Small Groundwater Basins Risk Assessment: Northern and Yorke Agricultural District

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Knowledge and Information

Department of Water, Land and Biodiversity Conservation

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FOREWORD

South Australia's natural resources are fundamental to the economic and social wellbeing of the State. One of the State's most precious natural resources, water is a basic requirement of all living organisms and is one of the essential elements ensuring biological diversity of life at all levels. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of these resources changes the natural balance and may cause degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Understanding the cause-and-effect relationship between the various stresses imposed on the natural resources is paramount to developing viable management strategies. Reports of investigations into the availability and quality of water supplies throughout the State aim to build upon the existing knowledge base enabling the community to make informed decisions concerning the future management of the natural resources thus ensuring conservation of biological diversity.

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INTRODUCTION

The Northern and Yorke Agricultural District encompasses an area of around 3.5 million hectares in central South Australia. It stretches north from the Adelaide Plains and Barossa Valley to the semi-arid central Flinders Ranges. It includes all of Yorke Peninsula and upper Spencer and St Vincent Gulf. To the east, the region adjoins the Murray-Darling Basin.

Land-use in the region is predominantly agricultural, with a history of broad-scale cereal cropping. Recent years have seen a trend towards irrigated agriculture both to increase crop yields and to expand the range of produce grown. The expansion in viticulture seen throughout much of southern Australia has featured in the region, which includes a small area of the Barossa Valley and the entire Clare Valley wine district.

Climatic patterns are typically Mediterranean tending to semi-arid, with rainfall generally predominant during the winter months especially in the south. Summers feature only occasional storm events from low-pressure systems moving across the continent from the tropical north-west. Annual rainfall in the region is as low as 200 mm, but in some areas, notably around the southern Flinders Ranges, reaches greater than 600 mm.

Partly due to climatic patterns, permanent surface water is scarce to absent throughout much of the region leading to a reliance on groundwater. In some areas the groundwater resource has been sufficient to support very significant development, with the Clare Valley region an example.

Typically where resources are placed under high levels of development pressure, the need for careful management is recognised. A number of regulatory provisions of the *Natural Resource Management Act 2004* can be brought into effect to protect the resource. Foremost of these is prescription. The prescription process includes a comprehensive technical evaluation to determine the sustainable limit for use. Sustainable use limits must by definition allow for environmental water requirements.

A good understanding of condition, capacity and use demand is required prior to considering options for the protection and management of a water resource. Resources that support significant water-use activity often attract attention for investigation.

In the case of small and isolated water resources even single users could potentially exceed the sustainable use limits of the resource. Natural resource management authorities must encourage sustainable use of all resources to maximise social, economic and environmental outcomes.

This study was commissioned by the Northern and Yorke Agricultural District (NYAD) Integrated Natural Resource Management (INRM) Committee to establish the level of risk to small groundwater resources posed by unregulated use, throughout the NYAD.

AIM AND OBJECTIVES

The aim of this project was to identify small groundwater resources in the Northern and Yorke Agricultural District where good quality groundwater is available. These resources were assessed to determine whether any of them should be considered at risk from over exploitation, whether this was due to irrigation, industrial or domestic water supply use. Additionally management recommendations were to be made, including monitoring, to support sustainable use.

The groundwater resources of the region can be categorised as two types of systems: small sedimentary groundwater basins; and, fractured rock systems of the Adelaide Geosyncline. The objectives of the project are therefore to:

- Identify the location, type, quality and quantity of groundwater contained in the smaller groundwater basins and fractured rock systems of the Northern and Yorke Agricultural District INRM Region.
- Identify parts of the NYAD that have seen an increase in the drilling of water wells in the last 15 years.
- Review the condition and suitability of existing groundwater monitoring networks.
- Gauge the present state of groundwater resources in the NYAD and make recommendations for further investigations.
- Present management options in the case where small groundwater resources may be at risk from overuse, salinisation or pollution.

METHODOLOGY

The following investigations were undertaken during this study:

- **Desktop studies**
  - Literature review
  - Interrogation of state drilling records
  - Assessment of the adequacy of existing monitoring networks
  - Risk assessment involving:
    - estimates of the current level of water-use; and,
    - comparison with predicted sustainable yields (where available)
- **Field evaluations**
  - Inspection of monitoring networks
  - Verification of irrigation activity

Desktop studies

Literature Review

A literature review of previous geological and hydrogeological investigations was conducted. Literature was obtained from Primary Industries and Resources of SA (PIRSA) library and included reports on geological and hydrogeological investigations and water well surveys. Reports by O'Driscoll (1956), Hillwood (1967), Cobb and Smith (1977), Shepherd (1978), Sibenaler (1980), Matthews (1988), Clarke (1996), and Martin et al (1998) were extensively used.

State Drillhole Database Interrogation

Access to information contained within the state drillhole database, SA Geodata can be accessed at:

https://info.pir.sa.gov.au/des/desHome.html

Using SA Geodata, Geographic Information Systems (GIS), and hydrogeological information; parts of the NYAD were identified that had good quality groundwater and suitable yields for supporting irrigated horticulture and town water supplies (TWS).

Search criteria included groundwater of salinity less than 3000 mg/L, wells having yields greater than 1 L/s and a high well density relative to the size of the resource. Search results were verified by field inspection.

SA Geodata was interrogated to find the regions where new water wells had been drilled in the last 15 years. In particular, regions where new wells were drilled for the primary purpose of irrigation, industrial or town water supply (TWS) purposes. Regions identified on the basis of the above analysis or from personal communications were identified specifically as potential areas where new wells could have been constructed and used for development. Other regions where community concerns were expressed or anecdotal evidence suggested either current or historical groundwater use were also identified.

The drilling of new wells were divided into three time periods:

- 1990 – 1994
- 1995 – 1999
- 2000 – 2004

Well statistics were tabled and maps were then created for each of the basins/regions, showing where recent drilling activity had taken place.

Monitoring records

The Department of Water, Land and Biodiversity Conservation (DWLBC) maintains a database of all current wells used for resource monitoring. This information can be accessed via the Internet at:

https://info.pir.sa.gov.au/obswell/new/obsWell/MainMenu/menu

This database was inspected for information on existing and prior monitoring wells and field notes on wells were reviewed. Monitoring wells were assessed based on: relevance to each basin (strategic location); ability to measure accurate standing water level readings (SWL); and, whether a representative water sample could be obtained.

Field inspections were carried out to determine whether any well rehabilitation would be required (see below). Recommendations concerning the adequacy of monitoring networks are found in the Recommendations and Monitoring Sections within each chapter. Smaller networks monitoring dryland soil salinisation (Jamestown, Minlaton) were noted but close inspection was not undertaken.

Risk assessment – evaluating existing pressure

(i) Areas of irrigation

Landsat 5 imagery was obtained from the Department for Environment and Heritage (DEH) for the years 1995 and 2004, and was geo-rectified to Landsat 7 data from summer 2000 (Cameron, 2004). Landsat 5 imagery was used to gauge whether plant health increased, decreased or showed no change between the summer months of 1995 and 2004. This remote sensing technique identifies areas where irrigation was occurring due to the timing of the image capture and the condition of the vegetation. It did not however differentiate whether plant health increased or decreased from other factors such as low rainfall, crop rotation or increased grazing pressure. Ground verification of the data was required to determine this.

Enhanced satellite imagery (ESI) was used to visually inspect the NYAD region to determine whether irrigation was taking place at any of the identified small groundwater basins. This was for the years 1995, 2000, and 2004. The ESI enhances those regions that have healthy vegetation, such that they can be easily distinguished when looking at satellite imagery from a computer desktop. In general, irrigated areas could be located from green areas on the imagery that stood out from surrounding fields. An "irrigation areas" coverage provided by DEH was also used to confirm this.

A report on the analyses of the satellite imagery (provided by J. Cameron, DEH) can be found in Appendix F.

(ii) Estimating water use

Estimates of water use for irrigation were calculated using "target irrigation requirements " provided by Tony Thomson, Irrigation Engineer, DWLBC. The target irrigation requirement is the depth of irrigation water required (mm/year) to sustain an irrigated crop, whether it be for irrigated pasture, grapes or olives.

Estimates of water use were calculated by:

- Identifying the irrigated property on a GIS Arc Map coverage
- Creating a GIS shapefile around the irrigated property
- Calculating the area of irrigated land (m^2)
- Identifying the target irrigation required for the particular crop and region (eg 1600 mm/year required for the irrigation of lucerne in the Willochra Basin)

Irrigation volumes were then estimated using the formula:

$$\text{Irrigated Volume (ML/year)} = [\text{Target irrigation (m/year)} \times \text{area of irrigation } (m^2)] / 10^3$$

This calculation was used for irrigated lucerne in the Willochra Basin. It should be noted that the target volumes required are those that are actually required in average conditions, over the region. Actual application rates applied by farmers could be an order of magnitude greater or less, due to variation in climatic or other conditions, and differing irrigation techniques. Thorough monitoring and field investigations are required to determine the actual groundwater use for particular areas to a high degree of certainty.

(iii) TWS Extraction Data.

TWS extraction data for Independent Systems* was obtained from SA Water, Crystal Brook by reviewing annual reports, Northern Regions from 1980-1993. Annual reports were not produced from 1994 onwards so extraction data was obtained from information provided by Kym Hoffrichter (Engineering Manager, SA Water Crystal Brook). Data was provided for the townships of Quorn, Wilmington, Melrose, Orroroo, Hammond/Willowie and Warooka. Data from the year 2000 to present was not available at the time of visit.

*Independent systems refer to TWS that are not delivered via a River Murray Pipeline, i.e. pumped from an extraction bore.

Risk assessment – comparing estimated use with sustainable yields

Values for sustainable yield from previous investigations were used wherever possible for comparison with the estimated water use. In the case where no reliable value for sustainable yield has yet been determined, or widely variable values had been published, best estimates are given based on desktop investigations. Where it is not possible to make any meaningful estimate of likely sustainable yield this gap in knowledge has been identified.

Field evaluations

Inspection of monitoring wells

The condition of the existing groundwater monitoring networks was inspected in August 2004. Each of the observation wells (obswells) in the Willochra, Walloway, Booborowie, Balaklava, Baroota, Carribie and Para-Wurlie Basins were examined with photographs and notes taken. Results of the inspections are seen in Appendix A to E.

Field verification

Areas identified from satellite imagery as having active irrigation were inspected on site (where possible) while reviewing existing monitoring wells. A higher level of investigation however is required to accurately predict crop type, areas under irrigation and reliance on groundwater for all of the identified small groundwater resources.

RESULTS - OVERVIEW OF SMALL GROUNDWATER RESOURCES

Introduction

Table 1 shows the areas identified as having small groundwater resources potentially capable of supplying irrigation quality groundwater and/or for larger scale domestic needs. The locations of the main resources are shown in Figure 1.

Table 1. Groundwater resources reviewed in this report

Sedimentary Basins	Fractured Rock	Other Groundwater Resources
Willochra	Spring Creek (Wilmington)	Clare Valley
Walloway	Quorn	Baroota
Booborowie	Rocky River	Marion Bay
Balaklava	Bangor	Nelshaby / Napperby
Carribie		Mambray Coast
Para-Wurlie		Stansbury / Pine Point

Other groundwater resources identified as having historic or minor use included Marion Bay, Foul Bay, Spear Creek, Hawker, and the Stansbury/Pine Point region. The Clare Valley Prescribed Water Resource Area and the Baroota Area under a Notice of Intent to Prescribe were also noted but limited time was spent reviewing these areas due to the high level of attention they already receive.

Small Groundwater Basins

The following sections provide a background on the groundwater resources in the NYAD region based on previous investigative and exploratory work, as well as presenting the information collected from desktop studies. For some of the regions there were a number of investigative reports detailing information relevant to the resource. Other areas however have not been hydrogeologically investigated. Identified knowledge gaps that will help to plan for future investigations and on ground works have been noted within this report.

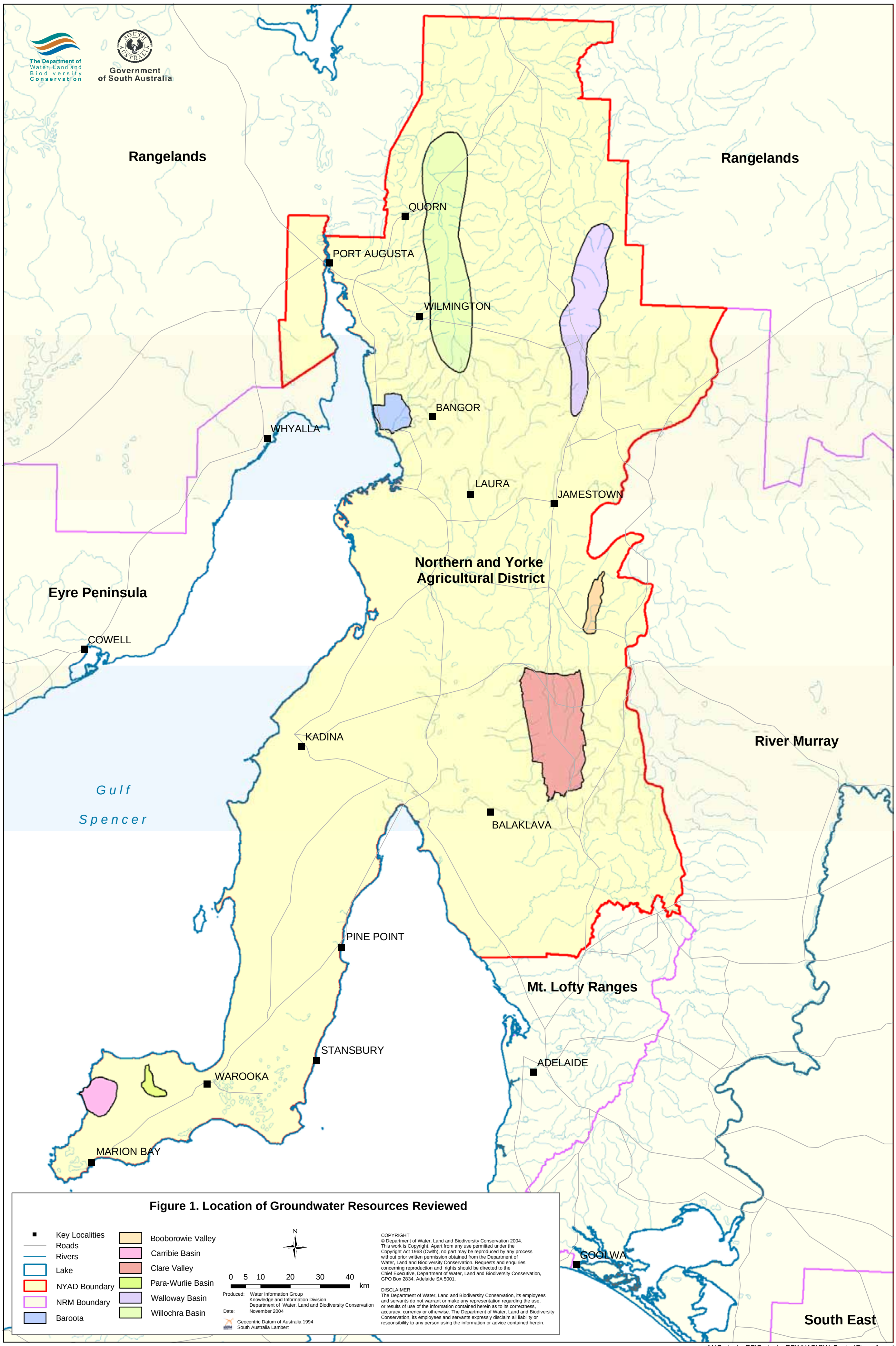

Figure 1. Location of Groundwater Resources Reviewed

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Table 2. Summary table of main groundwater resources reviewed.

Resource Name	Aquifer	Estimated Sustainable Yield (ML/yr)	Estimated Usage (ML/yr)	Expected Salinity Range (mg/L)	Comment
Willochra	Quaternary	N/a	N/a	600-14000	▪ Recharge processes poorly understood. ▪ Recent history of declining water levels.
	Tertiary	400	>400	600-7000	▪ Usage estimate is preliminary and requires additional information on surface water use, irrigation application rates and farm dam storage. Major use for stock/domestic and pasture irrigation.
	Total resource	4000[1]	No reliable estimates	600-14 000	▪ Sustainable use estimate includes all water within the basin, including irrigation and stock quality groundwater. ▪ Significant knowledge gaps relating to recharge rates and sustainable yield of all basin aquifers.
Walloway	Quaternary	unknown	unknown	> 2000	▪ Groundwater quality at upper limit for irrigation of salt tolerant species.
	Tertiary	unknown	160	1500-1700	▪ Town water supply usage and small quantities of irrigation present. Does not include stock or domestic use. ▪ Major knowledge gaps in recharge processes and sustainable yield. ▪ Limited development potential. ▪ Rehabilitation and/or backfilling of leaky wells required, particularly in Tertiary Aquifer.

Resource Name	Aquifer	Estimated Sustainable Yield (ML/yr)	Estimated Usage (ML/yr)	Expected Salinity Range (mg/L)	Comment
Booborowie	Alluvial deposits (mostly quaternary)	No current estimates	1000-1200 when irrigating	1200-3000	▪ Recharge, connectivity, sustainable yield and general aquifer parameters moderately to poorly understood. ▪ Most productive aquifers from valley fill deposits. ▪ Small size of the resource raises risk of unsustainable use.
	Fractured Rock	unknown	unknown	> 2000	▪ Aquifer low yielding, primarily for stock use. Aquifer poorly understood.
Balaklava	Tertiary			2000-3000	▪ Aquifer salinity within 5-6 km of the Wakefield River considerably lower than surrounding area. Aquifers reliant on recharge from intermittent surface flows. ▪ Small resource, not sustainable for major use. ▪ Existing use fairly low, but due to small size resource is potentially vulnerable to large scale over extraction.
Carribie	Unconfined Limestone	1000-1400	Not known	600-1200	▪ Stock and domestic use only – soil capacity limits irrigation development. ▪ Significant volumes relative to the region of under-utilised groundwater – susceptible to high water demand development. ▪ Potentially vulnerable to pollution.
Para-Wurlie	Unconfined Limestone	400	200	600-1200	▪ Town water supply usage only – does not include stock and domestic use ▪ Limited water may be available for additional use, but would not support significant water demand development. ▪ Requires protection as a town water supply.

