13	182	101	37	1.5	0.2
RN006105	16/04/1992	3150	1150	524	643	713	12	242	102	12	0.8	0.2
RN006105	27/10/1995	2570	817	548	560	661	10	122	81	8	1.2	0.1
RN006105	31/07/1996	3310	1210	620	680	848	13	131	101	5	2.4	0.1
RN006105	30/07/1997	4244	1488	701	918	1213	14	206	127	7	1.9	0.1
RN006105	04/06/1999	3000	991	582	631	770	9	170	83	8	1.5	0.11
RN006105	22/03/2000	2986	1009	570.5	620	790	10	180	86	8	1.5	1.1
RN006518	01/09/1954	835	140	323	95	148	90	22	17		0.38	
RN006518	15/02/1956	682	120	295	81	147	6	12	18	3	0.4	
RN006518	02/01/1962	598	80	262	67	150	5	18	10	5	0.9	
RN006518	27/09/1962	705	130	275	77	160	7	31	13	11	0.6	
RN006518	19/05/1963	667	140	256	65	156	7	26	14	2	0.7	
RN006518	14/10/1963	982	235	287	151	220	9	55	22	2	0.7	
RN006518	31/10/1983	2730	770	925	457	876	33	76	55	2	1	0.1
RN006518	18/11/1983	2970	850	968	546	1000	42	78	58	3	0.7	0.3
RN006518	16/02/1988	2270	617	797	400	674	13	114	60	10	0.9	0.7
RN006518	22/07/1988	2380	594	904	330	678	17	66	44	7	1.2	0.1
RN006518	18/03/1992	1795	455	741	320	538	10	80	40	7	1.1	0.2

RN006518	22/09/1992											
RN006518	11/11/1992											
RN006518	11/11/1992	1790	432	743	326	538	10	71	35	7	1.3	0.3
RN006518	12/12/1992											
RN006518	14/12/1992	1760	431	719	322	540	10	74	35	7	1.3	0.1
RN006518	08/11/1994	1730	450	701	310	537	2	87	37	7	1	0.1
RN006518	08/02/1995	1720	446	734	305	541	11	71	36	5	1.2	0.2
RN006518	13/08/1996	2046	578	812	387	675	12	55	47	5	0.9	0.1
RN006547	16/12/1968	400	82	116	45	128	8	18	10	11	0.5	0.1
RN006547	30/07/1969	880	205	447	112	250	11	40	20	6	0.3	0.2
RN006547	04/11/1969	440	88	116	45	125	8	18	11	14	0.4	0.9
RN006781	17/05/1964	387	25	191	23	110	6	22	7	2	0.7	
RN006781	30/10/1968	370	56	95	32	80	6	22	8	10	0.5	0.1
RN006782	16/12/1968	1020	210	229	132	300	11	55	24	13	0.5	0.1
RN006782	27/09/1978	990	247	442	158	260	16	60	34	12	0.5	0.6
RN006782	29/09/1978	1000	252	442	164	277	15	62	32	14	0.8	0.4
RN006782	24/06/1981	950	240	476	144	250	18	64	34	1	0.8	1.1
RN006782	22/09/1981	1000	240	485	160	258	25	67	35	3	0.5	0.1
RN006782	28/07/1982	1040	240	500	164	273	29	71	36	3	0.5	0.5
RN006782	05/11/1982	990	230	484	158	259	25	65	33	4	0.5	0.6
RN006782	22/01/1983	990	230	486	146	240	30	64	33	1	0.5	0.1
RN006782	28/06/1983	960	225	464	150	251	30	58	30	3	0.5	0.1
RN006782	20/11/1984	900	200	439	140	230	14	47	26	4	0.4	
RN006782	15/02/1988	885	186	457	127	243	20	46	26	1	0.5	0.1
RN006782	21/07/1988	915	193	448	123	245	9	49	27	4	0.4	0.1
RN006782	04/10/1989	775	163									
RN006782	14/04/1992	645	125	373	92	178	17	31	17	1	0.5	0.1
RN006782	22/09/1992	655	116	374	87	181	18	35	17	2	0.5	0.3
RN006782	11/11/1992											
RN006782	11/11/1992	627	129	367	91	176	19	33	16	3	0.5	0.1
RN006782	14/12/1992	649	118	375	91	173	18	32	16	2	0.5	0.1
RN006782	08/11/1994	619	123	346	93	169	19	32	17	1	0.5	0.1

RN006782	08/02/1995	632	119	349	97	166	31		17	1	0.5	0.9
RN006782	09/12/1996	803	208	390	106	206	23	43	26	1	0.5	4.3
RN006782	29/04/1997	1093	304	515	181	272	28	73	36	2	0.7	0.3
RN006782	14/11/2000	1195	345	465	220	308	26	60	41		0.3	5.8
RN006783	22/12/1961	1828	385	541	325	450	5	93	26	3	0.4	
RN006783	28/06/1962		775	531								
RN006783	19/05/1963	1581	340	476	271	400	4	64	23	2	0.7	
RN006783	17/05/1964	1811	430	474	325	445	7	93	32	4	0.7	
RN006783	12/12/1992											
RN006817	02/01/1962	360	50	160	38	72	4	25	7	3	0.9	
RN006817	27/09/1962	392	60	163	50	86	5	16	8	3	0.8	
RN006823	03/07/1962	378	52	178	30	84	6	15	7	5	0.8	
RN006823	09/07/1962	304	40	186	30	82	5					
RN006823	13/07/1962	372	45	185	30	81	5	12	7	6	0.6	
RN006823	18/07/1962	368	40	188	26	82	5	11	9	6	0.6	
RN006900	06/06/1962	228	11	145	8	27	4	22	7	4	0.5	
RN006900	06/06/1962	218	11	137	7	28	4	19	6	5	0.5	
RN007008	09/02/1970	2390	790	444	515	680	11	69	68	8	2.2	13
RN007506	05/04/1962	610	110	190	115	148	4	25	12	5	1	
RN007506	30/05/1962		125	207								
RN007506	28/06/1962		130	213								
RN007506	08/08/1962		365	535	310	420		80	25			
RN007506	08/08/1962		185	288	173	225		40	15			
RN007506	08/08/1962		325	458	259	390		74	26			
RN007506	09/08/1962		160	249	160	200		34	13			
RN007506	17/05/1964	734	190	250	173	58	5	37	16	4	1	
RN007506	06/04/1976											
RN010284	15/02/1972	150	9	124	9	18	7	16	6	1	0.3	46
RN010284	12/05/1982	2510	950	341	500	712	25	124	53	1	0.9	4.4
RN010284	08/12/1982	2030	668	409	210	600	28	66	33	1	0.7	14.7
RN010284	31/05/1983	1520	500	384	299	465	17	56	26	1	0.7	5.8
RN010592	14/05/1973	3110	912	544	615	805	6	120	83	29	1.4	6.2

RN010592	14/08/1975	5160	1820	1032	1080	1400	10	232	159	20	1.4	2
RN010593	02/05/1973	160	27	82	8	19	7	14	7	1	0.4	0.5
RN010594	04/05/1973	160	27	67	6	19	7	13	7	1	0.3	0.4
RN010595	06/05/1973	160	27	83	6	20	7	14	7	1	0.3	0.3
RN010983	25/09/1959	470									0.8	
RN010984	30/09/1959	617									0.5	
RN010985	30/10/1959	547								2	0.7	
RN010986	01/10/1959	312								2	1.1	
RN010988	28/10/1959	423								1	0.6	
RN010989	04/11/1959	1133								2	1.6	
RN010990	02/01/1962	696	125	225	102	154	6	33	33	18	0.3	
RN010990	23/01/1985	1500	410	226	370	247	35	121	64	69	0.8	0.1
RN010990	01/11/1985	1870	770	293	322	474	12	119	65	23	0.2	1
RN010990	07/09/1988	2640	911	469	484	700	10	170	72	17	0.2	0.3
RN011024	15/01/1960	350	20	205	21	76	7	10	7	3	0.7	
RN011024	15/01/1960	314	25	175	22	71	5	7	8	3	0.5	
RN011025	20/01/1960	444	35	246	33	102	7	9	8	3	0.6	
RN011025	20/01/1960	475	30	267	36	113	7	11	7	3	0.7	
RN011025	20/01/1960	462	35	259	34	102	8	11	9	3	0.8	
RN011026	05/02/1960	551								2	0.7	
RN011028	17/02/1960	580	75	289	37	138	6	14	10	10	1.1	
RN011029	19/02/1960	509	66	236	33	121	6	16	16	14	0.7	
RN011030	17/05/1960	540	68	193	42	101	6	18	10	2	0.2	
RN011030	17/05/1960	399	95	195	50	94	6	13	9	5	0.4	
RN011030	16/06/1960	523	88	222	61	110	6	23	12		1.3	
RN011031	17/05/1960	325	50	148	27	71	6	13	8	2	0.4	
RN011031	17/05/1960	367	50	178	26	82	5	15	7	4	0.3	
RN011032	19/05/1960	320	40	150	33	66	5	15	7	4	0.2	
RN011038	28/07/1960	511	60	248	51	111	6	18	10	6	1	
RN011038	28/07/1960	494	63	231	53	106	6	18	10	6	1	
RN011038	29/07/1960	586	98	224	81	126	6	33	12	5	0.8	
RN011038	29/07/1960	541	75	236	66	117	6	24	11	5	1.4	

RN011039	03/08/1960	380	20	223	22	95	3	8	3	5	0.8	
RN011040	05/08/1960	684	95	281	100	158	2	33	11	3	0.6	
RN011041	08/08/1960	1234	334	355	159	289	3	57	36		0.7	
RN011041	08/08/1960	758	152	270	110	168	2	36	19		1	
RN011042	11/08/1960	1034	265	312	128	252	8	37	28	3	0.6	
RN011042	11/08/1960	1185	310	345	160	270	7	55	34	3	0.5	
RN011044	09/01/1961	9707								1	1.6	
RN011045	16/01/1961	291								2	0.2	
RN011045	14/10/1996	572	119	271	40	77	18	50	26	20	0.4	1
RN011046	13/01/1958	1013	200	334	134	273	9	13	19	30	1.2	
RN011050	13/07/1983	1480	370	556	27	375	25	86	61	7	0.9	0.1
RN011050	09/08/1984	1210	260	537	224	324	13	60	40	6	0.7	
RN011050	19/09/1989	2790	700	943	546	740				36		
RN011050	13/04/1992	2660	640	1007	526	846	13	60	44	35	1.3	0.1
RN011050	27/10/1995	724	114	432	110	244	7	11	10	5	1.2	0.1
RN011050	31/07/1996	2120	466	1020	380	658	14	40	50	23	2.8	0.1
RN011050	16/04/1997	1330	304	588	238	452	12	22	24	10	1.3	0.47
RN011050	10/07/1998	1428	283	752	234	444	12	35	30	8	0.7	0.1
RN011050	24/03/2000	912	152	541.3	142	290	10	23	18	5	1	
RN011050	25/08/2000	741	121	415	106	204	9	17	13	6	0.9	0.1
RN011053	09/10/1975	2790	706	1054	480	845	19	104	84	175	0.8	
RN011057	19/01/1961	324								2	0.6	
RN011058	19/01/1961	336								2	0.6	
RN011059	16/01/1961	335									1.5	
RN011060	20/09/1966	132								2		
RN011062	10/02/1961	412								2	1.1	
RN011063	17/02/1961	308									1.6	
RN011065	23/02/1961	557									3	
RN011066	23/02/1961	1080								2	3	
RN011067	24/02/1961	1240								1	1.2	
RN011068	28/02/1961	995								2	5	
RN011069	01/03/1961	1410								1	1.2	

RN011070	09/03/1961	1727								2	1.1	
RN011071	07/03/1961	2184								2	0.8	
RN011072	09/03/1961	1906								1	1	
RN011076	19/06/1961	544								13	0.4	
RN011079	03/07/1961	321								2	2.1	
RN011080	05/07/1961	2151								4	1.6	
RN011082	04/08/1961	1384									0.6	
RN011083	08/08/1961	1283									0.6	
RN011084	15/08/1961	1921								2	0.6	
RN011085	23/08/1961	1437									0.8	
RN011086	25/09/1961	1618								10	1	
RN011087	25/09/1961	1231									1.8	
RN011088	17/05/1964	499								3	0.6	
RN011089	08/10/1961	1311								1	2.2	
RN011091	17/02/1961	258									1.3	
RN011125	20/09/1966	580									0.7	
RN011133	11/10/1957	865	190	297	84	205	10	37	17		1	
RN011134	11/10/1957	21107	7720	1330	4490	7300	8	52	128	2		
RN011134	29/01/1982	25000	12360	1766	5950							
RN011135	14/10/1957	1141	374	219	149	280	9	58	25	2	1.6	
RN011136	14/10/1957	861	155	342	80	210	8	27	14		1.6	
RN011138	31/10/1957	480	70	173	45	110	7	29	9		2.5	
RN011139	13/11/1957	248	35	122	21	45	7	8	9		1.3	
RN011144	20/11/1957	164									0.5	
RN011148	26/11/1957	1176									1.6	
RN011149	26/11/1957	312	35	150	19	77	5	11	5	10	0.9	
RN011149	09/08/1978	730	219	235	118	143	14	60	36	2	0.4	13
RN011149	24/09/1978	560	139	250	82	146	9	40	20	19	0.3	15
RN011149	28/07/1982	670	170	293	106	163	15	44	24	1	0.4	2.6
RN011149	05/11/1982	650	150	305	90	162	12	48	17	9	0.4	0.6
RN011149	28/06/1983	470	95	239	65	125	13	28	13	8	0.5	0.1
RN011149	20/11/1984	510	130	224	78	126	9	29	16	3	0.3	

RN011150	27/11/1957	1602	310	520	232	450	7	52	27	4	0.9	
RN011185	24/09/1981	906	260	308	169	278	15	37	16	1	0.3	4.1
RN011188	31/12/1957	5667								11	2.2	
RN011221	28/08/1956	3414	865	847	474	1100	5		25	45	3.3	1
RN011223	18/09/1956	202	20	124		25	5	5	9	4		
RN011225	17/01/1978	460	82	262	50	137	7	18	8	1	0.3	0.2
RN011226	07/09/1956	92	10	49	3	8	5	8	5	2		
RN011229	18/09/1956	197								4		
RN011232	17/09/1956	1609	330	661		490	7	14	24	54		
RN011233	06/02/1976	660	181	276	102	200	11	36	11	1	0.1	0.3
RN011233	15/06/1977											
RN011233	18/01/1978	720	178	323	101	208	10	38	14	1	0.3	2
RN011234	17/09/1956	189	25	102		42	3		12	5		
RN011382	01/07/1976		412	750								
RN011382	01/07/1976		1137	2547								
RN011382	03/07/1976	680	194	253	104	143	9	66	25	5	0.8	5.2
RN011382	14/07/1976	2300	672	696	408	632	12	120	63	2	0.8	1.3
RN011382	10/08/1976		670	732								
RN011382	10/08/1976	2260	691	732	375	680	12	113	62	12	1	1.2
RN011382	11/08/1976		651	734								
RN011382	11/08/1976	2230	676	732	378	670	12	117	60	11	1	0.4
RN011382	11/08/1976	2250	691	739	370	670	12	121	63	12	1	0.9
RN011382	31/07/1978	1640	446	674	305	530	14	64	38	6	0.8	2.1
RN011382	24/06/1981	2050	550	641	320	504	14	107	54	15	0.9	9.7
RN011382	19/02/1988	2200	608	742	407	636	9	108	53	12	1	0.2
RN011382	22/07/1988	2185	601	730	395	635	10	110	55	13	0.8	0.1
RN011382	28/09/1990	1960	535	747	377	590	10	97	48	10	1	0.2
RN011397	02/02/1962	664								31	0.7	
RN011595	01/05/1962	1481								22	2.4	
RN011611	22/08/1977	700	83	442	102	184	7	32	29	23	5	20
RN011675	06/11/1977	2320	652	763	375	610	15	140	65	66	0.6	4
RN011675	15/02/1978	2830	772	930	480	744	16	172	75	81	0.4	0.4

RN011811	25/07/1978		1168	622						29		
RN011812	26/07/1978	4340	1366	1089	840	1575	30	52	40	23	1.6	2.6
RN011812	27/07/1978	3020	1139	372	600	610	15	269	118	24	0.7	5.7
RN011812	27/07/1978		1238	409								
RN011812	27/07/1978		1317	546						35		
RN011813	29/07/1978	1230	257	641	180	420	40	28	16	2	0.9	
RN011813	30/07/1978	600	184	204	96	155	12	40	19	2	0.4	
RN011813	30/07/1978	630	126	348	89	180	12	38	16	15	0.5	25
RN011815	03/08/1978	590	18	509	56	210	10	6	5	1	2.6	
RN011815	04/08/1978	590	133	262	106	78	33	74	31	3	0.4	21
RN011815	12/05/1982	1670	520	592	270	420	16	148	52	13	0.5	
RN011816	11/08/1978	1040	267	458	154	238	35	68	48	2	0.5	
RN011816	11/08/1978	900	252	366	156	205	37	60	38	4	0.3	3
RN011816	13/08/1978	670	129	336	102	183	30	28	16	21	0.5	3.9
RN011817	05/09/1978		228	339								
RN011817	23/09/1978	1079	233	366	134	215	16	55	33	2	0.4	0.1
RN011817	24/06/1981	940	220	379	136	209	19	61	32	1	0.4	0.5
RN011817	28/07/1982	1030	244	501	170	275	29	70	30	1	0.5	0.2
RN011819	07/09/1978		396	342								
RN011819	09/09/1978	1230	388	348	205	238	10	136	48	12	0.4	1
RN011819	18/11/1982	1490	460							11	0.5	
RN011819	09/12/1983	2430	730	723	436	621	15	164	61	16	0.6	0.1
RN011819	23/04/1992	1065	315	385	171	226	11	103	36	2	0.3	0.4
RN011820	11/09/1978		485	744								
RN011820	08/10/1978	1740	475	723	310	538	11	88	45	18	1.4	0.4
RN011951	15/06/1978		5740	378								
RN011952	16/06/1978		5450	482								
RN011953	17/06/1978	3550										
RN011954	23/06/1978	1410	327	464	343	357	5	96	44	1	1	
RN012039	11/01/1979	2330	686	877	340	764	12	67	53	37	5.1	0.1
RN012040	16/12/1978	1158	235	497	219	351	12	46	24	12	2.2	2.7
RN012040	18/01/1979	1163	220	525	206	330	8	44	24	10	2.1	12.9

RN012044	02/02/1979	1750	405	714	293	594	23	36	25	38	2.2	1.2
RN012199	16/04/1959	1849									0.6	
RN012202	29/11/1979	810	235	287	118	194	12	54	24	1	0.4	0.1
RN012202	04/08/1983	1040	330	307	158	229	19	88	34	1	0.3	10
RN012202	14/10/1989	640	194									
RN012211	28/10/1955	188	15	122	14	20	1	7	10			
RN012212	17/09/1956	219								11		
RN012215	15/09/1953	7859	1952	1775	1556	2309		33	176		11	
RN012215	17/09/1956	285	25	154		65	3	5	8	13		
RN012216	18/09/1956	129	20	56		10	7	1	12	11		
RN012218	22/10/1956	290	30	146		65	3	11	9	9	0.3	
RN012220	28/08/1956	539	35	207	67	85	11	23	9	100	0.7	1
RN012221	05/03/1954	3381	462	1049	697	800	328	8	14		5.2	
RN012221	27/08/1956	2804	480	932	388	871	3	10	16	30	5.4	1
RN012221	31/12/1957	5667	1680	908	1289	1500	10	126	141	11	2.2	
RN012222	10/12/1955	1471	335	310	280	500		20	24		2.16	
RN012222	20/08/1956	1728	490	256	353	510	5	9	40	15	0.3	
RN012223	20/08/1956	936								7	5	
RN012224	28/08/1956	316								10		
RN012225	28/05/1956	5646								16	0.3	
RN012226	03/04/1957	1759									0.6	
RN012228	20/02/1956	2269	440	573	235	750	10	11	58	6	1.5	
RN012229	28/08/1956	1012	185	437	35	273	9	11	16	26	1.6	1
RN012233	16/06/1960	680								11	5.4	
RN012235	13/05/1958	1563	305	576	188	340	8	82	44	20	0.8	
RN012238	27/08/1956	1526								5	0.4	
RN012247	15/10/1963	396									1.5	
RN012248	23/01/1957	937	250	285	133	115	16	77	52	9		
RN012250	04/02/1997	279	37	190	34	76	8	17	10	1	0.2	1.9
RN012251	03/10/1961	2595									0.7	
RN012252	07/01/1957	744	105	359		175	33	26	27	87		
RN012254	03/06/1957	1576	235	627	199	450	5	15	15	21	2	

RN012259	31/12/1957	390	35	183	68	70	6	14	12	1	1.5	
RN012259	09/07/1993	336	46	221	45	91	10	17	9	1	0.3	0.5
RN012272	07/09/1956	152	7	98	15	10	5	7	10			
RN012274	17/08/1960	6925								10	0.7	
RN012275	08/03/1960	690								3	0.6	
RN012276	07/09/1956	157	20	73	7	12	7	16	6	4		
RN012278	28/08/1956	105	10	67	20	10	4	3	8	2	1	
RN012279	18/09/1956	197	20	122		25	10		16	4		
RN012280	06/06/1979	1040	277	437	154	280	15	68	36	21	0.4	0.5
RN012283	07/07/1964	469									0.6	
RN012284	11/09/1964	1032	185	418	115	220	12	52	25	5	0.3	
RN012290	21/11/1956	201	20	93	16	25	7	10	11	5	0.06	1
RN012291	29/04/1958	807	135	215	74	215	10	12	13	16	0.2	
RN012293	14/08/1964	410									0.6	
RN012295	25/02/1963	423									1	
RN012297	14/10/1979	1580	366	761	235	463	14	68	41	11	0.7	0.5
RN012298	23/01/1963	734									0.4	
RN012306	28/07/1964	555									0.4	
RN012473	24/06/1980	1180	305	454	225	293	13	86	44	12	0.6	1.9
RN012651	01/06/1980	740	167	389	116	201	13	44	22	8	0.8	2.4
RN012718	24/07/1980	1230	358	409	210	365	37	44	24	2	0.7	8.3
RN012732	01/09/1980	1147										
RN012732	01/09/1980	2001										
RN012732	01/09/1980	1314										
RN012732	01/09/1980	1120										
RN012732	01/09/1980	1443										
RN012732	12/05/1982	1490	400	586	270	396	27	90	45	10	0.6	0.5
RN012732	05/11/1982	1530	370	611	290	441	45	51	51	16	0.4	1.5
RN012732	01/06/1983	1450	340	756	255	405	37	94	48	14	0.4	2.3
RN012732	28/09/1989	1790	344									
RN012733	11/12/1980	1250	308	503	270	345	17	70	38	3	0.4	0.8
RN012733	10/08/1984	1690	410	686	293	467	19	84	42	9	0.4	4.4

RN012983	05/11/1982	1760	440	607	318	492	19	73	42	1	1.8	4.9
RN012983	28/06/1983	2090	580	729	377	574	30	128	67	11	0.9	0.1
RN012983	10/07/1984	1890	500	712	368	535	16	98	48	14	1.2	0.1
RN012983	02/10/1989	1495	325									
RN013195	16/09/1981	1940	1060		610	814				45	0.6	
RN013195	09/12/1983	2500	750	741	445	639	15	164	62	11	0.5	0.1
RN013197	05/10/1982	890	210	378	154	221	18	61	31	1	0.6	0.1
RN013235	07/10/1982	950	260	287	154	265	13	37	16	21	0.6	0.2
RN013235	11/07/1984	800	230	275	114	232	9	36	15	2	0.3	4
RN013236	08/09/1982	540	130	223	80	152	11	25	9	1	0.5	
RN013236	11/07/1984	880	240	321	125	244	11	44	18	2	0.3	6.4
RN013237	06/09/1982	520	130	226	79	153	13	27	10	1	0.3	
RN013237	07/10/1982	510	124	259	78	163	11	26	10	1	0.3	0.6
RN013238	02/09/1982	760	190	296	116	240	11	29	10	3	0.6	
RN013346	28/10/1982	880	280	268	112	226	27	45	19	1	0.4	1.7
RN013624	11/01/1984	2000	380	573	406	396	24	183	57	230	0.9	0.2
RN013625	19/03/1984	830	240	300	154	244	11	42	21	1	0.5	0.6
RN013625	12/05/1984	790	220	291	136	248	11	33	17		0.6	0.1
RN013625	16/04/1997	463	109	195	74	132	7	19	9	1	0.5	0.9
RN013625	01/06/1999	371	75	185	53	106	6	16	8	1	0.5	0.1
RN013625	22/03/2000	236	28	168	29	72	5	9	4	1	0.6	0.2
RN013625	18/08/2000	365	110	153	34	86	6	20	10	1	0.4	0.1
RN013771	30/11/1983	870	260	310	141	243	15	53	25	1	0.4	0.2
RN013860	03/02/1984	1040	270	373	181	288	12	59	31	2	1.4	0.8
RN013860	09/11/1994	1690	510	620	343	457	13	123	51	7	0.3	0.6
RN013860	27/05/1996	839	190	400	140	228	21	50	27	1	0.6	6.2
RN013912	03/01/1984	1480	480	456	234	440	22	70	27	3	0.7	0.1
RN013912	03/01/1984	1290	380	427	205	366	24	70	24	5	1	0.1
RN013912	04/01/1984	1200	380	311	221	329	16	70	36	2	0.3	0.1
RN013912	04/01/1984	1240	400	345	229	355	20	74	33	2	0.7	1
RN013912	05/01/1984	315	54	185	35	77	7	25	6	2	0.5	0.1
RN013913	11/01/1984		60	263		122	9	20	5		0.2	0.8

RN013913	11/01/1984	205	24	135	17	51	4	9	5	3	0.4	0.3
RN013913	12/01/1984	230	35	135	22	55	5	11	5	6	0.6	0.1
RN013914	16/01/1984	1060	335	292	188	288	16	64	29	1	0.6	0.1
RN013914	16/01/1984	980	320	271	159	253	17	61	28	1	0.2	
RN013914	16/01/1984	1290	395	375	238	355	24	72	29	3	0.6	0.1
RN013915	19/01/1984		200	184	117	206	16	27	12	4	0.9	0.1
RN013915	20/01/1984	1320	440	335	236	334	32	84	40	1	0.3	
RN013916	24/01/1984	1310	400	454	181	402	29	52	23	12	1.7	0.1
RN013917	27/01/1984	1260	380	392	288	346	19	84	83	3	0.7	0.3
RN013917	28/01/1984	1340	480	237	235	165	17	162	66	14	0.4	0.1
RN013917	28/01/1984	1410	365	348	226	330	39	102	42	130	0.3	
RN013918	31/01/1984	3780	1400	634	790	1075	29	224	105	25	0.5	1
RN013918	31/01/1984	4541	1500	646	938	1610	23	54	30	32	4.4	
RN013918	31/01/1984		1800	723	941	1789	25	6	3	32	16.7	0.1
RN013919	20/03/1984		78	162	50	94	6	20	10	1	0.4	0.1
RN013921	04/02/1984	850	150	393	161	214	7	50	27	1	1.2	
RN013923	11/04/1992	2065	550	770	360	684	17	43	25	17	1.3	11.7
RN013923	24/10/1995	1320	330	555	230	438	14	34	20	6	1.1	4
RN013923	30/07/1996	1900	524	734	360	626	14	37	31	9	1.8	2.2
RN013923	14/04/1997	2073	559	778	395	650	23	65	45	11	1.3	1.35
RN013923	07/07/1998	1613	396	675	312	526	16	45	28	7	1.2	8.8
RN013923	01/06/1999	1257	307	576	259	404	14	33	19	5	1.5	0.2
RN013923	21/03/2000	1567	398	621	264	477	18	50	35	6	1.3	1.5
RN013923	21/08/2000	1536	367	651	266	414	18	55	33	6	1.3	0.3
RN014095	09/09/1984	1030	300	333	181	286	1	62	26	1	0.2	
RN014095	29/03/1988	730	184	303	112	230	9	37	14	1	0.4	0.4
RN014095	22/07/1988	645	160	302	78	189	7	35	13	1	0.4	0.1
RN014095	21/02/1992	1185	390	310	211	310	13	77	31	2	0.3	0.8
RN014095	07/11/1994	881	294	266	131	224	11	60	24	1	0.3	0.2
RN014095	08/02/1995	395	99	181	25	96	9	32	11	4	0.3	0.3
RN014095	11/10/1995											
RN014095	11/10/1995	607	204	240	70	145	9	52	21	1	0.3	0.1

RN014095	31/07/1996	646	221	217	97	168	9	41	18	1	0.3	0.2
RN014095	16/04/1997	340	71	205	46	89	8	12	7	1	0.3	0.16
RN014095	17/07/1998	466	111	202	65	121	6	23	9	1	0.3	3.2
RN014095	30/06/1999	568	158	209	94	154	8	35	14	1	0.3	0.1
RN014095	24/03/2000	226	25	143	27	53	6	17	7	1	0.3	0.1
RN014095	21/08/2000	351	73	220	41	72	6	28	12	1	0.5	0.1
RN014196	23/03/1985	2510	870	546	425	580	12	194	77	26	0.3	0.4
RN014222	05/06/1985	2070	600	732	368	540	12	141	49	14	0.5	1.4
RN014407	30/08/1985	2130	600	732	355	580	11	126	50	15	0.5	0.3
RN014407	09/05/1987	2120	624	776	377	600	10	140	51	13	0.6	0.4
RN014407	22/02/1988	2080	588	747	365	568	12	142	46	9	0.6	0.1
RN014407	12/05/1988	1635	426	660	279	429	11	124	40	6	0.8	0.2
RN014407	13/03/1992	1830	515	671	308	511	11	106	37	10	0.7	0.1
RN014407	22/09/1992											
RN014407	22/09/1992	1840	450	710	300	516	10	113	34	6	0.7	0.1
RN014407	11/11/1992											
RN014407	11/11/1992	1720	466	657	309	497	10	105	35	6	0.7	0.1
RN014407	12/12/1992											
RN014407	14/12/1992	1730	470	643	302	504	10	105	34	7	0.7	0.1
RN014407	12/01/1993											
RN014407	12/01/1993	1720	466	642	299	503	10	109	35	6	0.7	0.1
RN014407	08/11/1994	1730	475	664	327	474	10	111	36	6	0.7	0.1
RN014417	03/02/1986	620	140	255	103	171	8	27	12	1	0.5	0.5
RN014417	11/12/1992	494	103	232	79	160	6	14	6	2	0.4	5.3
RN014417	11/10/1995											
RN014417	11/10/1995	268	43	164	36	65	6	16	7	1	0.3	0.8
RN014429	18/03/1986	960	185	506	141	254	18	53	33	4	0.4	0.5
RN014432	09/12/1996	1180	216	547	198	366	12	37	22	3	0.9	0.1
RN014433	25/04/1986	1900	460	712	308	532	17	90	48	13	1	0.2
RN014433	19/02/1988	1710	387	726	302	484	14	75	40	10	1.1	0.1
RN014433	22/07/1988	1630	342	725	265	448	13	70	35	11	0.9	0.1
RN014433	13/03/1992	1430	307	688	225	472	11	32	18	10	2.4	0.1

RN014433	22/09/1992											
RN014433	22/09/1992	1260	247	605	201	402	12	42	21	7	1	0.1
RN014433	11/11/1992	1240	262	606	207	402	13	41	22	6	1	0.1
RN014433	12/12/1992											
RN014433	14/12/1992	1240	265	605	211	398	13	43	23	8	1	0.1
RN014433	12/01/1993											
RN014433	12/01/1993	1230	265	604	192	391	13	44	24	7	1.1	0.1
RN014433	08/11/1994	1200	277	566	209	360	13	39	22	10	0.9	0.1
RN014433	08/02/1995	1190	277	573	214	392	12	43	21	4	0.9	0.1
RN014433	29/04/1997	1214	245	492	210	380	12	42	24	3	0.9	0.1
RN014433	14/07/1997	1116	197	540	196	334	11	43	21	3	0.8	0.1
RN014433	13/07/1998	1077	235	511	191	320	10	38	22	3	0.5	1.5
RN014433	24/03/2000	1006	225	478	168	288	10	38	20		0.7	0.1
RN014433	14/11/2000	1091	245	531	218	326	11	44	24		0.7	0.4
RN014836	01/05/1986	765	182	359	126	197	13	47	26	1	0.4	0.3
RN014837	21/05/1986	580	125	274	85	152	7	34	15	5	0.3	0.8
RN014837	15/02/1988	540	113	251	77	138	7	31	13	5	0.4	0.1
RN014837	21/07/1988	280	40	173	27	60	6	23	8	1	0.2	5.1
RN014837	28/09/1989	515	118	259	72	138				3		
RN014837	12/03/1992	440	66	266	62	113	9	26	11	5	0.4	0.8
RN014837	22/09/1992	545	100	264	81	141	7	33	13	6	0.3	0.2
RN014837	11/11/1992	558	107	313	81	141	7	47	13	6	0.4	0.1
RN014837	12/12/1992											
RN014837	14/12/1992	488	100	260	77	136	7	31	12	5	0.4	0.1
RN014839	30/04/1986	2020	520	785	309	598	16	82	44	9	1.4	0.7
RN014839	22/07/1988	1675	356	729	268	468	12	63	35	9	1.2	0.3
RN014839	08/11/1994	1430	317	677	249	471	11	34	20	4	2.1	0.1
RN014839	08/02/1995	1350	307	662	241	466	11	27	18	3	2.1	0.1
RN014839	27/05/1996	1390	305	647	220	462	11	40	22	3	1.6	0.1
RN014839	09/12/1996	1133	235	550	195	370	10	23	14	3	1.5	0.1
RN014839	29/04/1997	1226	270	591	222	382	12	44	24	3	0.9	0.1
RN014839	13/07/1998	1411	302	638	246	397	12	46	30	8	0.9	0.5

RN014839	24/03/2000	1513	317	747	269	450	13	50	29	9	1.2	0.1
RN014839	14/11/2000	1368	305	634	256	426	12	37	24	9	1.5	1.1
RN015094	08/09/1988	1765	387	793	332	608	14	64	30	14	0.7	
RN015094	11/04/1992	1615	540	295	335	372	14	108	50	8	0.3	5.1
RN015094	24/10/1995	408	56	292	46	139	5	9	4	1	1.1	0.4
RN015094	30/07/1996	3360	1020	959	770	873	23	158	101	31	1.6	0.1
RN015094	14/04/1997	675	71	438	137	233	7	16	9	1	1.3	1.31
RN015094	07/07/1998	512	62	374	79	155	7	13	7	1	0.7	0.7
RN015094	02/06/1999	576	119	325	87	182	11	16	7	1	0.6	0.1
RN015094	21/03/2000	450	41	332	57	150	8	10	5	4	0.6	0.2
RN015094	21/08/2000	688	28	358	107	161	16	35	18	1	0.3	0.1
RN015095	24/03/1988	1675	490	612	255	486	20	71	41	6	0.8	209
RN015096	26/03/1988	985	260	405	146	299	8	49	25	6	0.8	
RN015096	27/03/1988	950	255	370	151	256	8	52	24	5	0.6	10.7
RN015096	22/04/1988	835	218	336	126	232	7	43	20	6	0.5	0.3
RN015099	14/04/1992	420	86	215	65	112	7	23	12	3	0.2	0.1
RN015099	22/09/1992	405	77	199	58	110	6	22	9	3	0.2	0.1
RN015099	11/11/1992											
RN015099	11/11/1992	379	81	204	58	109	7	21	9	2	0.2	0.1
RN015099	12/12/1992											
RN015099	14/12/1992	397	79	210	58	110	7	21	10	3	0.3	0.1
RN015099	08/11/1994	372	71	214	59	105	7	19	9	6	0.2	0.1
RN015099	08/02/1995	379	69	213	57	105	7	9	9	3	0.2	0.1
RN015099	27/05/1996	404	62	233	62	110	6	26	9	2	0.3	0.1
RN015099	08/12/1996	404	62	240	57	109	6	19	9	3	0.3	0.1
RN015099	29/04/1997	400	67	254	63	110	6	17	9	3	0.3	0.1
RN015099	14/07/1997	406	60	331	57	118	6	17	10	3	0.3	0.1
RN015099	24/03/2000	355	62	204	15	95	6	16	8	2	0.3	0.2
RN015099	14/11/2000	345	58	232	46	92	6	22	8	1	0.3	
RN015211	25/07/1989	710	176	203	95	128	11	60	27	9	0.2	0.5
RN015211	08/11/1989	650	193									
RN015211	14/04/1992	780	243	257	115	165	11	63	27	5	0.3	0.1

RN015211	22/09/1992											
RN015211	22/09/1992	823	257	258	117	176	12	74	30	6	0.3	0.1
RN015211	11/11/1992											
RN015211	11/11/1992	818	270	257	108	168	11	78	30	6	0.3	0.1
RN015211	12/12/1992											
RN015211	14/12/1992	829	265	255	129	182	12	75	31	5	0.3	0.1
RN015211	08/11/1994	969	327	276	158	201	13	97	37	6	0.3	0.1
RN015211	09/02/1995	974	337	260	151	193	14	99	39	5	0.2	1.3
RN015752	02/08/1990	2830	550	1421		970	41		4		6.1	
RN015753	09/08/1990	3600	1100	1125	568	1090	26	110	60	14	0.4	0.1
RN015753	19/09/1991											
RN015753	20/09/1991	2810	822	879	509	908	22	94	49	7	0.3	0.1
RN015753	23/07/1992	960		218	185	161	5	7	4	30	0.9	
RN015753	24/07/1992	1160		189	124	132	5	7	5	45	1.1	
RN015753	08/09/1992	1410	342	565	251	453	10	41	22	3	0.5	0.1
RN015753	15/12/1992	1070	284	387	193	330	9	32	20	1	0.4	7.3
RN015753	12/01/1993	1200	294	495	227	385	10	39	20	1	0.5	1.2
RN015760	22/09/1990	2210	584	844	445	680	12	95	53	13	0.8	2.2
RN015760	27/09/1990	2220	584	867	428	700	10	92	50	12	0.8	0.1
RN015760	03/10/1990	2415	620	904	419	740	10	95	48	11	1.1	0.1
RN015760	13/03/1992	2580	683	1003	451	810	11	94	49	11	1.4	0.9
RN015760	22/09/1992											
RN015760	22/09/1992	2240	543	867	389	695	10	81	40	6	1.5	0.2
RN015760	11/11/1992	2180	563	855	413	698	10	76	39	10	1.5	0.1
RN015760	08/11/1994	2140	550	845	387	698	2	83	39	10	1.4	0.1
RN015760	08/02/1995	2240	584	879	470	710	10	85	44	11	1.5	0.1
RN015760	09/12/1996	1782	426	750	311	555	8	56	31	7	1.6	0.1
RN015760	13/07/1998	1387	326	632	231	404	7	50	27	2	1.1	0.4
RN015760	24/03/2000	1347	327	653	232	396	9	54	30		1.3	0.1
RN015761	06/02/1991	1210	280	539	189	364	25	60	32	14	0.9	0.5
RN015761	09/12/1996	1065	230	516	173	312	21	36	24	4	0.9	0.3
RN015761	29/04/1997	1003	221	576	177	292	15	46	24	5	0.9	0.1