[1]This estimate is for all water available in the Tertiary and Quaternary Aquifers and is based on rudimentary estimates of aquifer spatial parameters by Martin et al, 1998. This should not be considered as a reliable basis to determine sustainability of use.

WILLOCHRA BASIN

Description

The Willochra Basin (Figure 2) is a north-south oriented trough approximately 80 km long and 16 km wide located in the Southern Flinders Ranges, lying immediately to the east of Quorn and extending from Simmonston in the north to Booleroo centre in the south (O'Driscoll, 1956). It covers substantially the hundreds of Boolcunda, Palmer, Willochra, Gregory and Willowie, and extends into Kanyaka, Yarrah, Pichi Richi, Coonatto and Pinda. The Basin is bound by late Proterozoic and Cambrian rocks of the Adelaide Geosyncline and is filled by Tertiary and Quaternary sediments (Shepherd, 1978).

Originally the basin had been used for dryland agriculture such as crop/grazing rotation and grazing of modified pasture. In the 1870's the basin was developed for agriculture but after extensive crop failures and erosion, the whole northern part is now only used for stock grazing (Lay pers. comm., 2004). Although the majority of landuse on the Willochra Plain is for pasture and grazing purposes, there are two main areas where irrigation occurs, as well as some smaller vineyards and olive groves around Wilmington that utilise groundwater for irrigation.

Recharge to the confined Tertiary Aquifer is believed to occur on the western margin of the basin, where surface drainage features pass over heavily faulted zones in the basement rock. The resulting accretion of good quality water to the aquifer has kept salinity low along the western margin, and this intake is believed to be the source of the good quality artesian/sub-artesian water encountered throughout the basin (O'Driscoll, 1956). Groundwater salinity in the Tertiary Aquifer is lowest in the vicinity of the intake areas, being less than 1400 mg/L near Mt Remarkable. Over much of the southern half of the basin salinity is less than 2000 mg/L rising to 7000 mg/L in the north (Shepherd, 1978).

The overlying unnamed Quaternary Aquifer is comprised of mottled clays, with frequent thin sand and gravel beds, particularly near drainage lines (Martin et al, 1998). Estimates of recharge to the Quaternary Aquifer are currently unknown, but it is likely to be replenished on a seasonal basis via streamflow from existing drainage lines (O'Driscoll, 1956). Groundwater varies from stock quality to saline, with the exception of the area located near Spring Creek where good quality water is available and used for irrigation purposes.

The sustainable yield for the Tertiary Aquifer has been estimated as being of the order of 400 ML/yr (O'Driscoll 1956, Shepherd 1978). Sustainable yield for the Basin as a whole (both Tertiary and Quaternary Aquifers) was estimated at up to 4000 ML/yr by Martin et al, 1998, but this figure is under review.

Average rainfall at Melrose Post Office (at the base of Mt Remarkable close to the Spring Creek subcatchment) since 1889 is 598 mm/yr while average rainfall at Booleroo Centre, away from the climatic influence of the ranges is 395 mm/yr (Risby et al., 2003). This demonstrates the decrease in rainfall on the leeward side of the Ranges and the importance of the recharge derived from streams draining the relatively high rainfall from Flinders Ranges subcatchments.

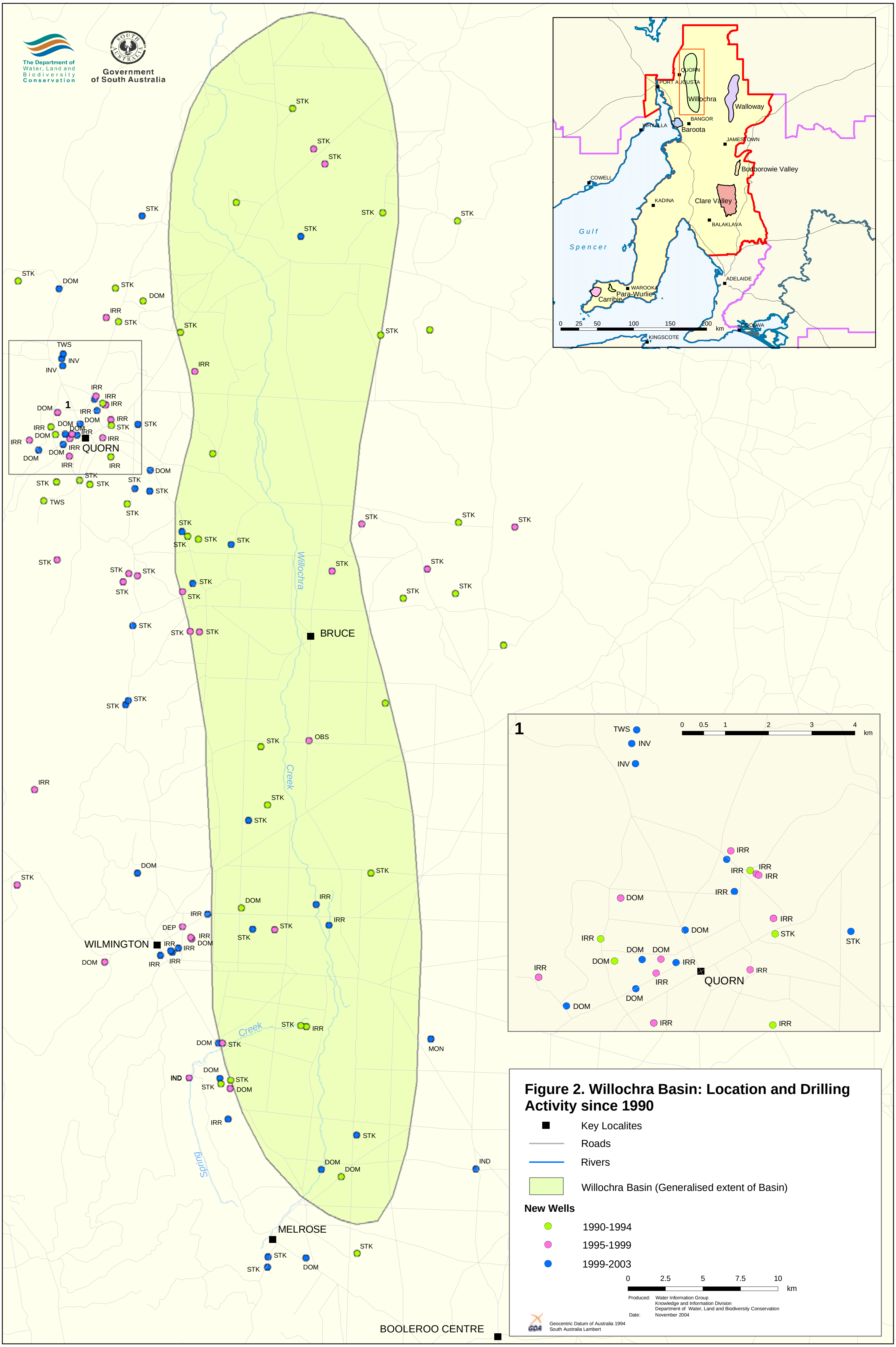


Figure 2. Willochra Basin: Location and Drilling Activity since 1990

Review of Drilling Activity

Records from SA Geodata (2004) indicate that the number of water wells in the basin presently stands at around 790. Since 1990, 65 new wells have been drilled into the basin. Of these, 43 were for stock purposes, 8 for domestic, and 10 for irrigation. The table below summarises drilling activity in the past 15 years. The location of these is shown in Figure 2.

Table 3. Willochra Basin drilling records for years 1990-2004

Period	Total	Stock	Domestic	Irrigation	Other	Comments
1990-94	22	17	2	1	2	
1995-99	19	13	2	1	3	1 new obswell/industrial
2000-03	25	13	4	8	0	
Total	**66**	**43**	**8**	**10**	**5**	

1. Total = new wells drilled during the period

Of the ten new irrigation wells, six were constructed close to Wilmington where vineyards and olive groves have been established in the last 5-10 years. One well was constructed into the Quaternary Aquifer near Spring Creek, while two wells were constructed into the Tertiary Aquifer on the plain in the Hundred of Willochra. The remaining irrigation well was constructed into fractured rock adjacent to the range between Melrose and Wilmington. This was subsequently abandoned and backfilled.

Estimated Water Use

IRRIGATION

Currently there are three irrigators in the district who use groundwater for the irrigation of lucerne, based on satellite imagery results and observations from field inspections. There are also a number of relatively new vineyards in the Wilmington area and in the hills close to Melrose. Figure 3 shows the locations that are listed in SA Geodata as having an operational irrigation bore, while the blue “irrigation area” layer shows the inferred irrigation areas seen from Landsat 5 imagery, ESI and observed from field inspections.

It can be seen from Figure 3 that there are a number of properties with irrigation wells in the region. Some lie outside the Willochra Basin (i.e., drilled into fractured rock within the Willochra Catchment), while the remainder penetrate the basin sediments. There are three operational Irrigation bores (as listed in SA Geodata) close to Spring Creek, while the remainder are located on the Plain northeast of Wilmington. The irrigation bores recently drilled close to Wilmington (seen in Figure 2) were not listed in SA Geodata as being operational.

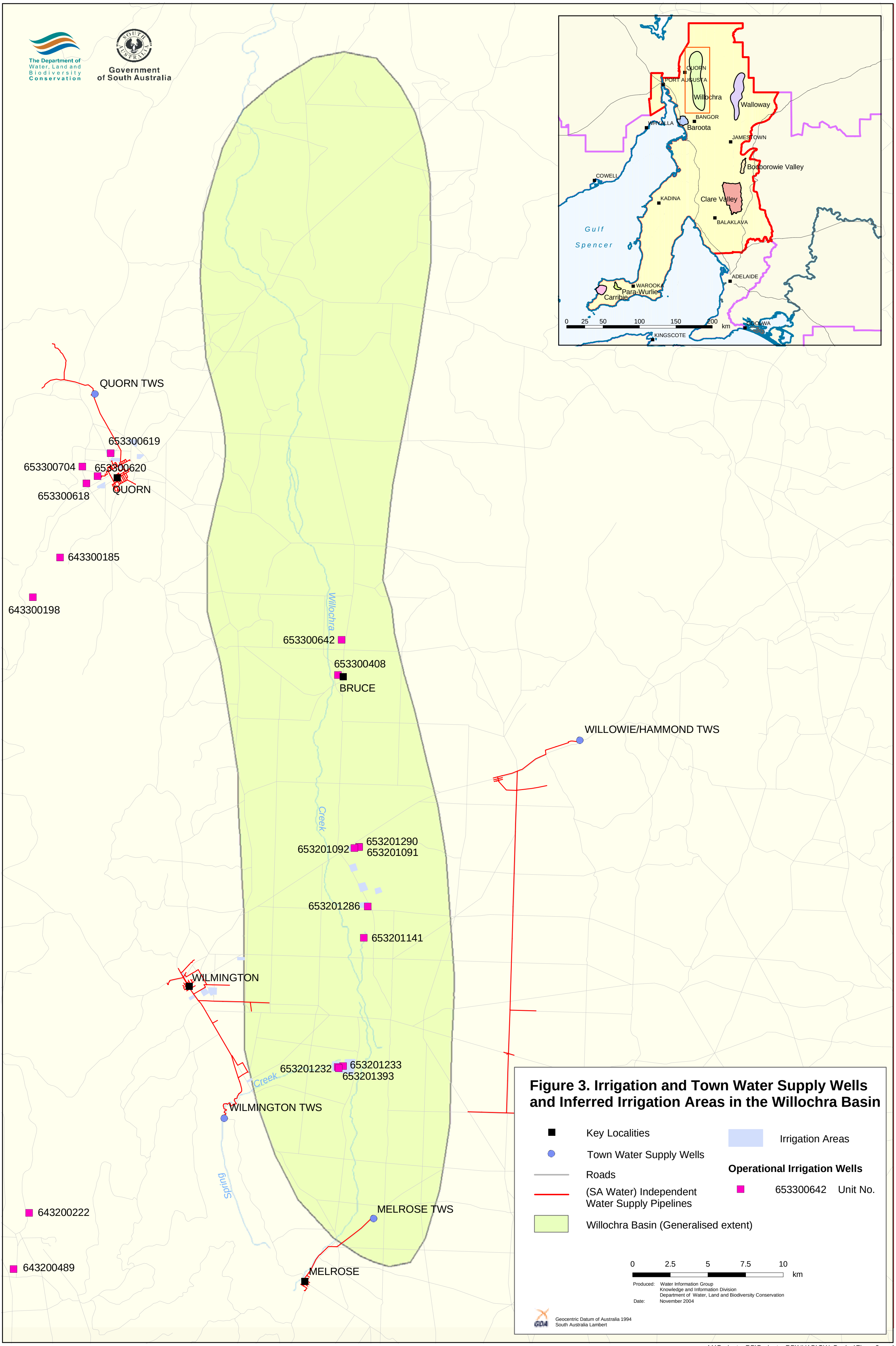


Figure 3. Irrigation and Town Water Supply Wells and Inferred Irrigation Areas in the Willochra Basin

Spring Creek

There are currently three irrigation wells in the vicinity of Spring Creek, constructed into Quaternary sediments at depths between 30 and 35 m. Two of these wells were drilled in 1982 while a third irrigation well was drilled in 1993. Recorded salinities are between 350 and 500 mg/L. Table 4 lists the irrigation wells, as well as the relevant stock wells.

Table 4. Summary of Water Wells on main irrigation property, Spring Creek.

Unit Number	TDS (mg/L)	Yield (L/s)	Use[1]	Status[2]	Depth Drilled (m)	Drill Date	Comment
6532-1393	400	9	IRR	OPR	34.27	5/12/1993	Operational irrigation well
6532-1375	374	10	STK	OPR	35.00	19/2/1991	Stock well
6532-1234	683	N/a[3]	N/a[3]	N/a[3]	31.47	17/11/1982	Status/use unclear
6532-1233	506	4.5	IRR	OPR	35.66	10/11/1982	Operational irrigation well
6532-1232	386	4	IRR	OPR	33.55	9/11/1982	Operational irrigation well
6532-1025	433	N/a[3]	STK	OPR	9.00	3/7/1975	Shallow stock well

1. Use refers to the wells main purpose. Can be either stock, domestic, irrigation or exploration/investigation.
2. Refers to the wells present status. OPR - Operational, ABD - abandoned, BKF - backfilled and CLP - collapsed.
3. N/a = No available information on SA Geodata.

Figure 4 shows ESI at Spring Creek in March 2004. It can be seen from the Figure that there is centre pivot irrigation on the southern side of Spring Creek. Field inspection (December 2004) revealed irrigated lucerne as well as the presence of an irrigated vineyard.

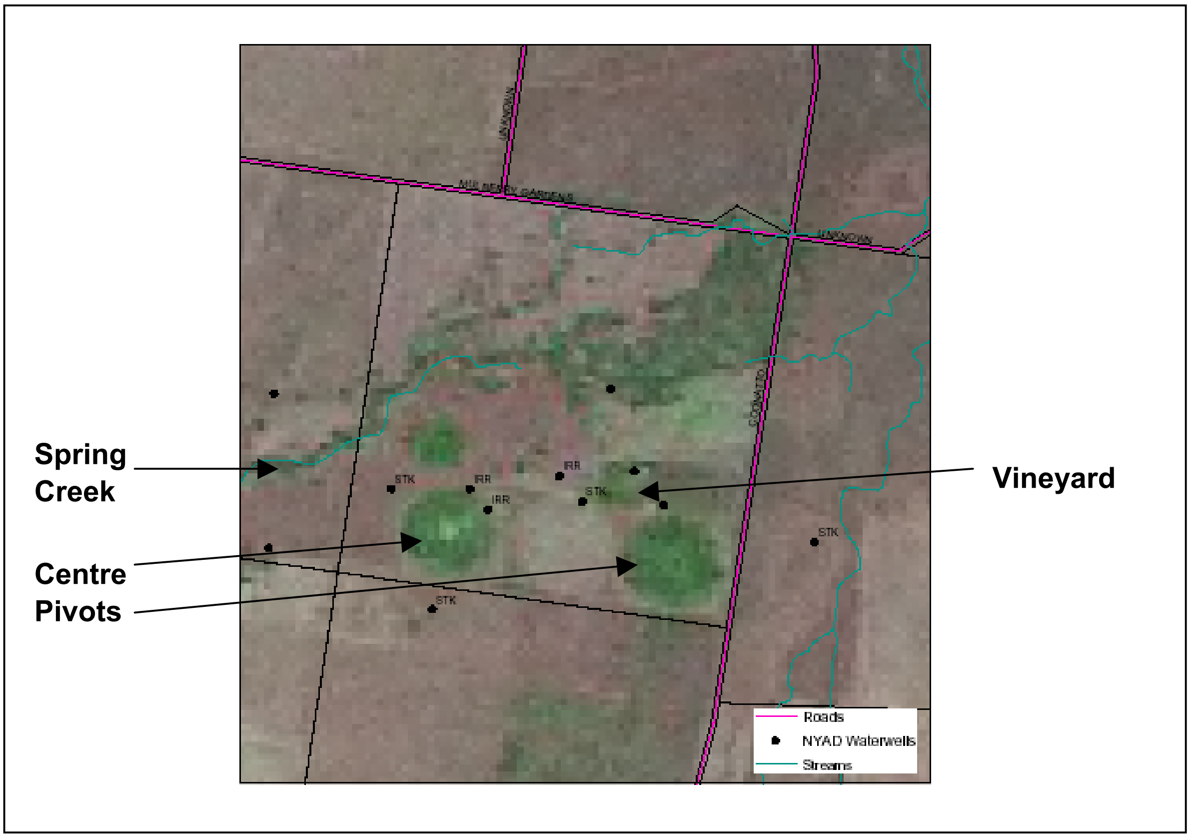


Figure 4. Enhanced satellite imagery (March 2004), irrigation and stock wells, Spring Creek.

Wilmington

Field evidence has revealed the presence of a number of relatively new vineyards and olive groves around the Wilmington Township that appear to be between 5 and ten years old. Drill records indicate that there have been a number of new irrigation bores drilled in the area but evidence suggests that water used for these developments is principally sourced from the Wilmington TWS (Robinson pers. comm., 2005). Consultation with landowners would help to clarify this.

Northeast of Wilmington

The other main area of irrigation is approximately 13 km northeast of Wilmington in the Hundred of Willochra. There are 5 property parcels that appear to use groundwater for the irrigation of pasture (lucerne). There are a total of 9 wells on the five properties, four of which indicate their primary purpose as irrigation. All of these wells were constructed prior to 1990. Eight out of the 9 wells have been drilled greater than 80 m deep, suggesting that they are in the Tertiary Aquifer. Salinity is as low as 600 mg/L and Clarke (pers. comm., 2004) indicates that this region has some of the best quality artesian/sub-artesian water in the basin. Table 5 presents a summary of water quality, yield and depth for the 9 wells. It should be stressed however that the data presented in Table 5 is not very recent, and is likely to be a representative of groundwater salinity at the time of drilling. An update of present groundwater salinity information for the wells in question is required.

Table 5. Summary of water wells located 12-14 km northeast of Wilmington in the Hundred of Willochra.

Unit Number	TDS (mg/L)	Yield (L/s)	Use[1]	Status[2]	Depth Drilled (m)	Drill Date	Comment
6532-1092	591	2	IRR	OPR	83.3	1964	Current irrigation well
6532-1290	527	3	IRR	OPR	84.1	1982	Currently operating irrigation well
6532-1091	503	1.5	IRR	OPR	76.5	N/a[3]	Currently operating irrigation well
6532-1346	530	0.06	EXP	ABD	139	1987	Recently rehabilitated leaky artesian well.
6532-1123	471	N/a[3]	N/a[3]	CLP	91.44	N/a[3]	Collapsed
6532-1287	500	4.25	OBS	N/a[3]	102.1	1983	Historical observation well. Last checked 1995.
6532-1126	460	6.3	DOM/ STK	BKF	92.96	1967	Backfilled.
6532-1289	493	4.25	N/a[3]	N/a[3]	85.3	1983	N/a[3]
6532-1125	2443	9	N/a[3]	N/a[3]	84.73	N/a[3]	N/a[3]

1. Use refers to the wells main purpose. Can be either stock, domestic, irrigation or exploration/investigation.
2. Refers to the wells present status. OPR - Operational, ABD - abandoned, BKF - backfilled and CLP - collapsed.
3. N/a = No available information on SA Geodata.

Water Use - Irrigation

Water use for irrigation was determined by estimating the area of irrigated land seen in satellite imagery and multiplying the area by the standard application rate for the particular crop supplied by Thomson et al, 1996 (unpublished).

In the case of the Willochra basin, the majority of field irrigation appears to be for lucerne, except for those vineyards seen around Spring Creek and Wilmington. Based on an application rate for lucerne of 1600 mm, total area of irrigated lucerne equal to 76 ha; the volume of water used for lucerne irrigation is estimated at 1230 ML/yr from both the Tertiary and Quaternary Aquifers. From this figure, an estimated 640 ML/yr is extracted from the Quaternary Aquifer near Spring Creek and 590 ML/yr from the Tertiary Aquifer in the Hundred of Willochra. These figures are first order estimates only, but total above the sustainable yield of 400 ML for the Tertiary Aquifer estimated by O'Driscoll (1956) and Shepherd (1978).

TOWN WATER SUPPLIES

Summary

Melrose extracts its town water supply (TWS) from weathered basement rock on the Willochra Plain (Read, 1991) while Wilmington, Quorn and Hammond/Willowie obtain their supplies from fractured rock on the basin margins. The location of delivery pipelines of the TWS wells appears in Figure 3. Table 6 is a summary of annual volumes extracted for the relevant town water supply systems.

Table 6. Groundwater Extraction Volumes from Quorn, Melrose, Wilmington and Willowie / Hammond TWS Bores.

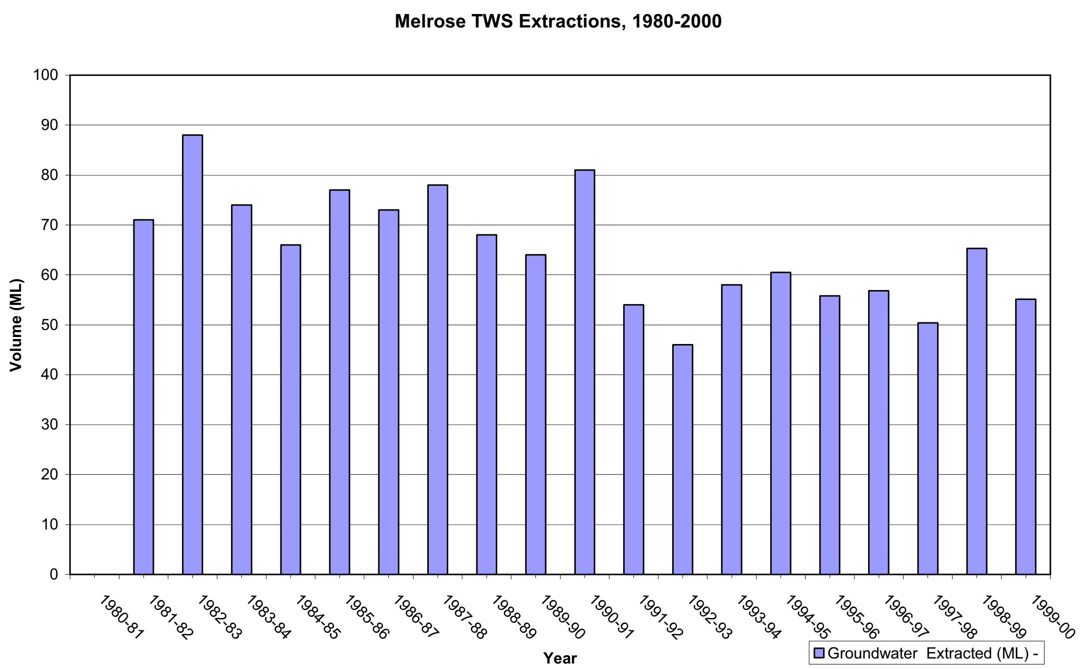
Year	Melrose G/W[1] (ML)	Hammond[2] G/W[1] (ML)	Wilmington G/W[1] (ML)	Wilmington S/W[1] (ML)	Quorn G/W[1] (ML)	Quorn S/W[1] (ML)
1980-81	n/a	29	93	21	205	n/a
1981-82	71	34	96	33	178	n/a
1982-83	88	26	98	32	295	n/a
1983-84	74	23	73	36	169	n/a
1984-85	66	22	74	40	200	0
1985-86	77	21	64	46	180	n/a
1986-87	73	17	25	44	61	85
1987-88	78	25	67	32	169	4
1988-89	68	26	48	56	169	0
1989-90	64	34	62	56	168	26
1990-91	81	35	88	24	156	52
1991-92	54	24	66	32	149	47
1992-93	46	17	10	89	135	n/a
1993-94	58	31	72	69	145	70
1994-95	60.5	24.1	83.5	40.6	104	7
1995-96	55.8	25.4	88.8	67.6	178	n/a
1996-97	56.8	26	90.4	30.4	194	5
1997-98	50.4	20.6	94.1	16.1	184	184
1998-99	65.3	28.1	132.5	1.3	207	0
1999-00	55.1	n/a	86.6	9.9	0	208

(Source SA Water Crystal Brook, EWS annual reports)

1. S/W = surface water use; G/W = groundwater use
2. Hammond / Willowie

Melrose

The Melrose TWS extracts groundwater from bore 6532-01383 located approximately 4.5 km northeast of the town. The present bore is surrounded by previously used TWS bores that are now used for observation purposes. The bore was constructed in 1991 in response to decreased yields at bore 6632-00568. The current bore has been drilled to a depth of 93 m, is screened at depths between 86.84 m and 92.84 m and extracts groundwater from Adelaidean Sandstones (Read, 1991). The overlying sediments comprise of Tertiary and Quaternary sediments of the Willochra Basin. SA Geodata (2004) indicates the current bore has a yield of 4.5 L/s and a salinity (as at 26/3/2003) of 1546 mg/L. Figure 5 below shows a graph of groundwater extractions for the period 1980-2000.



(Source: SA Water, Crystal Brook).

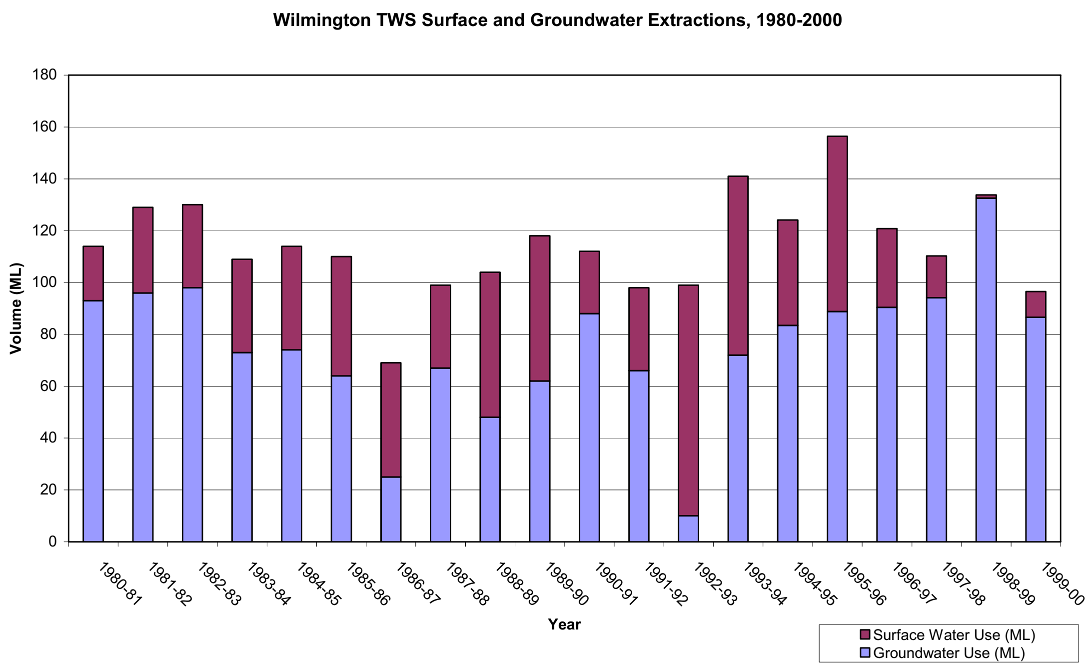
Figure 5. Melrose Town Water Supply Extractions; Period 1980-2000.

Wilmington

Wilmington obtains its TWS supply from a fractured rock aquifer approximately 9 km south-south east of the town, close to where Spring Creek emerges from the ranges to enter the Willochra Plain. Groundwater is extracted from a Mine Shaft that was constructed in the 1860's as part of a local copper mine, as well as a backup supply bore located approximately 150 m from the Shaft on the opposite side of Spring Creek.

The shaft penetrates into slates of the Tapley Hill Formation, which is located just above the Rhynie Sandstone (Read, 1980). Springs occur on the eastern side of the range, and also in Spring Creek 200 m downstream from the Mine Shaft. This shows that recharge is by direct infiltration through an outcrop on the range (Read, 1980). Aquifer tests were conducted in 1980 on the Shaft and the safe yield was calculated at 870 kL/day. Groundwater salinity was measured at 600 mg/L (Read, 1980).

Prior to 1995 the town mostly obtained its domestic supplies from a mixture of surface water (Spring Creek) and groundwater from the disused mine shaft. After the Cryptosporidium outbreaks in Sydney in 1995, SA Water has preferred to use groundwater to meet Wilmington's domestic needs (Hoffrichter pers. comm., 2004). Figure 6 below shows pumping records for the Wilmington TWS from the period 1980-2000. It can be seen from the graph that surface water use has gradually decreased from the mid nineties onwards, as groundwater has become the preferred use to supply the town.

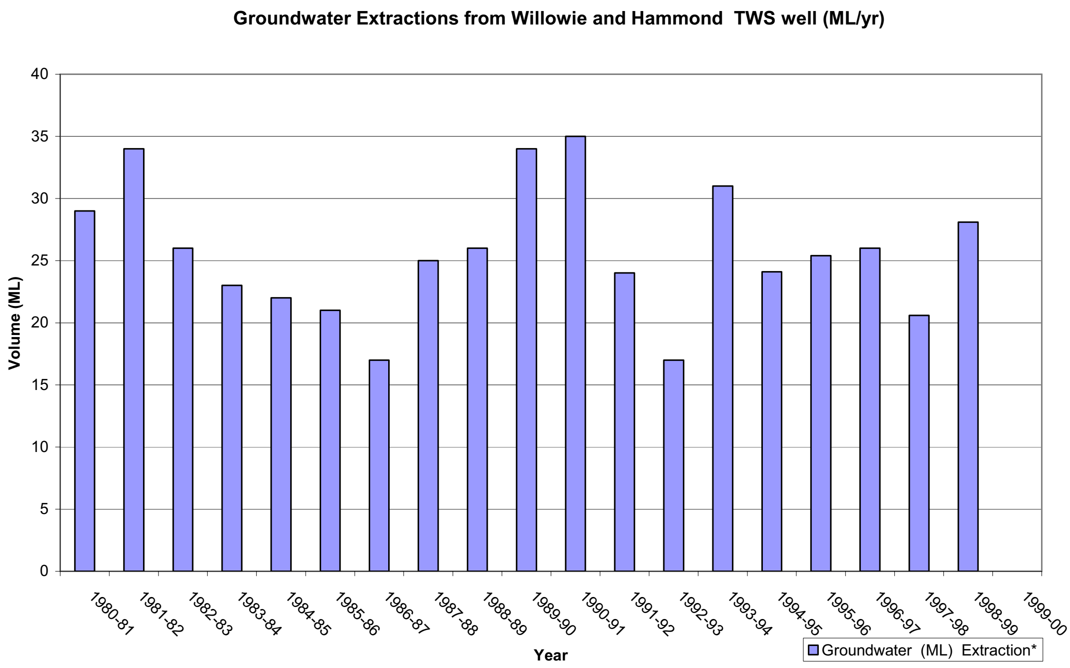


(Source: SA Water, Crystal Brook).

Figure 6. Wilmington Town Water Supply use – surfacewater and groundwater; Period 1980-2000.

Hammond and Willowie

The Hammond bore (6533-00138) supplies non-potable water to the settlements of Hammond, Willowie and Coonatto (Hoffrichter pers. Comm., 2004) and is drilled into fractured rock on the basin margins. The current depth of the well is not listed in SA Geodata. Extraction records for period 1980-2000 are presented in Figure 7. It can be seen that extraction has remained relatively stable over the last 20 years, with an average use of 25.7 ML/yr between the 1980-2000. The bore was last monitored on 30/11/1974 when the salinity was 3093 mg/L (SA Geodata, 2004).



(Source: SA Water, Crystal Brook)

Figure 7. Groundwater extraction volumes, Hammond / Willowie town water supply; Period 1980-2000.

Monitoring

The Willochra network is monitored every 6 months in the autumn and spring and is focussed on the areas of good quality groundwater in the Hundreds of Willochra and Gregory. These areas correspond to the current irrigation areas on the Willochra plain that use groundwater for irrigation of pasture and vines as well as the Melrose TWS. Most of the current monitoring wells have a half yearly dataset from 1985 to present. The current observation network can be seen in Figure 8.

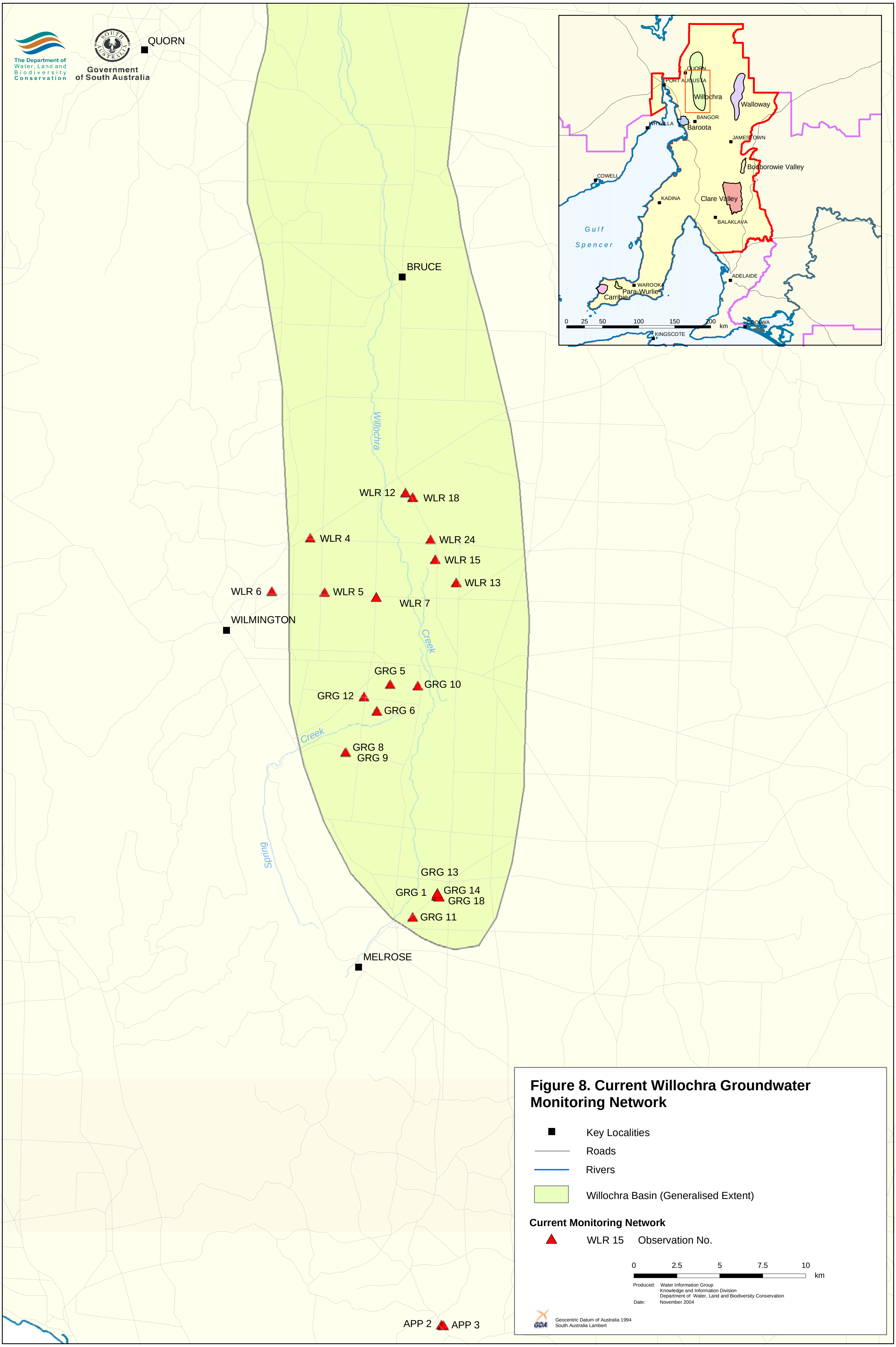


Figure 8. Current Willochra Groundwater Monitoring Network

It can be seen from Figure 8, that there is a group of observation wells that roughly follow the streamline of Spring Creek. These wells are drilled into the shallow Quaternary aquifers that are recharged by seasonal flow. This is indicated by the fact that the wells are shallow (less than 25 m) and have a low salinity, with total dissolved solids (TDS) of less than 600 mg/L.