RN015761	14/07/1997	1044	235	473	178	277	14	47	25	6	0.8	0.2
RN015761	24/03/2000	886	213	401	132	237	12	42	22	5	0.6	0.1
RN015761	14/11/2000	882	220	398	139	233	14	43	25		0.6	0.3
RN015904	15/07/1994	516	98	287	80	145	8	31	14	1	0.4	0.2
RN016250	15/04/1997	408	69	220	82	121	13	19	10	1	0.3	
RN016250	16/04/1998	343	64	202	48	99	7	15	6	1	0.2	
RN016250	07/07/1998	287	20	150	29	62	5	7	3	1	0.2	5.9
RN016250	01/06/1999	334	81	174	45	93	8	17	7	1	0.2	
RN016250	22/03/2000	242	28	146	29	63	6	8	3	1	0.3	
RN016250	18/08/2000	184	4	131	23	50	5	7	3	1	0.3	0.1
RN016356	19/03/1994	870	216	333	162	193	9	87	29	1	0.5	0.5
RN016356	22/03/1994	836	207	332	151	191	9	79	26	1	0.4	0.8
RN016356	23/03/1994	911	223	350	168	198	9	95	30	1	0.4	0.3
RN016356	09/11/1994	1030	275	387	199	212	9	116	33	2	0.4	0.1
RN016357	10/03/1994	922	212	365	174	211	8	88	28	1	0.5	2.3
RN016366	26/10/1995	2950	874	656	750	876	7	98	73	21	0.7	0.3
RN016366	20/08/1996	2687	813	631	655	850	6	60	69	18	0.4	0.2
RN016366	21/08/1996	2690	813	631	660	850	6	60	69	18	0.4	0.2
RN016366	17/04/1997	2689	735	825	732	815	7	75	60	17	1	0.55
RN016366	09/07/1998	2738	739	805	593	773	5	118	58	18	0.8	0.2
RN016366	23/06/1999	2572	723	757	612	770	6	81	54	19	0.8	0.1
RN016366	24/03/2000	2662	708	805	625	800	6	120	62	19	1	
RN016366	15/08/2000	2796	780	779	715	821	7	93	65	18	1.5	0.1
RN016605	23/02/1996	1370	413	450	220	395	11	53	28	1	0.7	1
RN016605	15/04/1997	1891	559	667	342	575	15	69	50	1	0.8	0.31
RN016605	25/10/1997	1306	427	455	223	401	11	54	31	1	0.7	0.1
RN016605	17/12/1997	1367	451	470	214	375	10	73	29	1	0.8	0.2
RN016605	27/02/1998	1363	422	467	215	381	11	59	32	1	1.6	0.3
RN016605	25/03/1998	1351	418	469	233	380	11	60	30	1	0.7	0.3
RN016605	16/04/1998	1356	422	470	207	384	10	56	29	1	0.8	0.6
RN016605	22/05/1998	1362	412	461	195	388	10	57	30	1	0.8	0.1
RN016605	18/06/1998	1394	436	463	220	388	11	59	32	1	0.1	0.3

RN016605	13/08/1998	946	197	487	103	187	6	72	52	7	0.6	0.3
RN016605	24/09/1998	1343	374	464	206	357	11	48	32	1	0.8	0.3
RN016605	29/10/1998	1380	446	468	215	478	11	57	29	1	0.8	0.3
RN016605	25/11/1998	1385	424	459	218	376	10	55	25	1	0.8	0.2
RN016605	25/03/1999	1425	460	462	253	410	12	63	31	1	0.8	0.1
RN016605	29/04/1999	1379	436	462	288	392	11	60	30	1	0.8	0.3
RN016605	02/09/1999	1389	448	492	261	406	10	58	30	1	0.8	0.1
RN016605	21/03/2000	1990	574	620	329	552	14	92	47	1	0.7	0.2
RN016605	21/08/2000	1429	428	479	214	366	11	63	31	1	0.8	0.1
RN016606	08/03/1996	14000	5870	399	3000	3370	31	862	463	2	0.1	
RN016606	15/04/1997	14980	6150	788	3020	3720	40	780	480	5	0.3	
RN016606	17/12/1997	15860	6432	736	2985	3838	28	1255	448	2	0.3	
RN016606	16/07/1998	14640	6144	836	3200	3434	28	1020	457	5	0.2	3.9
RN016606	03/06/1999	15896	6336	860	3770	3600	30	1000	440		0.5	
RN016606	22/03/2000	13300	6014	863	3160	3700	30	1030	500		0.2	
RN016606	22/08/2000	14370	6200	867	3185	3470	30	997	454		0.2	0.8
RN016631	06/05/1997	1005	320	379	145	248	12	74	30	7	0.4	0.5

Table C-3 Total organic carbon analyses

RN	Date	Total Organic Carbon mg/L	Date	Total Recoverable Hydrocarbons
1909	7/6/1990	1.8		
4442	14/12/1992	0.9		
5808	27/8/1990	1.7		
6518	7/6/1990	4.2		
6518	12/06/1992	2.0		
6518	14/12/1992	1.7		
6782	14/12/1992	0.9	25/3/2002	ND
13625	18/7/1990	7.6		
13625	27/8/1990	1.2		
13625	11/6/1992	3.0		
13915	27/8/1990	1.5		
13916	18/7/1990	30.2		
13916	27/8/1990	4.1		
13916	11/6/1992	5.0		
13920	27/8/1990	0.9		
14095	27/8/1990	1.2		
14407	7/6/1990	3.2		
14407	12/06/1992	2.0		
14407	14/12/1992	1.4		
14433	14/12/1992	1.3	25/3/2002	ND
14837	14/12/1992	0.5		
15099	12/06/1992	1.0	25/3/2002	ND
15099	14/12/1992	0.3		
15211	14/12/1992	0.6		

(1) ND is not detected. All of the 4 categories of chain length were below detection limits, that is the total is < 0.25 mg/L.

Table C-4 Gross alpha and beta activity

RN	Date	Gross alpha, mBeq/L	Gross beta, mBeq/L
3706	27/6/1985	33	<10
5829	27/6/1985	13	<10

Table C-5 Pesticides and other organics

RN	3064	15753	14407	14433	3758
Date	11/01/1993	11/01/1993	11/01/1993	12/01/1993	12/01/1993
Total VCH μg/L	ND	ND	ND	14.0	ND
Trichloroethylene				2.0	
Tetrachloroethylene				12.0	
Total insecticides μg/L	0.18	0.12	0.02	0.06	0.24
Dieldrin μg/L	0.01	0.01	ND	0.04	0.01
Lindane μg/L	0.12	0.09	0.02		0.17
Malathion μg/L	0.05	0.02	ND	0.02	0.06
Total Herbicides μg/L	ND	ND	ND	ND	ND
PCB's μg/L	ND	ND	ND	ND	ND
PAH's μg/L	ND	ND	ND	ND	ND
Total petroleum hydrocarbons mg/L	5.90	ND	ND	ND	7.00
GC/MIS scan, methylene chloride					Detected
Phenols	0.018	0.018	0.010	<0.010	0.056
Cyanide	<0.05	<0.05	<0.05	<0.05	<0.05

ND, not detected
VCH, volatile chlorinated hydrocarbons

Table C-6 Bacteriological tests in the Town Basin

Bore	Date Time	Plate Count ()	Total coliform (count/ 100 mL)	Faecal coliform (count/ 100 mL)	Faecal Streptococci (count/ 100 mL)	Enterococci count (count/ 100 mL)
RN003064	11-Jan-93	8900		0		
RN003758	12-Jan-93	6200				
RN004442	22-Sep-92	10000	0	0		
RN004442	11-Nov-92	0	0	0		
RN004442	12-Dec-92	170	50	2		
RN004656	07-Jul-78		0	0		0
RN006518	09-Jun-92	25	0	0		
RN006518	22-Sep-92	10000		310		
RN006518	11-Nov-92	23		700		
RN006518	12-Dec-92	53	94	0		
RN006782	09-Jun-92	5	14	2		
RN006782	22-Sep-92	10000	0	0		
RN006782	11-Nov-92	0	2	0		
RN006783	12-Dec-92	100	4	0		
RN007506	06-Apr-76		20	1	20	
RN011233	11-May-77		30	0		1
RN011233	15-Jun-77		2	0		0
RN014407	22-Sep-92	10000	0	0		
RN014407	11-Nov-92	0	0	0		
RN014407	12-Dec-92	0	0	0		
RN014407	12-Jan-93	54	0	0		
RN014433	22-Sep-92	10000	0	0		
RN014433	12-Dec-92	5	2	0		
RN014433	12-Jan-93	92	8	0		
RN014837	22-Sep-92	10000	0	0		
RN014837	11-Nov-92	0	0	0		
RN014837	12-Dec-92	4	0	0		
RN015099	09-Jun-92	36	16	0		
RN015099	22-Sep-92	10000	0	0		
RN015099	11-Nov-92	0	0	0		
RN015099	12-Dec-92	23	0	0		
RN015211	22-Sep-92	10000	0	0		
RN015211	11-Nov-92	0	72	0		
RN015211	12-Dec-92	32	6	3		
RN015753	11-Jan-93	4300		0		
RN015760	22-Sep-92	10000	0	0		
RN015760	11-Nov-92	5	0	0		

APPENDIX D

POTENTIOMETRIC SURFACES AND DIFFERENCES

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LIST OF FIGURES

1957

In 1957 (Fig. D-1) the grid was very sparse. The hydraulic gradient was away from the Todd, probably part pumping induced.

12/ 1957

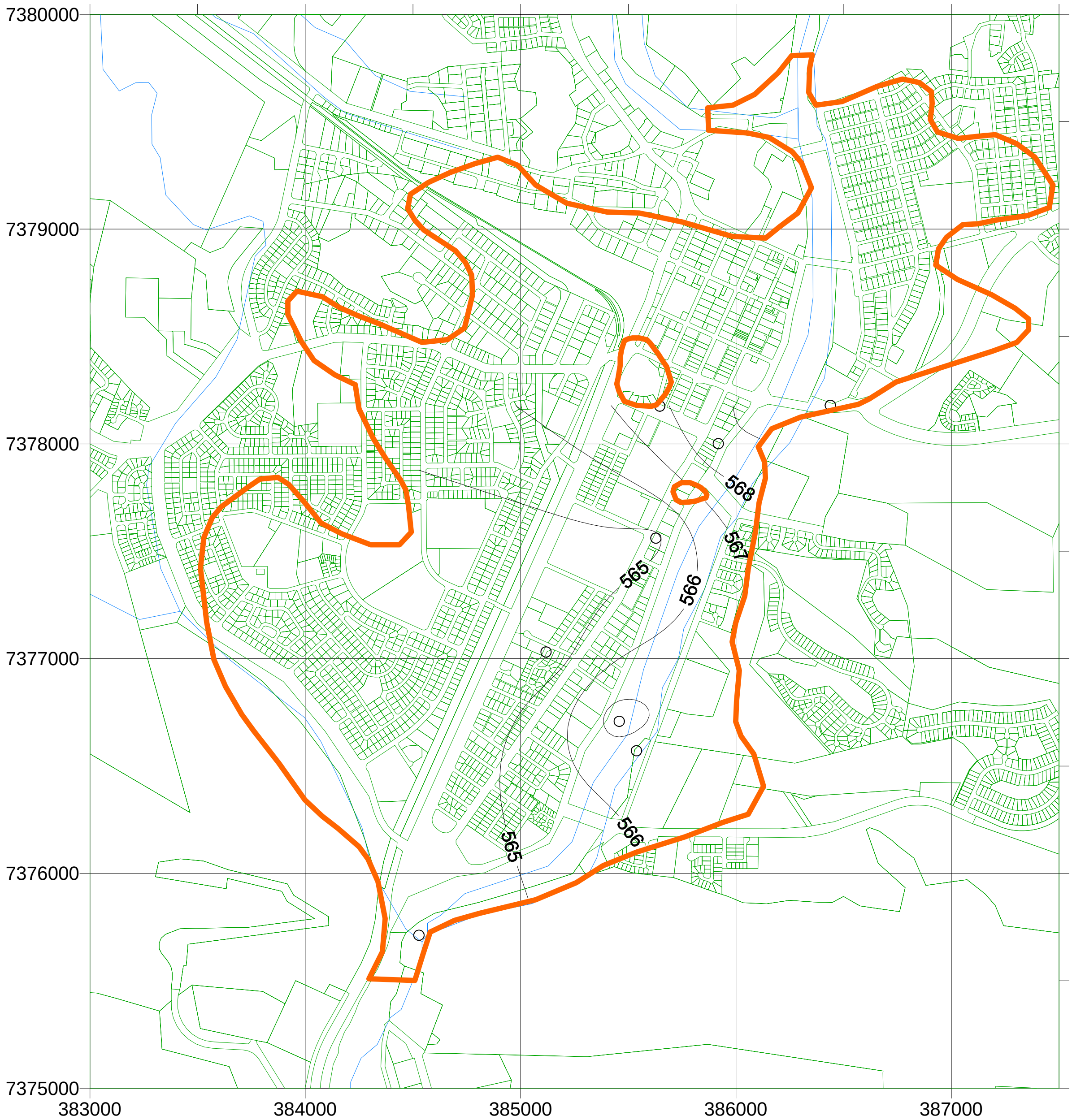

Figure-D 1 Potentiometric Surface at 12/1957

1960
At this time the grid was too limited to draw conclusions. Steep gradients are apparent at the boundary of the Northern and Southern Zones

22/01/60

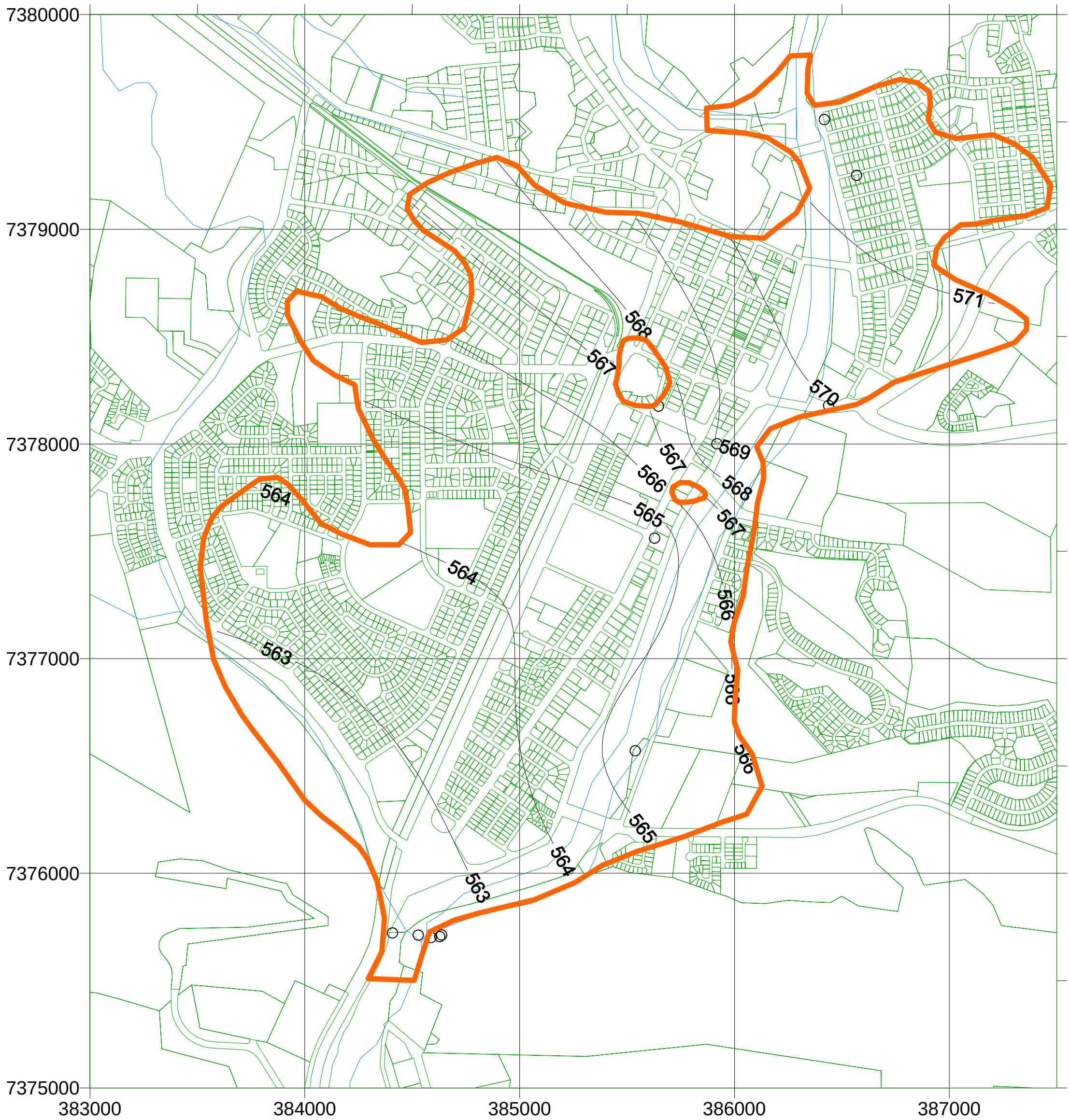

Figure-D 2 Potentiometric Surface 01/1960

1964

By this time the grid had been extended to west. Some tight contours due to pumping are evident. There is a distinct gradient from the Gillen toward the Gap area. Note that Gillen was not developed at this time.

23/10/64

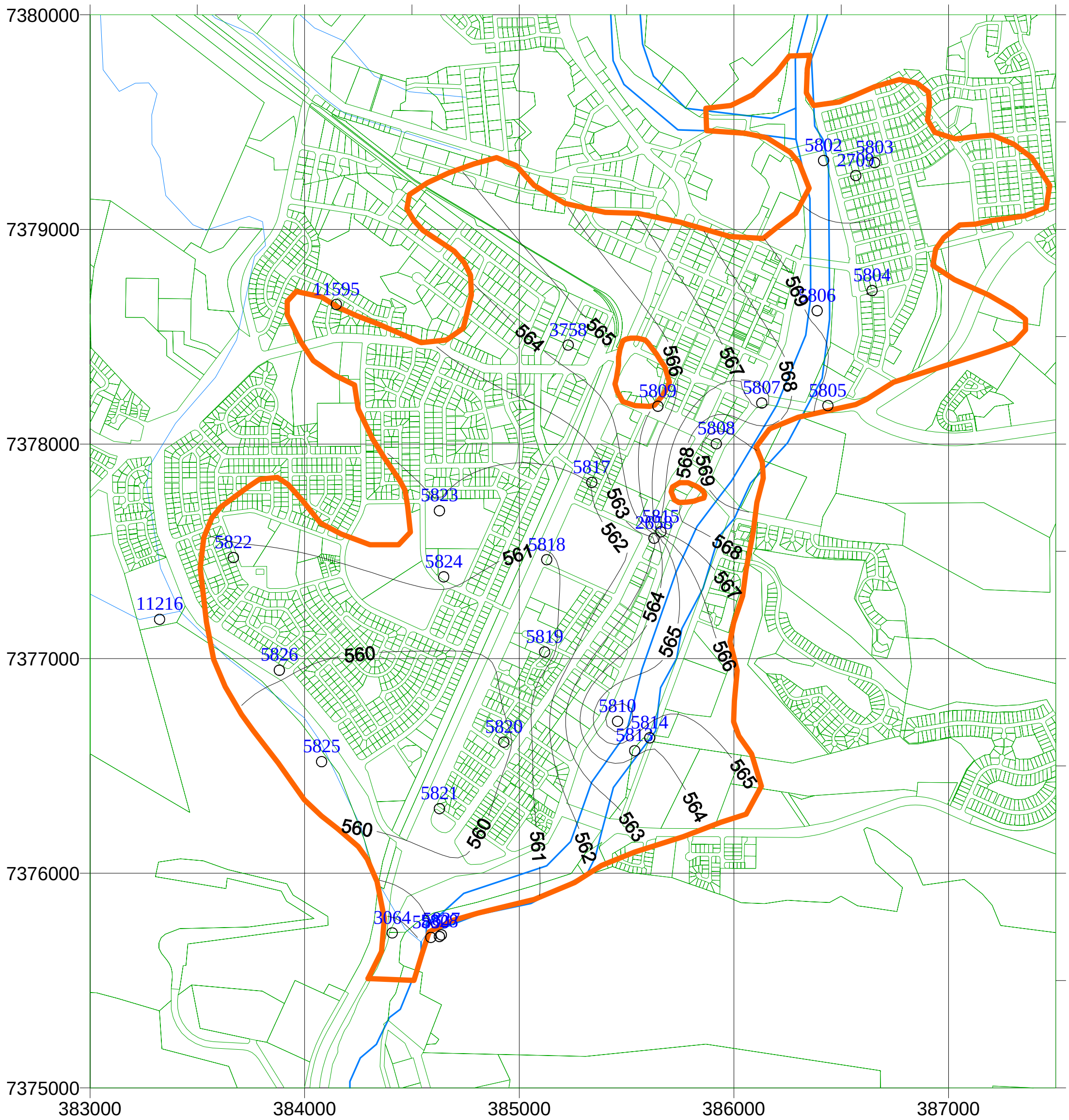

Figure-D 3 Potentiometric Surface 23/10/1964

1970

12/05/70

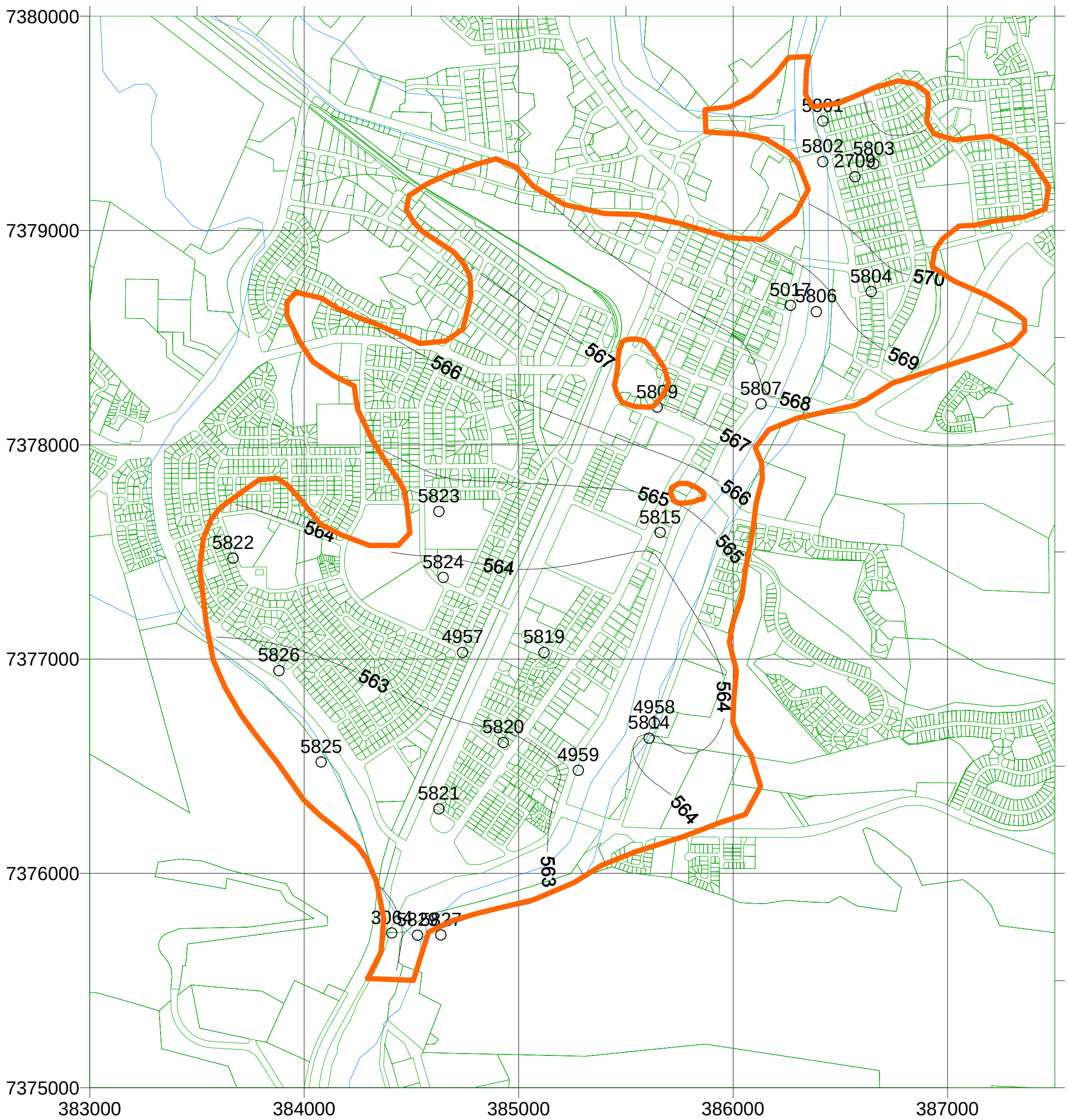

Figure-D 4 Potentiometric Surface 12/05/70

1972

At this time the Todd is an obvious source of recharge. There is a definite gradient from the Todd toward the main aquifer zone.

03/72

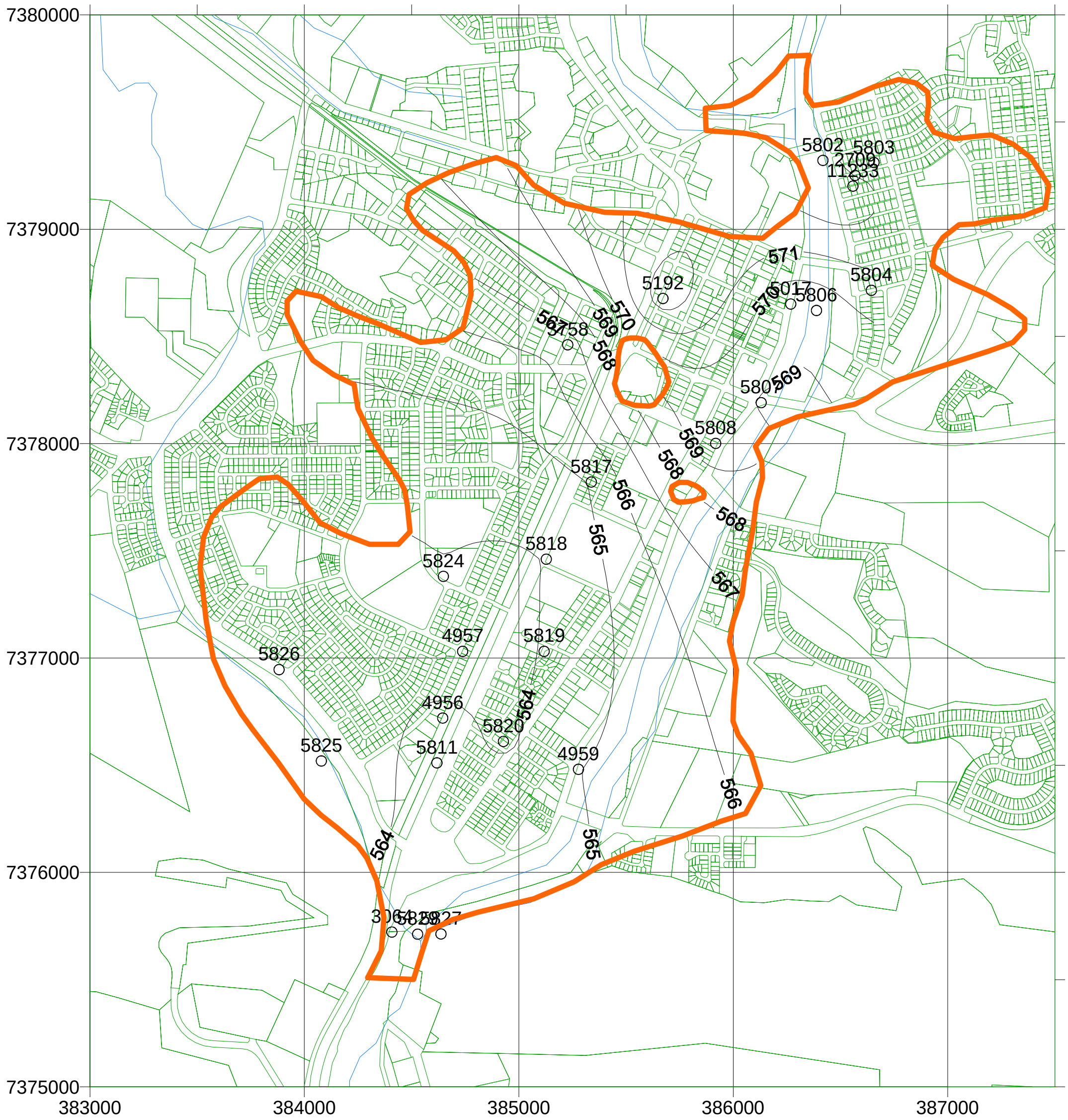

Figure-D 5 Potentiometric Surface 03/72

1975

This is the earliest available whole of basin monitoring (Fig.-D 6) after the extremely wet year of 1974. The basin would have been still full at that time. The Todd is not an obvious source of recharge, showing that extensive direct infiltration had occurred. Figure-D 7, showing the water level rise from the previous monitoring demonstrates this more clearly. The greatest rises in water level of some 5 to 6 m have occurred in the western part of the basin, compared to some 3 or 4 m near the Todd River. From this it is concluded that some 2 m of water level rise is due to direct infiltration. This implies that around 140 mm of rainfall became recharge in the period from March 1972 to July 1975.

Surfer was used to estimate diffuse recharge in the Southern Zone as follows:

Rises in water level near the Todd were about 3 m, hence it was assumed that rises above this over the rest of the basin were diffuse recharge.

An increase in saturated volume of 9288677 m^3 was calculated, giving an increase in storage of 650 ML.

The assumed area of the Southern Zone is 5.3 km^2, giving an average recharge of 123 mm.

2/07/75

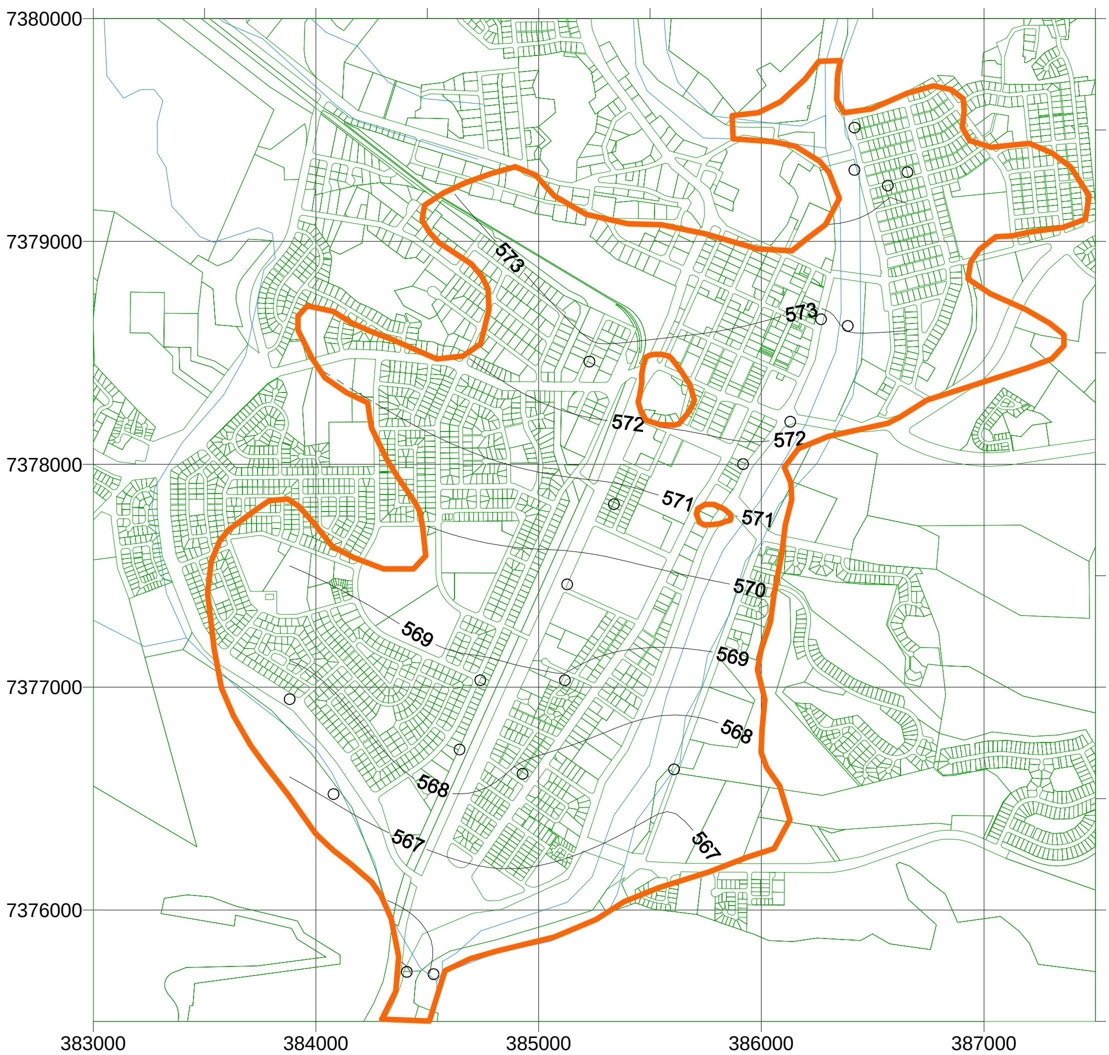

Figure-D 6 Potentiometric Surface 07/75

2/07/75 minus 28/03/72

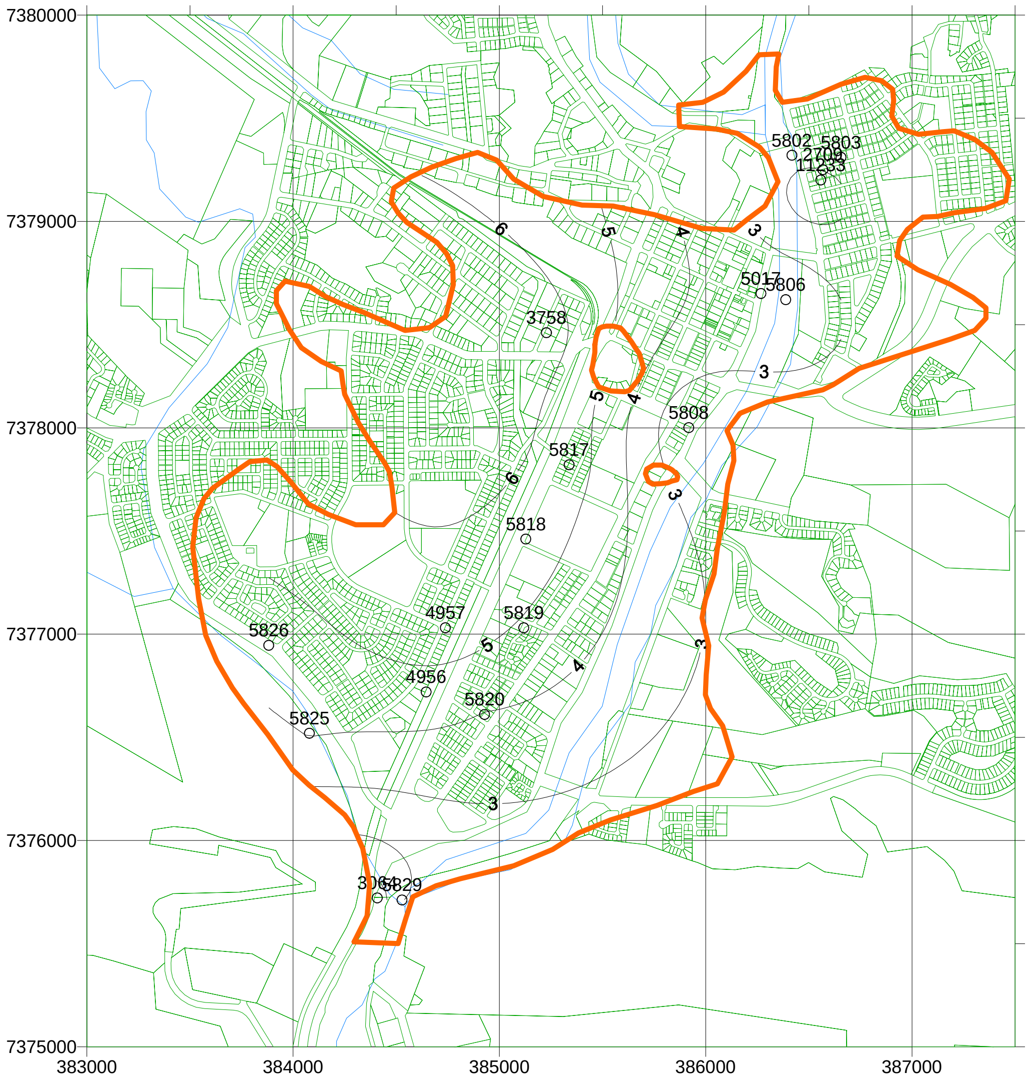

Figure-D 7 Rise in Water level from 03/1972 to 07/1975

1976

Figure-D 8 is very similar to Figure-D 6. Bradshaw Drain is receiving groundwater discharge. At this time there was little pumping from the basin.