The other main area of irrigation northeast of Wilmington utilises groundwater from the Tertiary Aquifer. This area has some of the best quality sub-artesian/artesian groundwater on the plain (Clarke, pers. comm., 2004) and is monitored by the observation wells WLR 12, WLR 24, WLR 15, and WLR 13. Three of these wells monitor standing water levels (SWL) while well WLR 24 is an irrigation well. WLR 18 (6532-01346) was a leaky artesian well, but has since been fitted with a ball valve (as observed 15/12/04).

The Melrose TWS, which is approximately 4.5 km northeast of the town – has four wells that have been drilled within approximately 100 m of each other. Presently there is one well (GRG 13) that is used to measure SWL while a salinity reading can been taken from the operational TWS well (GRG 18). The remaining two wells GRG 1 and GRG 14 have been abandoned (and backfilled).

Observation wells WLR 7, WLR 5, WLR 6, WLR 4 were inspected to the northeast of Wilmington. WLR 7 has a depth of 5.5 m and was found to be dry and should be removed from the network. WLR 5 could not be accessed (blocked) so a SWL measurement was taken from a new domestic well (6532-01395), located on the same property. This well had a depth of 95 m and was drilled into the Tertiary Aquifer. This well will be added to the monitoring network.

The three remaining wells monitor fractured rock aquifers outside of the Willochra Basin. WLR 6 is located on the outskirt of Wilmington while there are two wells in the Hundred of Appila (APP 2 and APP 3) where a sample and SWL reading is available. These are located on a large property in Wirrabara that is presently used for the irrigation of vines.

Discussion

The Willochra Basin has good quality groundwater in the south-western section of the basin, particularly in the Tertiary Aquifer but also in the Quaternary Aquifer close to Spring Creek. The potential for the resources of the Basin to support significant irrigation or other development appears limited due to the restricted extent of the good quality water and the resource capacity.

Work was done by O'Driscoll (1956) to investigate whether the Basin could be developed for irrigation purposes. He concluded that only 250 to 415 ML per year could be safely extracted from the Tertiary Aquifer – the equivalent of three bores of suitable irrigatable yield spaced 3 km apart. Shepherd (1978) also suggested a safe yield for the Tertiary Aquifer in the vicinity of 400 ML/year.

Calculations indicate that approximately 590 ML/yr is potentially being extracted from the Tertiary Aquifer for the irrigation of pasture while irrigation from the Quaternary Aquifer at Spring Creek is estimated at 640 ML/yr. It should be noted that due to the lack of information regarding stock and domestic use, surface water use for irrigation, and actual irrigation application rates, these numbers are indicative of the level of risk only.

Previous estimations of significantly higher yield, of the order of 4000 ML/yr (Martin *et al* 1998, references within) did not differentiate between use from the Tertiary and Quaternary resources. Nor did this estimate specify the type of use supported at this volume. It is presumed that these estimates include all water use within both aquifers and were not limited to water of a quality suitable for irrigation use or better.

Until further work is done to refine estimates for recharge, current figures for adopted sustainable use should be based on the lower Tertiary Aquifer. Both resources warrant careful management, which should be informed by continued monitoring and timely interpretation of resource trends in the light of known use and recent climatic trends.

The current monitoring network sufficiently covers the important areas, including major extractive pressure on the Willochra Plain.

However, Spring Creek receives recharge from seasonal surface water flow emphasising the need for conjunctive management of surface and groundwater resources. Reductions in surface water runoff are likely to have an impact on replenishment of the resource and further understanding of this is required. An initial priority should be to install an expanded monitoring network in the vicinity of Spring Creek (Clarke pers. comm., 2004).

Recent development of irrigated horticulture on the Wilmington Area is likely to place additional stress on the Wilmington TWS supplied from Spring Creek. Careful management of this resource is required which may include the development of council regulations restricting further horticultural developments in the area. The capacity of the Spring Creek Mine has a definite upper limit (870kL/day), and additional stress to the system from unregulated development would seem unsustainable.

Recommendations

Management

- The level of use in the mid to southwest section of the basin is sufficiently high to warrant closer regulation of irrigation activities and other extractive development.
- Monitoring records need to be regularly evaluated to provide an early indication of resource change, allowing management intervention if necessary to preserve the integrity of the resource.
- The apparent direct connectivity between the surface and groundwater resources warrants a holistic approach to water use policy.

Knowledge gaps

- Improved understanding of recharge processes is a key requirement for improved management. In particular the importance of surface water streamflow for recharge should be established and identified recharge areas along the relevant streams protected from pollution, inappropriate development or excessive surface water diversions.
- Further studies should occur to accurately determine groundwater use; to differentiate between groundwater and surface water use and farm dams, and to evaluate total withdrawals for stock and domestic purposes.

Monitoring

- Monitoring of the existing groundwater monitoring network continue at minimum 6 month intervals.
- A suitable monitoring network be established for the Wilmington TWS.
- A new monitoring well be added to the network close to the Spring Creek irrigation wells (Quaternary Aquifer).
- That the leaky artesian wells be identified and rehabilitated/backfilled.
- That well WLR 7 be removed from the network.
- That well 6532 01395 be added to the network to replace WLR 5.
- That bore information be updated in SA Geodata, including the updating of existing operational irrigation wells.

WALLOWAY BASIN

Description

Located approximately 260 km north of Adelaide, the Walloway Basin is a north-south orientated intermontane (between mountain) basin, approximately 80 km long, with a maximum width of 16 km, and a total area of 650 km^2. The Basin is an ancient valley, filled with outwash deposits to form a relatively mature and flat land surface (Hillwood 1967).

The basin is in marginal cropping country, with predominant landuse for pasture and grazing of stock. Average rainfall over the basin is 330 mm/yr. There are no permanent streams.

The nearest major township is Orroroo, located in the mid-western section of the basin. Further north is the settlement of Johnburgh, an area previously used for crops but now abandoned and primarily used for stock grazing. Figure 9 shows the location of the Walloway Basin.

Geophysical surveys indicate that the basin is probably a fault angle depression, with a fault along the south-western margin (Martin et al., 1998). The unnamed Tertiary succession thickens south-westwards and also west of a probably major basement fault extending north-northwest from Orroroo (Martin et al., 1998). The greatest thickness of the Tertiary Sediments was penetrated by well 663200875, 10 km north of Orroroo at 287 m.

Sediment at the base includes fine-grained sands, clayey sands and clays with minor lignite, of middle to late Eocene age (Shepherd, 1978). The overlying sediments include up to 70 m of clays with coarse gravel beds, often lenticular. These overlying sediments range in age from mid-Tertiary to Quaternary. Obscuring the Quaternary are older deposits of recent alluvium and outwash material, derived from the surrounding Pre-Cambrian rocks (Shepherd, 1978).

Artesian and sub-artesian groundwater is available from various aquifers in the basin.

Shallow groundwater occurs less than 30 m deep throughout most of the basin. This water is contained in the recent outwash and alluvial material and is dependent on local runoff for recharge. Consequently there are wide variations in groundwater salinity (Hillwood, 1967).

The Tertiary Aquifer is more uniform and extends throughout the basin in contrast to the shallow Quaternary unconfined aquifers. Salinity in the Tertiary aquifer is between 1500-1700 mg/L, and in parts of the mid-section of the basin has been artesian.

Recharge to the shallow unconfined and deeper Tertiary Aquifer is not well known although it is predominantly thought to be from Pekina Creek that flows from the south-west onto the plain. Recharge via this source is estimated to be at a rate between 5-10 mm/yr (Martin et al., 1998).

Previous investigations have not established a sustainable yield for the basin, although they show that long-term use has resulted in a loss of head and reduction in flows. It appears there is limited scope for large-scale irrigation in the area.

There were attempts to establish irrigation in the 1950's (Pekina Irrigation Scheme) by using surface water from the Pekina Reservoir south-west of Orroroo. The reservoir subsequently filled with silt and irrigation was abandoned.

Investigations were undertaken by Sprigg in 1947 (as cited in Crawford, 1961) and Hillwood (1967) to establish the suitability of the Tertiary (Artesian) Aquifer for irrigation. Sprigg drilled 2 bores adjacent to the Pekina Irrigation Area. Bores flowed at over 440 kL/day (5 L/s) but rapidly diminished due to head loss and silting up of bore casing.

A successful screened test bore was drilled by Hillwood (1967) into the Tertiary (Artesian) Aquifer adjacent to the Pekina Irrigation Area. He performed a pump test and found that 66 kL/hr (18.3 L/s) was obtainable over a 24 hr period with a maximum drawdown of 45 m.

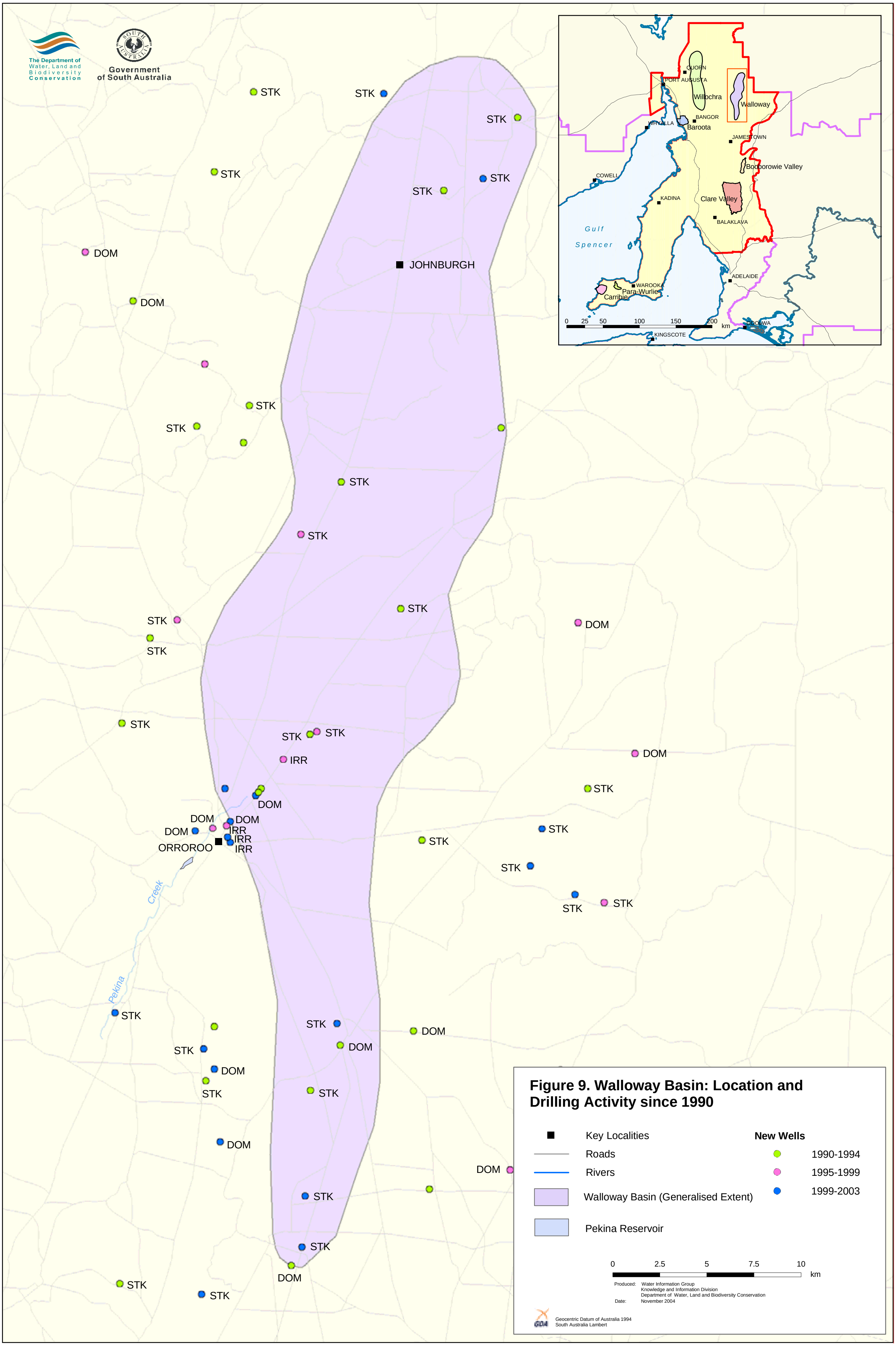


Figure 9. Walloway Basin: Location and Drilling Activity since 1990

Review of Drilling Activity

Table 7 shows the statistics for the recently drilled wells, while Figure 9 shows the new wells that have been drilled into the basin since 1990. It can be seen (from Figure 9) that 19 new wells have been drilled into the basin sediments, with a number of other wells drilled on basin margins. These are mainly close to Orroroo.

Four new wells were drilled for irrigation, with two of these abandoned and backfilled. Six stock wells have been drilled in the northern section of the basin while a new town water supply well was drilled in 2001 approximately 4.5 km north-east of the town (well unit number 663201140).

Table 7. Drilling records for Walloway Basin and surrounds, years 1990-2004.

Period	Total[1]	Stock	Domestic	Irrigation	Other	Comments
1990-1994	17	11	4	0	2*	*2 wells backfilled
1995-1999	6	3	1	2	0	1 IRR well abandoned
2000-2003	10	6	2	2*	0	1 IRR well abandoned
Total	**33**	**20**	**7**	**4**	**2**	

1. Total = new wells drilled during the period

Estimated water use

IRRIGATION ACTIVITY

There are currently 10 wells drilled into the basin that have their primary purpose (stated in SA Geodata) as irrigation. Of these ten wells, four have been drilled since 1990 with two of these now abandoned. Field inspection (December 2004) reveals that there is presently one small block of irrigated olives located on the plain.

Figure 10 shows the location of the irrigation wells, with most of the irrigation wells (8) located near the western margin of the basin near Orroroo. This is close to the presumed recharge zone (Pekina Creek) where there would be lower groundwater salinity.

The remaining two wells are located north of Johnburgh, and are unlikely to be used due to high groundwater salinities. There are also scattered wells drilled into the fractured rock of the surrounding hills that were listed as being for irrigation in SA Geodata. Table 8 shows statistics for each of the irrigation wells.

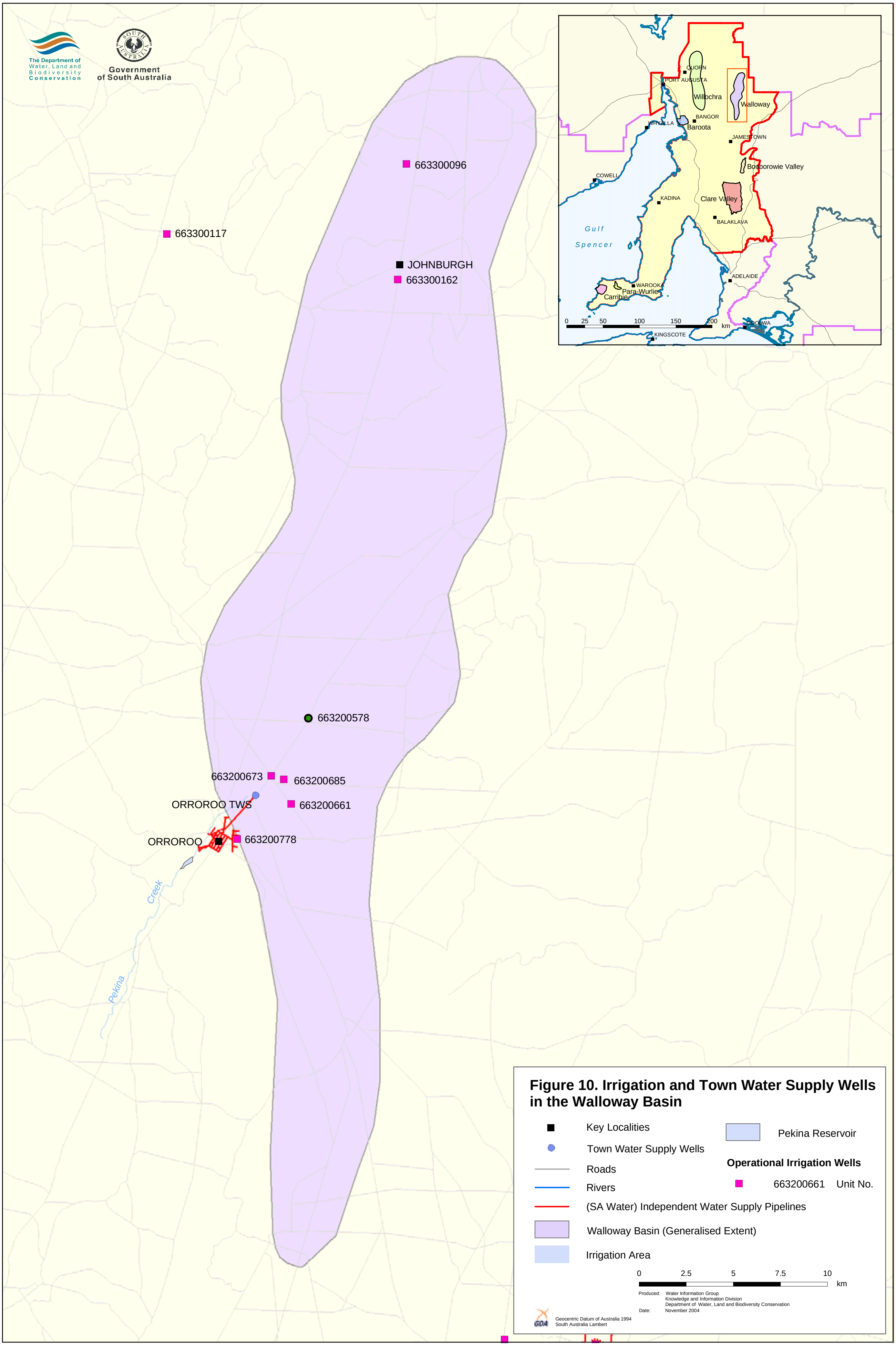


Figure 10. Irrigation and Town Water Supply Wells in the Walloway Basin

Table 8. Statistics on Present Irrigation Wells, Walloway Basin

Unit Number	Drill Date	Drill Depth	Yield (L/s)	TDS mg/L	Status
6633-0096	1952	80.77	N/a	2685	Listed as operational
6633-0162	1964	16.76	0.17	4570	Listed as operational
6632-1065	1997	25	N/a	N/a	abandoned
6632-0673	1947	126.8	0.57	1692	Listed as operational
6632-0685	1979	22.86	12.63	2109	Listed as operational
6632-0661	1946	201.47	5.3	1770	Listed as operational
6632-1071	1998	32.6	1	2154	Unclear
6632-1109	2000	38	1.1	2761	Unclear
6632-1108	2000	48	0.5	N/a	abandoned
6632-0778	1979	33	1.15	1743	Listed as operational

(Source, SA Geodata, 2004).

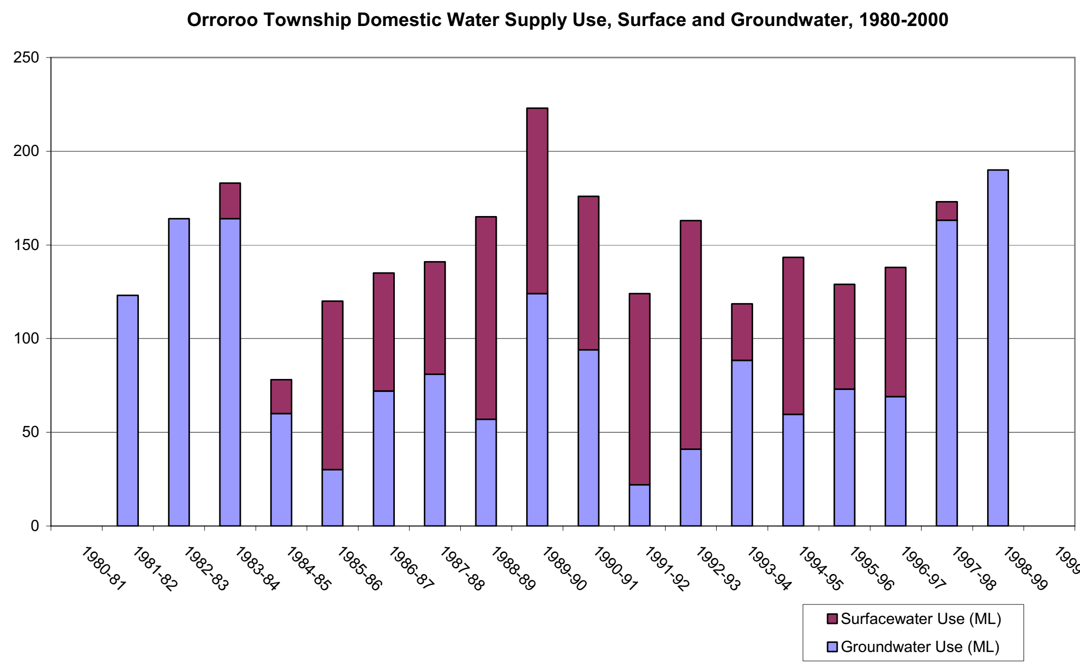
TOWN WATER SUPPLIES

Orroroo TWS

Orroroo's town water supply is served by two extraction wells (6632-01140, 6632-00621) located approximately 4.5 km north-east of Orroroo, on the Orroroo to Minburra Road. Both of these wells are drilled to a depth of 120 m into the Tertiary (Artesian) Aquifer. Well 6632-1140 is the newer of the wells, drilled in 2001. The standing water level at the time of drilling was 10 m, whilst the latest salinity (26/3/2003) reading is 1799 mg/L. Water well 6632-00621 (WAW 5) was drilled in 1969, has a yield of 12.6 L/s, SWL of 9.03 m (27/03/2002), and latest salinity of 1803 mg/L (27/03/2001).

Surface water can be harvested from a pumping station in the hills to the south-west of the town. This is from a waterhole in the Pekina Creek below the abandoned Pekina Reservoir. At the time of visiting (5/8/2004) the source was not being utilised, and appears to be used as an emergency supply. Salinity in the water hole is around 1400 mg/L (Clarke pers. comm., 2004).

Figure 11 below shows the groundwater (and surfacewater) volumes extracted for the Orroroo TWS for the period 1980-2000. The surface water extractions were likely to come from the permanent rock pool in the hills to the south-west of the town (WAW 6, Figure 12). The town water supply is now reliant upon groundwater to meet its domestic needs since the phasing out of surface water. The average water use in the town over the period was 138 ML/yr.



(Source: SA Water, Crystal Brook).

Figure 11. Orroroo TWS Use from Surface and Groundwater, Period 1980-2000.

Monitoring

Figure 12 shows that the current observation network is focussed on the mid to mid-western section of the basin. This is in the region of better quality groundwater in the Tertiary (Artesian) and Quaternary Aquifers.

From the south, WAW 15 is a waterpoint[1] that monitors a natural flowing spring entering Pekina Creek from the hills south-west of Orroroo. Water depth is measured from a gauge

[1] water point refers to an observation made or sample taken from a naturally flowing creek or spring. i.e. not a groundwater well.

board inside a concrete weir. At the time of inspection the spring was flowing at approximately 1 L/s, and was at the lowest level recently seen (Clarke pers. comm., 2004).

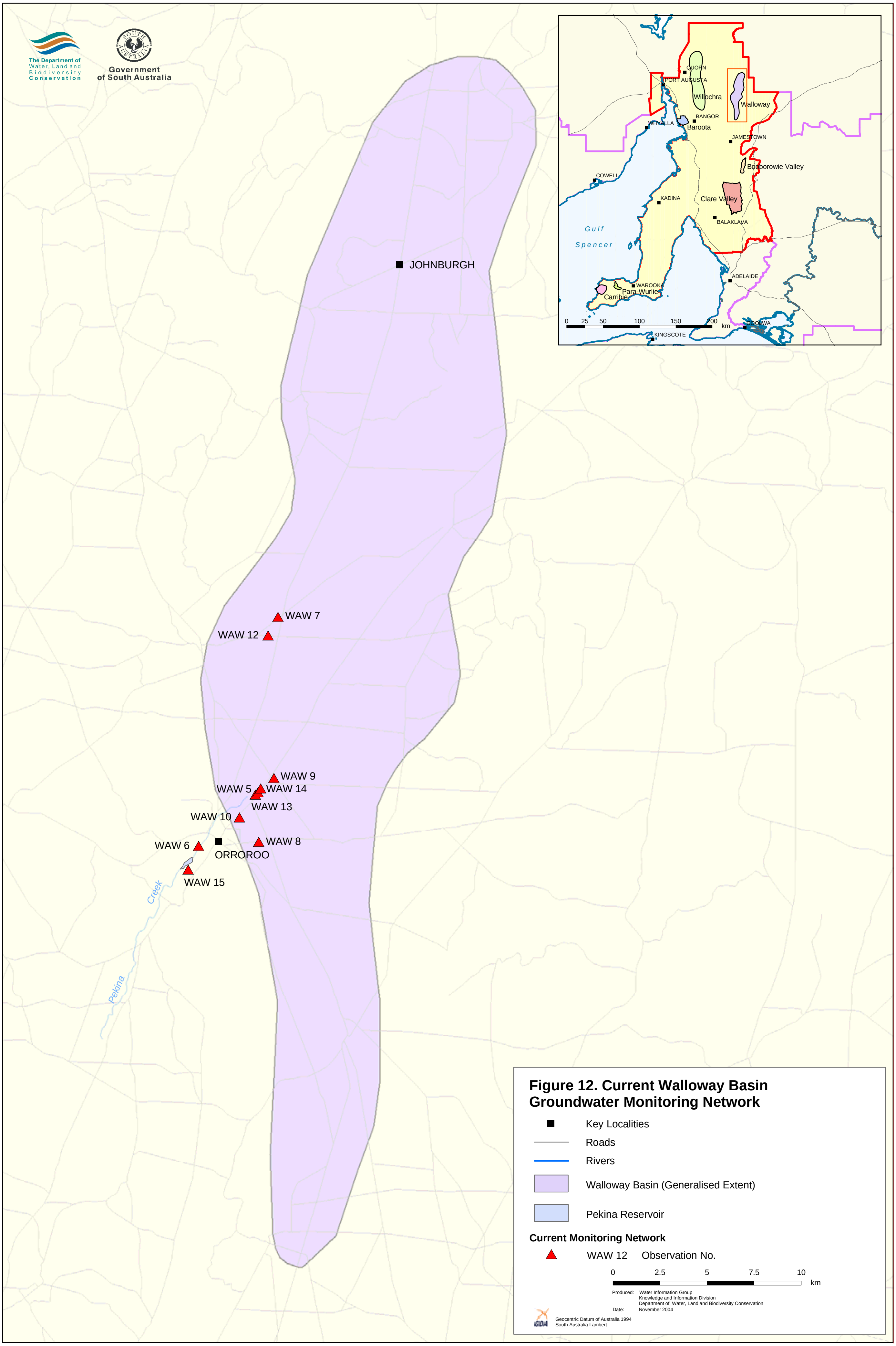


Figure 12. Current Walloway Basin Groundwater Monitoring Network

WAW 6 is a water point where samples are collected from a permanent rock pool located in the hills south-west of Orroroo. This is near the SA Water pumping station, downstream of the Pekina Reservoir. A water sample is available but is likely to be higher that the true representation of groundwater salinity as it is exposed to the atmosphere and would suffer evaporative effects. The water is sourced from seepage from surrounding rock and is thought to have a salinity of 1400 mg/L.

The remaining monitoring wells are located on the Walloway plain and have been drilled into the sedimentary aquifers. WAW 7, 8, 9 and 10 are private wells that have good access to measure a standing water level and monitor the shallow Quaternary aquifers. WAW 5, 13 and 14 are Orroroo TWS wells where a salinity sample is available when pumping. These are drilled into the Tertiary (Artesian) Aquifer. The most recently drilled TWS well (6632-01140) is presently not being monitored but it is recommended that it be added to the observation network.

WAW 12 is the deepest well drilled into the basin sediments at 287 m. This was constructed for the Department of Mines in 1981 and has been consistently monitored since then. Water levels have dropped recently in this well suggesting corrosion of casing and loss of pressure head. It is recommended that this well be rehabilitated (pressure cemented) to ensure that useful information continues to be recorded (Clarke pers. comm., 2004).

Discussion

The Walloway Basin has moderate quality groundwater in both the Quaternary and Tertiary aquifers with the larger quantities of groundwater available in the mid-western section of the Basin, close to the present TWS wells.

Groundwater use from the Basin is primarily for stock and domestic, with the majority of extractions coming for the Orroroo TWS – estimated at 160 ML/yr. There appear to be a number of bores on the Plain that could be used for irrigation purposes, although none appear to be active. It is unclear whether the one property currently irrigation is obtaining water from a bore or from the TWS system. Contact with the landowner would help to determine this.

The Walloway Basin is a limited resource, and large-scale irrigation would not be viable, particularly if multiple users were involved. Previous attempts to establish irrigation in the region have failed. Any attempts to establish irrigation would need to be for salt tolerant crops such as olives and lucerne, and would need to be on a small scale.

Historically groundwater levels from the Tertiary (Artesian) Aquifer have been above ground level in the northern part of the basin. No artesian flowing wells were observed during inspection in August 2004, however it was noted in December 2004 that there was significant subsurface moisture present near well 6632-00578 (see Figure 10). This well has been noted as having an artesian flow from time to time. This well requires rehabilitation to ensure further loss from the aquifer does not occur.

There are still significant knowledge gaps with regard to recharge mechanisms and quantifying the sustainable yield of the Basin. Given the high costs involved and limited interest in establishing irrigation, this investment is considered a low priority for the region.

Recommendations

Management

- Irrigation should be limited to small-scale developments as there is limited sustainable quality groundwater.
- Old abandoned, corroded and disused wells should be decommissioned.
- That Department of Mines observation well WAW 12 (6632-00875) be rehabilitated, as well as leaky artesian well 6632-00578.
- A detailed review of monitoring well data to help understand regional trends should be undertaken.
- Well information should be updated in SA Geodata.

Knowledge gaps

- Investigate and assess recharge processes and sustainable yield (low regional priority at this point in time).

Monitoring

- The present network is adequate, but the new TWS well (6632-01140) should be added to the observation network.
- The groundwater monitoring network should continue to be monitored at 6 monthly intervals.

BOOBOROWIE VALLEY

Description

The Booborowie Valley (Figure 13) is located approximately 180 km north-northeast of Adelaide and is one of a series of north-south trending alluvium filled valleys separated by ranges and basement rocks (Cobb and Smith, 1977). The valley is of low relief, bounded on either side by low to moderate hilly terrain. It is infilled with approximately 30-50 m of poorly sorted piedmont gravels, silts and clays. Basement rocks consist of slates, siltstones, tillites, sandstones and quartzites of the Adelaide Geosyncline (Shepherd, 1978).

There are no permanent streams in the Valley but ephemeral creeks that drain the adjacent ranges. Flows that reach the Valley floor are rare, but these travel in a southerly direction via Booborowie Creek, meeting Farrel Flat Creek just south of Booborowie (Cobb and Smith, 1977).

While aquifers are highly variable and localised in the surrounding hills, there are two rather extensive and transmissive aquifers in the floor of the Valley (Clarke, 1996). Recharge to these aquifers is via direct infiltration (from rainfall) and from abutting basement rock (Cobb and Smith, 1977). Water quality ranges from fair to poor for irrigation, although generally adequate for salt tolerant crops such as lucerne (Clarke, 1996). Yields are usually small (< 1 L/s) in the hard rock areas, but can be very high in the Valley, with several wells yielding up to 40 L/s (Clarke, 1996). The general pattern of water movement is from the ranges to the flats, where it then moves in a southerly direction (Cobb and Smith, 1977). Average rainfall at Booborowie Post Office is 440 mm.

Landuse

The region has had a long history in the lucerne industry. The early conditions of the Valley were well suited to the growing of unirrigated lucerne, with shallow water tables and swamps common in the early part of the century. Declines in the water table in the 1950s and 1960s saw a move to the establishment of irrigation to increase crop yields.

Present day irrigation mainly occurs in the northern part of the Valley, and is grazed by numerous Marino sheep. Free, non-irrigated lucerne also occurs throughout the whole district, and extends south Gum Creek.

Investigative work

Cobb and Smith carried out a study in the early seventies in response to concerns raised by local landowners as to the reasons for the drop in the water table. A groundwater investigation commenced in 1971 to establish the effect of groundwater extraction, quantify aquifer parameters, and estimate aquifer storage. A preliminary water well survey commenced in the Hundreds of Ayers and Anne, with fifty-three wells selected to form the Booborowie observation network. Test drilling began in 1973 to obtain data on the nature and distribution of valley fill material. Five test-holes were drilled to fresh bedrock and completed as watertable observation points (Cobb and Smith, 1977). A 3 x 100 minute step test was performed on observation well AYS 36, followed by a 46 hour constant rate discharge test. A transmissivity value of 200 m^2/day was calculated, with an estimated hydraulic conductivity equal to 7.4 m/day.

Cobb and Smith (1977) concluded that the water table had reduced primarily due to introduction of the lucerne industry, but at the time of investigation had sufficiently stabilised. Fluctuations in the water table at the time were estimated at around 1 m/yr, depending on seasonal rainfall. No investigative work has occurred in the Valley since Cobb and Smiths study of 1977. Hydrographs of groundwater levels show a long term lowering of groundwater levels since the last major, above average rainfall event in the winter, spring and summer months of 1992/1993, but whether current day declines compare with historically low groundwater levels is yet to be determined.