15/01/76

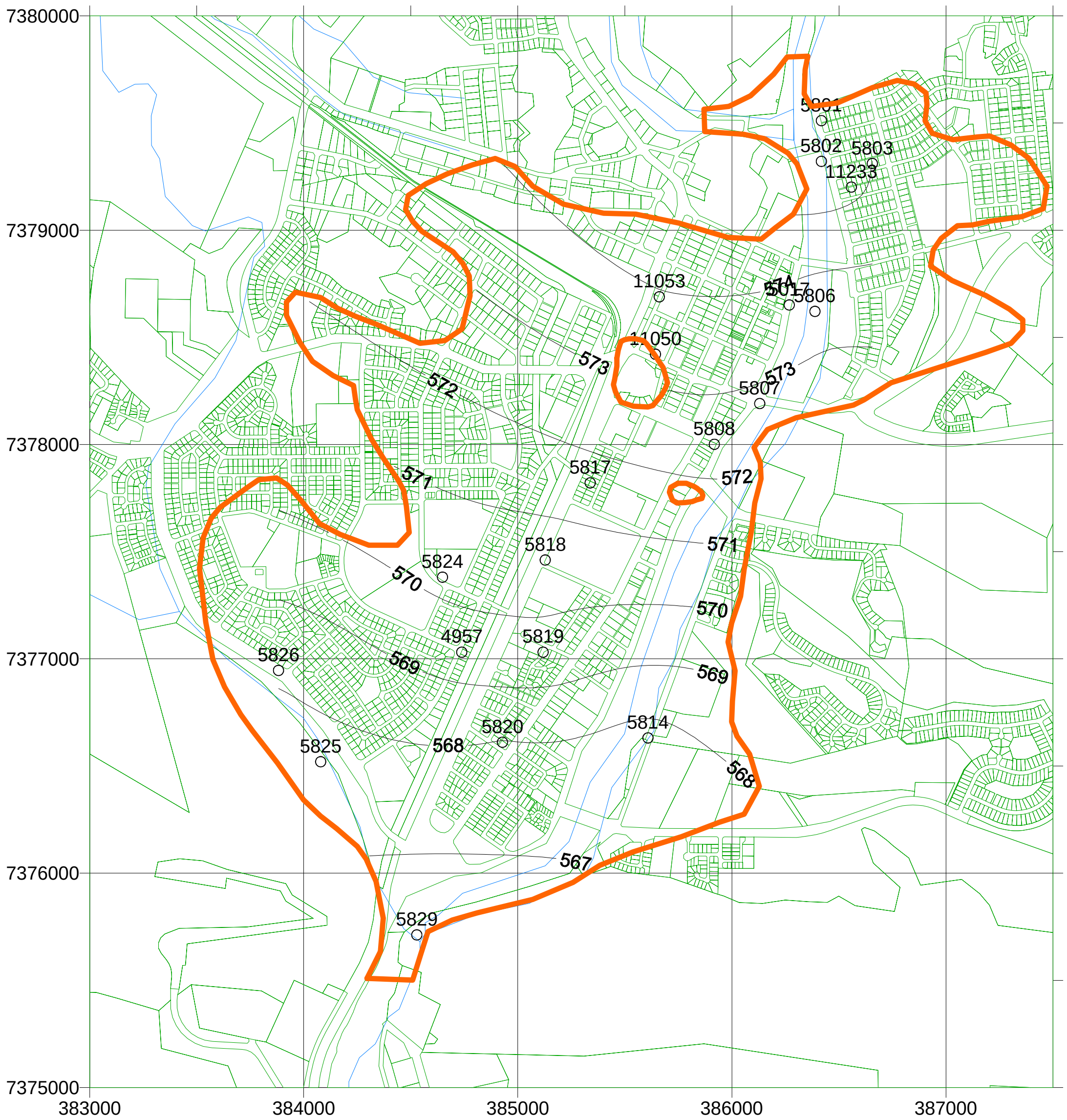

Figure-D 8 Potentiometric Surface 01/1976

13/03/1976

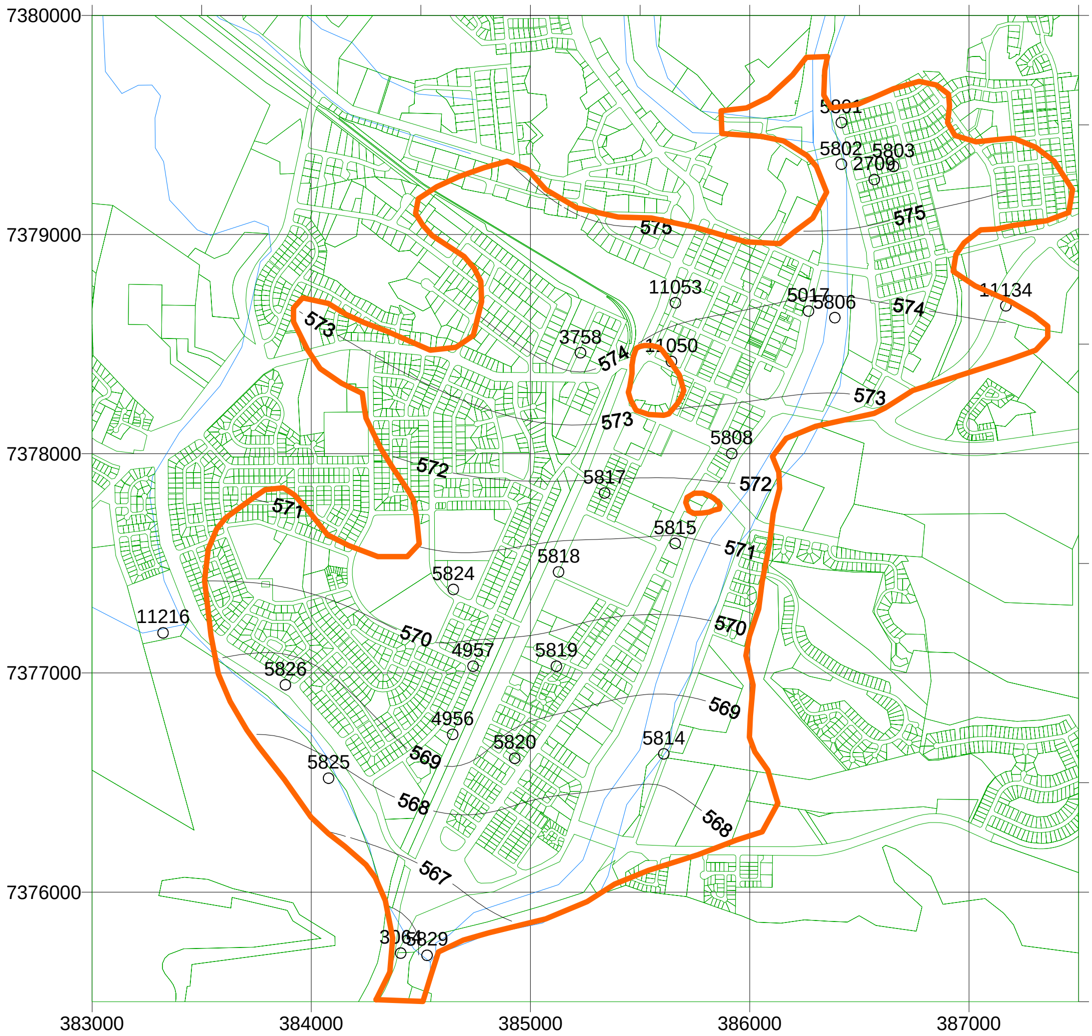

Figure-D 9 Potentiometric surface 13/03/1976

1997

Figure-D 10 shows the potentiometric surface in October after a reasonably wet summer. Figure-D 11 shows rise in water level for a period with about 30 mm of rain, but no flow in the Todd past the Anzac gauge. There is a recharge mound centred on where the Eastside drain enters the Todd.

30/10/97

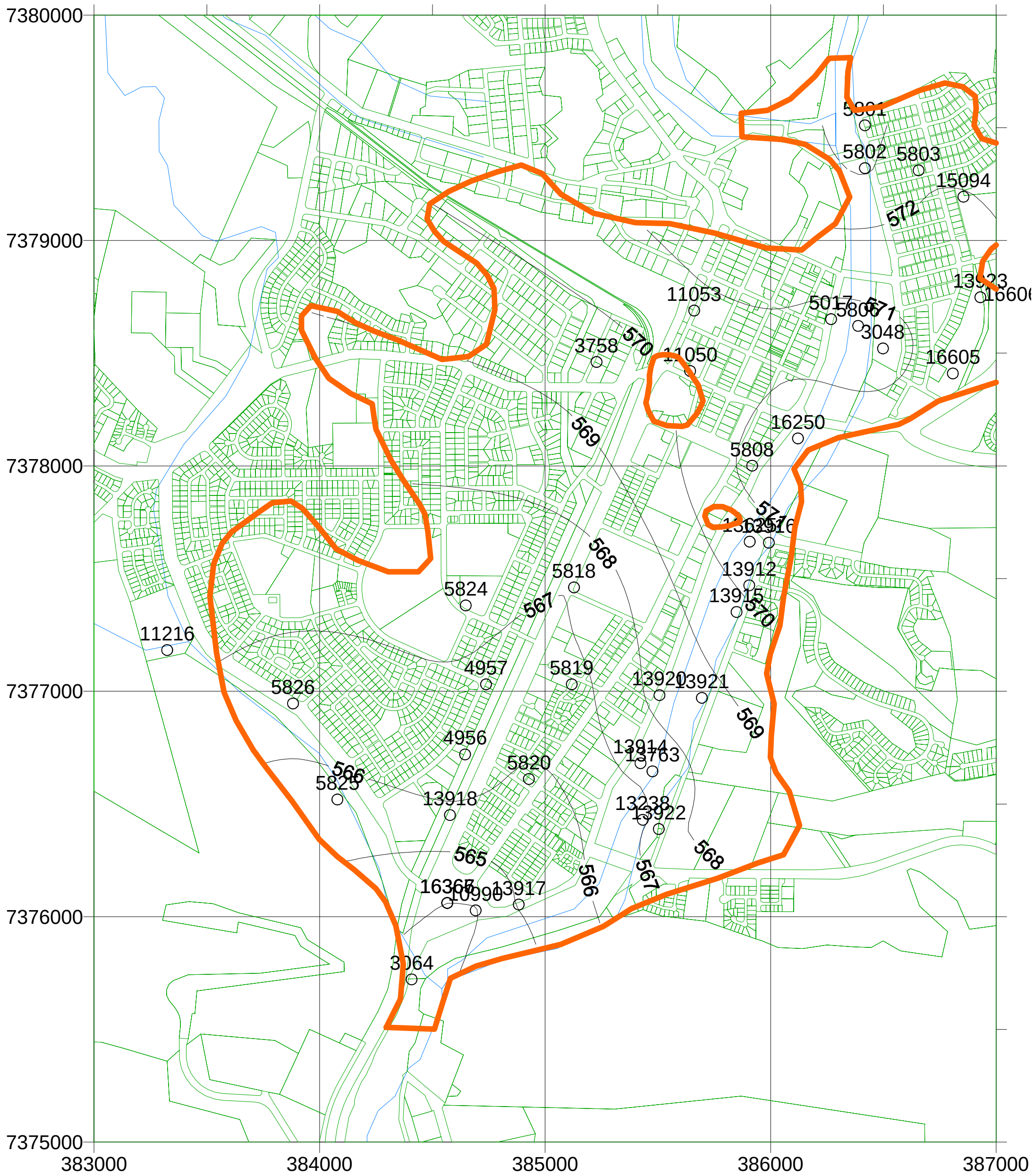

Figure-D 10 Potentiometric surface 10/1997

30/10/1997 minus 30/09/1997

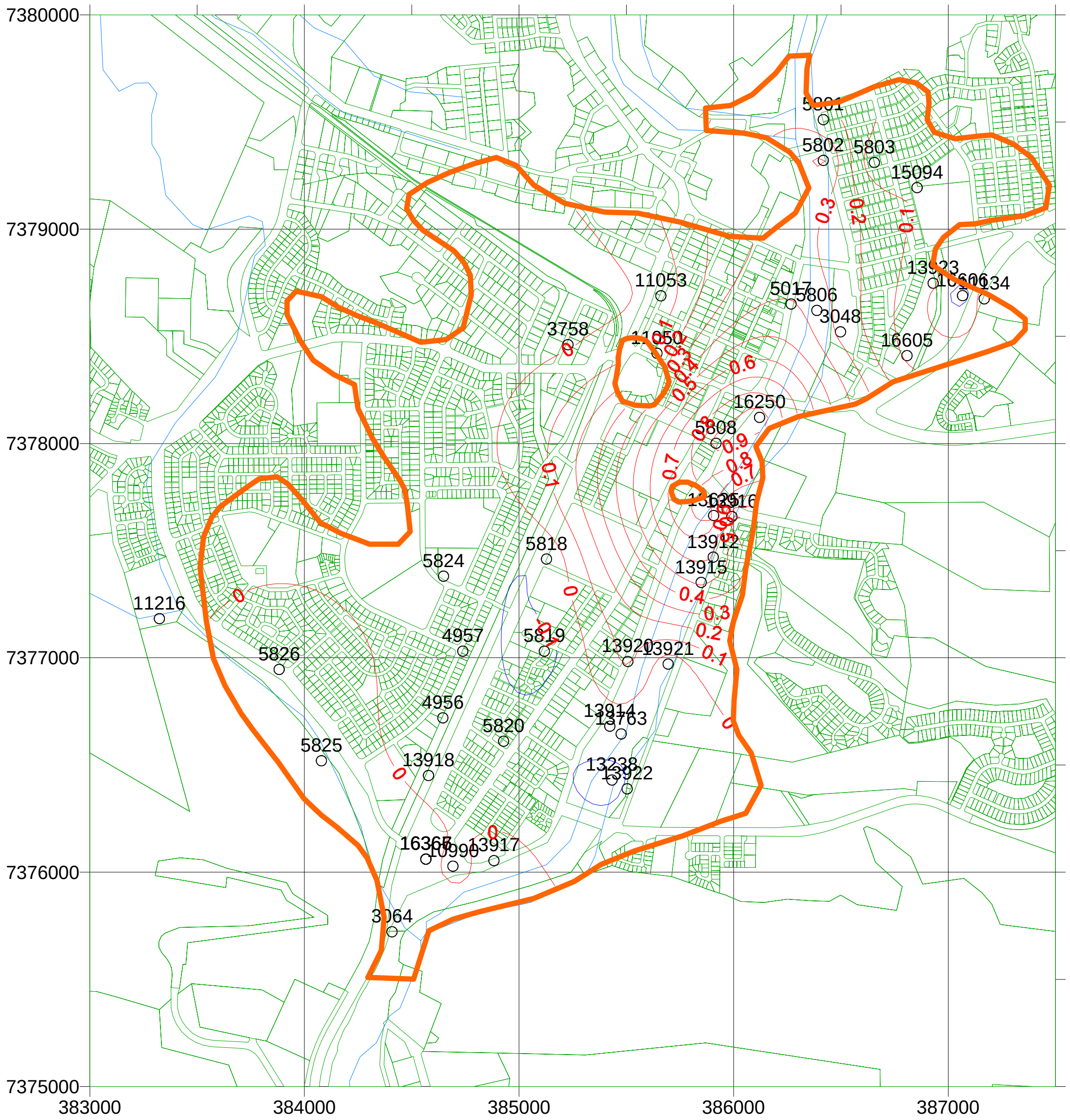

Figure-D 11 Rise in Water level from 09/1997 to 10/1997

1998

At this time there was moderate pumping from the Town Basin. There is an obvious gradient away from Todd toward the main aquifer zone. There is still a SE gradient from Gillen area.

5/01/1998

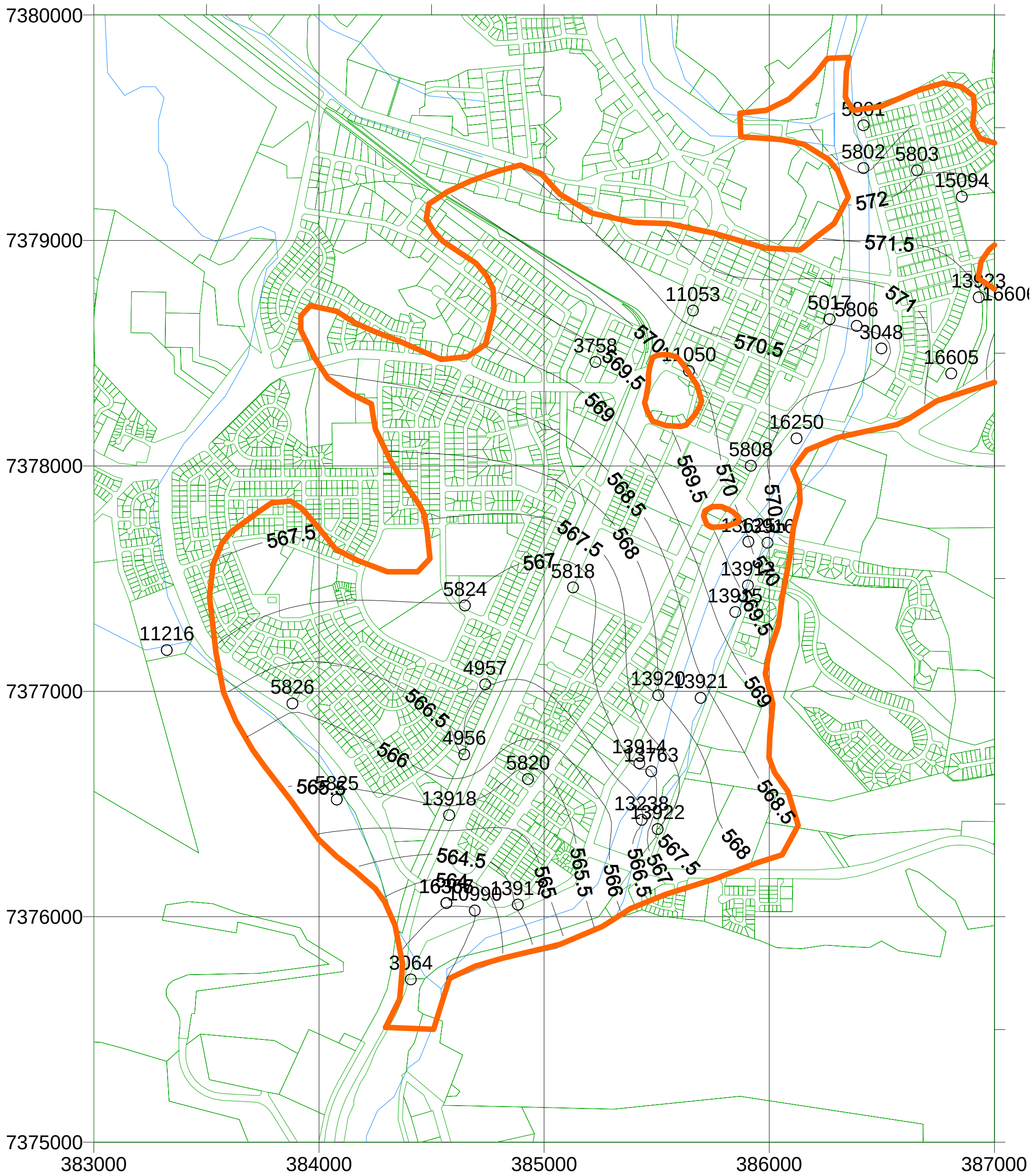

Figure-D 12 Potentiometric surface 01/1998

12/98

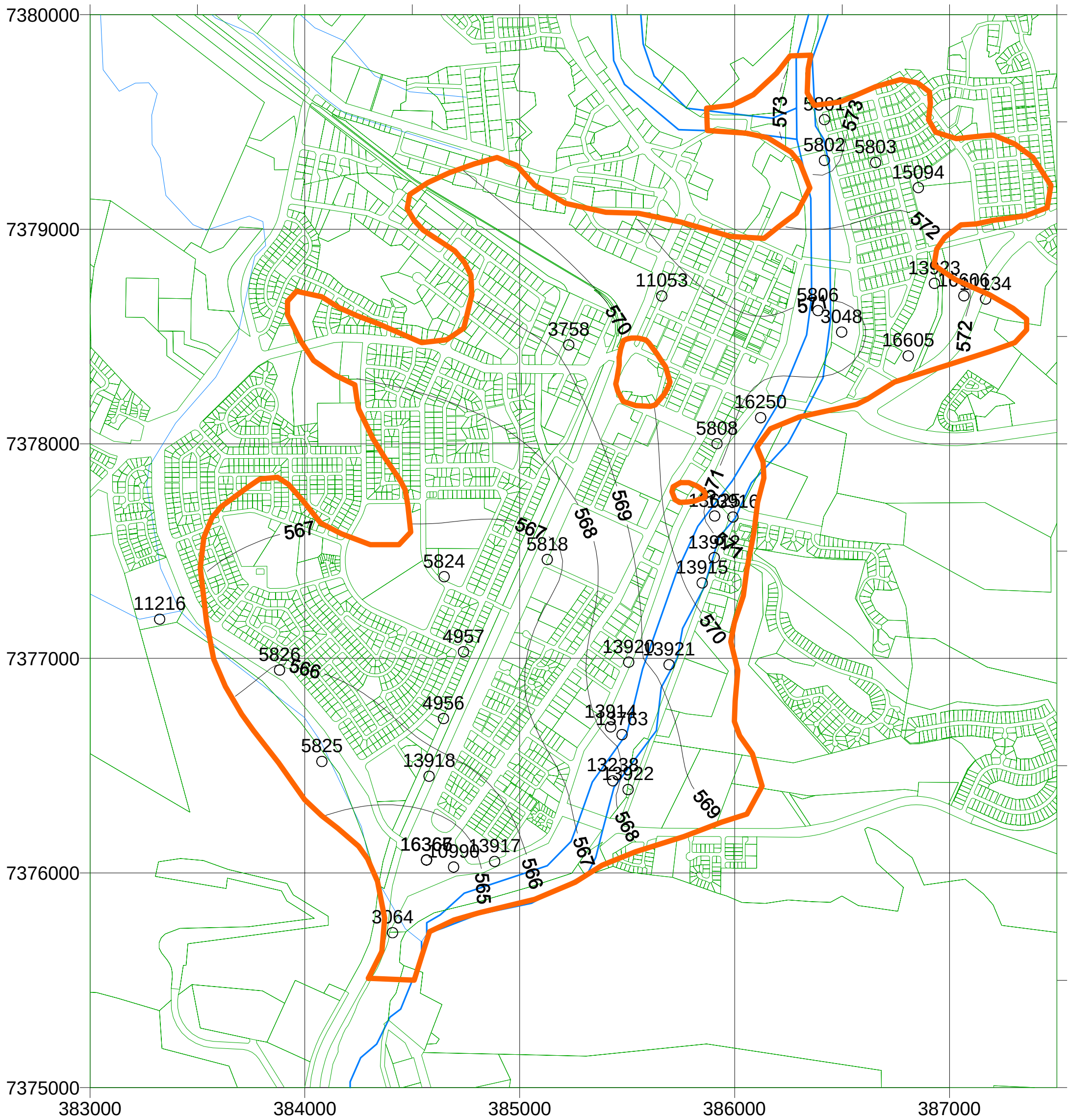

Figure-D 13 Potentiometric Surface 12/98

1999

Figure-D 13 is after a dry period. There is a pronounced gradient away from the Todd, and a trough due to pumping.

9/12/1999

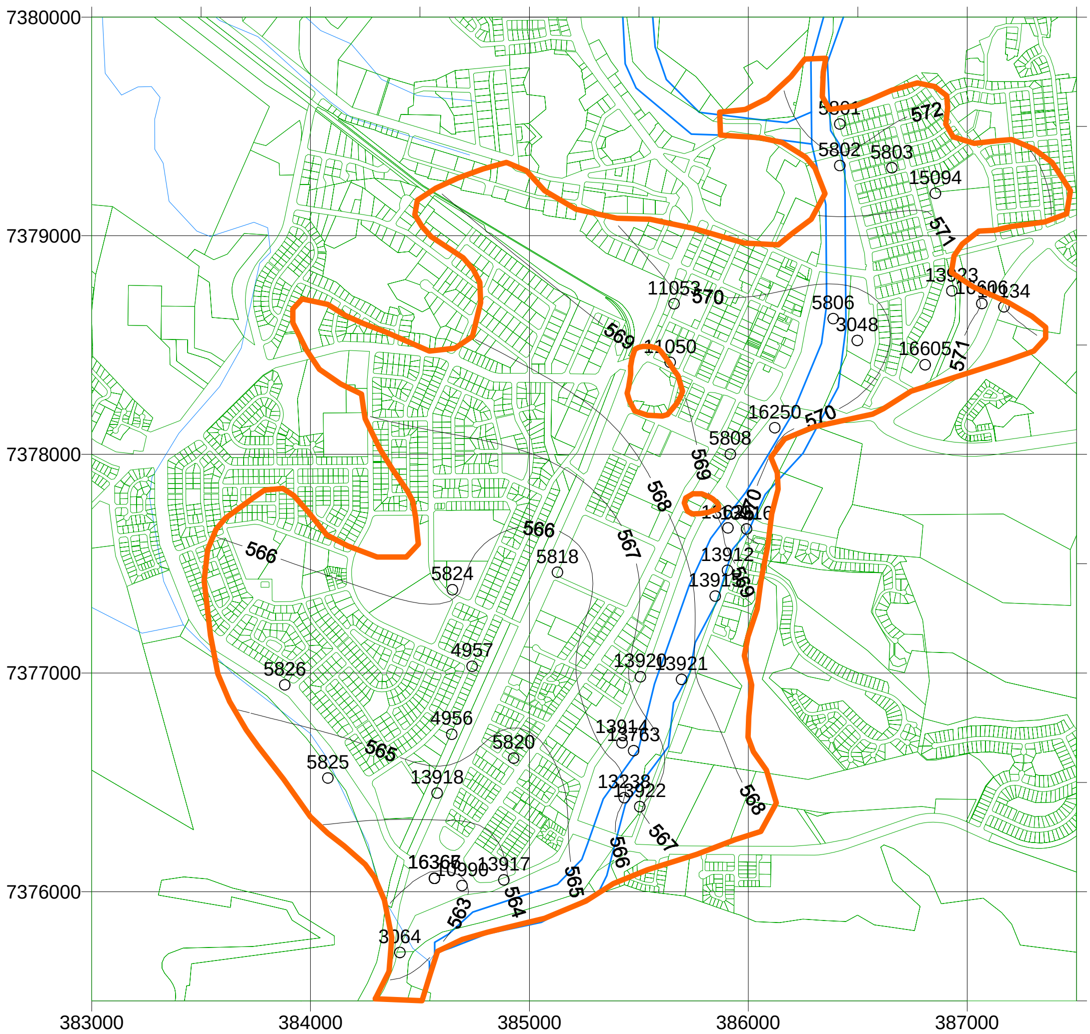

Figure-D 14 Potentiometric surface 12/99

2000

Major recharge events occurred in February and April. Figures-D 14 to 17 show the progressive rises in water level.
Figure-Ds 18 to 21 show differences between stages. In Figure-D 21 it can be seen that as in 1975 the largest rise of up to 2 m occurred in the west of the basin, compared to around 0.8 m near the Todd. About 1 m of water level rise in the western areas must be due to direct infiltration, or about 70 mm of rainfall.
Rises in water level near the Todd were about 0.4 m, hence it was assumed that rises above this over the rest of the basin were diffuse recharge.
An increase in saturated volume of 6233129 m^3 was calculated, giving an increase in storage of 436 ML.
The assumed area of the Southern Zone is 5.3 km^2, giving an average recharge of about 80 mm.

06/03/2000

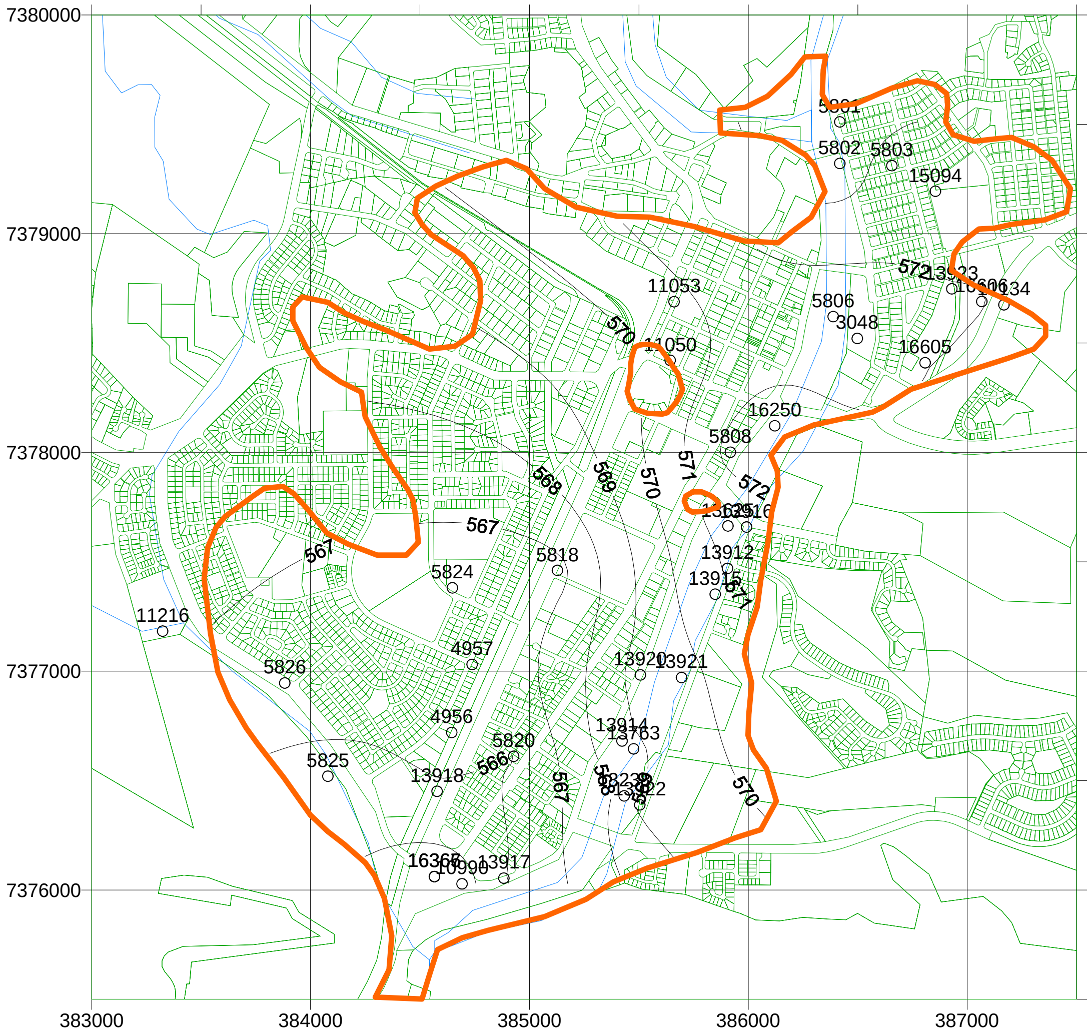

Figure-D 15 Potentiometric Surface 03/00

03/04/2000

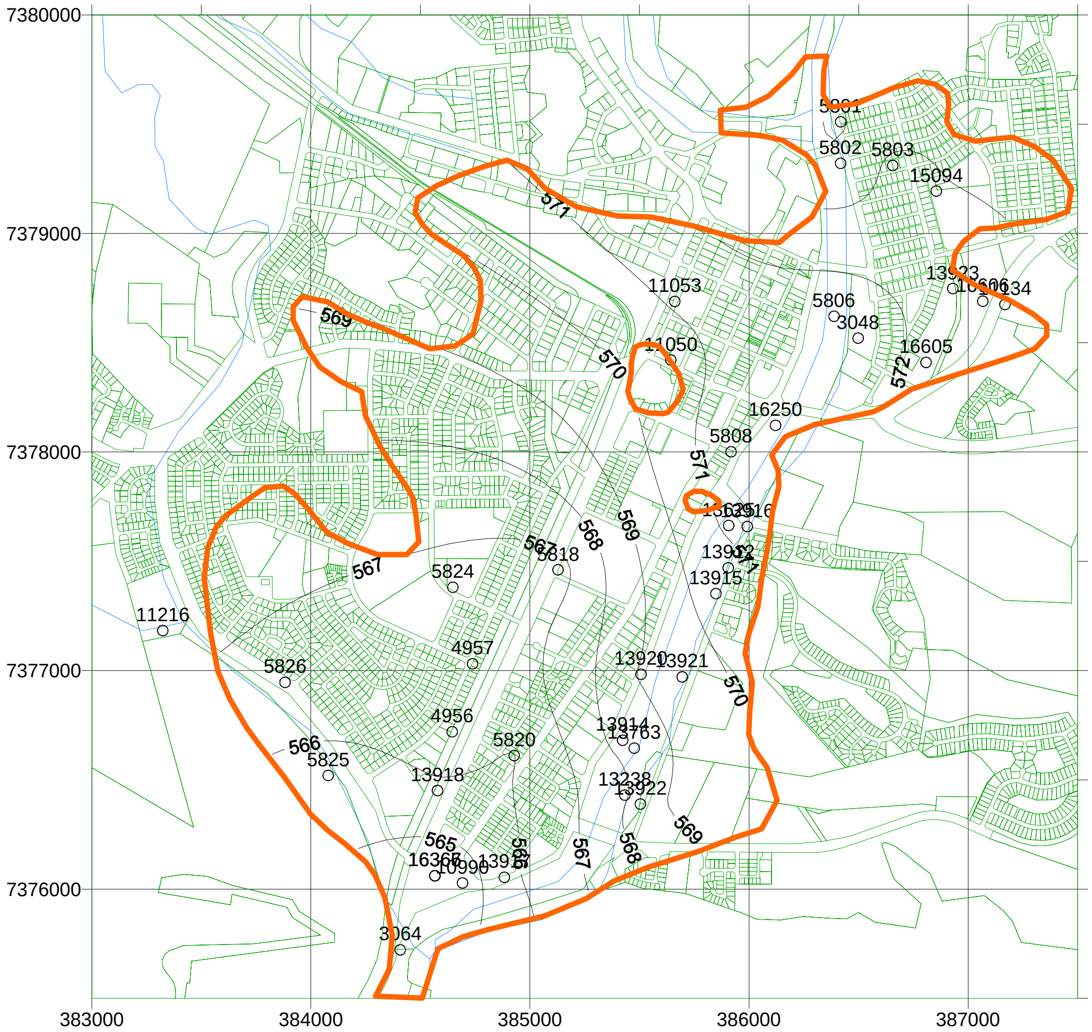

Figure-D 16 Potentiometric Surface 04/00

15/05/2000

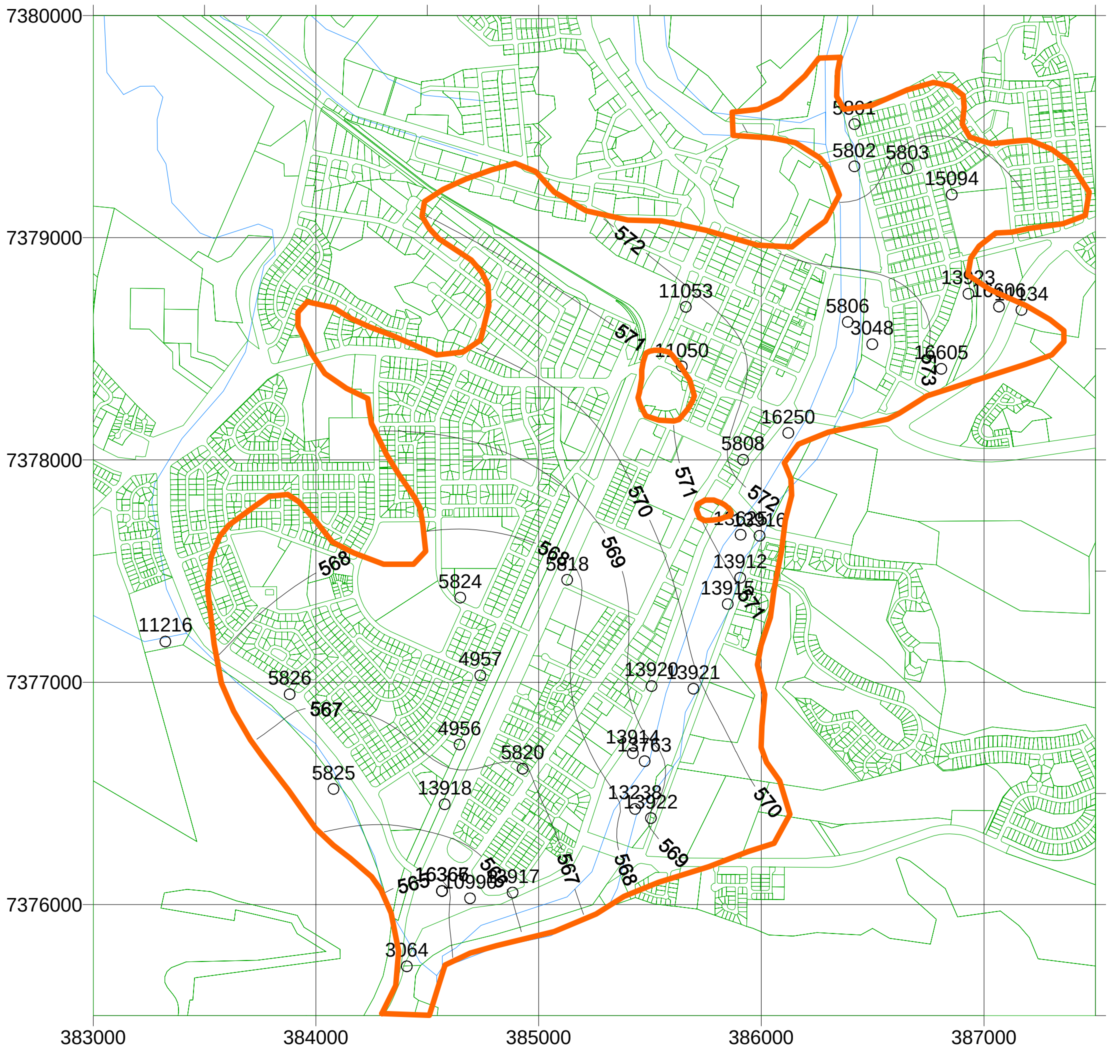

Figure-D 17 Potentiometric Surface 05/00

19/06/2000

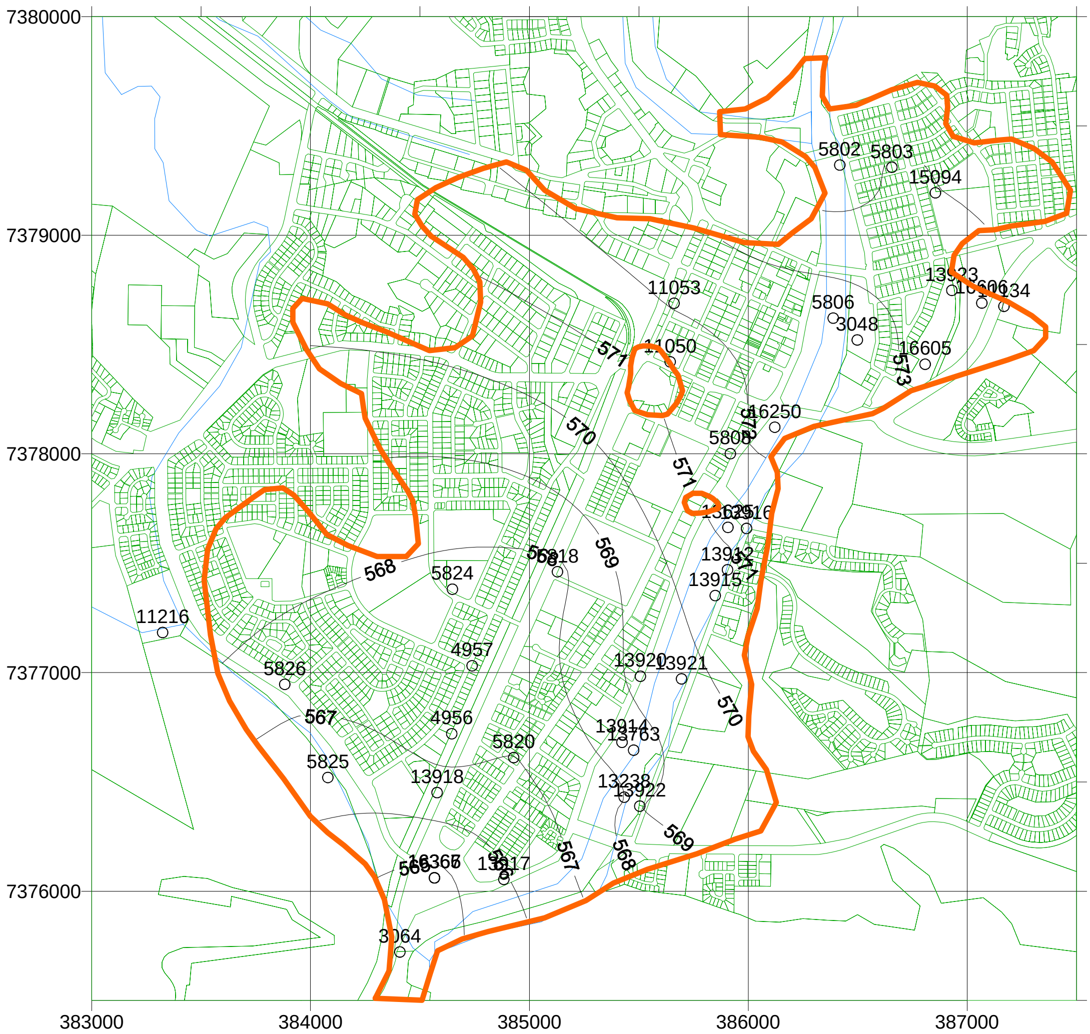

Figure-D 18 Potentiometric Surface 19/06/2000

03/00 minus01/00

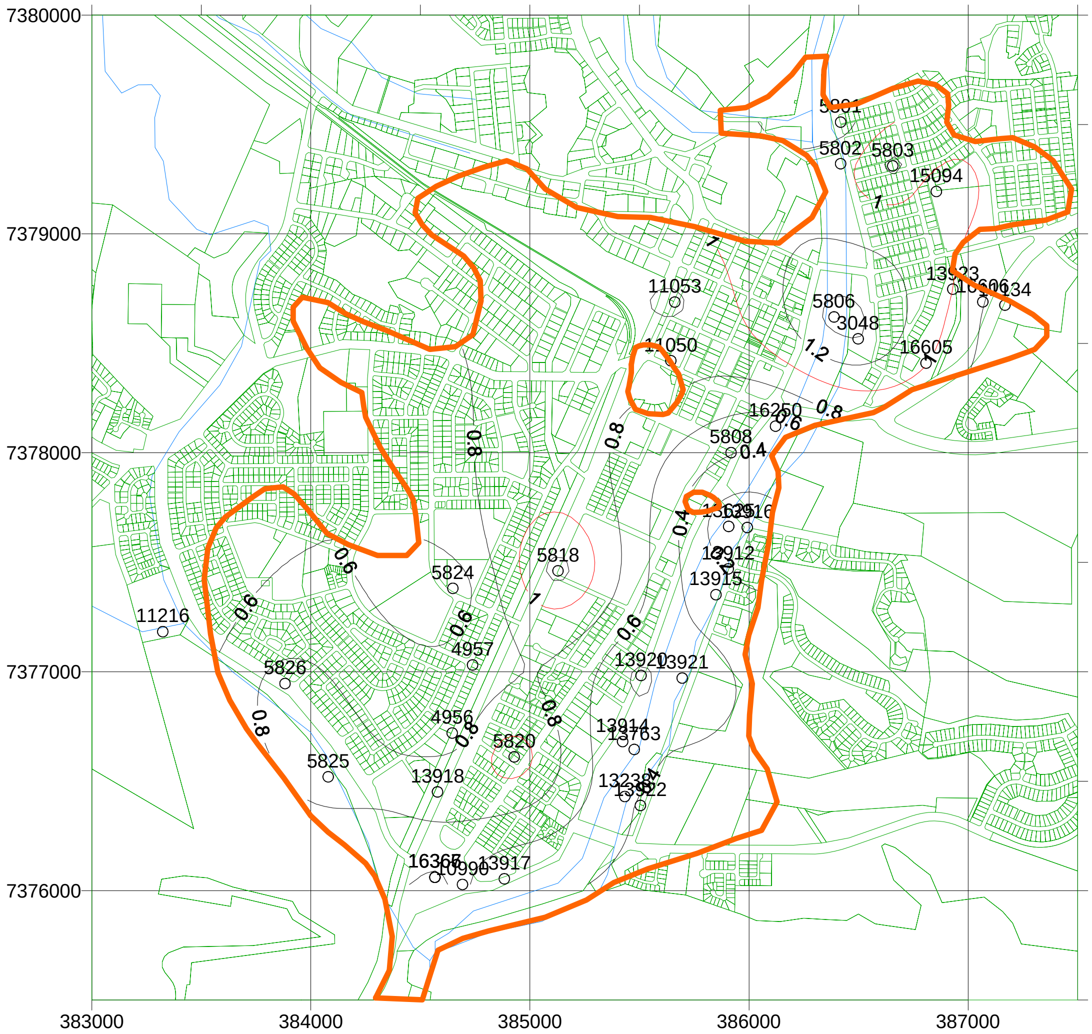

Figure-D 19 Rise in Water level from 01/2000 to 03/2000

06/2000 minus 04/2000

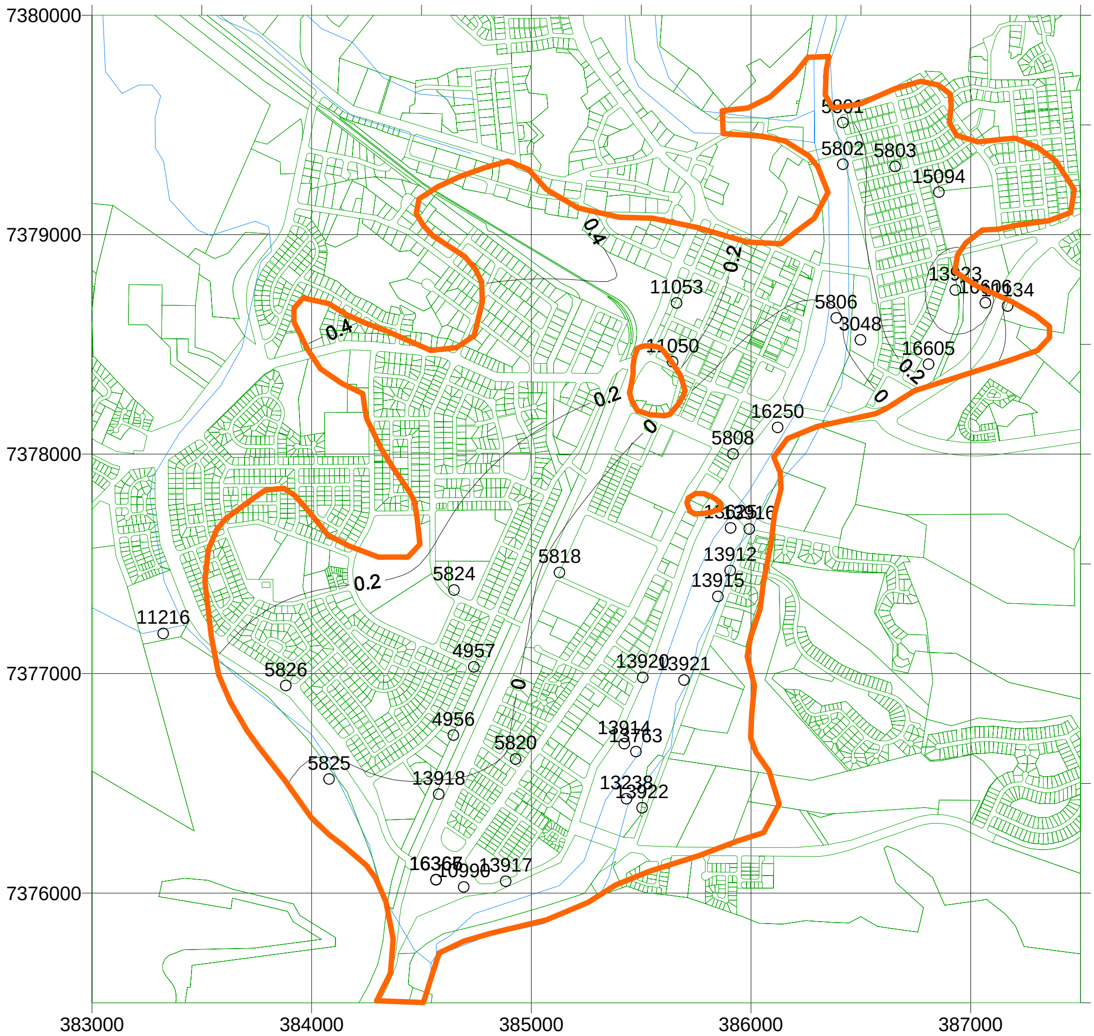

Figure-D 20 Rise in Water level from 6/03/2000 to 3/04/2000

06/2000 minus 04/2000

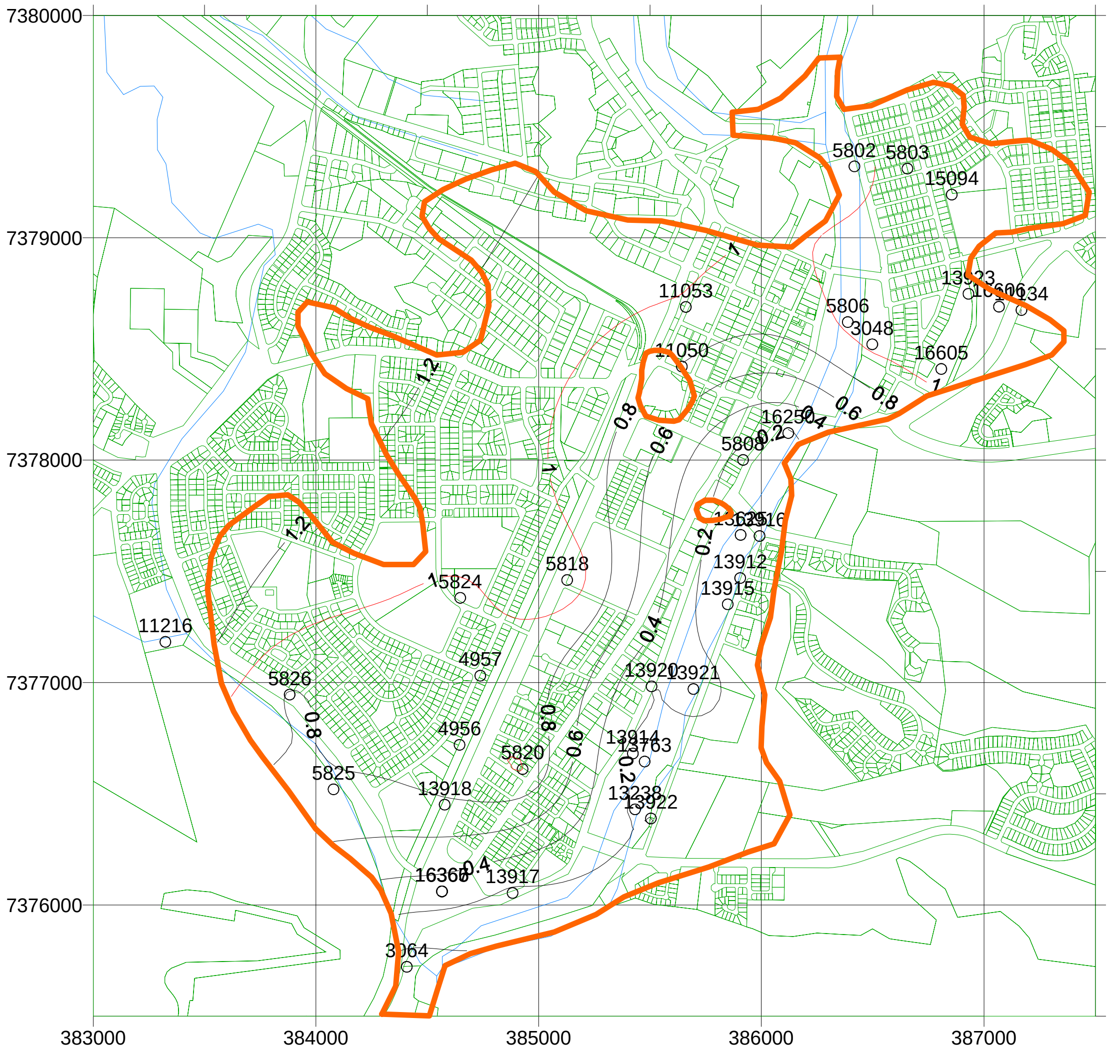

Figure-D 21 Rise in Water level from 3/04/2000 to 19/6/2000

06/2000 minus 01/2000

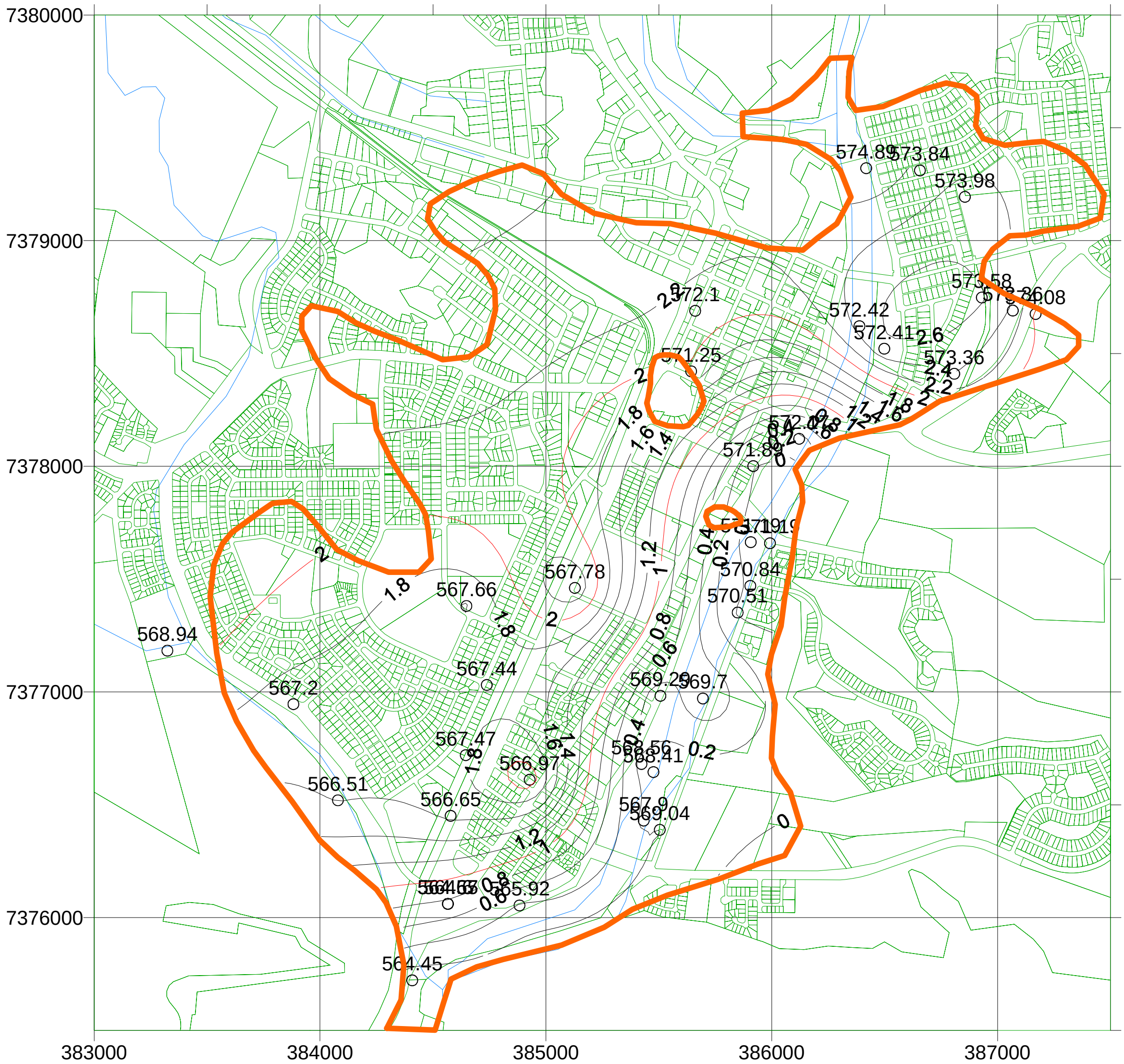

Figure-D 22 Rise in water level, 01/2000 to 06/2000

2001

Figures-D 23 to 25 show the potentiometric surface during this year.

01/01

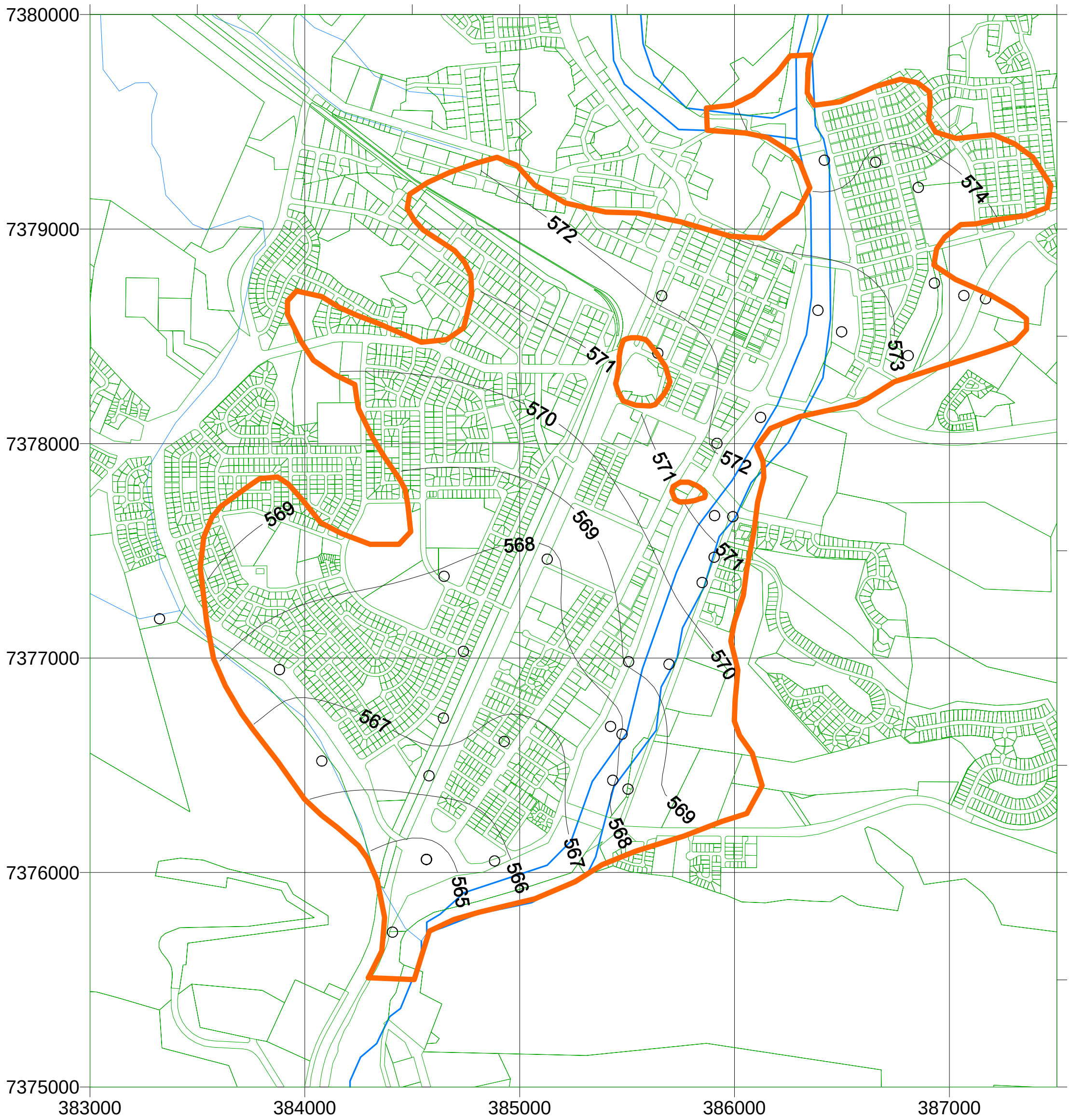

Figure-D 23 Potentiometric Surface 01/01

04/2001

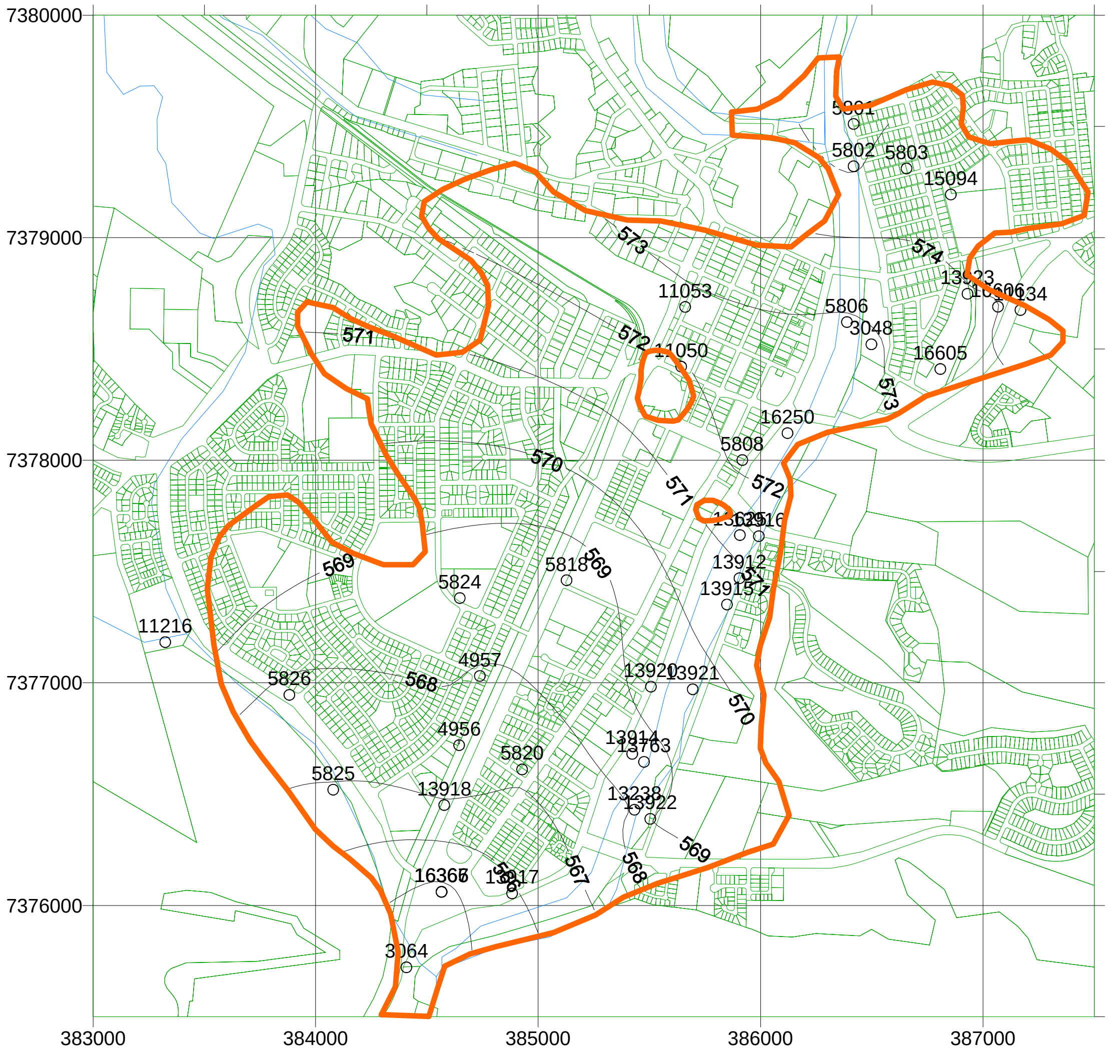

Figure-D 24 Potentiometric Surface 09/04/2001

03/07/2001

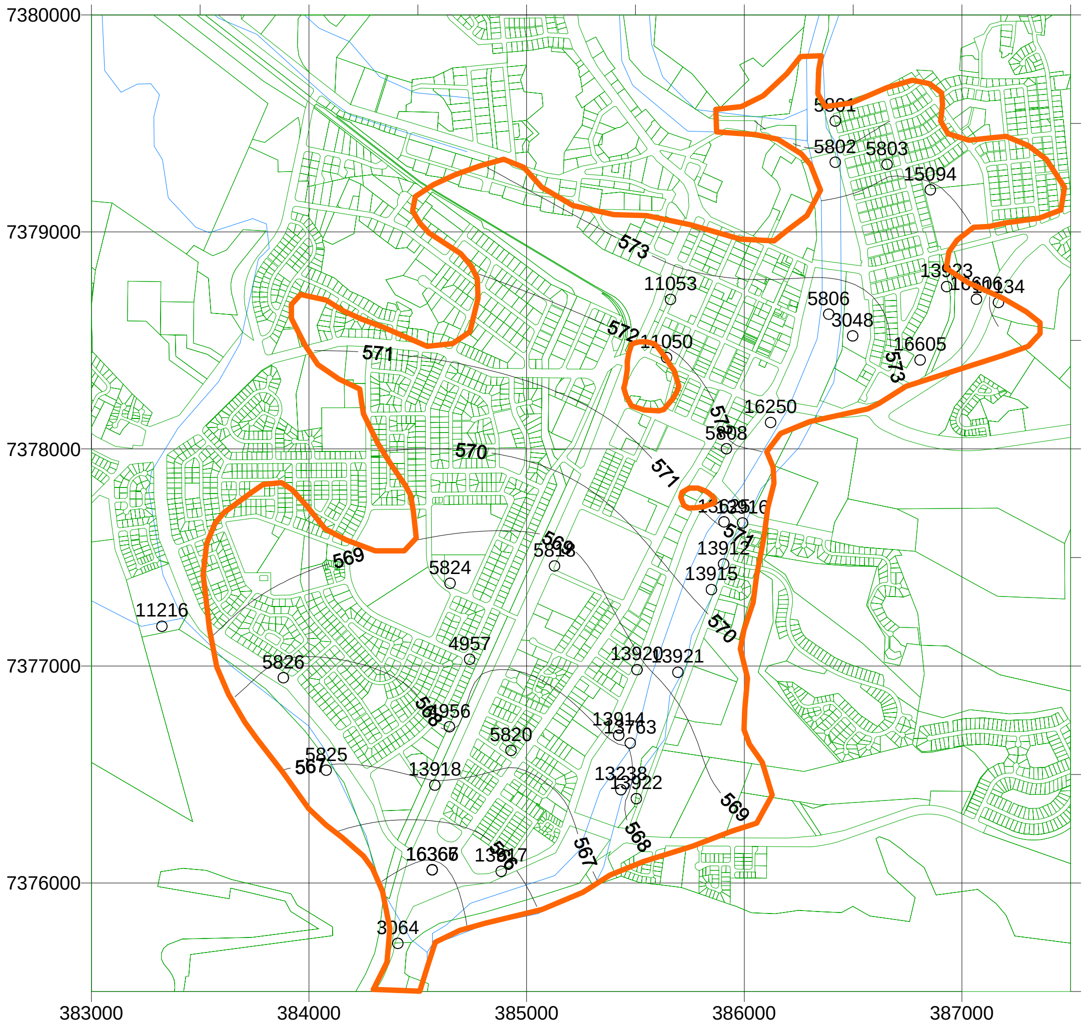

Figure-D 25 Potentiometric surface 03/07/2001

07/01 minus04/01

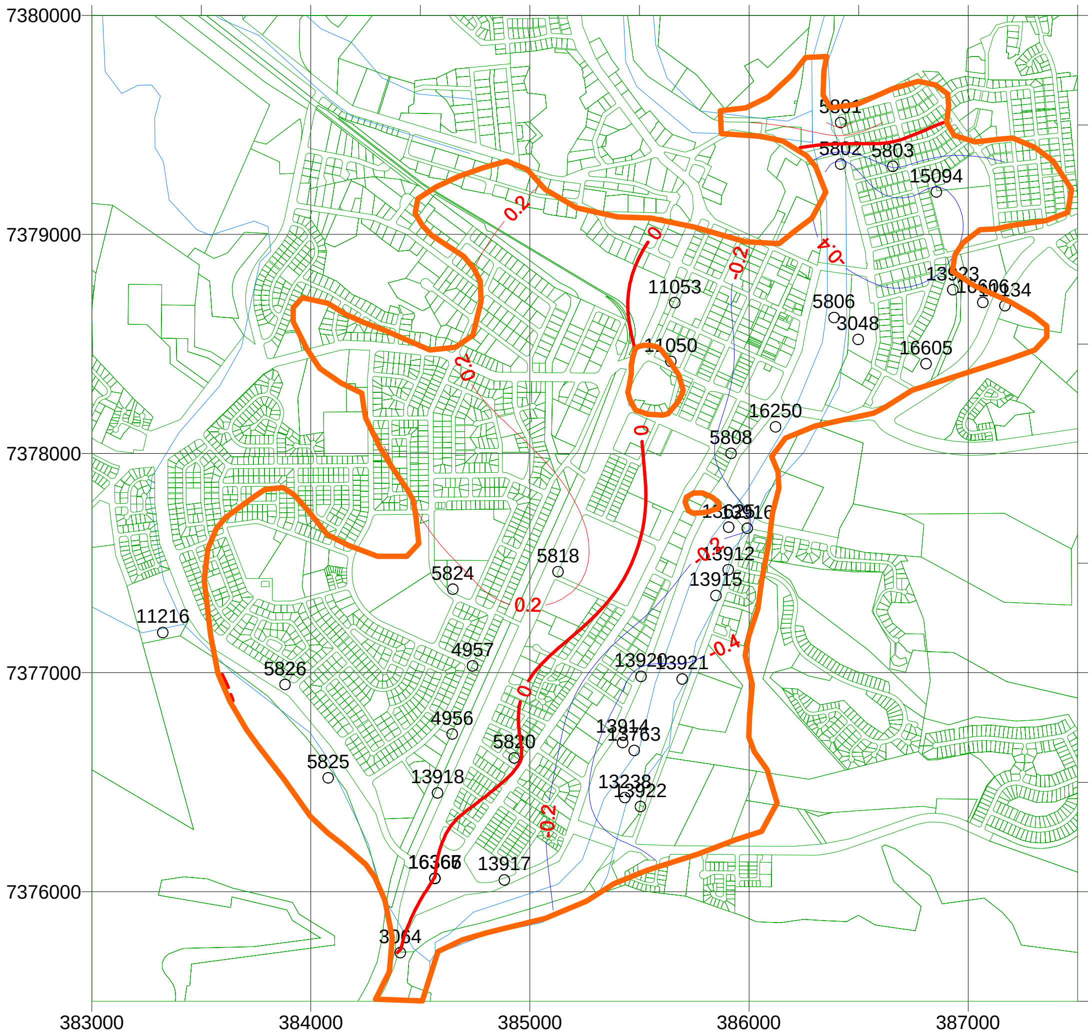

Figure-D 26 Rise in Water level from 04/2001 to 07/2001

APPENDIX E

SALINITY TRENDS IN PRODUCTION BORES

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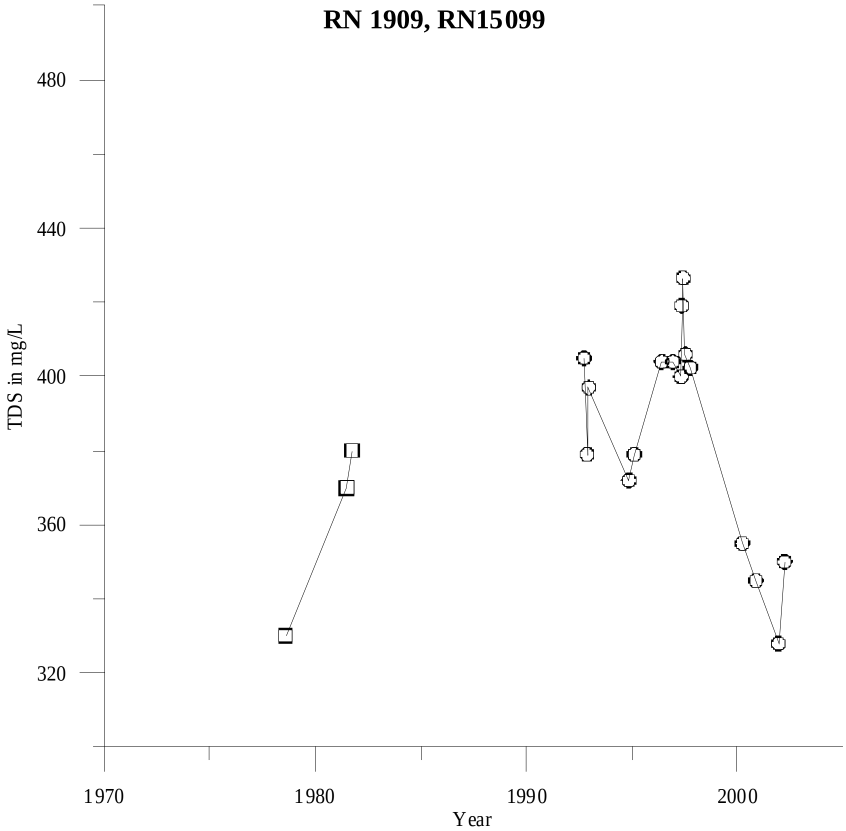