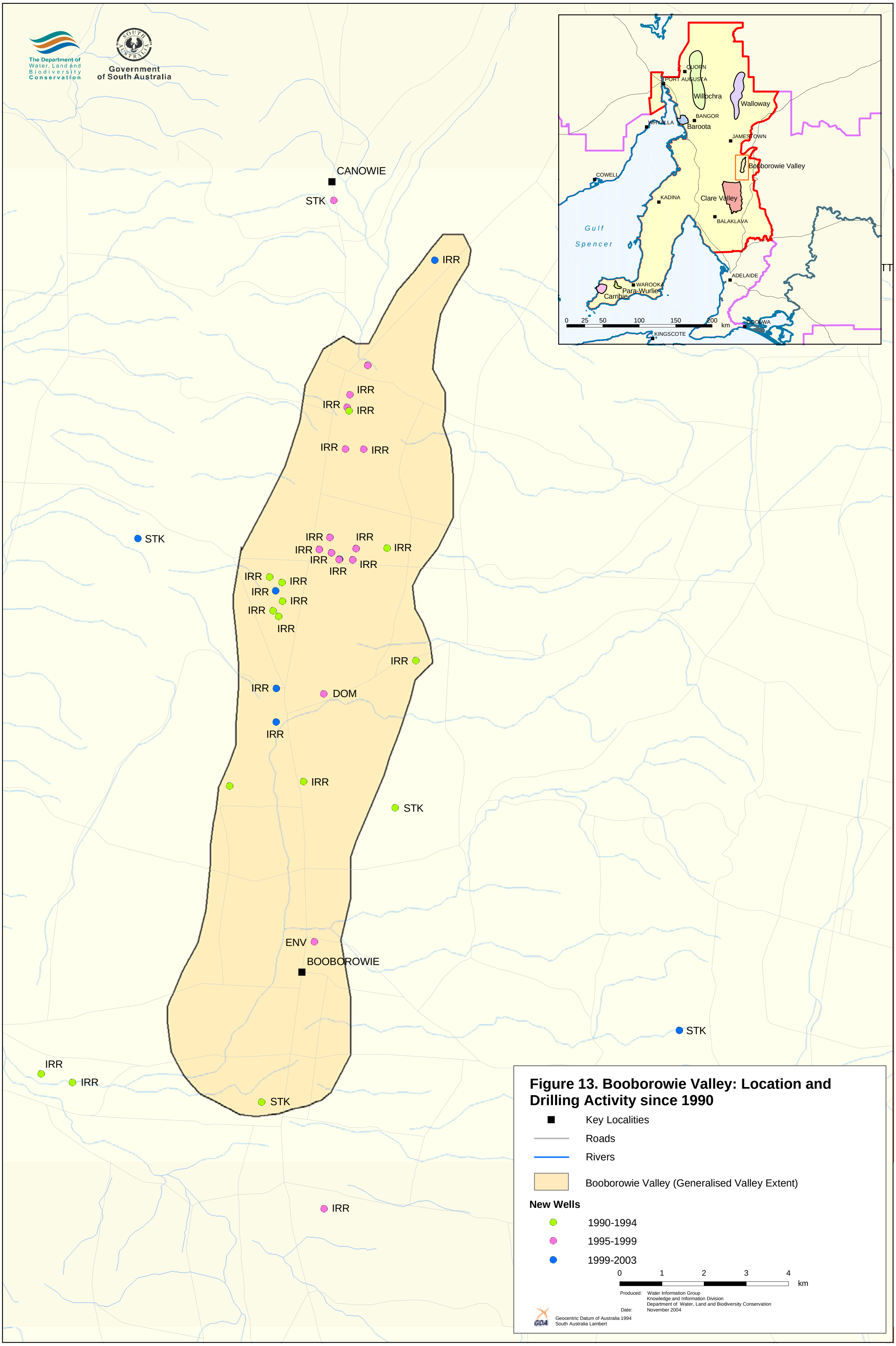


Figure 13. Booborowie Valley: Location and Drilling Activity since 1990

Review of Drilling Activity

Figure 13 shows the new wells drilled in the Booborowie Valley since 1990. A review of SA Geodata drilling records indicate that in total 32 new wells have been drilled in the area during this time. Table 9 is a summary of these wells. Four wells had their primary purpose for stock, one for domestic, 24 for irrigation purposes with three having no description. Fourteen of the 24 new irrigation wells have since been abandoned.

Table 9. Summary table of drilling activity between years 1990-2004, Booborowie Valley

Period	Total	Stock	Domestic	Irrigation	Other	Comments
1990-1994	15	4	0	10	1	6 IRR wells abandoned
1995-1999	13	0	1	10	2	7 IRR wells abandoned
2000-2003	4	0	0	4	0	1 IRR well abandoned
Total[1]	**32**	**4**	**1**	**24**	**3**	

1. Total = new wells drilled during the period

Most of the wells have been drilled in the early to mid 1990's in an area 9-10 km north of Booborowie. Figure 13 shows the location of the newly drilled wells.

There are currently 231 wells in the Hundred of Anne and 430 wells in the Hundred of Ayers (SA Geodata, 2004). The majority of the wells are for stock and domestic purposes.

Estimated water use

IRRIGATION ACTIVITY

Records from SA Geodata indicate that there are 50 wells in the Valley that have their primary purpose for irrigation (although some are now abandoned). The target aquifer for the majority of the irrigation wells is the coarse gravel and sand sediments found at depths between 30 and 45 m. Many of the wells drilled at these depths have high yields, often greater than 20 L/s with salinities between 1500-2500 mg/L.

The highest yield encountered of the presently operational wells is well 6631-00723, which has a reported yield of 59 L/s. This has been drilled to a depth of 45 m (SA Geodata, 2004). The salinity in the irrigation wells is lowest at the northern end of the valley, with a gradual increase to the south. Figure 14 shows the presently operational irrigation wells as listed in SA Geodata (2004).

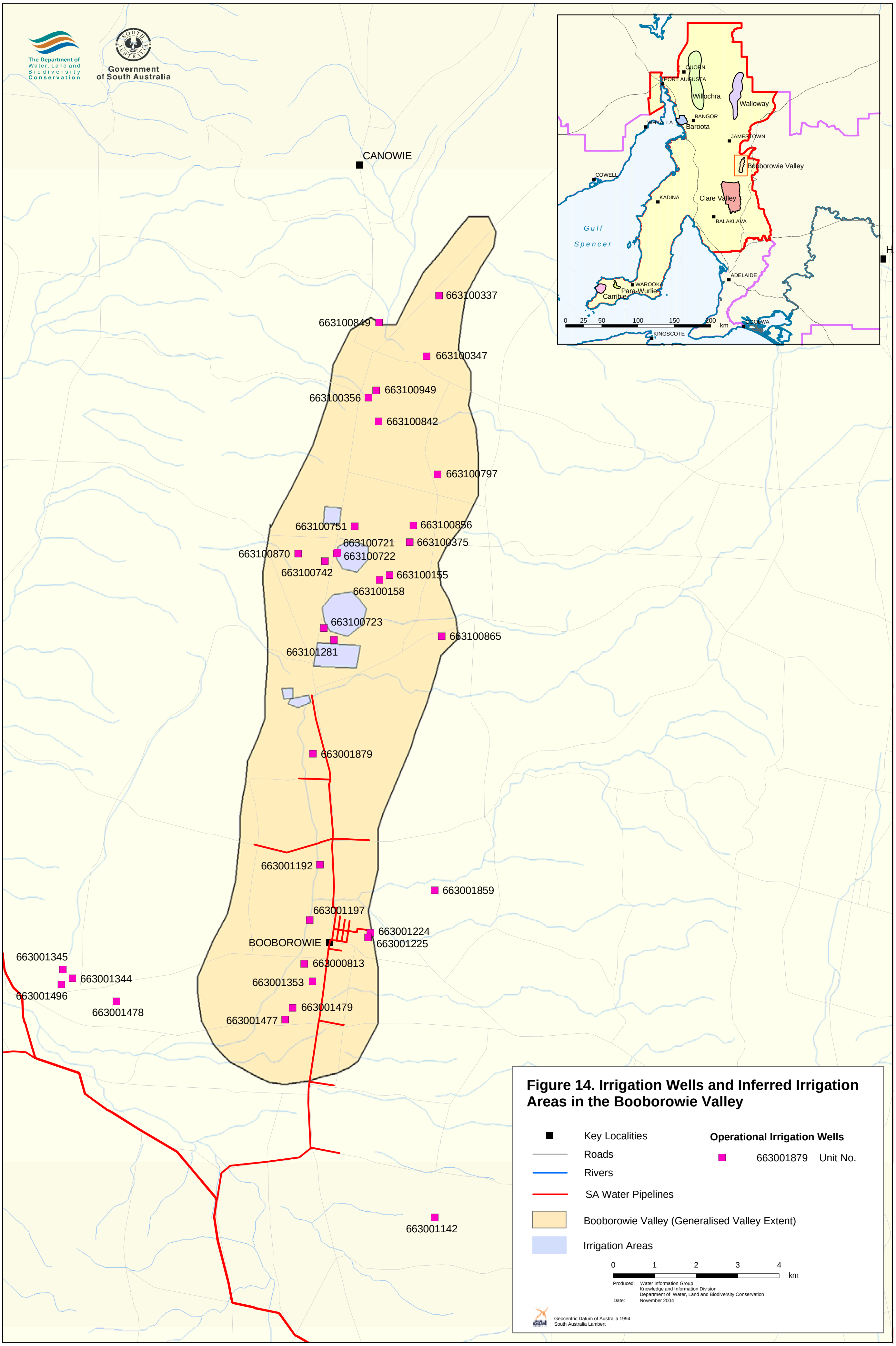


Figure 14. Irrigation Wells and Inferred Irrigation Areas in the Booborowie Valley

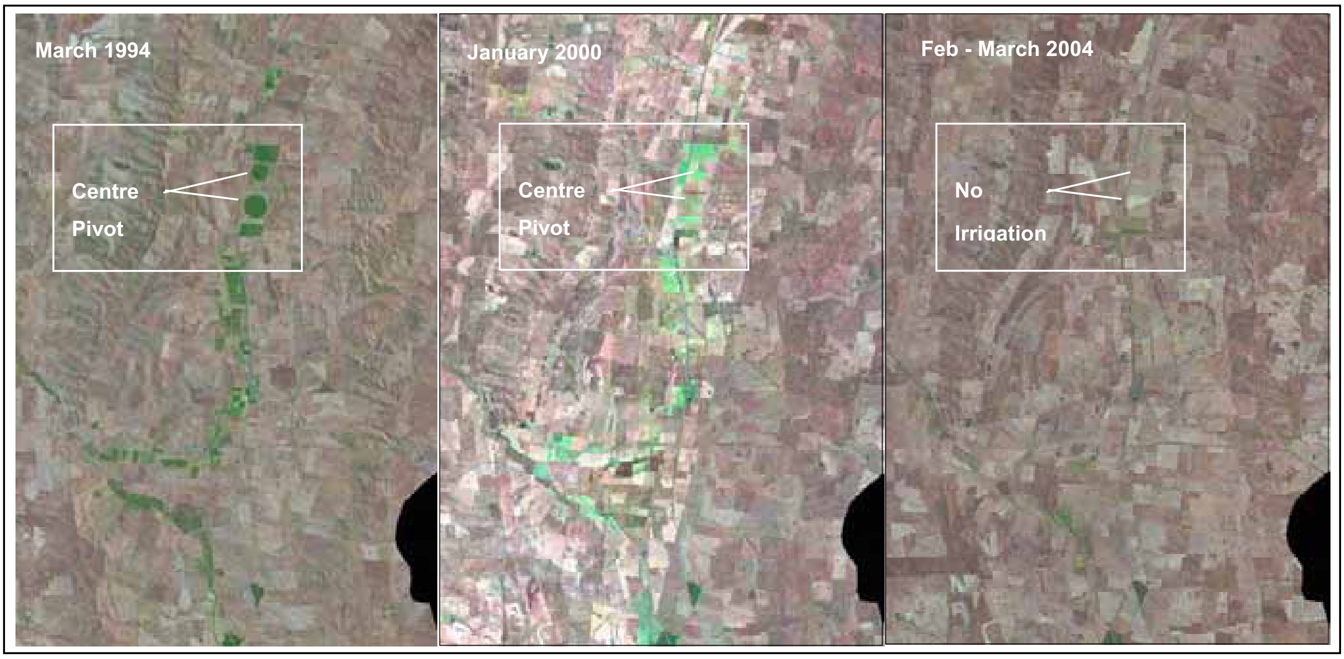


Figure 15. Vegetation condition in the Booborowie Valley: Comparison in summer 1994, 2000 and 2004

Figure 15 shows false colour, enhanced Landsat 5 imagery for the Booborowie region in the summer months of 1994, 2000 and 2004. This highlights the health of vegetation using normalised difference vegetation index[1] (NDVI). The NDVI is used to infer information on the condition of vegetation. In this analysis, vegetation in good condition appears green.

The green healthy vegetation seen in Figure 15 is assumed to be unirrigated/irrigated lucerne. Examination of the satellite imagery shows that there has been a substantial decrease in healthy vegetation in the Valley sometime after the year 2000, apparently due to a decrease in unirrigated/irrigated lucerne. The centre pivot irrigation in Figure 14 confirms this, as indicated by the disappearance of the circular fields from February-March imagery of 2004.

A local landowner at Gum Creek (December, 2004) advised that lucerne plots require a “resting time” or non irrigation period to control soil condition. If this is the case then the reduction in lucerne would be for the purpose of resting the soil, rather that the unavailability of irrigation water. There is the possibility that replanting and irrigation of lucerne may increase again after this resting period.

[1]for the technical report on the analyses see Appendix F.

TOWN WATER SUPPLIES

Booborowie township receives its potable water from the River Murray, with the main Morgan-Whyalla pipeline passing west and southwest of the town, approximately 7 km away. A smaller connector pipe delivers water to the town and extends 5 km to the north where it then terminates. Farmers to the north of this point rely on on-farm water sources to provide their water supply needs.

Monitoring

The Booborowie observation network (Figure 16) is one of the largest networks in the NYAD region, encompassing 49 observation wells in the Hundreds of Anne and Ayers. The network extends through the central section of the valley, slightly south of Canowie to 6 km south of Booborowie.

The monitoring network is evenly spaced throughout the valley and surrounding hills, with the majority of wells on private land. Monitoring initially began in early 1971, stopped in 1973, and then recommenced in 1990. Most of the current obswells have a complete data set from 1990 onwards. The early observation readings (1970-1973) were monitored 6-7 times per year. The current measurements are taken half yearly in the autumn and spring.

The majority of the observation wells are used for stock (mostly windmills) located on private land, with 5 wells installed by the Department of Mines in 1973. Due to a number of new stock wells installed in the area, the majority of wells are in good condition and suitable for a standing water level measurement. Many of the windmills have overflow tanks where salinity measurements can be taken, and when pumping can give a good representative sample for groundwater salinity.

It was noted at the time of inspection that ANN 8 no longer had access for a SWL measurement and ANN 31 was found to be collapsed and dry. Both of these wells should be removed from the network. A number of other wells were located in farm paddocks that required opening a number of gates and were in difficult to access places. Some of these could be removed from the network.

The current network adequately monitors the valley as a whole, and there are sufficient observation wells that monitor areas of high use. There is adequate monitoring around wells that have their primary purpose stated as irrigation.

Given the fact that the Booborowie Network is quite large, further reductions in the network could be made by examining hydrograph data, and selecting only those wells that yield useful information. This would help to save time in the monitoring process.

Further comments on observation wells can be seen in Appendix C.

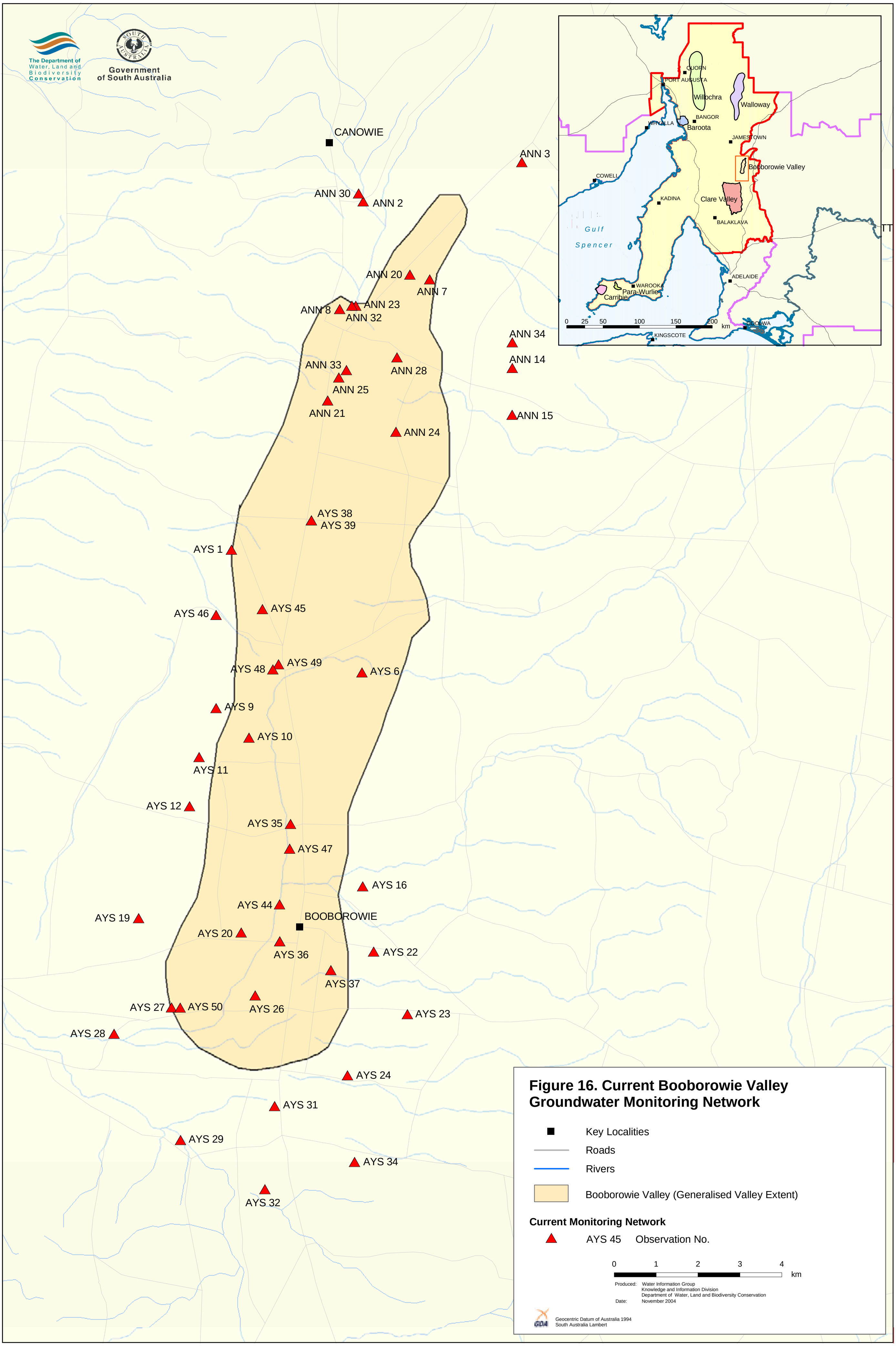


Figure 16. Current Booborowie Valley Groundwater Monitoring Network

Discussion

Booborowie Valley contains moderate quality groundwater suitable for stock and the irrigation of salt tolerant crops such as lucerne and olives. The majority of irrigation water is pumped from the alluvial aquifer comprising of Quaternary clays, sands and gravels, with highest yields in the northern section of the valley. Salinity is generally in the range 1200-3000 mg/L.