Figure E- 1 RN 1909 and RN 15099

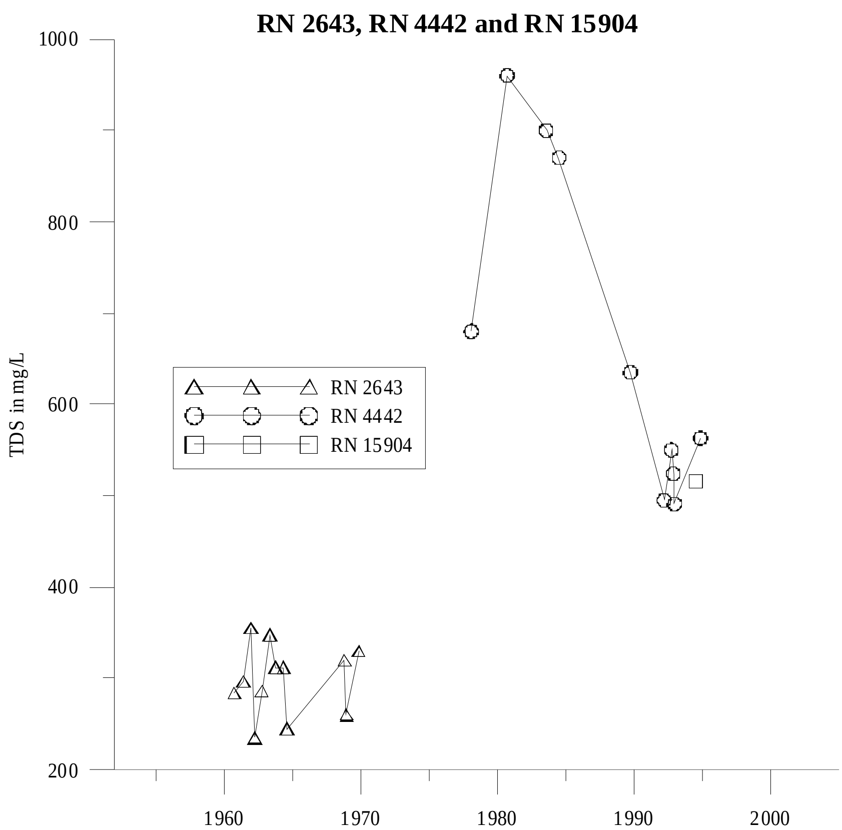

Figure E- 2 RN 2643, RN 4442, RN 15904

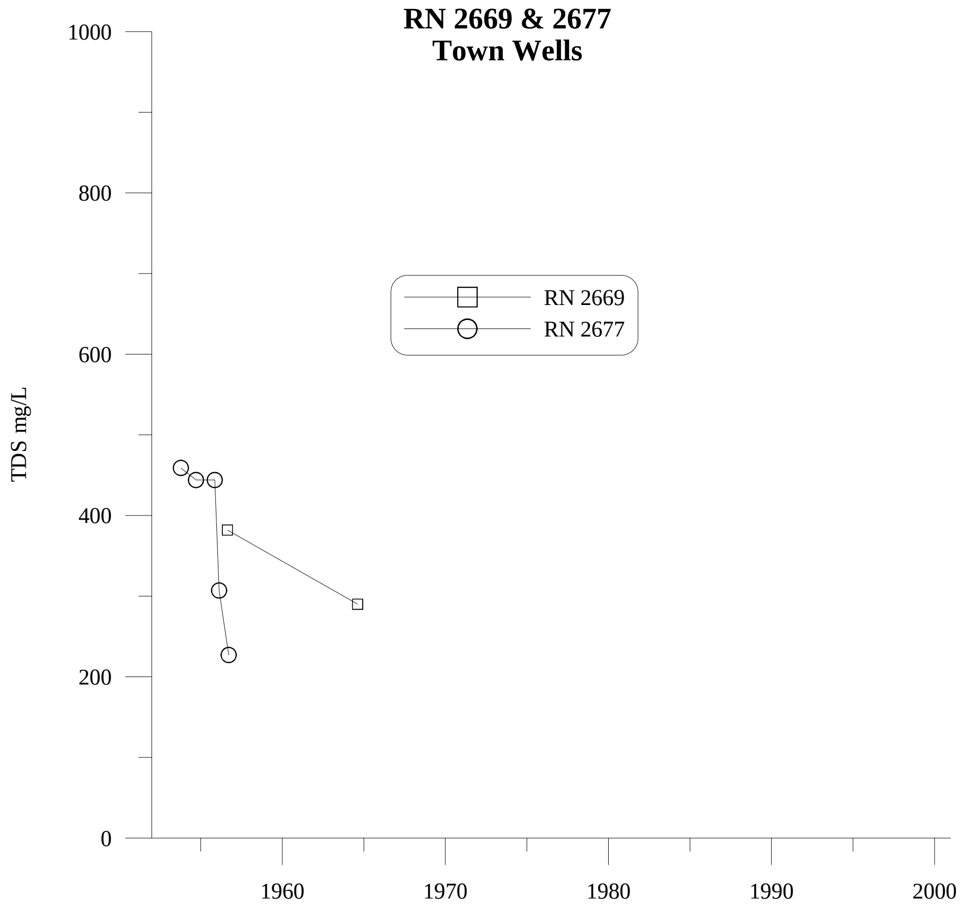

Figure E- 3 RN 2669 and RN2677

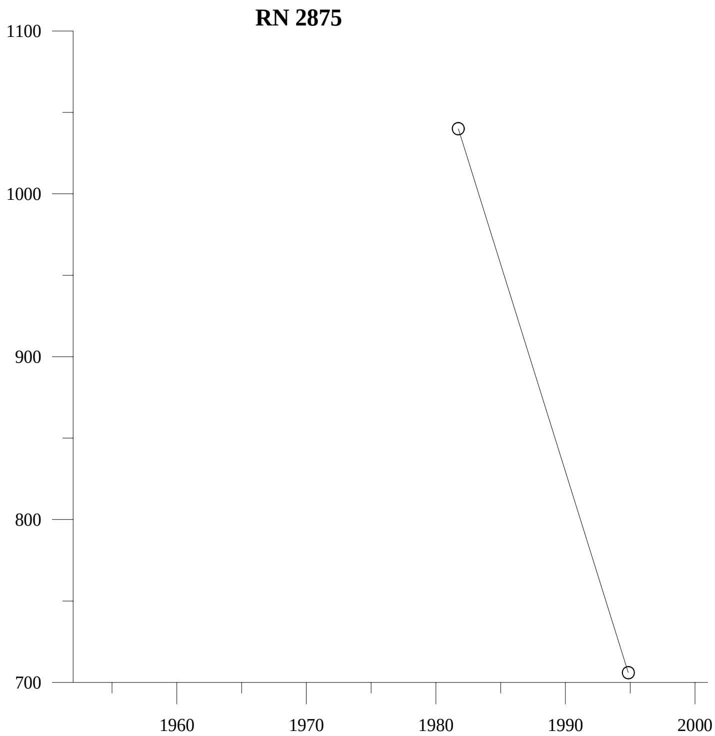

Figure E- 4 RN 2875

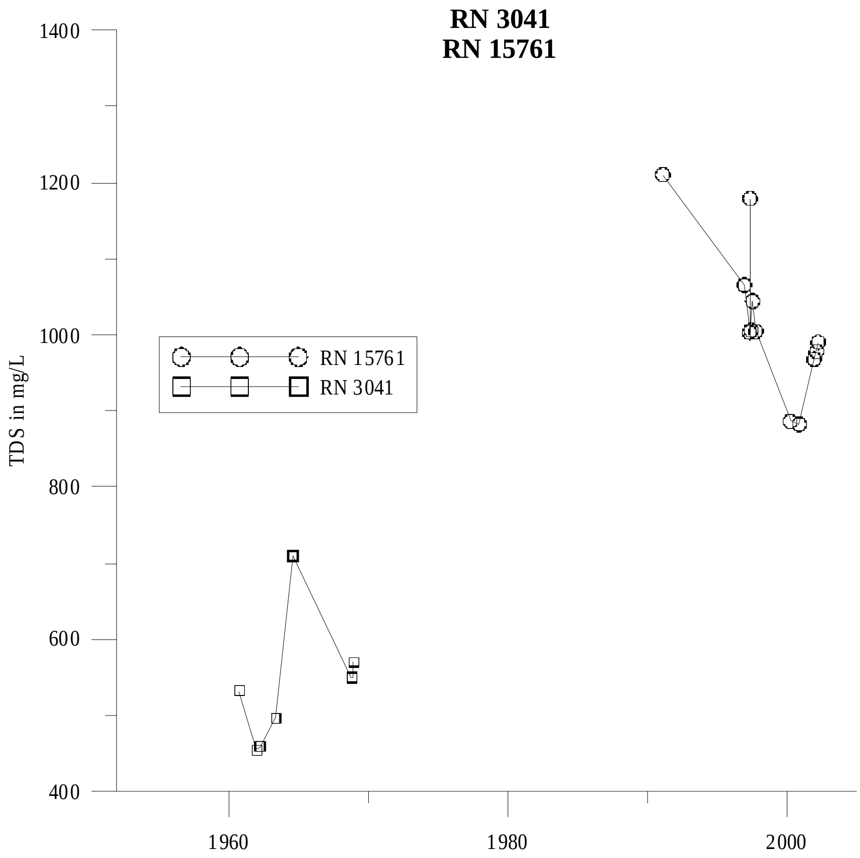

Figure E- 5 RN 3041 and RN 15761

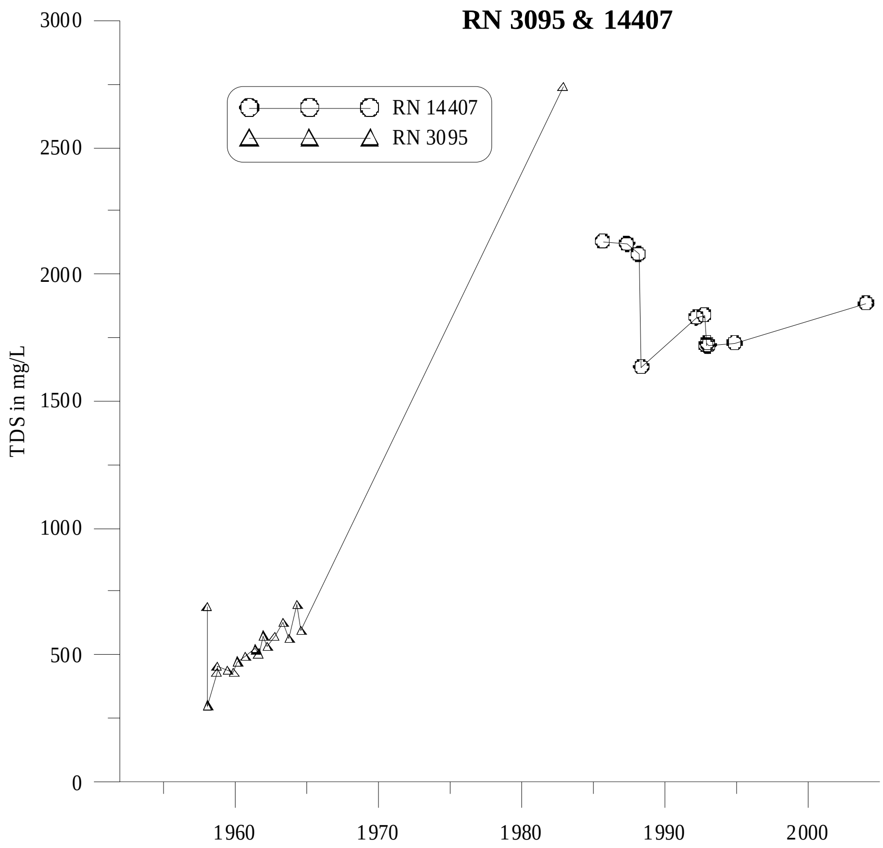

Figure E- 6 RN 3095 and RN 14407

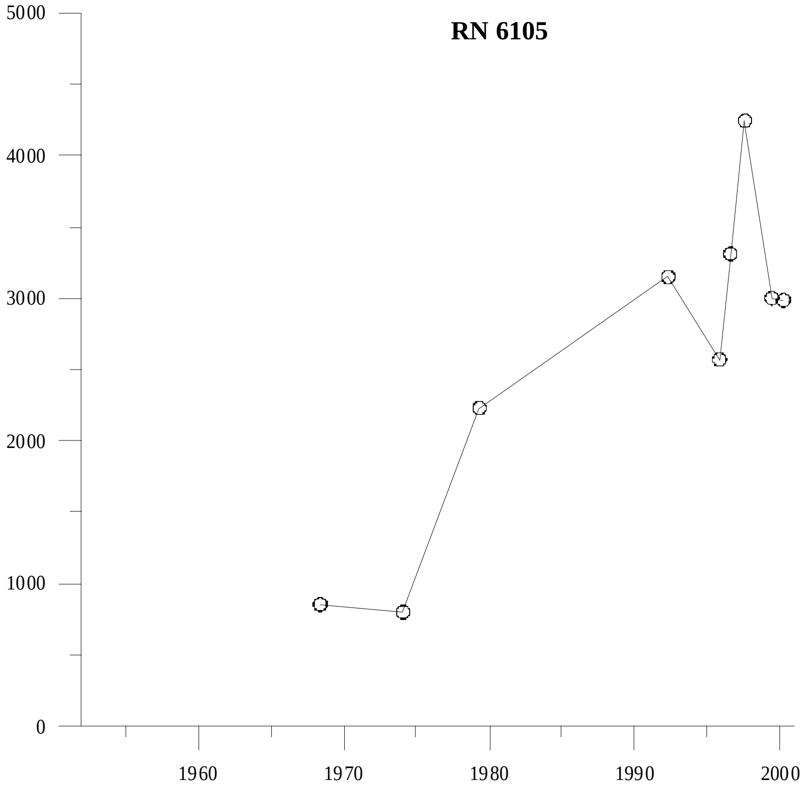

Figure E- 7 RN 6105 TDS

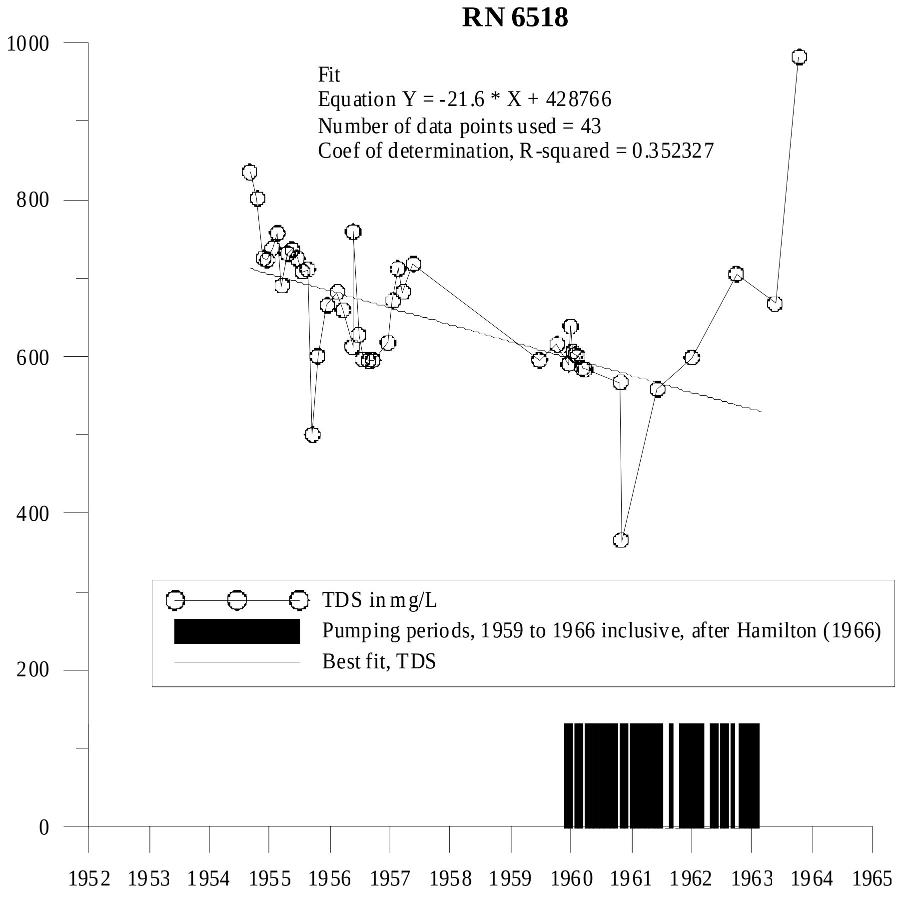

Figure E- 8 RN 6518, to 1965

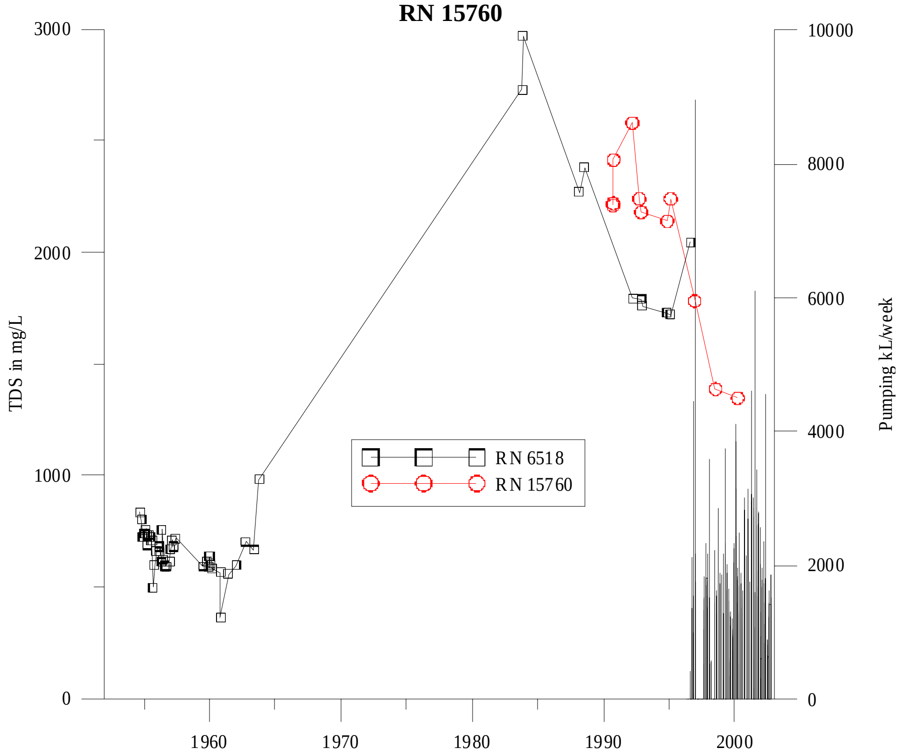

Figure E- 9 RN 6518 and RN 15760

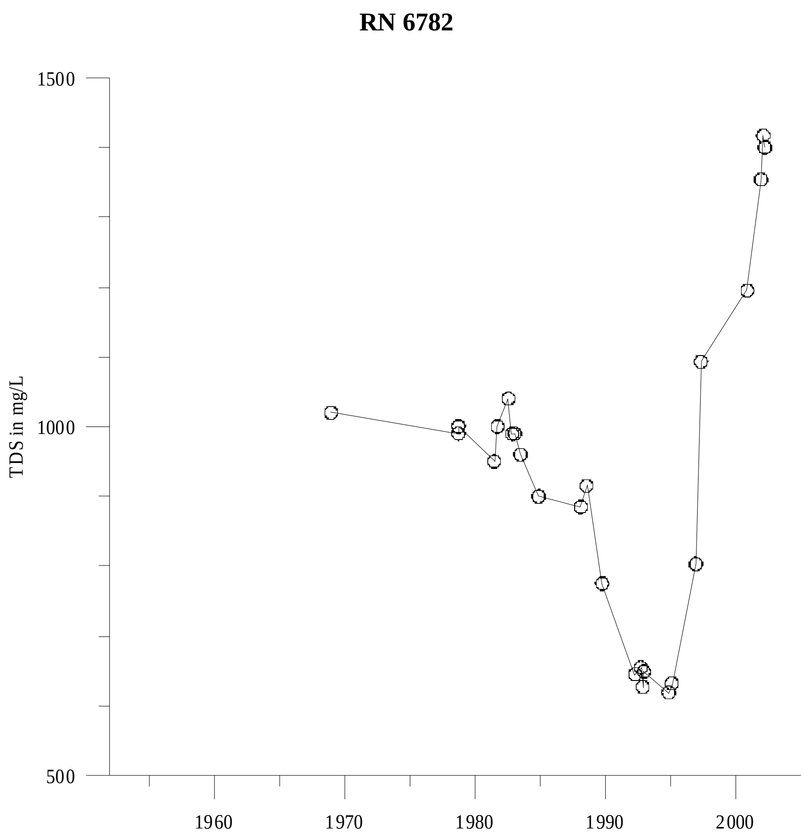

Figure E- 10 RN 6782 TDS

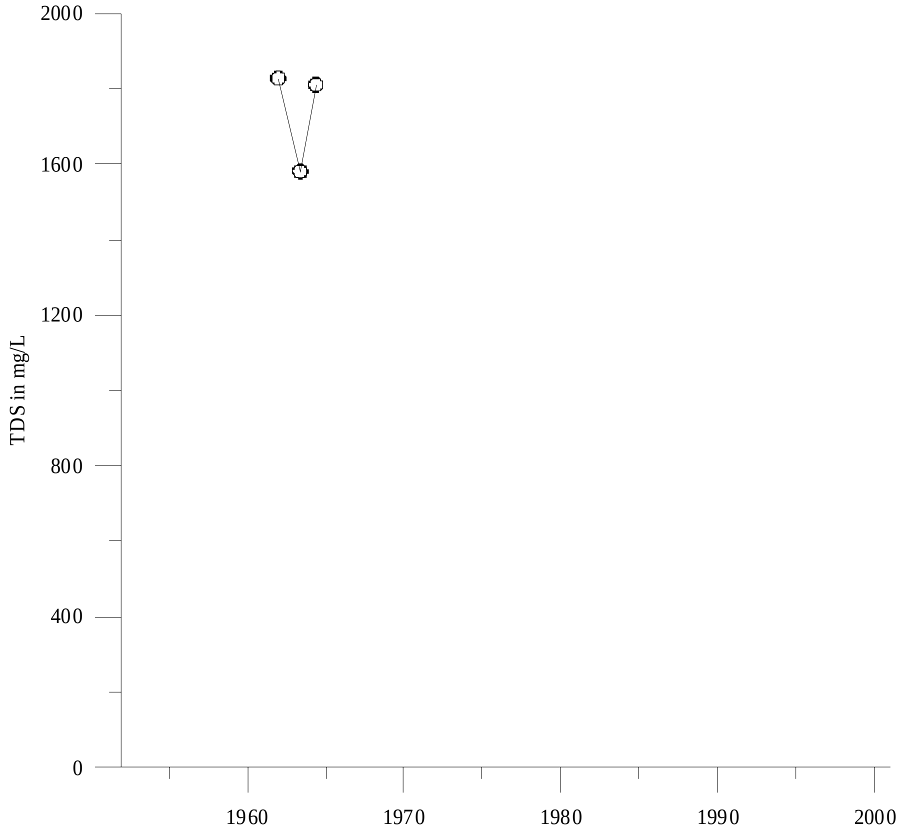

Figure E-11 RN 6783

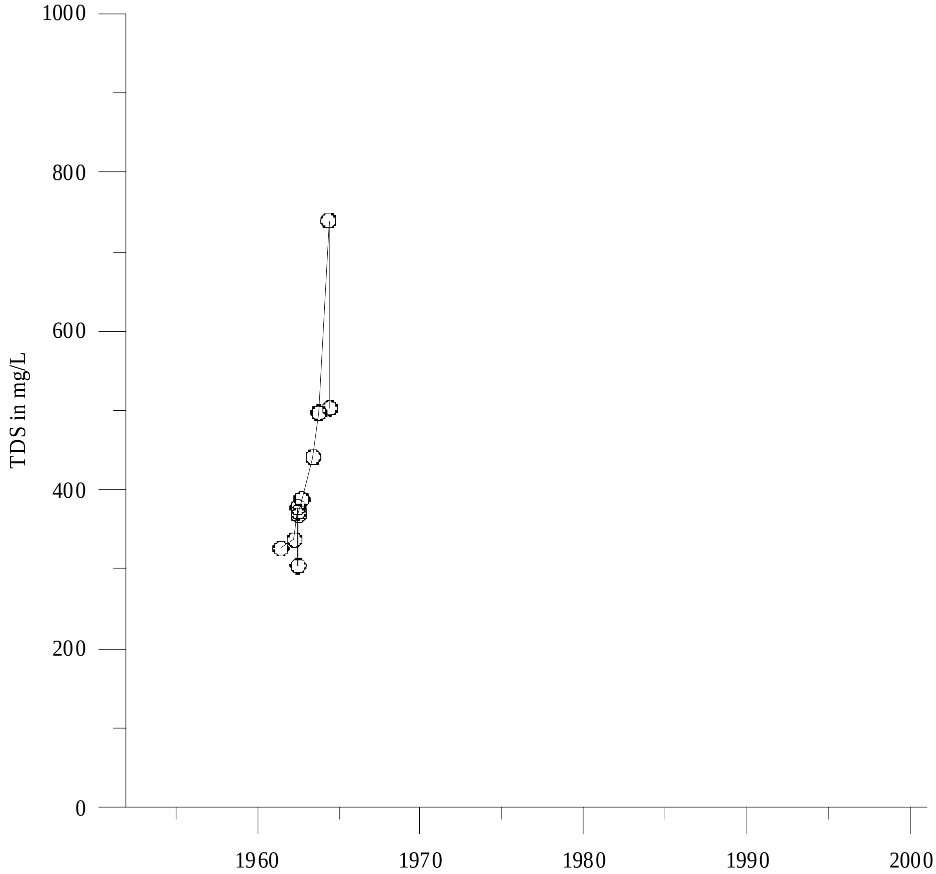

Figure E-12 RN 6823

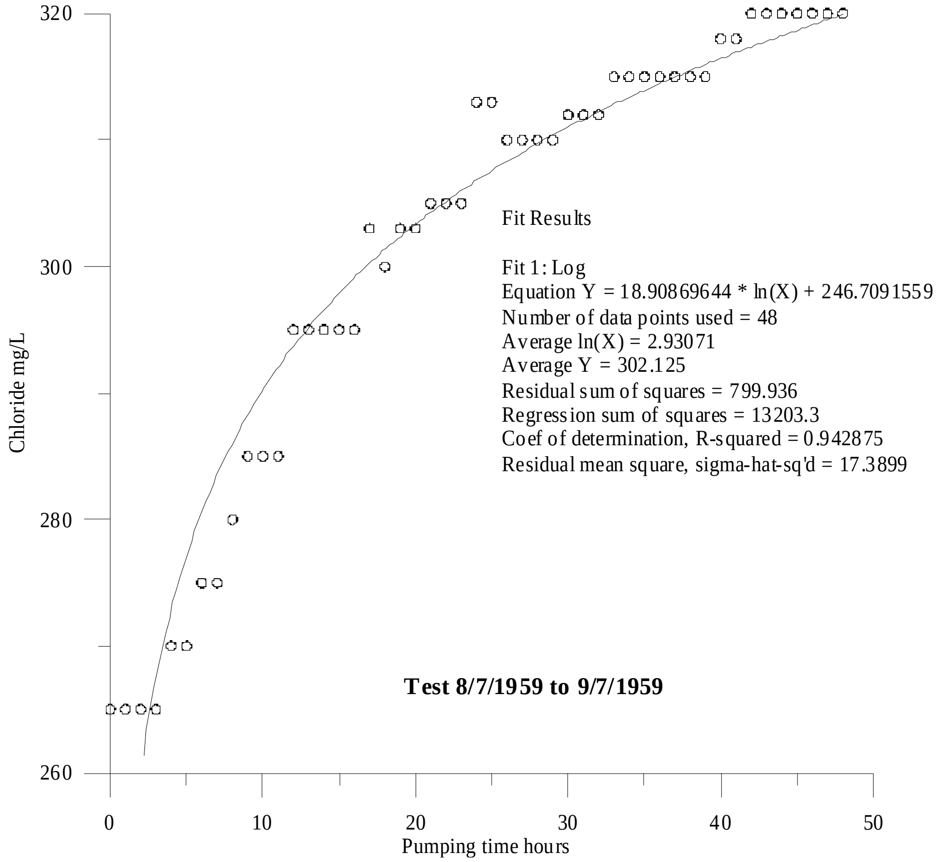

Figure E-13 RN 7506, test in 1959

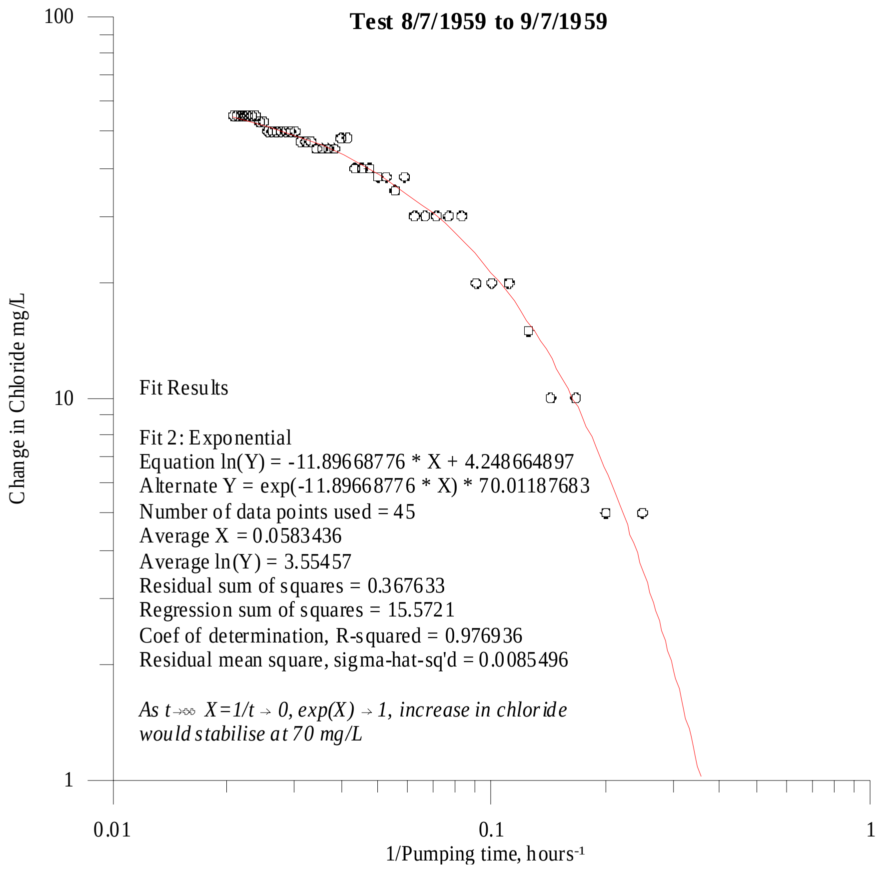

Figure E-14 RN 7506, test in 1959 plotted against inverse t

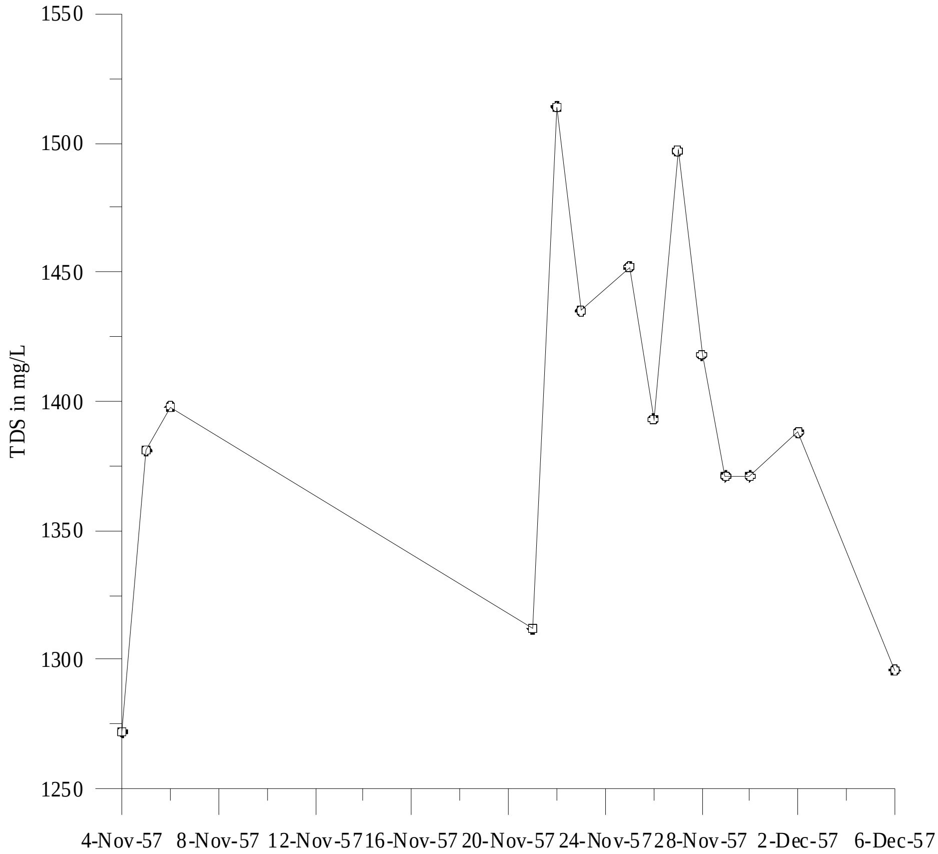

Figure E-15 RN 7506, sampling in 1957

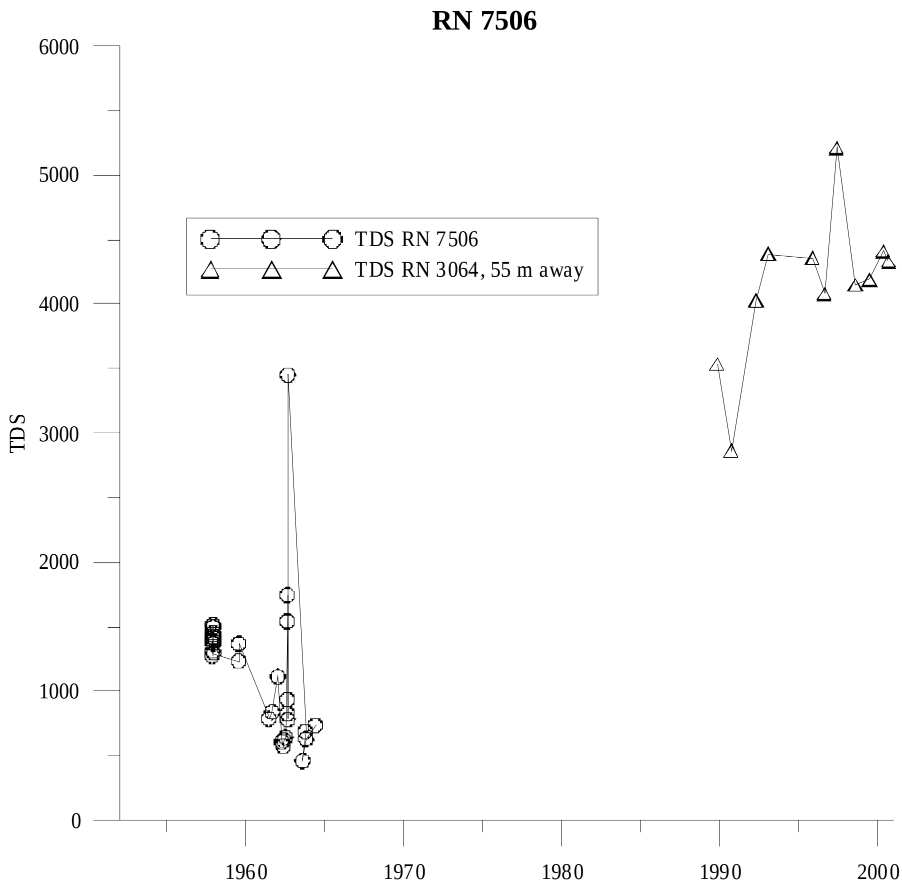

Figure E- 16 RN 7506

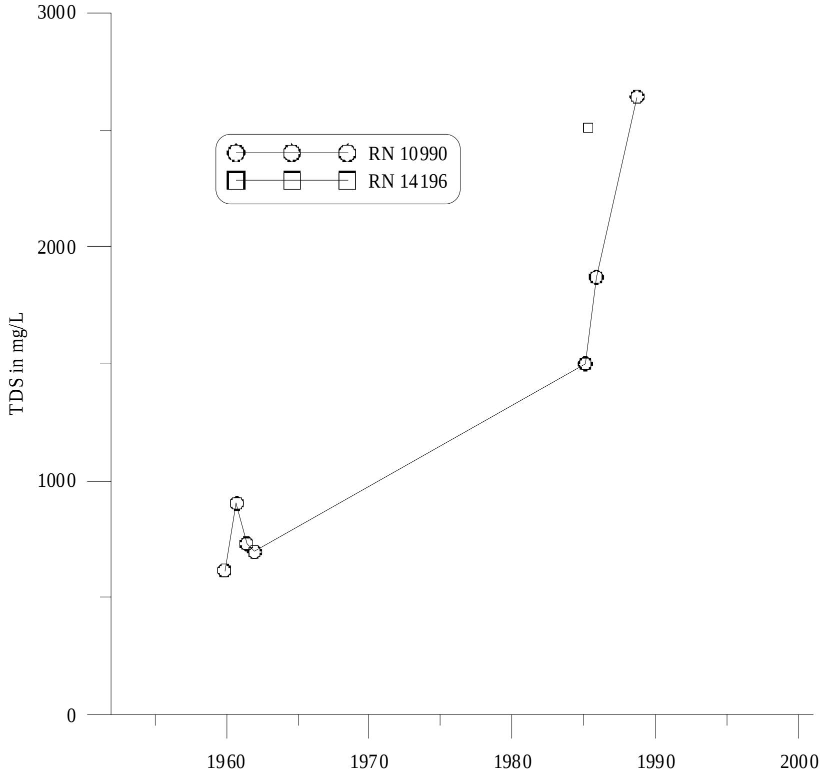

Figure E- 17 RN 10990 & 14196

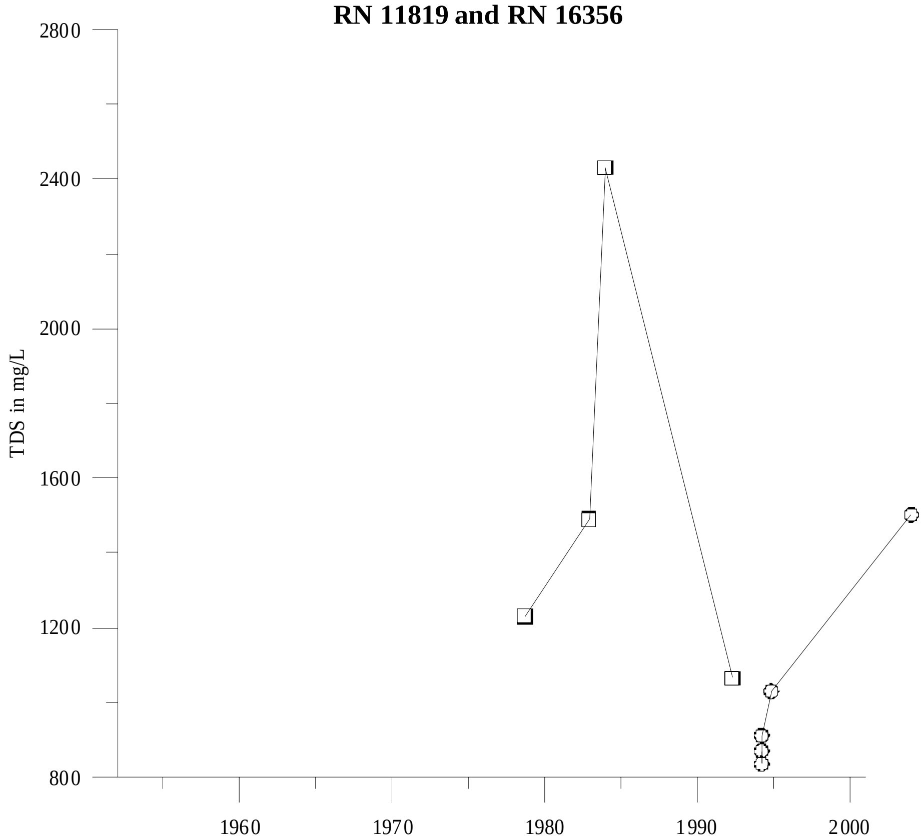

Figure E- 18 RN 11819 and RN 16356

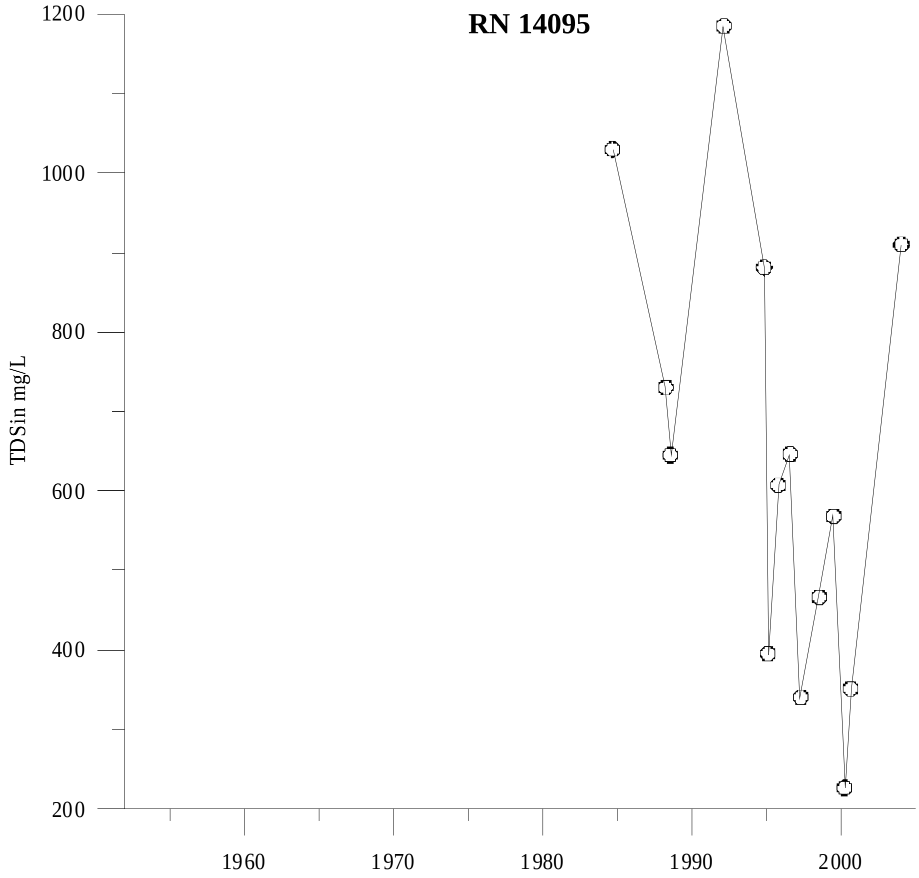

Figure E- 19 RN 14095 TDS

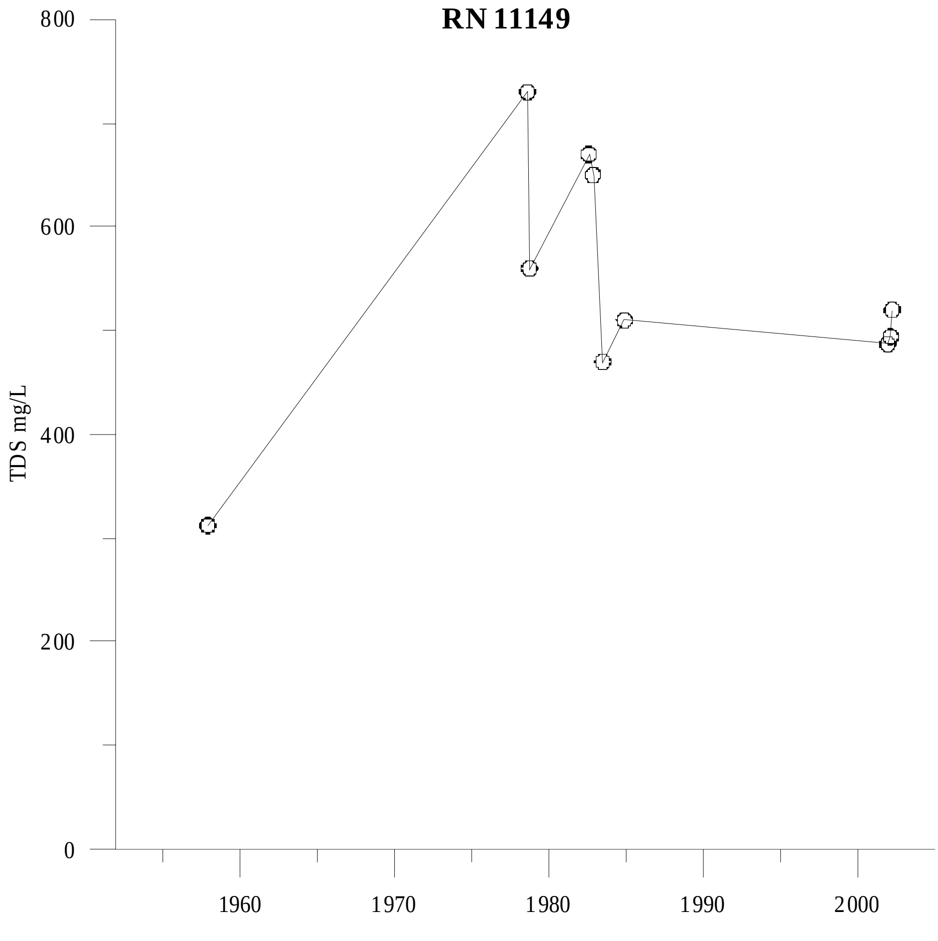

Figure E- 20 RN 11149 TDS

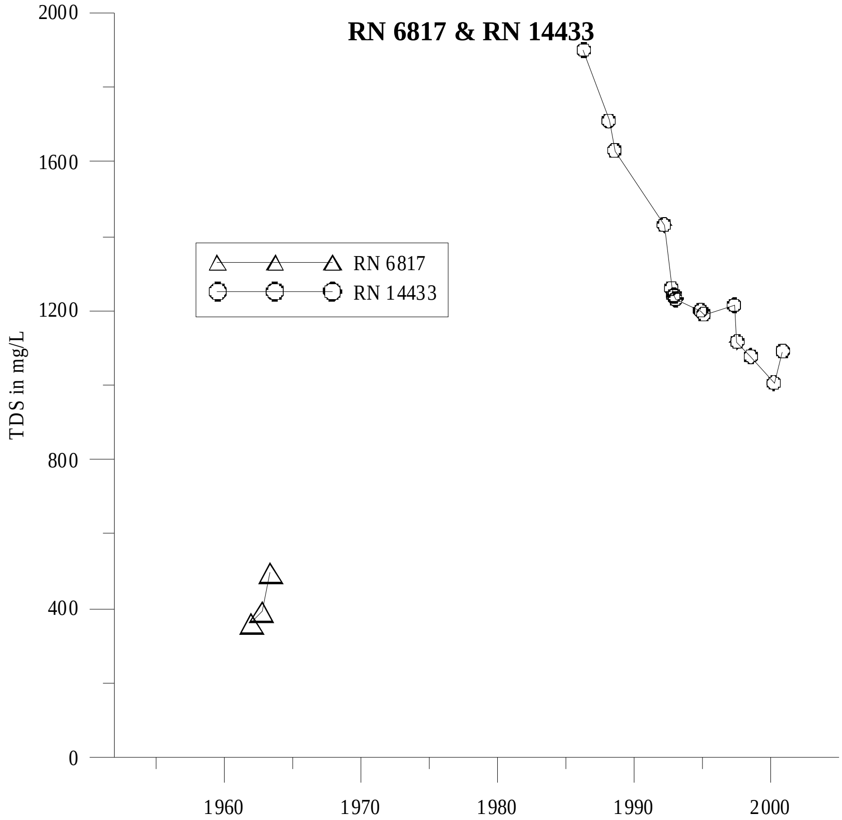

Figure E- 21 RN 6817 and 14433 TDS

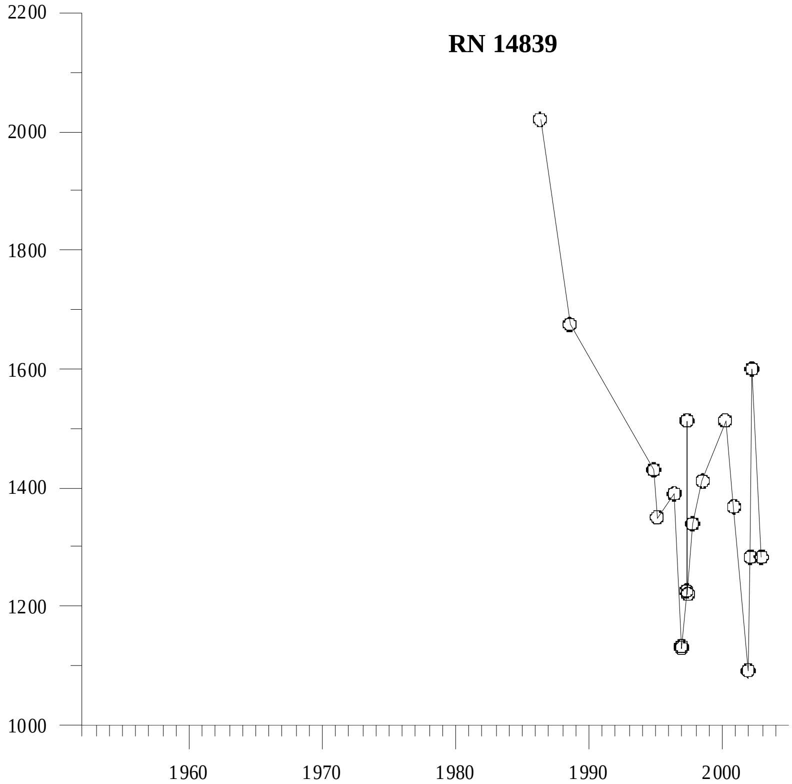

Figure E-22 RN 14839

APPENDIX F

BASIN PARAMETER USED IN BERRY (1992) MODEL

List of Tables

GROUNDWATER FLOW MODEL - 1991-92 RECHARGE ARRAY (m/d *10-5)

	2		4		6		8		10		12		14		16		18		
0.	0.	0.	0.	0.	0.	0.	16.	16.	0.	0.	16.	16.	16.	15.	16.	16.	16.	16.	1
0.	0.	0.	0.	0.	0.	16.	16.	16.	16.	16.	16.	16.	16.	15.	16.	16.	16.	16.	2
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	16.	16.	16.	16.	16.	16.	3
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	16.	0.	0.	16.	16.	16.	0.	16.	4
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	15.	16.	0.	0.	5
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	15.	16.	0.	0.	6
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	16.	16.	0.	0.	7
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	8
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	9
0.	0.	24.	24.	24.	24.	24.	24.	24.	24.	36.	0.	0.	0.	0.	0.	0.	0.	0.	10
0.	0.	24.	24.	24.	24.	24.	24.	24.	24.	36.	0.	0.	0.	0.	0.	0.	0.	0.	11
0.	0.	24.	24.	24.	24.	24.	24.	36.	36.	36.	36.	24.	0.	0.	0.	0.	0.	0.	12
0.	0.	24.	36.	24.	24.	24.	24.	36.	36.	36.	24.	24.	0.	0.	0.	0.	0.	0.	13
0.	0.	36.	36.	24.	24.	24.	24.	36.	36.	24.	24.	24.	0.	0.	0.	0.	0.	0.	14
4.	4.	36.	36.	24.	24.	24.	24.	24.	24.	24.	24.	24.	0.	0.	24.	24.	24.	24.	15
4.	4.	36.	36.	24.	24.	24.	24.	24.	24.	24.	24.	24.	0.	0.	24.	24.	24.	24.	16
4.	4.	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.	0.	0.	24.	24.	24.	24.	17
0.	4.	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.	0.	0.	24.	24.	24.	24.	18
0.	0.	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.	24.	0.	0.	24.	24.	0.	0.	19
0.	0.	0.	0.	24.	24.	24.	24.	24.	24.	24.	24.	24.	0.	0.	0.	0.	0.	0.	20
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	21
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	22
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	23
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	24

Table 1 1991 to 1992 recharge array

GROUNDWATER FLOW MODEL - STORAGE COEFFECIENT (*10-3)

	2		4		6		8		10		12		14		15		18		
1.	1.	1.	1.	1.	1.	1.	260.	260.	1.	1.	30.	30.	30.	30.	30.	30.	30.	30.	1
1.	1.	1.	1.	1.	1.	260.	260.	260.	260.	130.	130.	130.	130.	130.	130.	30.	30.	30.	2
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	130.	130.	130.	130.	130.	130.	130.	30.	30.	3
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	130.	130.	130.	130.	130.	130.	130.	130.	30.	4
1.	1.	1.	20.	20.	30.	30.	130.	130.	130.	130.	130.	130.	130.	130.	130.	130.	130.	30.	5
1.	1.	20.	20.	20.	30.	30.	130.	130.	130.	130.	130.	130.	260.	130.	130.	130.	30.	30.	6
1.	1.	20.	20.	20.	30.	30.	130.	130.	130.	130.	130.	130.	260.	130.	130.	30.	30.	30.	7
1.	1.	20.	20.	20.	30.	30.	130.	130.	130.	130.	130.	130.	260.	130.	1.	1.	1.	1.	8
1.	1.	20.	20.	20.	20.	20.	1.	1.	130.	130.	130.	130.	260.	1.	1.	1.	1.	1.	9
1.	1.	10.	30.	30.	30.	30.	30.	30.	130.	130.	130.	130.	260.	260.	1.	1.	1.	1.	10
1.	1.	10.	30.	30.	70.	70.	70.	70.	70.	130.	1.	1.	260.	260.	3.	3.	1.	1.	11
1.	1.	10.	30.	30.	70.	70.	70.	70.	70.	70.	130.	130.	260.	260.	3.	3.	1.	1.	12
1.	1.	10.	30.	30.	70.	70.	70.	70.	70.	70.	130.	130.	260.	260.	3.	3.	1.	1.	13
1.	1.	10.	30.	70.	70.	70.	70.	70.	70.	70.	130.	130.	260.	1.	1.	1.	1.	1.	14
3.	3.	10.	30.	70.	70.	70.	70.	70.	70.	70.	130.	130.	260.	130.	3.	3.	3.	3.	15
3.	3.	10.	10.	70.	70.	70.	70.	70.	70.	70.	130.	260.	260.	130.	3.	3.	3.	3.	16
3.	3.	10.	10.	10.	70.	70.	70.	70.	70.	130.	260.	260.	260.	260.	3.	3.	3.	3.	17
3.	3.	10.	10.	10.	70.	70.	70.	70.	130.	260.	260.	260.	260.	260.	130.	3.	3.	1.	18
3.	3.	10.	10.	10.	70.	70.	70.	70.	130.	260.	260.	260.	260.	130.	130.	3.	1.	1.	19
1.	3.	3.	10.	10.	10.	70.	70.	130.	130.	260.	260.	130.	130.	1.	1.	1.	1.	1.	20
1.	1.	3.	3.	10.	10.	70.	70.	130.	260.	260.	260.	1.	1.	1.	1.	1.	1.	1.	21
1.	1.	1.	1.	1.	10.	10.	130.	260.	130.	1.	1.	1.	1.	1.	1.	1.	1.	1.	22
1.	1.	1.	1.	1.	1.	1.	130.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	23
1.	1.	1.	1.	1.	1.	1.	130.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	24

Table 2 Storage coefficient

GROUNDWATER FLOW MODEL - R.L. AQUIFER BASE (m A.H.D. - 500)

	2		4		6		8		10		12		14		16		18		
1.	1.	1.	1.	1.	1.	1.	71.	61.	1.	1.	66.	65.	67.	71.	72.	68.	65.	66.	1
1.	1.	1.	1.	1.	1.	71.	71.	61.	61.	61.	60.	60.	60.	60.	60.	63.	64.	67.	2
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	69.	68.	67.	66.	65.	59.	59.	67.	70.	3
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	70.	66.	68.	63.	63.	59.	59.	62.	67.	4
1.	1.	1.	70.	70.	70.	70.	70.	70.	68.	55.	62.	62.	62.	62.	58.	58.	62.	68.	5
1.	1.	70.	65.	65.	65.	62.	62.	62.	62.	51.	61.	61.	61.	57.	58.	58.	65.	70.	6
1.	1.	65.	65.	62.	62.	62.	62.	60.	60.	60.	66.	59.	56.	57.	57.	62.	67.	70.	7
1.	1.	65.	62.	62.	62.	62.	60.	60.	60.	64.	59.	55.	55.	56.	1.	1.	1.	1.	8
1.	1.	65.	62.	62.	62.	62.	1.	1.	60.	54.	54.	54.	65.	1.	1.	1.	1.	1.	9
1.	1.	62.	62.	61.	61.	60.	59.	58.	54.	54.	32.	62.	62.	65.	1.	1.	1.	1.	10
1.	1.	62.	64.	63.	59.	58.	58.	53.	53.	62.	1.	1.	61.	66.	65.	65.	1.	1.	11
1.	1.	62.	59.	58.	60.	57.	53.	53.	53.	60.	50.	60.	60.	60.	65.	65.	1.	1.	12
1.	1.	62.	61.	57.	57.	52.	52.	57.	52.	60.	60.	60.	60.	65.	65.	65.	1.	1.	13
1.	1.	60.	59.	56.	52.	52.	52.	52.	59.	59.	59.	61.	65.	1.	1.	1.	1.	1.	14
62.	62.	59.	58.	56.	51.	59.	56.	56.	59.	59.	59.	62.	65.	65.	65.	65.	65.	65.	15
61.	59.	58.	58.	55.	55.	56.	58.	55.	59.	59.	59.	64.	64.	64.	65.	65.	65.	65.	16
60.	58.	57.	57.	54.	55.	55.	58.	54.	55.	58.	58.	54.	63.	64.	62.	62.	65.	65.	17
59.	57.	57.	55.	53.	57.	54.	54.	54.	54.	52.	57.	60.	60.	63.	62.	62.	65.	1.	18
59.	57.	57.	55.	53.	57.	56.	56.	54.	54.	52.	55.	57.	60.	60.	62.	62.	1.	1.	19
1.	60.	57.	57.	55.	54.	56.	50.	50.	50.	50.	54.	59.	59.	1.	1.	1.	1.	1.	20
1.	1.	60.	53.	58.	57.	55.	53.	49.	49.	53.	57.	1.	1.	1.	1.	1.	1.	1.	21
1.	1.	1.	1.	1.	50.	56.	45.	48.	55.	1.	1.	1.	1.	1.	1.	1.	1.	1.	22
1.	1.	1.	1.	1.	1.	1.	62.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	23
1.	1.	1.	1.	1.	1.	1.	61.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	24

NOTE : DISCHARGE AT GAP (CELL 23,8) OCCURS FOR R.L.W.L. GREATER THAN 562m
INFLOW TO BASIN OCCURS AT R.L.W.L. LESS THAN 560m - REQUIRES CHANGED BOUNDARY CONDITION

Table 3 Aquifer Base

GROUNDWATER FLOW MODEL - CALIBRATED PERMEABILITY (m/d)

	2		4		6		8		10		12		14		16		18		
0.	0.	0.	0.	0.	0.	0.	10.	20.	0.	0.	1.	1.	1.	1.	1.	1.	1.	1.	
0.	0.	0.	0.	0.	0.	10.	10.	20.	20.	10.	10.	10.	10.	10.	10.	1.	1.	1.	2
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	20.	20.	5.	6.	6.	10.	6.	1.	1.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	2.	20.	6.	4.	10.	6.	2.	1.	4
0.	0.	0.	1.	1.	1.	1.	2.	2.	2.	2.	6.	5.	6.	4.	20.	6.	2.	1.	
0.	0.	1.	1.	1.	1.	1.	2.	2.	2.	6.	6.	6.	6.	4.	40.	6.	1.	11.	6
0.	0.	1.	1.	1.	1.	10.	2.	6.	6.	6.	6.	2.	50.	50.	50.	1.	1.	11.	
0.	0.	1.	1.	1.	1.	10.	6.	6.	6.	6.	20.	50.	50.	50.	0.	0.	0.	0.	8
0.	0.	1.	2.	1.	1.	10.	0.	0.	2.	50.	50.	50.	100.	0.	0.	0.	0.	0.	
0.	0.	2.	2.	2.	2.	4.	4.	4.	50.	50.	50.	5.	50.	1.	0.	0.	0.	0.	10
0.	0.	2.	2.	6.	10.	10.	10.	50.	50.	40.	0.	0.	50.	2.	1.	1.	0.	0.	
0.	0.	2.	4.	6.	10.	10.	70.	70.	70.	20.	4.	4.	50.	2.	1.	1.	0.	0.	12
0.	0.	2.	4.	6.	10.	50.	70.	70.	70.	20.	4.	4.	50.	1.	1.	1.	0.	0.	