The knowledge of aquifer parameters, recharge processes and aquifer connectivity is at best, moderately understood. Attempts were made by Cobb and Smith (1977) to quantify a sustainable yield, although approximations of parameters involved in the calculation of a water budget were largely general in nature. Interpretations from the one discharge test carried out on AYS 36 has several interpretations and further discharge tests are required for the valley (Clarke, 1990).

The remote sensing analysis and field inspections suggest that there has been a decrease in healthy vegetation in the last four years, which is likely to be due to the resting of lucerne blocks. Detailed consultation with the irrigation community is required to confirm this change.

There appears to be some potential for further groundwater use in the valley, but this would be limited to salt tolerant crops. In the absence of further information regarding sustainable yields, this should be undertaken in a conservative manner.

Further investigative work incorporating a review of monitoring records is required to refine initial estimates and hypothesis from Cobb and Smiths study in the 1970s.

Recommendations

Management

- Evaluations, including historical water level data should be undertaken to determine groundwater resource condition and trends.
- Updating of current well information in SA Geodata.

Knowledge gaps

- Aquifer connection, recharge processes and knowledge of aquifer parameters including transmissivity and storage.
- Present land use, application rates for irrigation and water use for stock.

Monitoring

- Groundwater monitoring should continue at 6 month intervals.
- Observation wells ANN 8 and ANN 31 should be removed from the network.

BALAKLAVA (NORTHERN ST VINCENT BASIN)

Description

The township of Balaklava is located approximately 90 kilometres north of Adelaide, and geologically it is part of the St Vincent Basin (Figure 17). Locally the basin is important as it supplies small quantities of groundwater for irrigation, industrial and stock use.

The predominant landuse is cereal cropping, piggeries and small-scale irrigation (olives). A number of wells access groundwater for stock, domestic, industrial and irrigation purposes.

The maximum width of the Basin is 48 km in the vicinity of Port Wakefield, and comprises of three sub-basins: the Adelaide Plains Basin which extends to the north and includes Balaklava; the Noarlunga Embayment; and the Willunga Embayment (Shepherd, 1978). Structurally the Basin is a graben, down faulted along the Para and other faults and extending beneath the Gulf St Vincent (Shepherd, 1978). Sediments of the basin are mainly Quaternary and Tertiary in age (Shepherd, 1978), with the main Tertiary Aquifer found at depths between 40 and 80 m in the northern portion. This consists of fine to coarse sand and gravels beds, often yielding greater than 10 L/s (SA Geodata, 2004). The Tertiary Aquifer is overlain by 20-30 m of Quaternary sediments, with yields however usually less than 1.0 L/s (SA Geodata, 2004).

Salinity varies regionally, with groundwater in the area having salinities between 2000 and 3000 mg/L. Better quality groundwater is found close to Balaklava due to recharge from the Wakefield River. The River is ephemeral in nature, and only flows for brief periods in the late winter and spring. Consequently recharge to local aquifers only occurs during peak flows.

Elsewhere in the region (away from the River) groundwater salinities are much higher, greater than 7000 mg/L and up to 30 000 mg/L in some places (SA Geodata, 2004). The northern St Vincent Basin is hydrogeolgically independent of the Adelaide Plains sub-basin and Willunga Embayment (Shepherd, 1978).

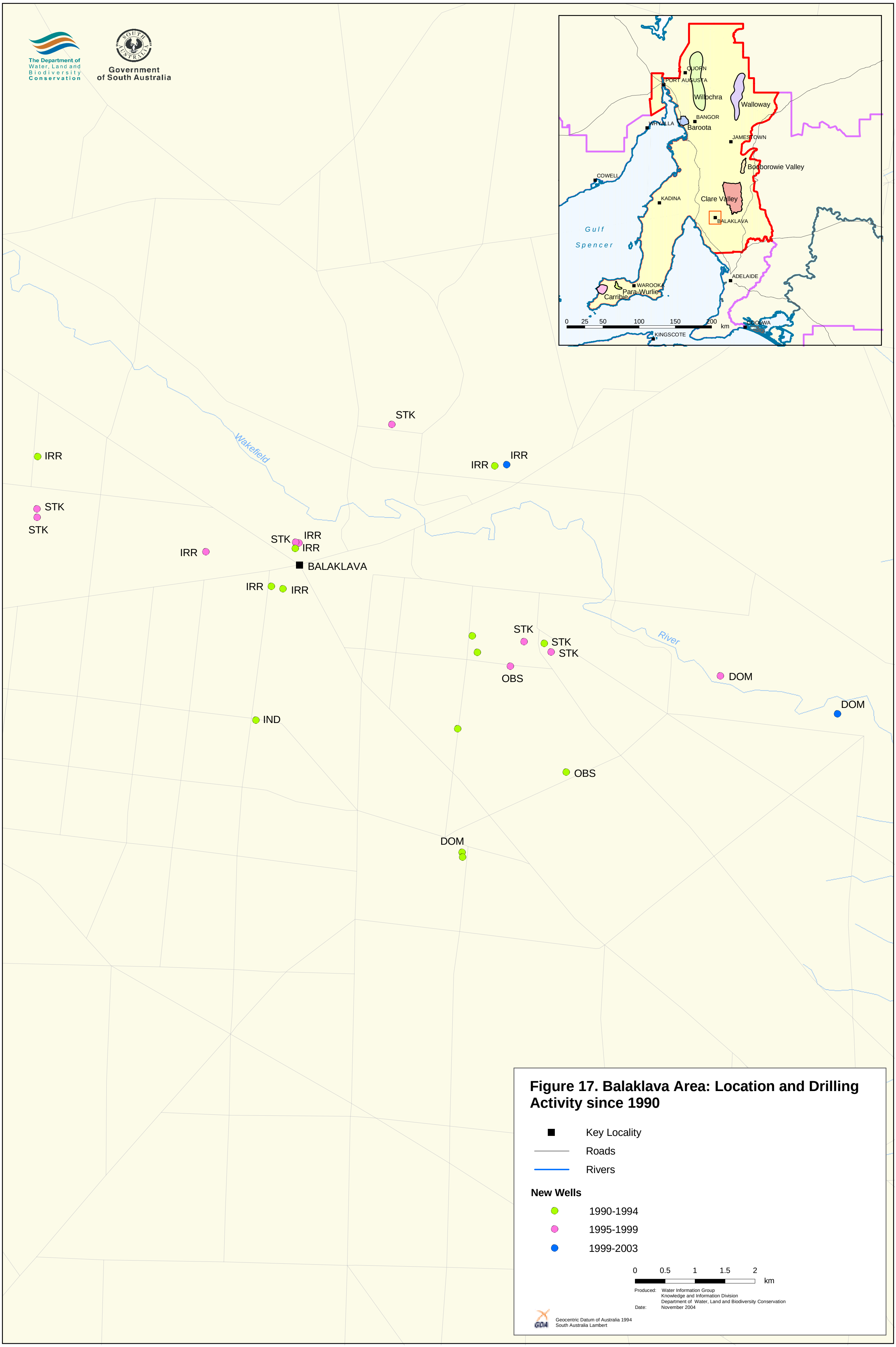


Figure 17. Balaklava Area: Location and Drilling Activity since 1990

Review of Drilling Activity

Figure 17 and Table 10 show the new wells drilled within a 7 km radius of Balaklava between the years 1990 and 2003. A number of irrigation wells were drilled in the region during the period 1990-1994.

Seven stock, three domestic and eight irrigation wells were drilled in the region. There was also an industrial well drilled to the south of the town as part of investigations into a proposed straw mill. This mill would have required a large volume of groundwater but the proposal did not eventuate (Clarke pers. comm. 2004). New wells were also drilled for the Balaklava Golf Course, Racecourse and Oval.

Table 10. Summary table of new wells drilled within 7 km radius of Balaklava between 1990 and 2003.

Period	Total[1]	Stock	Domestic	Irrigation	Other	Comments
1990-1994	15	1	1	5	6*	*4 wells abandoned
1995-1999	10	6	1	2	1	1 new observation well
2000-2003	2	0	1	1	0	
Total	**27**	**7**	**3**	**8**	**7**	

1. Total = new wells drilled during the period

Estimated water use

IRRIGATION ACTIVITY

Current information from SA Geodata lists 23 irrigation wells within a radius of 7 km from the Balaklava Township. Well statistics for the proven operational wells (based on field inspection) are presented in Table 11. Figure 18 is a map of presently operating irrigation wells in the district, and includes present irrigation areas as determined from desktop assessment and on-ground inspection.

Table 11 shows that most irrigation wells are drilled to depths greater than 40 m, with groundwater salinity usually greater than 2000 mg/L. The shallower wells in the Quaternary Aquifer generally have lower yields.

Table 11. Well Statistics for Presently Operational Irrigation wells.

Unit No	Depth (m)	Yield (L/s)	TDS	TDS Date	Purpose (other)	Comment
6529-00892	76	30	2041	4/06/1993		Balaklava Golf Course
6529-00894	72	20	1895	22/11/1993		Balaklava Oval
6529-00893	38.2	1.5	2927	26/07/1995	Stock	
6529-00898	82	4	2329	9/10/2002		Balaklava Racecourse
6529-01086	65.3	9	N/a[1]	N/a[1]		Balaklava Racecourse
6529-00945	71	5	2493	26/06/1995		
6529-00946	85	25	2086	15/06/1995	Stock	
6529-01087	70	30	2036	1/02/2002		Balaklava Golf Course

[1]N/a – no available information in SA Geodata

Figure 18 shows that there is a cluster of wells in the town itself, with scattered wells on the outskirts of the town. There are four irrigation wells at Balaklava Golf course, three wells at the Balaklava Oval, and two at the Racecourse. The local high school also has an operational irrigation well.

Ground inspection and evidence from satellite and Landsat 5 imagery revealed that the main areas of irrigation are the Balaklava Golf course, Racecourse and Oval. Aerial photography from 2000 shows an irrigated lucerne paddock to the west of the town (CT 5384 536). During field inspection, the landowner indicated that he stopped irrigating lucerne primarily due to the high Iron (Fe) content in groundwater that was scalding the foliage. He indicated that he would not irrigate lucerne again due to this problem.

TOWN WATER SUPPLIES

Balaklava obtains its town water supply from the River Murray, via the Morgan-Kadina pipeline.

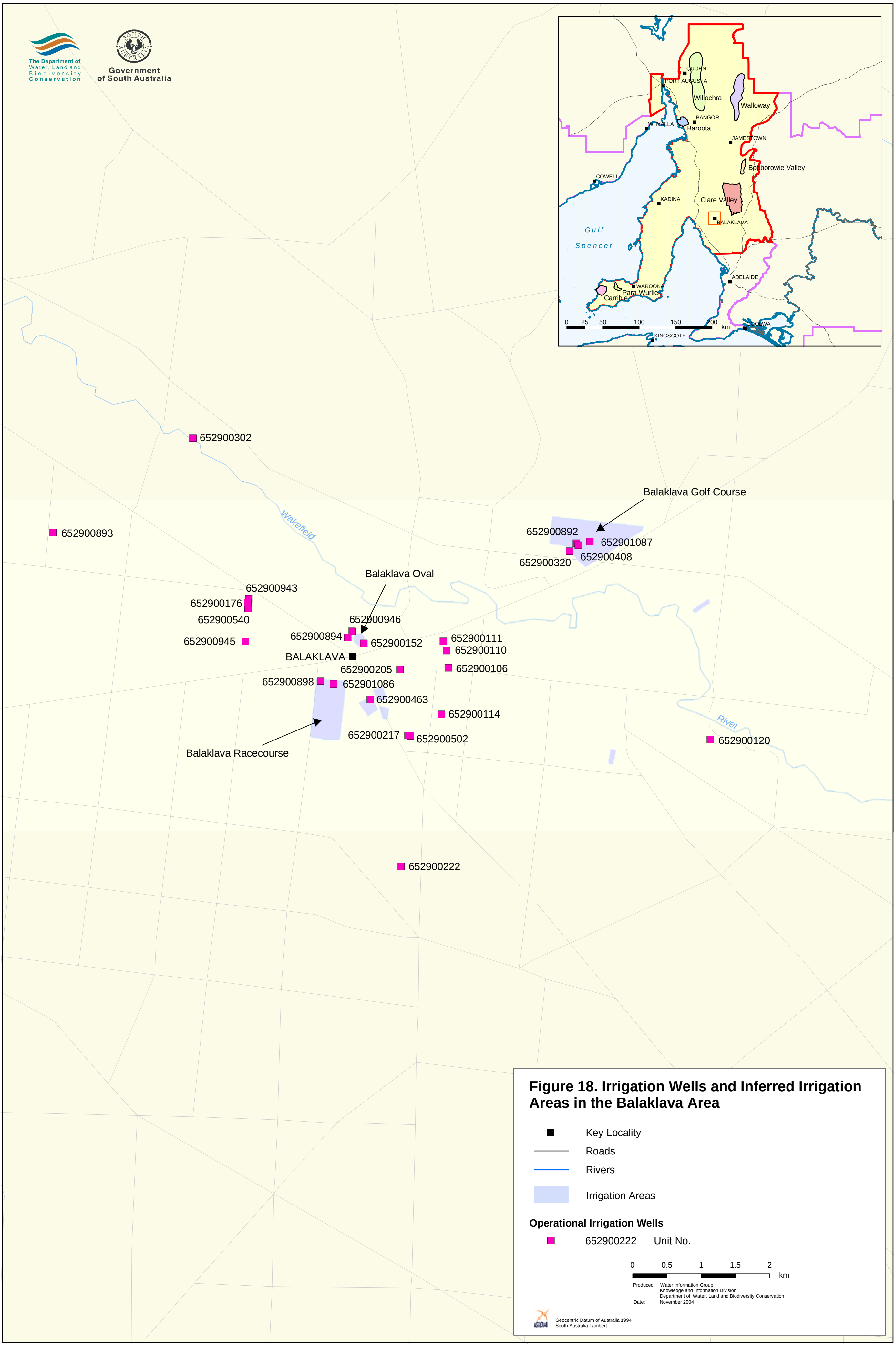


Figure 18. Irrigation Wells and Inferred Irrigation Areas in the Balaklava Area

Monitoring

A groundwater monitoring network at Balaklava began in 1990 in response to proposed large scale extractions by Arisa Ltd for a pulp/paper manufacturing plant from wheat straw. The current network is well spaced around Balaklava and the Wakefield River as shown in Figure 19. There are a total of 28 wells, most of which are located south of the town in the Hundreds of Balaklava and Dalkey. There are 6 wells in the Hundred of Hall. Approximately half of the observation wells are located on private land, with a number of these windmills and hand dug wells. Five to six of the windmills are abandoned, and only have access for a depth to water reading. The following is a brief summary of the important monitoring wells.

There are two irrigation wells at the Balaklava golf course (HAL 1 and HAL 2), with a third irrigation well available for further readings if required (irrigation well 6529-1087). This well was drilled in 2002. The Balaklava racecourse also has 2 wells (BAL 9 and BAL 10) where SWL readings are available and samples when pumping.

BAL 3 and BAL 4 are investigation wells drilled by Arisa at the time of the straw mill proposal. They were previously used for pump tests. Presently they are available for SWL readings only and require a key and pump if a sample is required.

There are two waterpoints, HAL 5 and DAE 10, where samples are taken from the Wakefield River (when flowing) and measured for salinity. These are taken as a representative sample of the water that is recharged to local aquifers. Water was not flowing at the time of inspection.

BAL 1 was a previous hand dug well that has been backfilled and replaced. The new well has been given observation well number BAL 11.

The current monitoring network adequately covers the main groundwater irrigation users from the Tertiary Aquifer in the district. Although it is advisable that the network continue to be monitored at 6 month intervals, the size of the network could be reduced to save time in the monitoring process. Examination of hydrograph data will help to determine which wells can be cut from the network.

For further comments related to the observation network refer to Appendix D.