0.	0.	4.	4.	20.	50.	70.	70.	70.	60.	20.	4.	4.	100.	0.	0.	0.	0.	0.	14
1.	2.	6.	10.	20.	70.	60.	60.	60.	60.	10.	4.	4.	100.	1.	1.	1.	1.	11.	
1.	2.	6.	10.	20.	40.	50.	50.	50.	50.	50.	4.	4.	160.	20.	1.	1.	1.	1.	16
1.	2.	6.	10.	20.	50.	50.	50.	10.	50.	50.	10.	50.	160.	20.	1.	1.	1.	1.	
1.	2.	6.	10.	20.	20.	50.	50.	50.	40.	70.	20.	20.	50.	20.	1.	1.	1.	0.	18
1.	2.	6.	10.	20.	20.	30.	20.	30.	30.	70.	20.	20.	50.	20.	10.	1.	0.	0.	
0.	1.	1.	2.	6.	10.	30.	20.	30.	70.	70.	20.	50.	50.	0.	0.	0.	0.	0.	20
0.	0.	1.	1.	1.	6.	30.	30.	20.	70.	30.	30.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	1.	2.	50.	50.	20.	0.	0.	0.	0.	0.	0.	0.	0.	0.	22
0.	0.	0.	0.	0.	0.	0.	56.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	56.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	24

NOTE : AQUIFER ANISOTROPY - RATIO K DOWN COLUMNS TO K ALONG ROWS = 1.8

Table 4 Permeability

GROUNDWATER FLOW MODEL - AQUIFER TOP (m A.H.D. - 500)

	2		4		6		8		10		12		14		16		18		
1.	1.	1.	1.	1.	1.	1.	90.	90.	1.	1.	90.	90.	90.	90.	90.	90.	90.	90.	1
1.	1.	1.	1.	1.	1.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	2
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	90.	90.	90.	90.	90.	90.	90.	90.	90.	3
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	90.	90.	90.	90.	90.	90.	90.	90.	90.	4
1.	1.	1.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	5
1.	1.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	6
1.	1.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	7
1.	1.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	1.	1.	1.	1.	8
1.	1.	90.	90.	90.	90.	90.	1.	1.	90.	90.	90.	90.	90.	1.	1.	1.	1.	1.	9
1.	1.	90.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.	90.	70.	1.	1.	1.	1.	10
1.	1.	90.	69.	69.	69.	69.	69.	69.	69.	69.	1.	1.	90.	69.	69.	69.	1.	1.	11
1.	1.	90.	68.	68.	63.	68.	68.	65.	68.	68.	68.	63.	90.	68.	68.	68.	1.	1.	12
1.	1.	90.	66.	66.	63.	66.	66.	66.	66.	66.	66.	65.	90.	66.	66.	66.	1.	1.	13
1.	1.	90.	65.	65.	65.	65.	65.	65.	65.	65.	65.	65.	90.	1.	1.	1.	1.	1.	14
90.	90.	90.	90.	64.	64.	64.	64.	64.	64.	64.	64.	64.	90.	90.	90.	90.	90.	90.	15
90.	90.	90.	90.	63.	63.	63.	63.	63.	63.	63.	63.	90.	90.	90.	90.	90.	90.	90.	16
90.	90.	90.	90.	90.	63.	63.	63.	63.	63.	63.	63.	90.	90.	90.	90.	90.	90.	90.	17
90.	90.	90.	90.	90.	62.	62.	52.	62.	62.	62.	62.	90.	90.	90.	90.	90.	90.	1.	18
90.	90.	90.	90.	90.	62.	62.	52.	62.	62.	62.	62.	90.	90.	90.	90.	90.	1.	1.	19
1.	90.	90.	90.	90.	90.	62.	52.	62.	62.	62.	90.	90.	90.	1.	1.	1.	1.	1.	20
1.	1.	90.	90.	90.	90.	62.	52.	62.	62.	90.	90.	1.	1.	1.	1.	1.	1.	1.	21
1.	1.	1.	1.	1.	90.	90.	62.	62.	90.	1.	1.	1.	1.	1.	1.	1.	1.	1.	22
1.	1.	1.	1.	1.	1.	1.	90.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	23
1.	1.	1.	1.	1.	1.	1.	90.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	24

NOTE : VALUE 1. INDICATES INACTIVE CELL
VALUE 90. INDICATES CELL REMAINS UNCONFINED

Table 5 Aquifer Top

APPENDIX G

WATER BALANCES

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DISCUSSION

Potentiometric surfaces (Appendix D) and pumping figures from 1996 to the end of 2002 were used to examine the water balance of the basin.

Stored volumes were estimated as follows:

- Grid files of potentiometric surfaces were generated in Surfer for each complete set of monitoring data in the basin.
- Saturated aquifer volume was then calculated using these files as the upper surface and a grid file for the basement as the lower surface.
- Stored volume was estimated by multiplying the saturated volume by 0.07.

Change in storage was then estimated by subtracting saturated volume of consecutive periods. Figure G- 1 shows change in storage and river flows and rainfall for the period examined.

The water balance equation for the aquifer is

$\Delta S = I + R_r + R_d + R_p + R_s + R_i - E - O_s - P - O$

Where

ΔS is change in storage
I is groundwater inflow, about 30 ML/year
R_r is river recharge
R_d is diffuse recharge
R_p is recharge from leaking pipes
R_s is recharge from sewers
R_i is recharge from irrigation return
E is evapotranspiration
O_s is outflow to sewers
P is pumping
O is outflow through Heavitree Gap, about 40 ML/year

Since P is known, and reasonable estimates exist for I and O. R_r and E vary with weather conditions. The remaining variables can be assumed to be constant with time.

Periods with no river flow were selected to attempt to estimate variable terms R_d and E and the aggregate of the other terms.

A wide range of values was obtained.

Examination of the data for some anomalous increases in storage, as from 4/1997 to 5/1997 showed that the apparent increase was due to a change in the monitoring grid. A contour map of changes in monitoring bores for the same period showed a small decrease.

Losses due to evapotranspiration and gains due to rainfall in periods with no river flow were estimated by an iterative process as follows:

- It was assumed that there is a linear relationship between evaporation as measured from the Class A Pan at Alice Springs Airport and evapotranspiration from the Town Basin.
- The volume change for each period, corrected for pumping was plotted against total daily evaporation at the airport for the same period.

- From this a first estimate was obtained of the relation between evapotranspiration and measured evaporation.
- Using this volume change corrected for evaporation was plotted against rainfall for each period, and a relation obtained between rainfall and diffuse recharge.
- The volume changes for each period were then corrected for rainfall using the above relation and plotted against measured evaporation (Fig. 2).
- The relation obtained from this graph was used for a second plot of change in storage corrected for pumping and evaporation against rainfall (Fig. 3).

From this the following estimates were obtained:
$E = 0.0687\ V$
Where E is evapotranspiration in ML as above
V is measured pan evaporation at Alice Springs Airport in mm. Since average annual V is 2374 mm/year, average E is 163 ML/year.

$R_d = 2.23\ G - 12.4$
Where R_d is diffuse recharge in ML, always ≥ 0.
G is rainfall at Anzac in mm.
The 5 mm threshold value seems too low, and is a result of the two month period. More realistically the threshold would be about 10 mm for a single event. The coefficient is also high. Since the Town Basin has an area of 7.2 km^2 it implies that 30 % of rain over the threshold becomes recharge. However when the nature of the town is considered it is possible. Much of the town area is hard surfaces, which produce a lot of run-off. Most of this run-off goes into the Todd, and becomes recharge. Drains from outside the 7.2 km^2 considered as Town Basin also flow to the Todd. Of the water that does not run to the Todd much is concentrated on areas such as lawns which are already well watered. Since periods of significant rainfall and no river flow are rare this equation must be considered very approximate, and extrapolating into wetter months is risky.
This is confirmed by the contours of rise in water level from September to October 1997 (App. D, Fig. 21) which is the high value in Figure G- 3. It can be seen that most of the water level rise is due to a recharge mound near where the Sadadeen Drain empties into the Todd.

Since some of this is not truly diffuse recharge it will be referred to as local recharge to distinguish it from recharge due to flow in the Todd above Anzac.

Applying this equation to 62 years of rainfall data from Alice Springs Airport gives an average local recharge of 538 ML/year. This calculation is not meaningful, since at times of river flow the contribution from the storm drains will make no difference to total recharge.

Averaging local estimated local recharge for monitoring periods with no flow gave 112 ML/year over the six years. This would be an underestimate as there would be events with significant rainfall and no river flow in the periods for which river flow occurred. A reasonable guess for local recharge is 200 ML/year.

(continued on p. G-4)

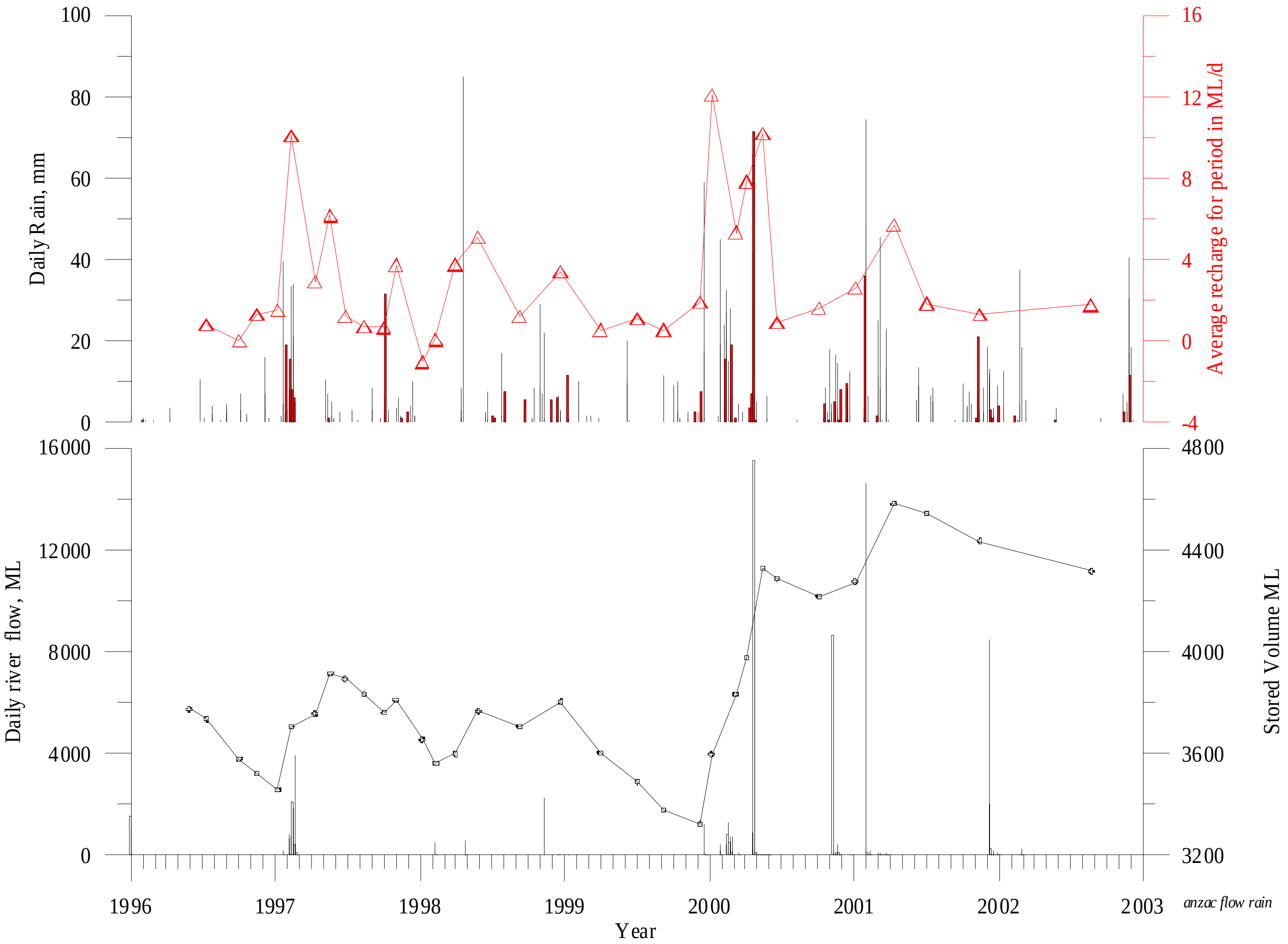

Figure G- 1 Storage, river flow and rainfall in the Town Basin

If the net outflow of 10 ML/year (that is I = 30 ML/year, O = 40 ML/year) is included in the water balance the equation needs to be

$R_d = 2.2\ (P - 10)$

The remaining terms, R_p, R_s, R_i, and O_s would appear to be so small as to be lost in the errors in the other estimates.

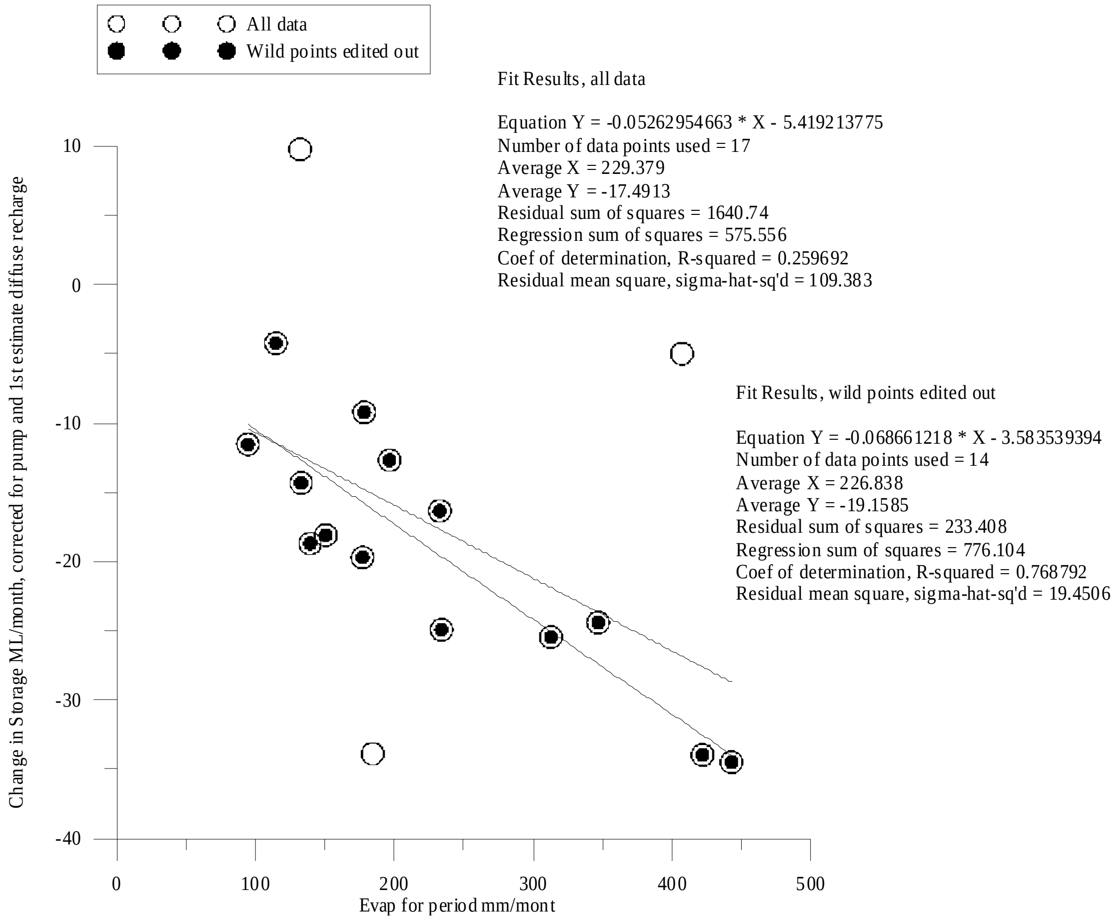

Figure G- 2 Estimated change in storage in ML/month, corrected for pumping and estimated diffuse recharge against pan evaporation at Alice Springs Airport.

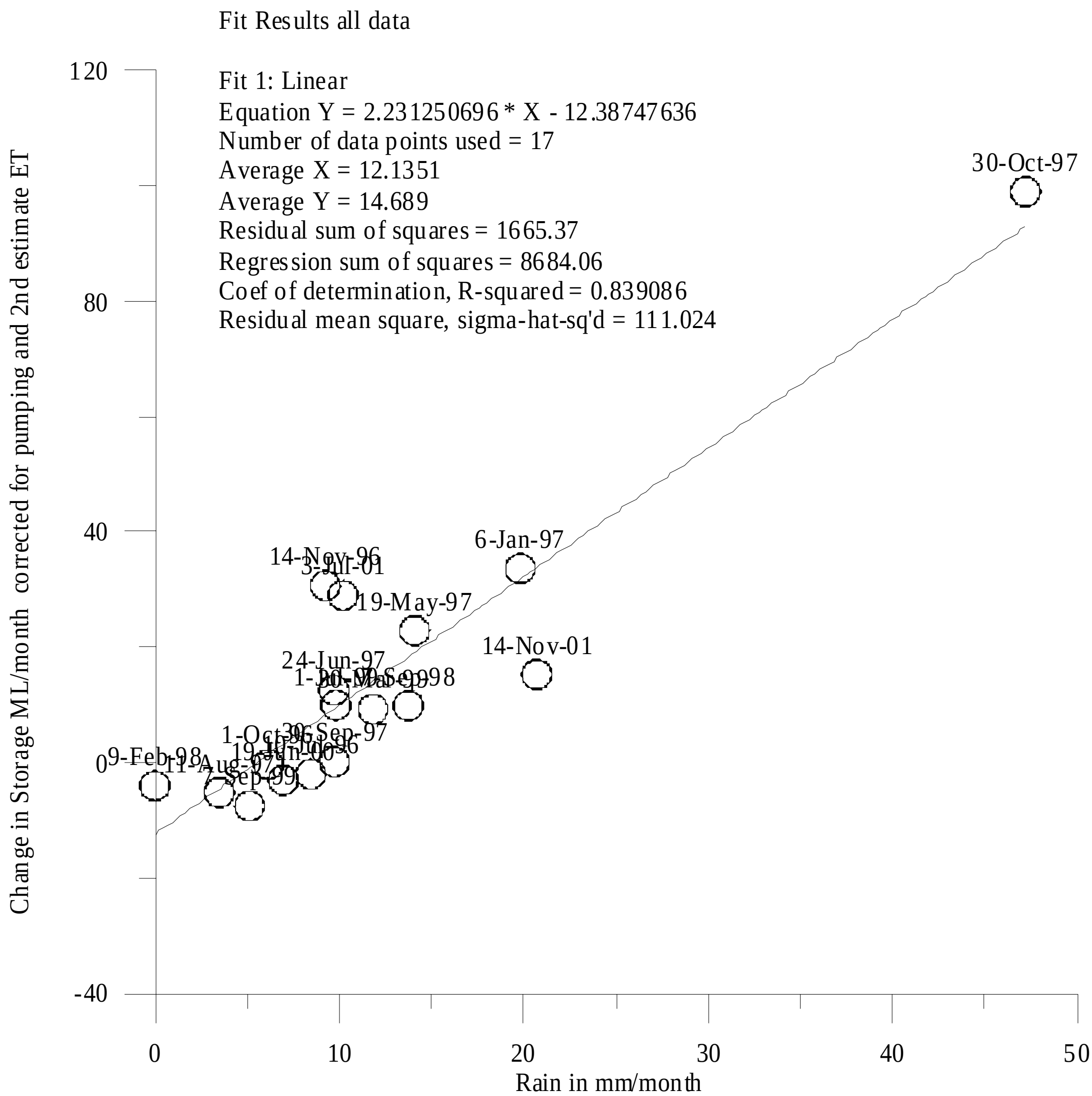

Figure G- 3 Change in storage corrected for pumping and evapotranspiration per month against rainfall in mm/month.

APPENDIX H

HYDROGRAPHS AND INFLOW OUTFLOW CALCULATIONS

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1 Outflow through Heavitree Gap

Figure H-1 shows the variation in head between RN 3604 and RN 3667.

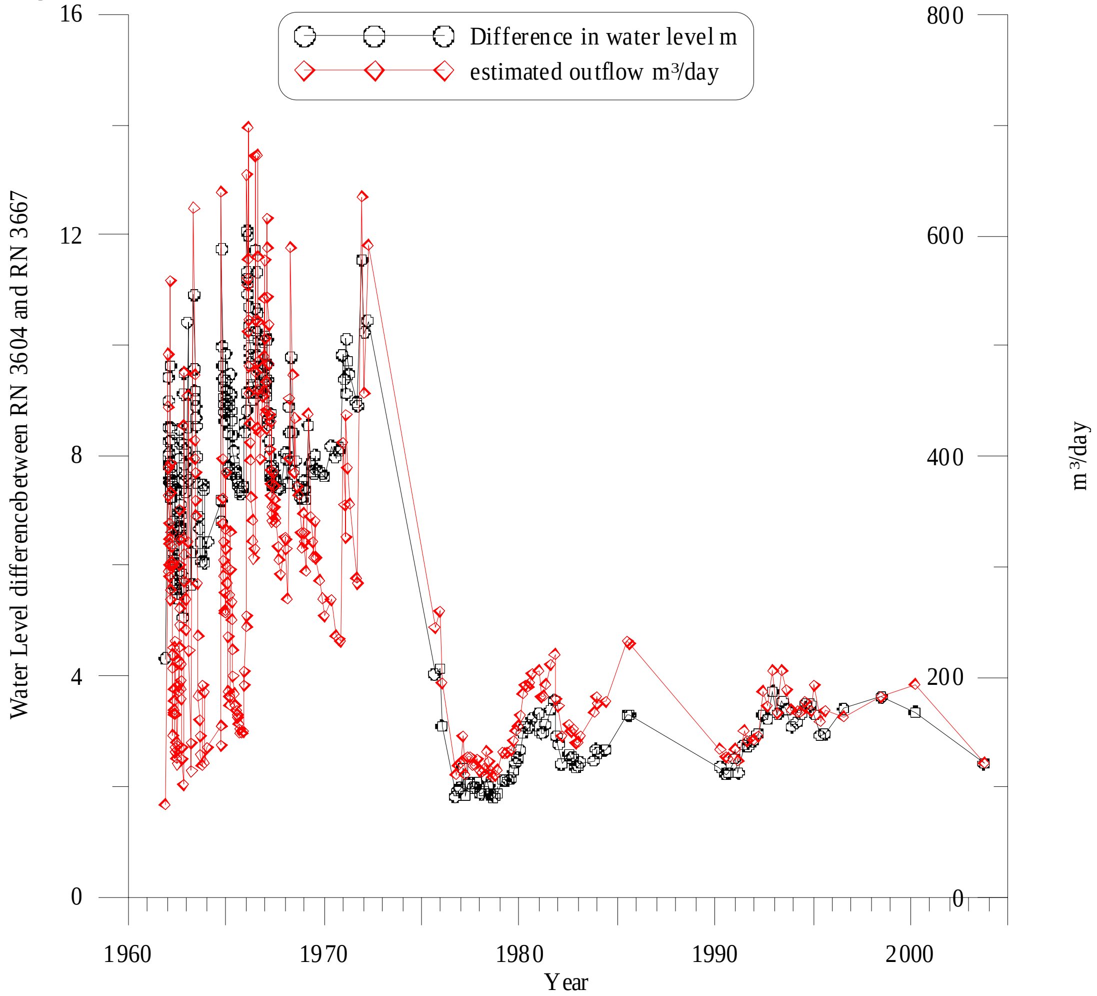

Figure H-1 Head difference through Heavitree Gap and estimate outflow

It can be seen that there has been a significant change in the head difference since about 1975. The influence of the change in saturated thickness was tested as follows: Hydraulic gradient through the gap was estimated as follows:

> The aquifer between RN 3064 and RN 3667 was considered to consist of a parallell-sided channel in the gap and a wedge below it. The angle of the wedge was adjusted to account for the increase in depth toward RN 3667.
> Assuming steady flow through the gap hydraulic gradient could then be described in terms of Darcy's Law through the gap and the Theim equation modified for a wedge from there on.
> With these assumptions the proportion of the head difference in the channel section downstream of RN 3064 was calculated to be 0.32.
> From this the hydraulic gradient in the channel aquifer was calculated to be the observed head difference multiplied by 0.0022.

The cross-section in Heavitree Gap (Figure H-2) was used to compile a graph of saturated area against head in RN 3067 (Figure H-3), and a polynomial fit to describe the area obtained.

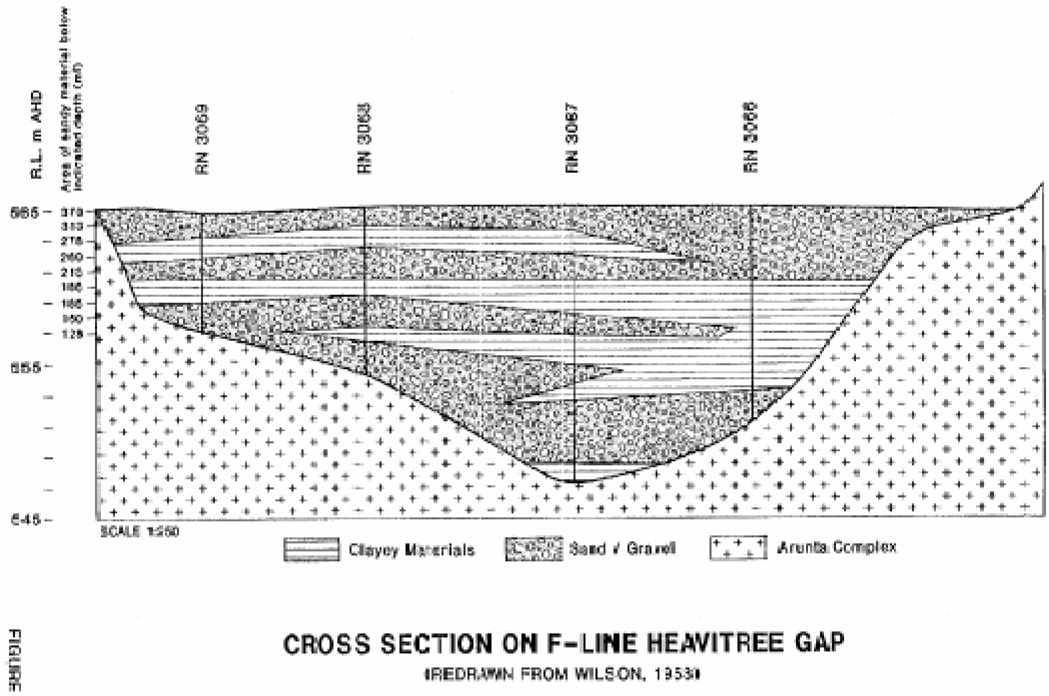

Figure H-2 Cross section at Heavitree Gap, from Berry (1992), after Wilson (1953)

Berry (1992) divided Heavitree Gap vertically into three zones with different permeabilities). These were used in conjunction with the hydraulic gradient estimated previously to estimate instantaneous discharge through the gap. Results are shown in Figure H-1, and summarised in Table H-1.

Table H-1 Outflows at Heavitree Gap

Outflow	Up to 1972		Since 1975	
	m3d	ML/year	m3d	ML/year
Maximum	679	246	253	92
Minimum	80	29	107	39
Average	297	108	213	77

Wilson (1957) measured hydraulic gradients in Heavitree Gap, but no data could be found to allow direct correlation of water levels in RN 3067 with the two monitoring bores. Wilson (1957) states that the hydraulic gradient in the gap ranged from 0.00369 to 0.0079.

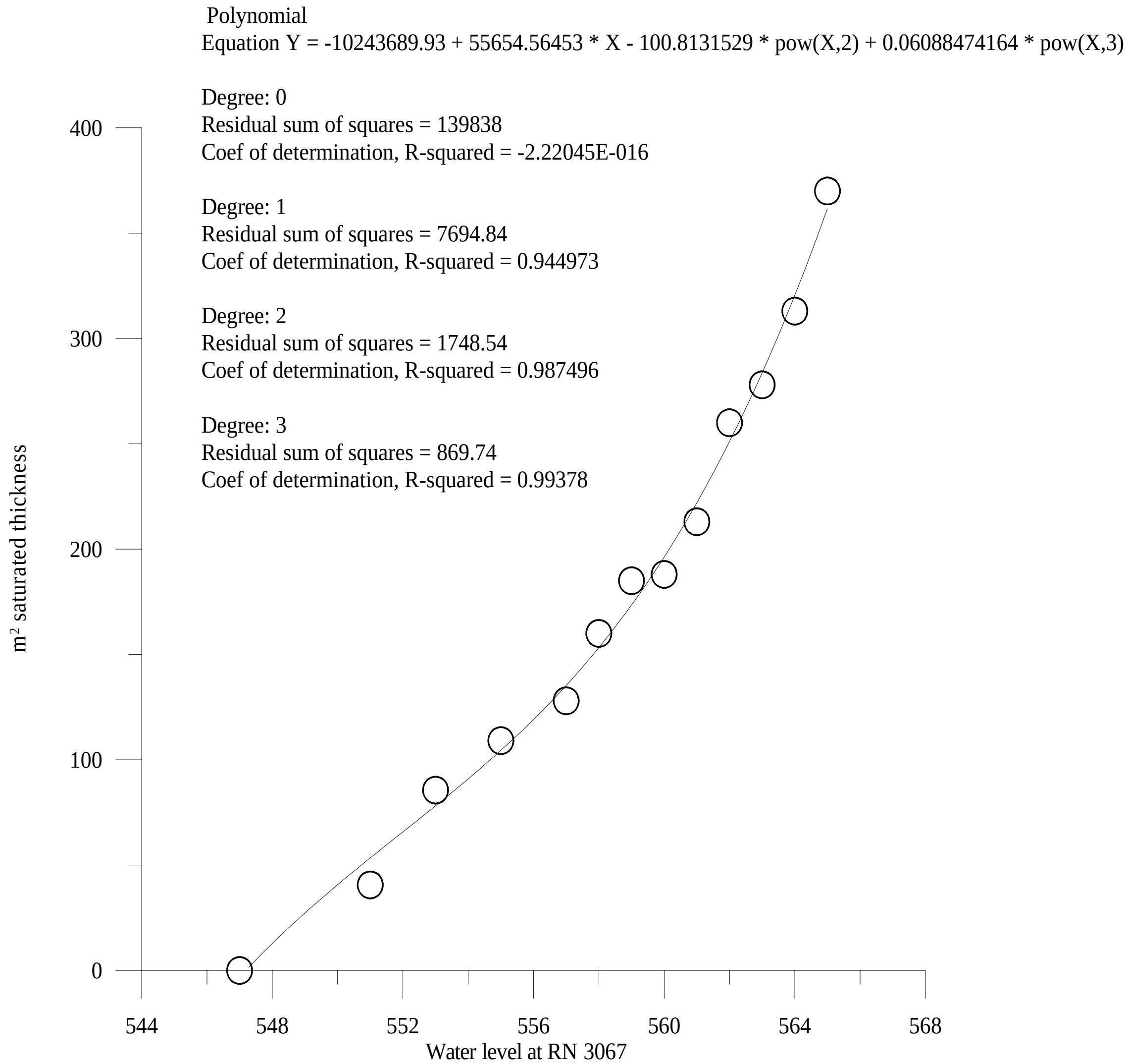

Figure H-3 Saturated area on F-line vs water level, after Berry (1992)

RN 4957

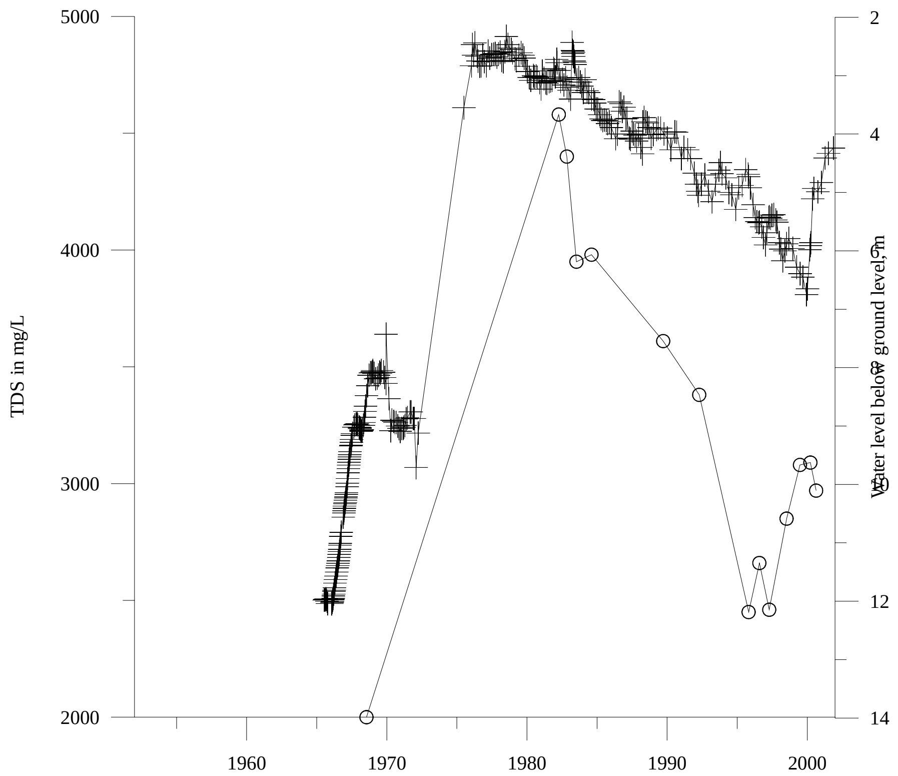

Figure H- 4 RN 4957, water level and TDS

2 Inflow to the basin

Figure H-5 was an attempt to examine changes in inflow to the basin over time using the difference in head between the northernmost two bores. The graph shows wide variation over the years, and is negative for a significant portion of the time. Clearly in the 1960's RN 5801 was affected by pumping from RN 2680 and RN 2643, and more recenly by pumping from RN 15904. The hydraulic gradient cannot be used to quantify inflow to the Town Basin.

Figure H-6 shows the difference between RN 5802 and RN 5803. Predictably the gradient is steepest immediately after river flows.

The gradient has been negative at times showing that RN 5802 has been affected by pumping

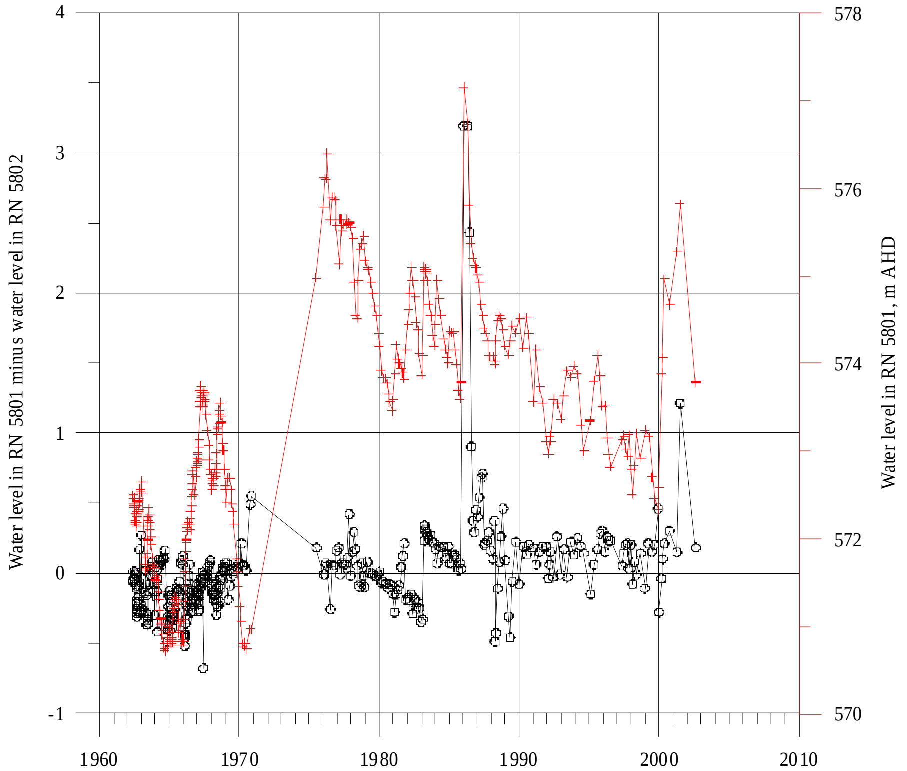

Figure H-5 Hydrograph RN 5801 and difference RN 5801 RN 5802

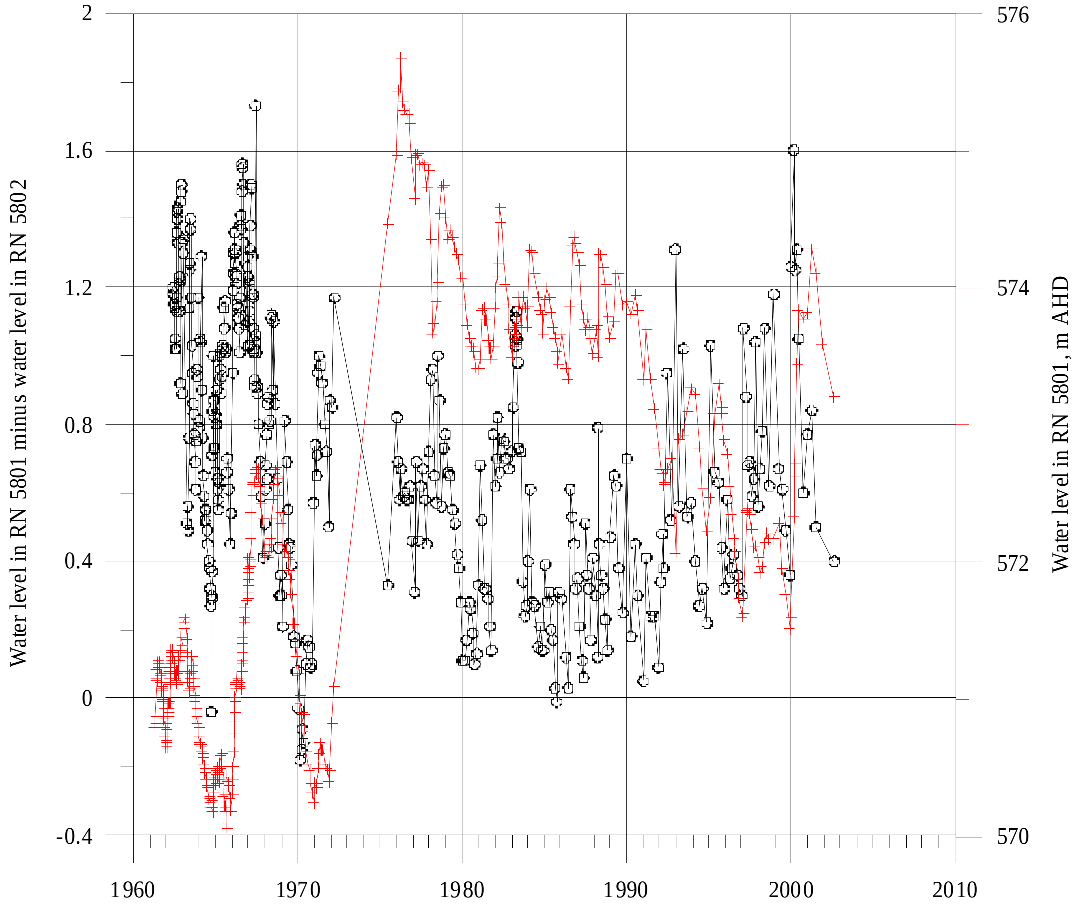

Figure H-6 Hydrograph RN 5803 and difference RN 5802 RN 58033

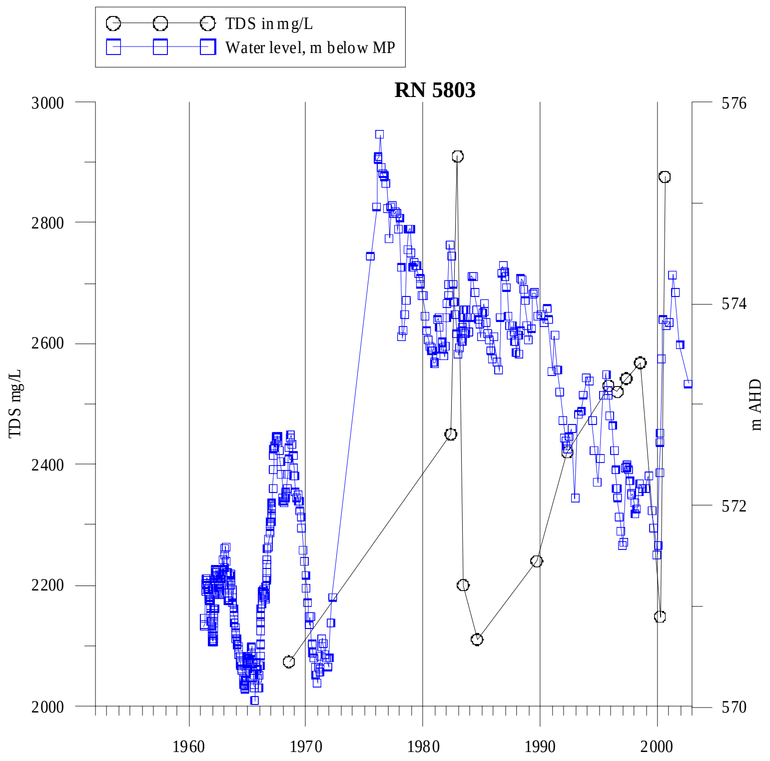

Figure H- 7 RN 5803, water level and TDS

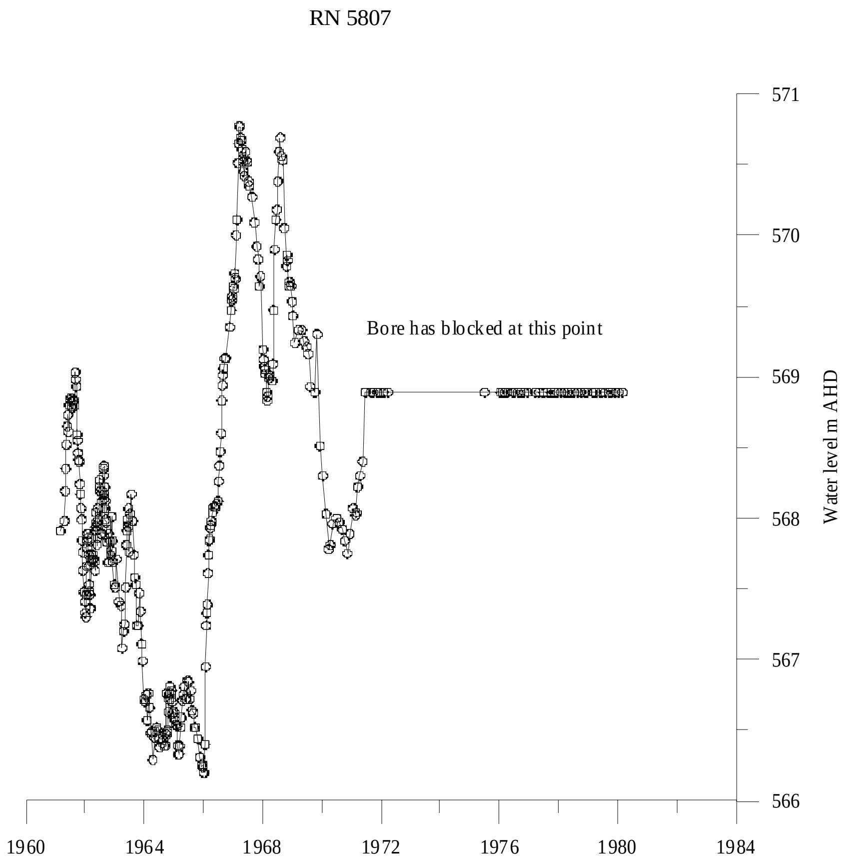

Figure H- 8 RN 5807

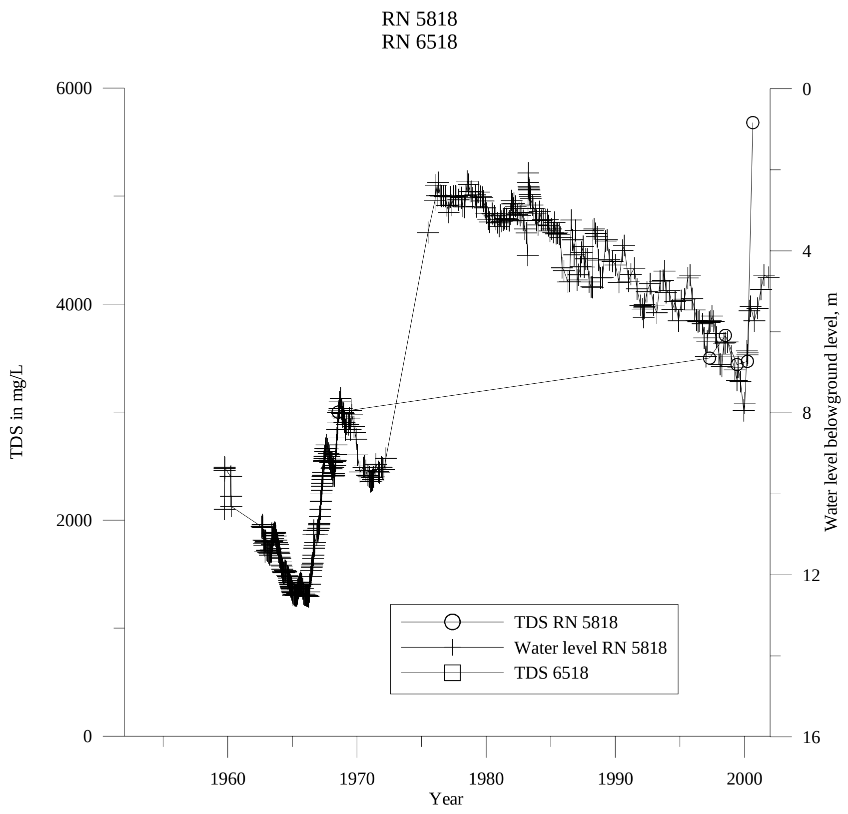

Figure H- 9 RN 5818 and RN 6518, water levels and TDS

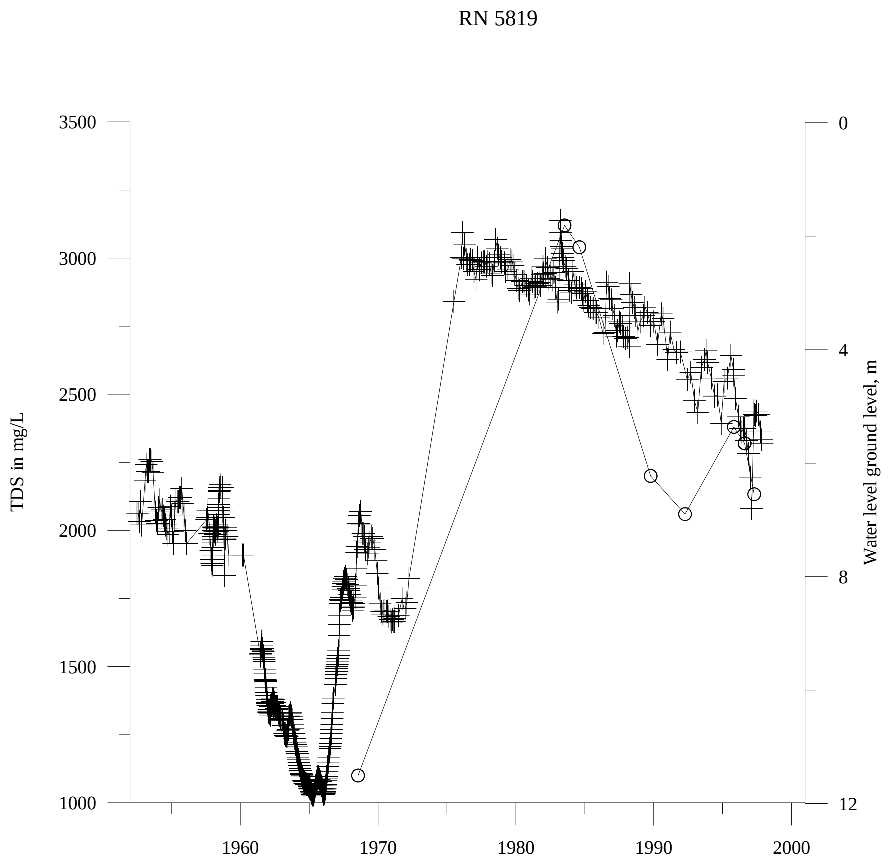

Figure H- 10 RN 5819, water levels and TDS

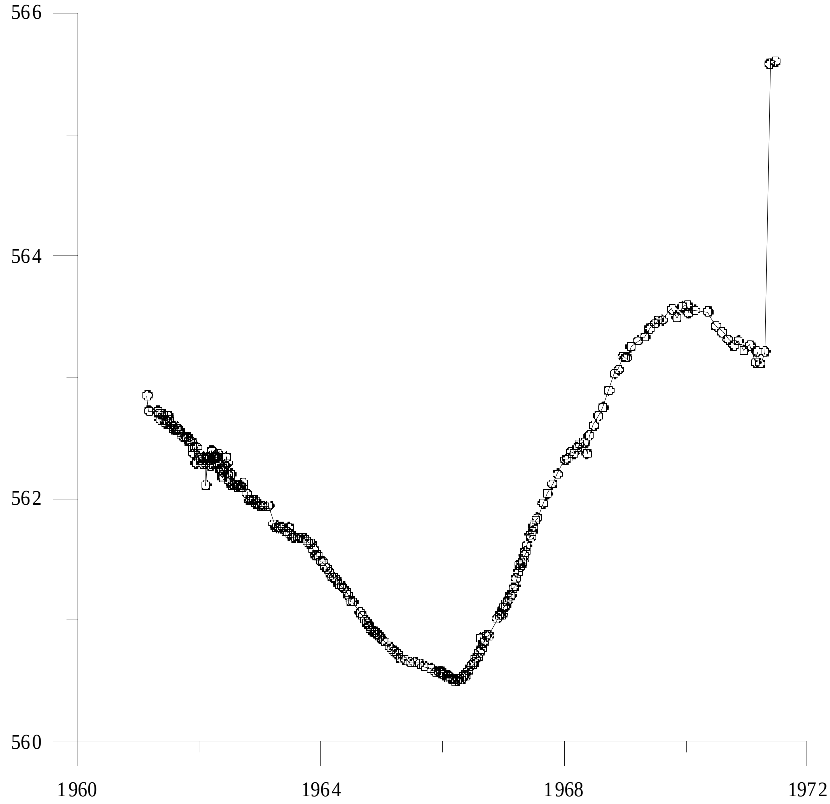

Figure H- 11 RN 5822

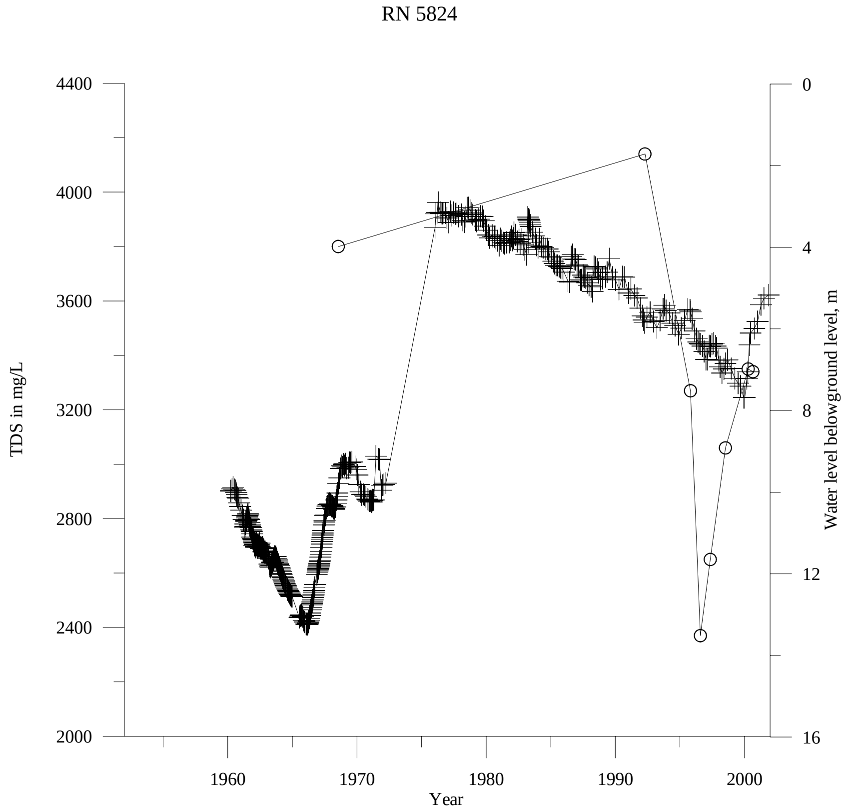

Figure H- 12 RN 5824, water levels and salinity

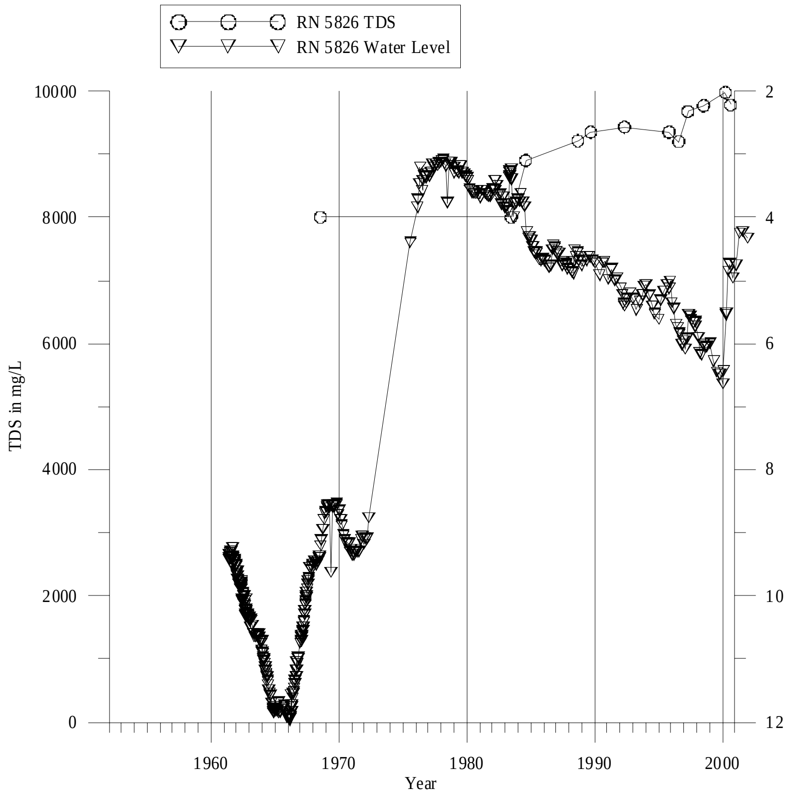

Figure H- 13 RN 5826, TDS and water level

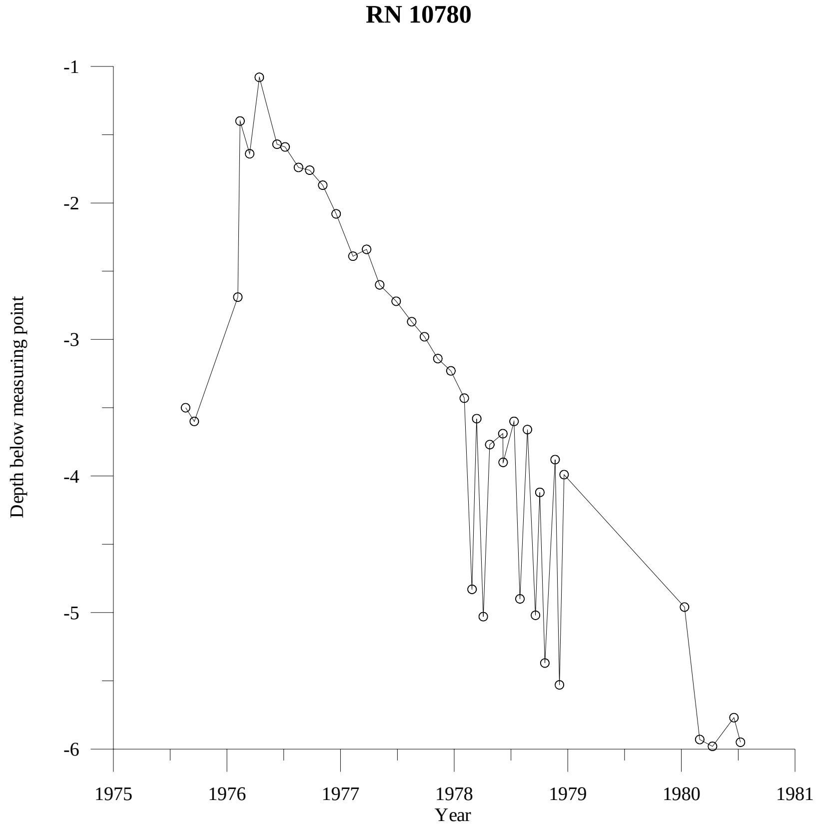

Figure H- 14 RN 10780, water levels

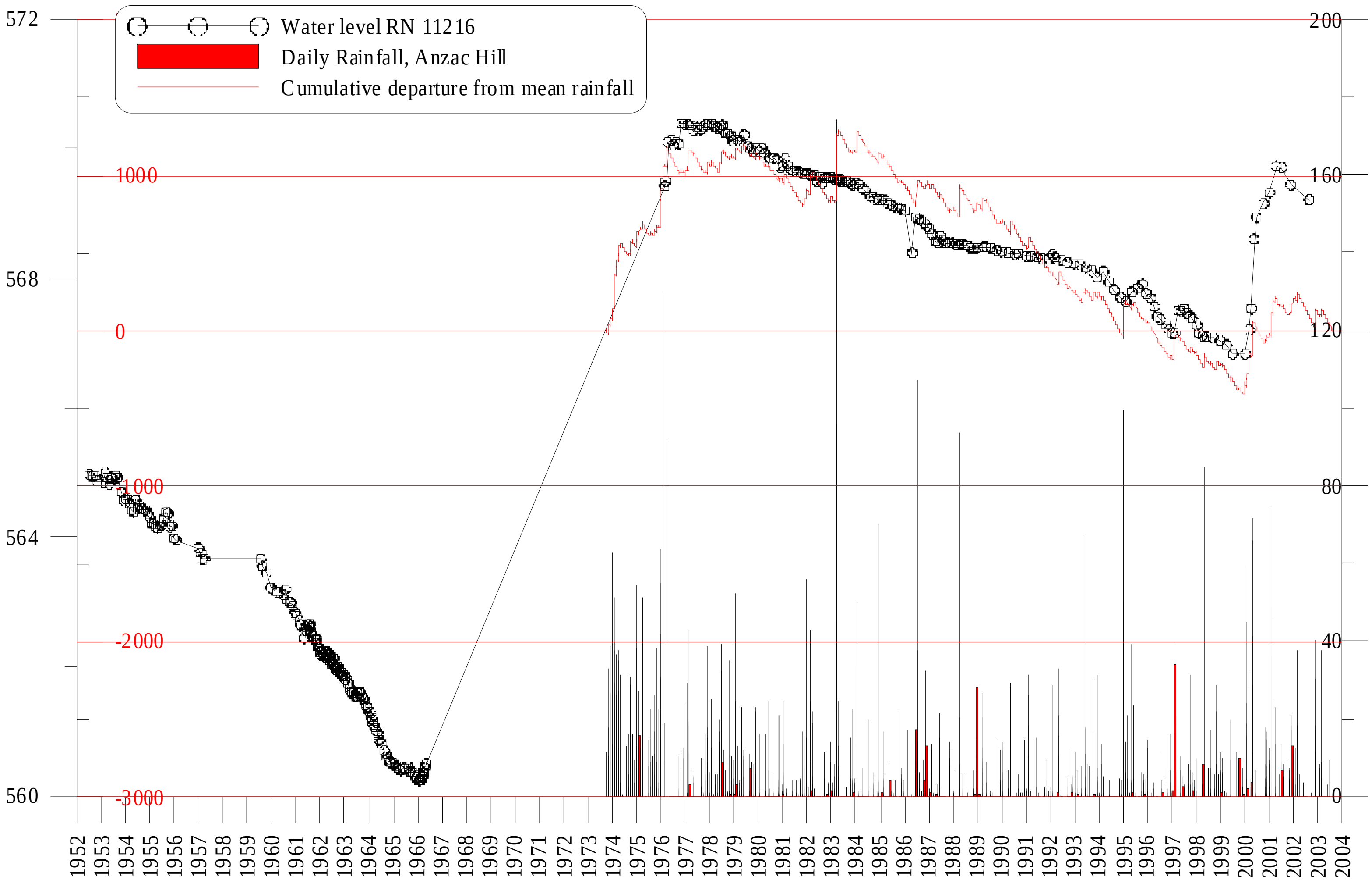

Figure H- 15 RN 11216, hydrograph and rainfall

APPENDIX I

BORE HYDRAULICS

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1 INTRODUCTION

There is a great deal of pumping test data available for the Town Basin, and it was not possible to analyse all of them for this report. Table I-1 lists all the tests in the Alice Springs pump test register.

2 DISCUSSION

Drawdown in a production bore at a given time can be described by the Jacob Equation.

$s=BQ+CQ^2$

Where

s is drawdown at a given time

Q is pumping rate

B is a constant that contains both aquifer losses and bore construction effects

C is a constant that describes the turbulent flow losses, usually in the bore screen and the immediately adjacent aquifer.

The constants were determined for all production bores for which suitable step tests could be found, and are shown in Table I-2 .

Figures I-1 to 7 show the relationships between the B and C parameters and screen length and aperture, to each other, and to transmissivity. The following conclusions can be drawn:

Neither parameter shows a correlation with screen length.

Both parameters show a correlation with screen aperture.

The parameters are strongly correlated to each other.

Both parameters are strongly correlated with transmissivity.

Hence screens of sufficient length have been used. The relationship with aperture is probably an indirect effect of the correlation between transmissivity and grain size.

Figure I-7 shows that the turbulent flow losses occur in the aquifer and not just in the slots.

The relationships with transmissivity provide a means of assessing the efficiency of bore completions. There are only four bores completed with 150 mm screens, and the plot of their performance is scattered. Based on this limited data set there is no evidence to show that the large diameter bores are more efficient than 150 mm bores.

3 FRINGE AREAS

4 I*ntroduction*

An attempt was made to estimate hydraulic parameters in the fringes of the Town Basin where few or no systematic pump tests have been conducted. Bores with yields were selected. In general it has been necessary to make assumptions as to storage coefficient and pumping times. In some cases qualitative descriptions such as “small” have been given a possible range of numerical values.

Many bores have no logs. Of those with drillers’ logs it is not possible to distinguish between alluvium and weathered bedrock. For most of the bores there is no record of where the water was cut, and it is not clear whether the aquifers are in alluvium, weathered bedrock or fresh fractured bedrock.

To estimate hydraulic conductivity it was generally assumed that the saturated thickness was the total depth of the bore below water table.

Table I-1 Pumping tests in the Alice Springs register

Book No	Date	Locality	Name	RN	(1)	
780	15/01/1980	Alice Springs	U.S.A. Air Force	2875		
86	29/09/1965			3089		
801	01/07/1980	Alice Springs		3095		
66	06/07/1964	Alice Springs	College Bore	4442		
281	16/07/1974	Traeger Park	Army Well # 2	6518	B	
1008	27/02/1984	Alice Springs	Army Well # 2	6518	B	
673	27/09/1978	Alice Springs		6782	B	
1088		Alice Springs		10990		
388	12/09/1975	A/S Commonage		11003		
670	28/08/1978	Alice Springs	Bent Tree	11088		
678	23/09/1978	Alice Springs		11149		
891	03/03/1981	Alice Springs		11149	B	
512	10/08/1976	Traeger Park		11382	B	I
676	29/08/1978	Alice Springs		11817	B	
671	07/09/1978	Alice Springs		11819		I
679	09/10/1978	Alice Springs		11820		
696	11/09/1978	Alice Springs		11820	B	
819	07/07/1980	Alice Springs	Jail Bore	12473	B	
882	08/12/1980	Alice Springs	Jail Prod # 1	12733		
1018	14/05/1984	Alice Springs	Spearpoint System	13625		
1127	04/05/1984	Alice Springs	Spearpoint System	13625		
1010	15/03/1984	Alice Springs		13919	B	I
1051	08/09/1984	Alice Springs		14095	B	I
1087	22/03/1985	Alice Springs		14196	B	I
1092	06/06/1985	Alice Springs		14222	B	I
1101	29/08/1985	Alice Springs		14407	B	I
1125	04/02/1986	Alice Springs		14417	B	
1132	17/03/1986	Alice Springs		14429	B	I
1137	24/04/1986	Alice Springs	Treager Park	14433	B	I
1141	01/05/1986	Alice Springs		14836		
1144	20/05/1986	Alice Springs		14837	B	I
1491	26/11/2002	Eastside Todd River	Riverbank Bore	14837		
1139	29/04/1986	Alice Springs	Treager Park	14839	B	I
1215	20/04/1988	Alice Springs Council	Todd Bank Carpark	15096	B	I
1197	22/07/1988	Alice Springs		15099	B	I
1208	25/07/1988	Alice Springs Council	Council Lawns	15211	B	I
1275	14/08/1990	Alice Springs Council	2 Prod books A & B	15753		
1281	02/10/1990	Alice Springs		15760	B	I
1287	05/02/1991	Alice Springs	Traeger Park School	15761	B	
1493	14/12/2002	Treager Park School		15761		
1386	14/07/1994	Alice Springs	St Philips College	15904		
1379	18/03/1994	Alice Springs	Kempe Street	16356		I
1378	25/02/1994	Alice Springs	Kempe Street	16357		

(1) B, tests listed by Berry 1992 and shown in Table 7 of the main text.
I, tests included in Table I-2 below.

Table I-2 Bore parameters

RN	Depth m	Date	Screened Intervals m	Screen Aperture mm	T m^2/d (1)	C $m/(L/s)^2$	B m/(L/s)	Non-linear losses at recommended rate m	Recommended Rate L/s
6782	19.2	26/06/1957	12.5-19	10 mm perf	130	0.052	0.48		
11382	18.0	13/07/1976	12-18	0.75	530	0.057	0.48		
11819			13-15	2.5		0.0054	0.052		
13919	13.0	02/02/1984	8-10.6	3	37	0.20	0.752		
14095	7.6	24/08/1984	2.5-5.5	3.5	1500	0.0017	0.044	0.37	15
14196	20.0	08/02/1985	16.5-19.5	2&2.5	131	0.038	0.17	3.11	9
14222	18.0	13/05/1985	11-14	4	1490	0.0012	0.044		
14407	18.7	09/07/1985	11-13, 17-18	2	790	0.0054	0.052	2.17	20
14429	16.5	26/02/1986	7-8, 13-15	2	169	0.012	0.26		
14433	18.0	10/04/1986	13-15	2	1200	0.0039	0.14	0.39	10
14837	16.4	09/05/1986	13-15	2	79	0.080	0.84	1.28	4
14839	19.0	12/04/1986	11-13	2	513	0.0096	0.079	0.96	10
15096	20.5	07/04/1988	12-14 18-20	0.75	108	0.15	0.88		
15099	21.4	07/06/1988	18-20	2	59	0.11	1.36		
15211	18.1	10/06/1988	15-17	2	62	0.059	1.62		
15760	14.0	20/09/1990	11-13	2	1725	0.0028	0.050		
15761	21.9	04/10/1990	9-11 16-18	1.75	1365	0	0.14		19
15762	22.8	18/12/1990	14-16	2	225	0.12	0.17		
16356	13.5		9.1-12.2	1	209	0.029	0.23	0.72	5

(1) By Jacob drawdown method

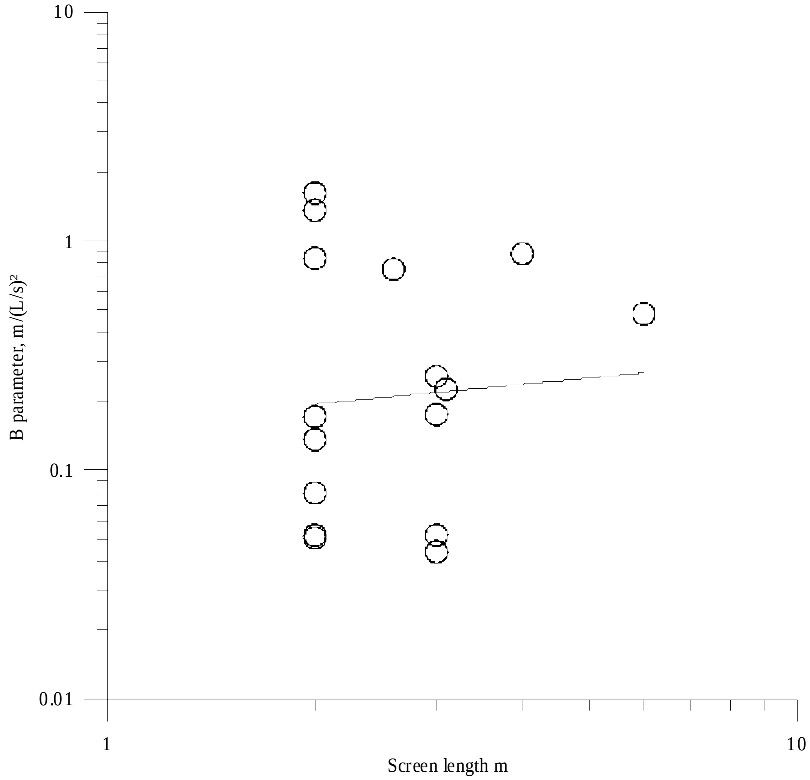

Figure I- 1 Relation between B and screen length

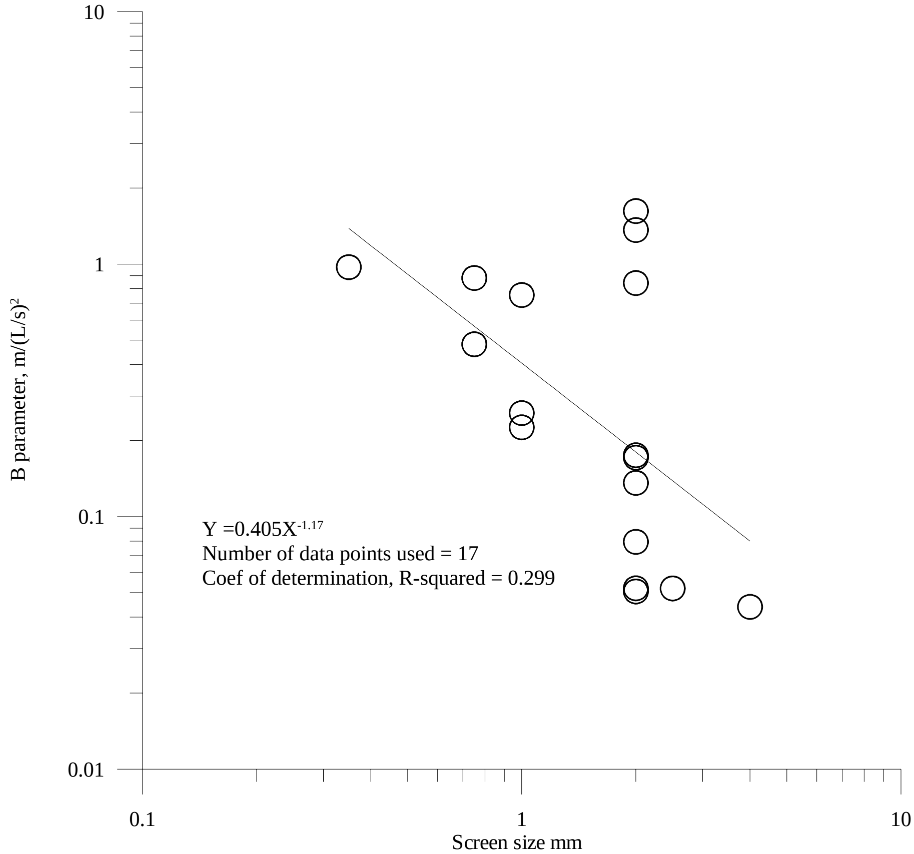

Figure I- 2 Relation between B and screen aperture

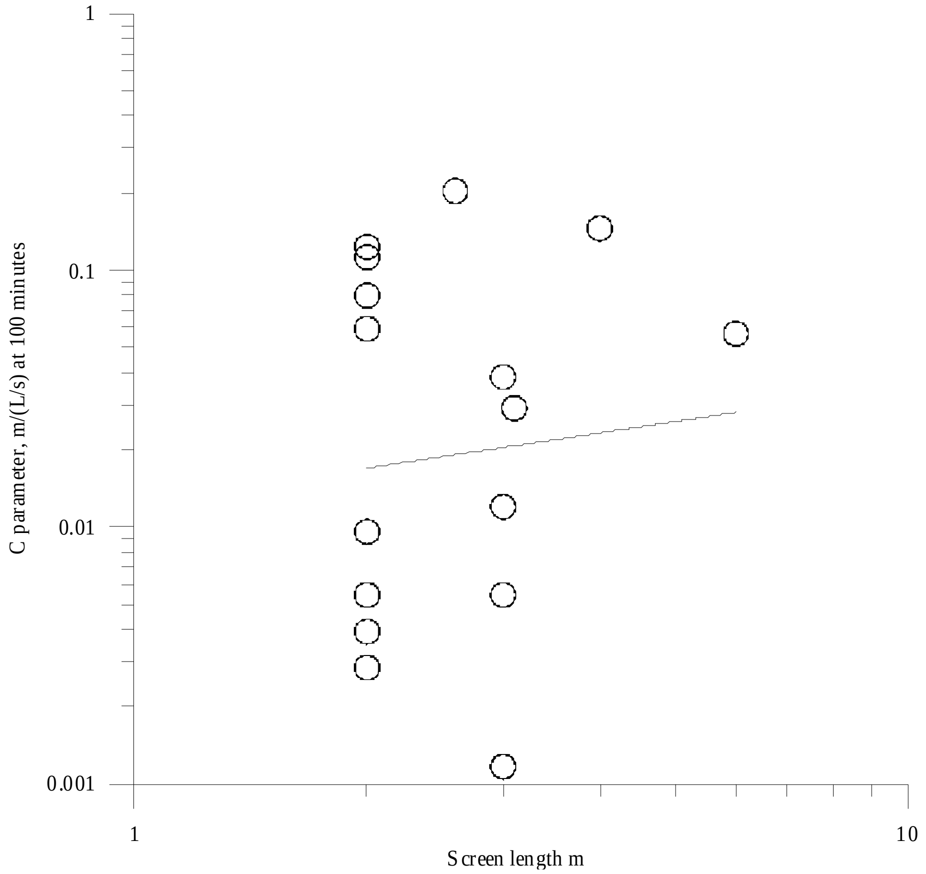

Figure I- 3 Relation between C parameter and screen length

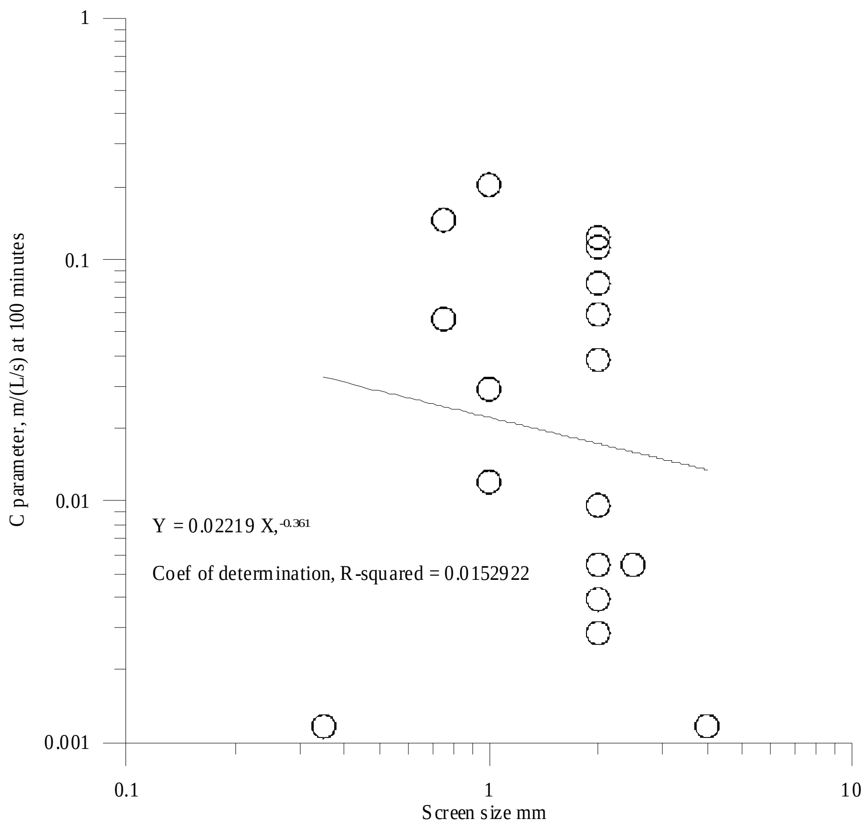

Figure I- 4 Relation between C parameter and screen aperture

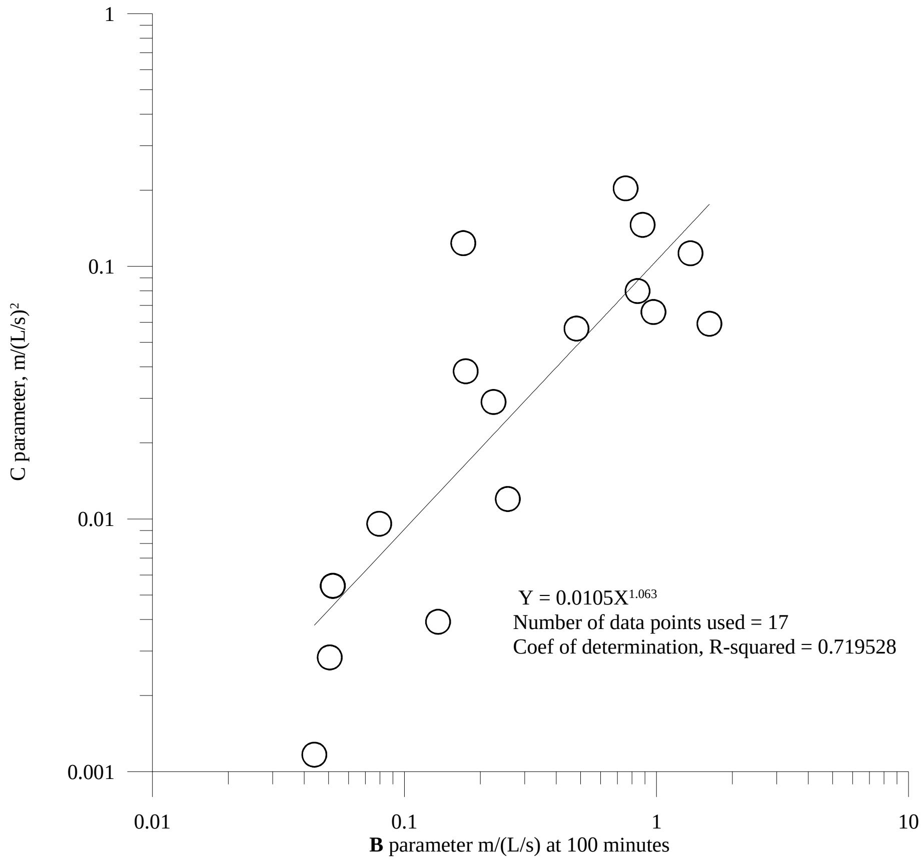

Figure I- 5 Relation of B and C parameters

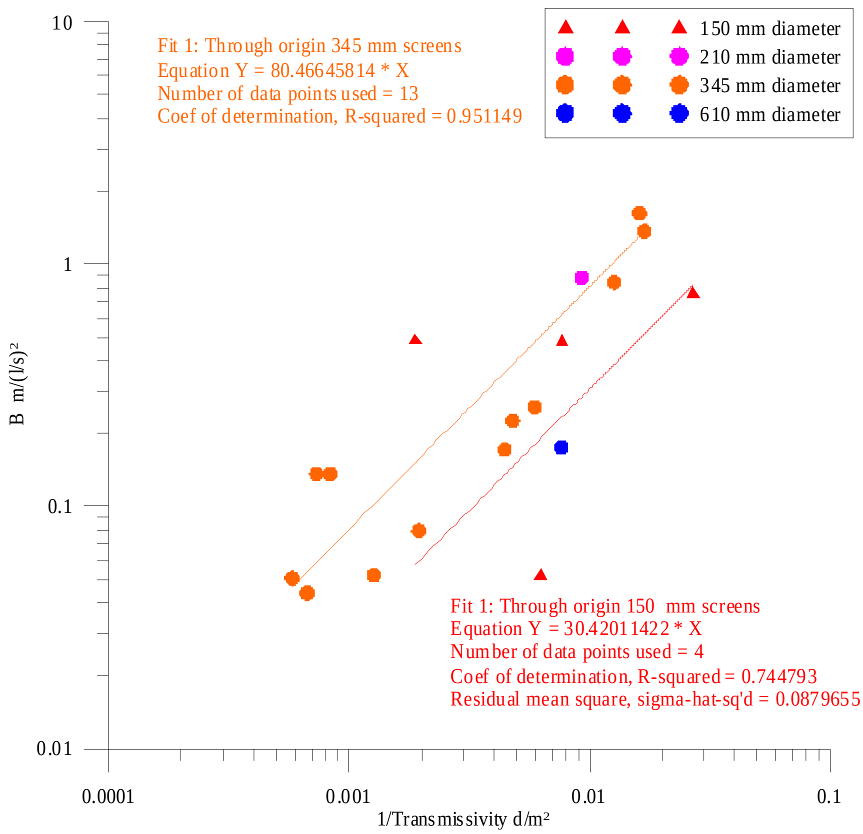

Figure I- 6 Relation between B and 1/transmissivity

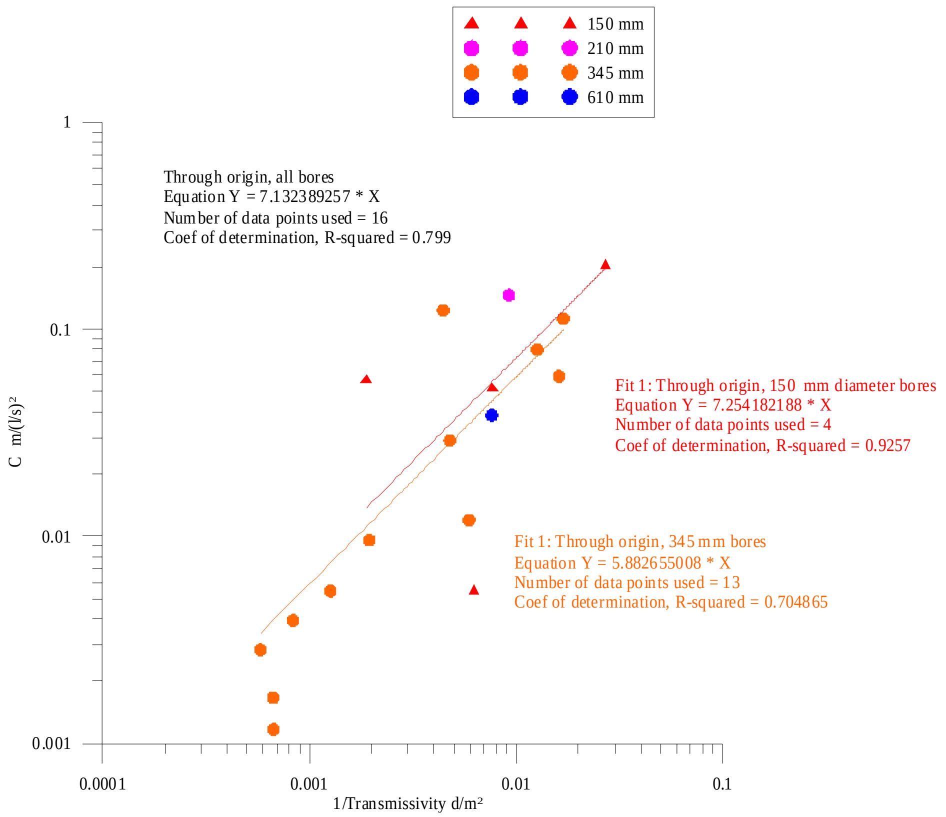

Figure I- 7 Relation between C and 1/transmissivity

4.1 Larapinta Area

Five bores are known in this area. None have any yield data.

4.2 Gillen Morris Area

There are a number of bores in this area, but most have little data, in some cases not even a total depth.

There is no record of strata for RN 2670 and RN 11595 are probably in alluvium of the former channel of a minor creek in the area.
The other two bores are known to be in little weathered Arunta Complex.
Summarised data is in Table I-3

Table I-3 Morris area, bores with yield data,

RN	Recorded data			Assumed parameters				Estimates		Comments
	Total Depth m	SWL m	Q L/s	Pump depth	SWL	Drawdown	Q L/s	T m^2/d (1)	K m/d	
2670	?	18.3	1.2	25	18.3	6.7	1.2	19	1.9	Cz
11595	28	20	0.375	Constant head test figures available, see Figure I-8				23	2.9	Recovery suggests leaky aquifer
12245	37		Small	37	20	17	0.1 to 0.3	0.4 to 1.4	0.08	0-3 Cz 3-12 wP 12-37 P
12299	45	25.5	Small	39	25.5	14.5	0.1 to 0.3	0.3 to 1	0.01 to 0.05	6-45 P Water cut 39

(1) This has been calculated by the single drawdown method using the following assumptions:

- The maximum drawdown is reached with 24 hours pumping.
- Well radius is 0.1 m.
- S is 0.001

(2) Pump setting in bore folder.

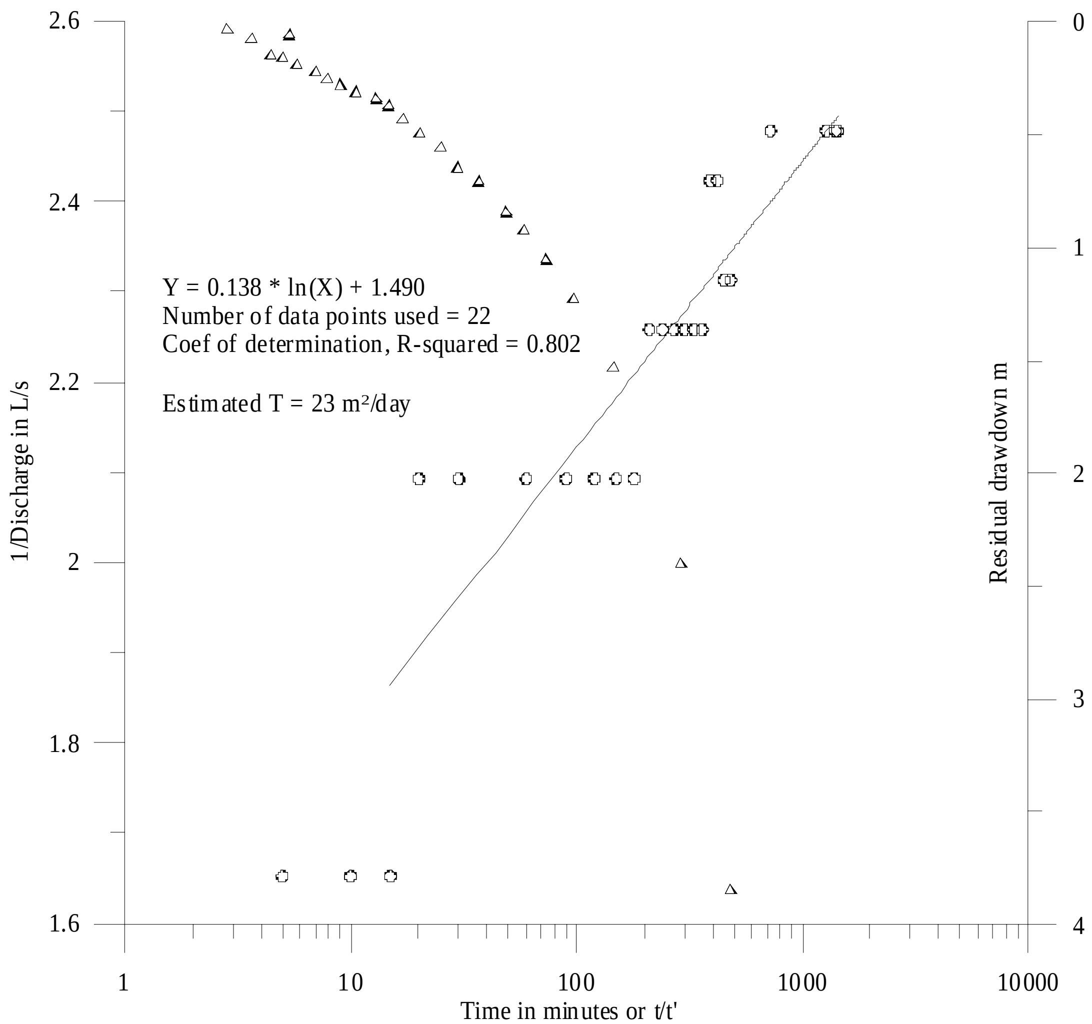

Figure I-8 RN 11595, constant head test

4.3 Sadadeen Zone, Eastside

There are a number of bores in this area, but most have little data, in some cases not even a total depth. An attempt has been made to estimate T and K using what little data there is (Table I-4).

Table I-4 Sadadeen, bores with yield data

	Recorded data			Assumed Parameters						Comments
RN	**TD m**	**SWL m**	**Q L/s**	**Pump depth m**	**SWL m**	**Dd (1) m**	**Q L/s**	**T m^2/d (2)**	**K m/d**	
13624	4.6	3.8	0.5	4.5	3.8	0.7	0.5	82	103	Presumably thin alluvium. Bore has probably not fully penetrated the aquifer.
14613	30	?	0	24	5	19	< 0.05	< 0.2	<0.01	Calculation applied to weathered Arunta Complex
14614	18	?	0	18	5	13	< 0.05	< 0.3	<0.02	Little weathered Arunta Complex
3330	24	?	little	15	5	10	0.1 to 0.3	0.8 to 2.4	0.08 to 0.02	Calculation applied to weathered zone

(1) Dd, drawdown
(2) This has been calculated by the single drawdown method using the following assumptions:
- The maximum drawdown is reached with 24 hours pumping.
- Well radius is 0.1 m.
- S is 0.001

4.4 Golf Course

No pumping tests could be found for this area. Data for 4 bores is in Table I-5

Table I-5 Golf Course, bores with yield data

	Recorded data			Assumed Parameters						Comments
RN	**TD m**	**SWL m**	**Q L/s**	**Pump depth**	**SWL**	**DD**	**Q**	**T m^2/d (1)**	**K m/d**	
3420	16	?	0	16	5	11	0.01	<0.05	<0.005	weathered Arunta Complex
6038	9	4.5	seep	5	4.5	0.5	<0.05	<10	<20	Cz
17000	24	15	0.5	20	15	5 (2)	0.5	10	2	weathered Arunta Complex
17001	30	15	1	24	15	9	1	11	0.7	Arunta Complex

(1) This has been calculated by the single drawdown method using the following assumptions:
- The maximum drawdown is reached with 24 hours pumping.
- Well radius is 0.1 m.
- S is 0.001

(2) Base of aquifer assumed to be base of weathering.

4.5 Gillen

Only three bores with yield data could be found in this area. Data is in Table I-6 .

Table I-6 Gillen, bores with yield data

	Recorded data			Assumed Parameters				Estimates		Comments
RN	**TD m**	**SWL m**	**Q L/s**	**Pump depth**	**SWL**	**DD**	**Q**	**T m^2/d (1)**	**K m/d**	
5826	29	4.46	0.3	17 (2)	4.46	12.54	0.3	1.6	<0.09	top pЄ at 10 m. This calculation assumes that the aquifer is in the fresh rock.
		4.46	0.3		4.46	5	0.3	4.4	<1	This calculation assumes that the aquifer is in the weathered rock.
12334	14.1	4.2	2.5	13	4.2	7	2.5	39	6	top pЄ at 11 m

(1) This has been calculated by the single drawdown method using the following assumptions:
- The maximum drawdown is reached with 24 hours pumping.
- Well radius is 0.1 m.
- S is 0.001

(3) This bore was pumped for sampling and a drawdown recorded. Pumping time, based on the practise of pumping three bore volumes was estimated to be 1 hour.

4.6 Discussion

4.6.1 Cainozoic

Two of the bores above appear to be in alluvium.
RN 6038 in the Golf Course area has a very thin saturated zone and is guessed to have a K of less than 20 m/day.
RN 13624 has an estimated transmissivity of 82 m^2/d. It may not have fully penetrated the aquifer.

4.6.2 Weathered Proterozoic

Five bores were identified as yielding water from the weathered zone, and possibly a sixth. Transmissivities range from <0.05 to 39 m^2/d, and K from < 0.005 to 6 m/d. For modelling a typical value would be <1 m/d.

4.6.3 Proterozoic

Four bores were identified as producing water from the crystalline Proterozoic rocks, and a fifth possibly. Transmissivities range from <0.05 to 1 m^2/d, and K from <0.02 to 7 m/d. It can be expected that permeability will depend on the presence and orientation of fractures.

4.7 Future Work

If better estimates are needed it would be possible to carry out small scale pumping tests on some of the monitoring bores, using a small submersible pump. This would give significantly improved estimates, and give information on aquifer depth and hence which unit it is in.

4.8 Slug tests