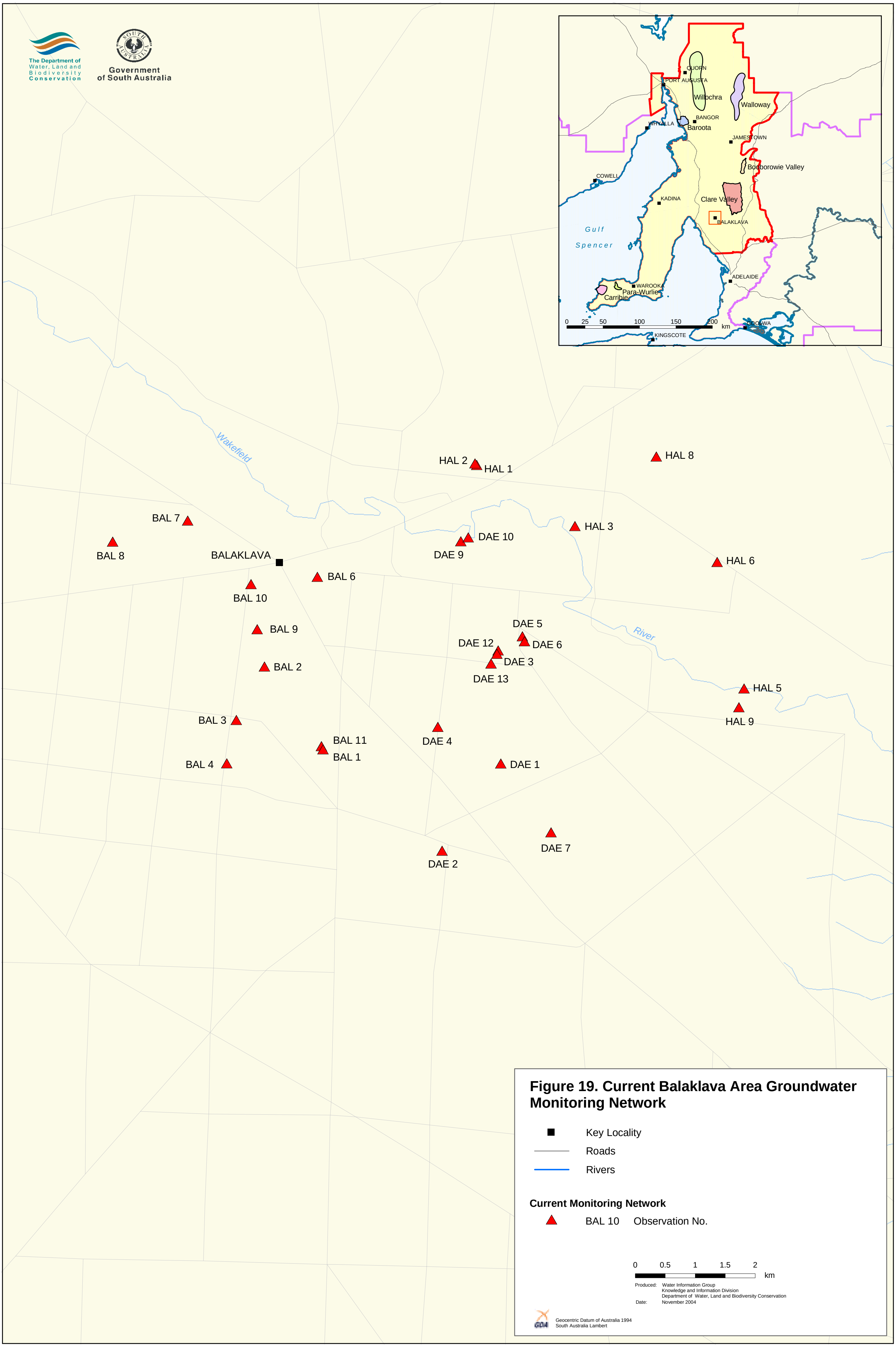


Figure 19. Current Balaklava Area Groundwater Monitoring Network

Discussion

Balaklava is located at the northern end of the St Vincent Basin, which regionally, has poor quality groundwater. There is a limited amount of moderate quality groundwater close to Balaklava due to its proximity to the Wakefield River, from which it derives its recharge. Water quality in the Tertiary and Quaternary Aquifer is between 2000 and 3000 mg/L, with the Tertiary Aquifer having the higher yields, often more than 10 L/s. Current landuse is primarily pasture, with scattered piggeries and small irrigation plots. There is currently no extensive irrigated horticulture in the district.

Primary groundwater use appears to be from the Balaklava Golf Course and Racecourse, with quantities also used for the Balaklava Oval and High School. There are also a number of stock and domestic wells in the district.

Based on the past usage history, current irrigation activity and the potential for increased usage, more detailed investigations regarding the condition of the resource are considered a low regional priority.

Recommendations

Management

- Evaluations of groundwater level information should be undertaken to determine groundwater level trends.

Knowledge gaps

- Usage information: current application rates and groundwater extractions.
- Aquifer information: sustainable yields; aquifer connectivity.

Monitoring

- Groundwater monitoring continue at 6 monthly intervals.
- Observation well BAL 1 be removed from the network.

YORKE PENINSULA

Regional Overview

The groundwater resources of the Yorke Peninsula vary largely due to the regional differences in geology, recharge and variations in local groundwater flow systems. The north-west section of the Peninsula contains sediments of the Pirie Basin, a multiple aquifer system comprised of Quaternary and Tertiary sediments. Groundwater salinities in these aquifers are high, with salinities up to 40 000 mg/L in some places (Martin et al, 1998).

The mid section of the Peninsula (roughly south of Wallaroo to Minlaton) comprises undifferentiated alluvial sediments overlying basement rock of the Stuart Shelf and Gawler Craton (Preiss, 1987). There are currently few operational water wells in this region, with low yields and high salinities (generally over 5000 mg/L) the limiting factor to development.

The major geological formation on southern Yorke Peninsula is aeolianitic limestone of the Bridgewater Formation, which is underlain by Archaean basement rock of the Gawler Craton. The Bridgewater formation covers most of the “foot” of the Peninsula. Regionally this is an important aquifer, and provides fresh groundwater for Warooka and Point Turton, as well as supplying stock and domestic water to local farmers. Other areas of note on Yorke Peninsula are discussed in the following sections.

CARRIBIE BASIN

Description

The Carribie Basin is located on the western part of the foot of Yorke Peninsula, between the townships of Marion Bay and Corny Point (Figure 20). The Basin covers an area of 116 km^2 and comprises unconfined Pleistocene aeolianite (Bridgewater formation) overlying Archaean/Lower Proterozoic basement (Hussin, 1966, as cited in Matthews, 1988). Vegetated coastal dunes are found on its western boundary, which consist of fine, unconsolidated sands overlying partially consolidated aeolian limestones.

Landuse is mainly cereal farming, sheep and cattle grazing. Extensive scrub remains on the foot of the Peninsula where it is too rocky for farmers to cultivate cereal crops. There are no permanent or clearly defined watercourses and any surface runoff collects in interdunal depressions. Recharge to the aquifer is from rainfall by direct infiltration, with average rainfall at Corny Point 9 km to the north 442 mm/yr.

Groundwater of salinity less than 1000 mg/L is available from most of the wells within the Basin with the exception of an area to the northeast where salinity is greater than 2000 mg/L (Matthews, 1988).

Investigations were undertaken by Hussin (1966) to establish the basin boundary and aquifer geometry. Sixteen observation wells were drilled into the basin, which confirmed the presence of an unconfined to semi confined aeolianite aquifer. The basin was found to have a maximum thickness of 24 m at its centre, thinning to 11 m at the basin boundaries (Hussin, as cited in Matthews, 1988). Pump testing of 7 wells by Bleys (1966) resulted in an average transmissivity of 2056 m^2/day, average hydraulic conductivity 109 m/day and specific yield 0.16. Furthermore, Bleys estimated recharge at 1400 ML/yr and safe yield at 1000 ML/yr (Bleys, 1966 as cited in Matthews, 1988).

Recharge was estimated at 47 mm/yr by Wischusen (1987) using fluctuations of the potentiometric surface (water table) and 35 mm/yr by Matthews (1988) using a chloride mass balance approach. The safe yield was also estimated by Wischusen at 1000 ML/yr (Matthews, 1988).

Review of Drilling Activity

Table 12 is a summary of the new wells drilled into the Carribie Basin and surrounds since 1990. It can be seen from the Table that of the 17 new wells drilled, 12 were stock, 3 for irrigation and 2 had no purpose description. The location of the new wells is shown in Figure 20.

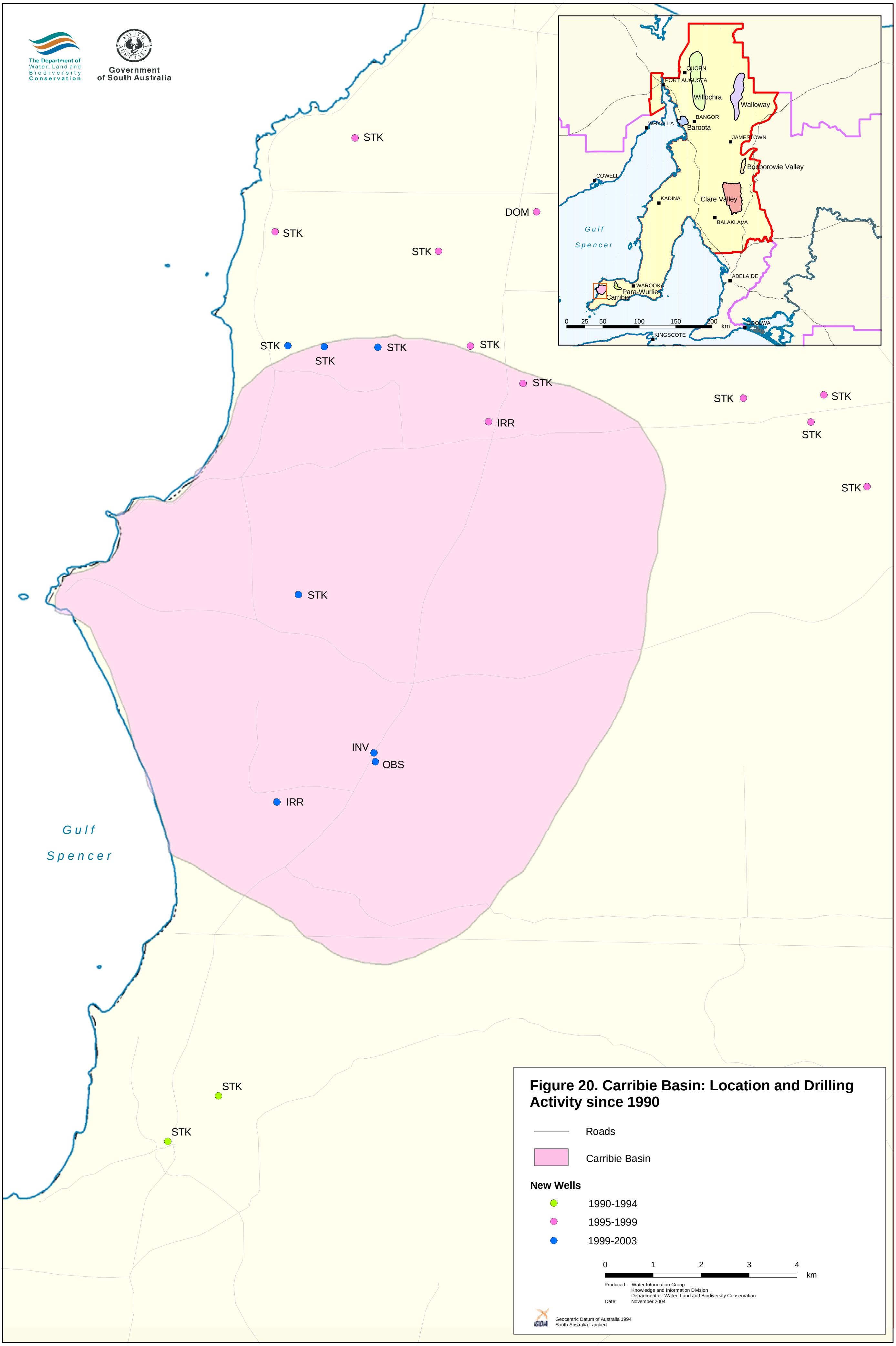


Figure 20. Carribie Basin: Location and Drilling Activity since 1990

Table 12. New Wells Drilled into the Carribie Basin since 1990.

Period	Total	Stock	Domestic	Irrigation	Other	Comments
1990-1994	0	0	0	0	0	No wells installed
1995-1999	9	8	0	1	0	1 irrigation well.
2000-2003	8	4	0	2	2	
Total[1]	**17**	**12**	**0**	**3**	**2**	

1. Total = new wells drilled during the period

Estimated water use

IRRIGATION ACTIVITY

Although there is an abundance of good quality groundwater in the Basin, poor soils and high drainage appear to be the limiting factors to the development of large-scale irrigation (Clarke, 1996). There are currently three wells indicating their primary use for irrigation, but evidence from Landsat 5 imagery, ESI imagery and field inspection shows that there is no irrigation taking place anywhere on the Carribie Basin.

TOWN WATER SUPPLIES

At present the basin is not used for town or public reticulation water supplies. There appears to be potential to utilise the resource as a town water supply but the present costs of infrastructure appears to be the limiting factor to large-scale development.

Monitoring

A number of 150-250 mm diameter holes, penetrating the upper unconfined aquifer remain from investigative work in the 1960s. The majority of these are located on roadsides and are unequipped. Due to the age of the wells, some of the surface casing is beginning to rust which may require rehabilitating. Some of these wells are important for the use in council roadworks.

The remaining observation wells are on private land, with the majority being windmills or shallow hand dug wells. Figure 21 is a map of the monitoring network. Further field notes can be found in Appendix E. The coverage of obswells is considered adequate for monitoring at the whole of basin scale. As there is no irrigation or major water users in the basin there is no particular area where more intensive monitoring effort should be targeted.

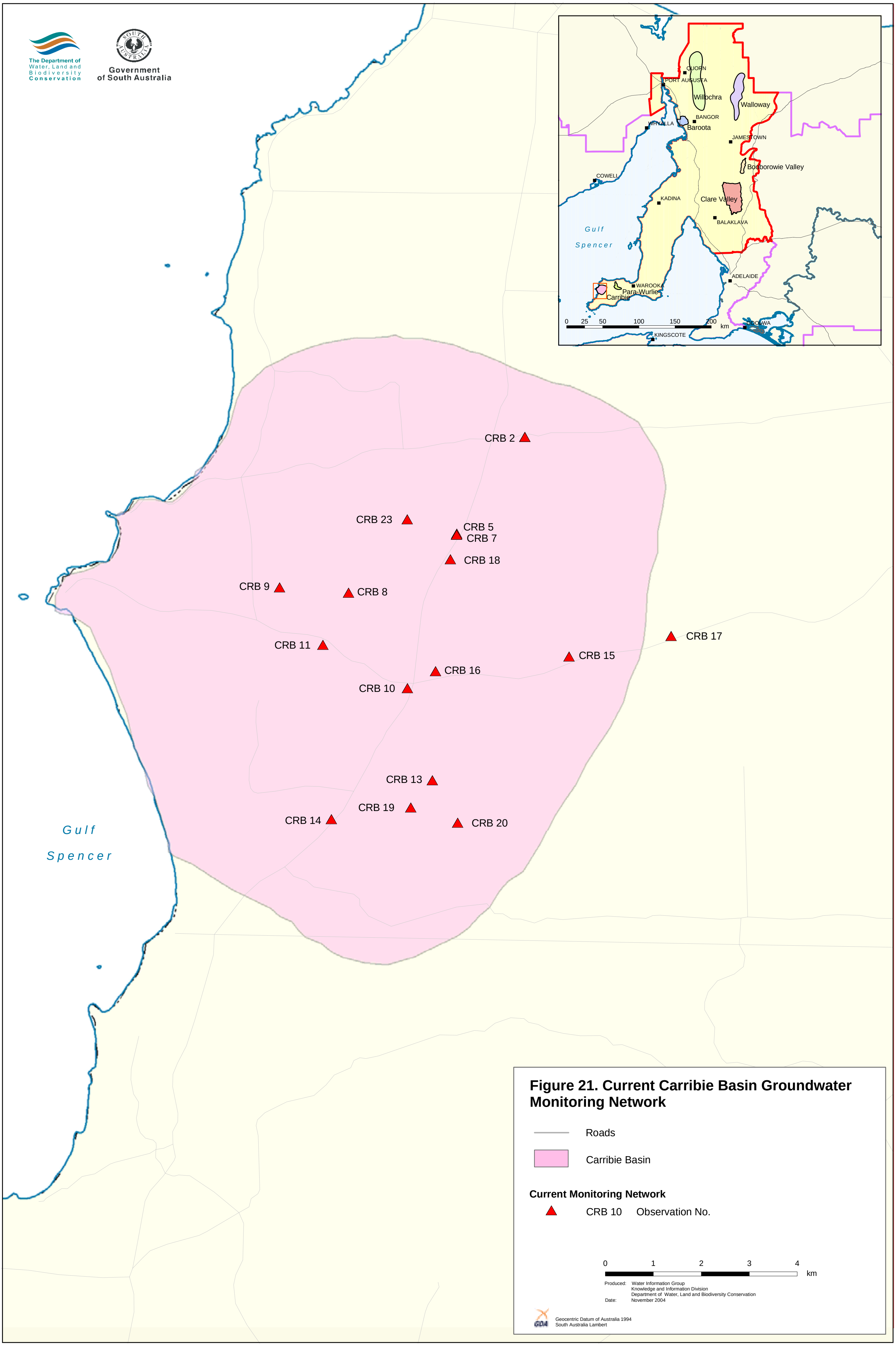


Figure 21. Current Carribie Basin Groundwater Monitoring Network

Discussion

The Carribie Basin consists of an unconfined to confined aeolianitic limestone aquifer comprising good quality groundwater generally less than 1000 mg/L. Current estimates of sustainable yield are between 1000-1400 ML/yr.

Current extraction from the resource is limited to stock and domestic purposes, as quality and depth of soils severely limit irrigated agriculture. The coastal dunes on the western section of the basin may have soils of sufficient quality and depth for irrigated agriculture (Clarke, 1996), however no evidence of irrigation is currently seen (field inspection, 2004).

The current monitoring network is evenly spaced throughout the Basin and comprises a mixture of government observation bores and private windmills. The age and condition of some of the government bores is of some concern and these may require rehabilitation in the near future.

Pollution from surface contaminants could potentially become an issue as the unconfined limestone aquifer is highly transmissive and watertable close to the surface. There is however no industry on the Basin that would warrant such concern.

In the short term the most apparent threat to the basin is from uncontrolled extractions. The basin appears to have underutilised resources, and 600-800 ML/yr of good quality groundwater may potentially be available, subject to appropriate extraction and management regimes. Considerable technical investigative work would be required prior to any potential increase in demand to verify previous findings and model the impact of any proposed extractions on aquifer recharge and behaviour.

Recommendations

- Continue groundwater monitoring at 6 month intervals and undertake periodic evaluation of monitoring data for signs of any trends in groundwater quality or quantity.
- Observation wells with corroded casing be identified and rehabilitated.

PARA-WURLIE BASIN

Description

The Para-Wurlie Basin (Figure 22) is a calcareous limestone aquifer located on the western part of the "foot" of Yorke Peninsula. Historically landuse on the basin has been for pasture and stock purposes, with little irrigation occurring on the shallow limestone soils. The general geology of the groundwater basin is semi consolidated calcareous aeolianite (Bridgewater Formation) overlying Archaean/Lower Proterozoic basement (Hussin, 1966 cited in Sibenaler, 1980). A great portion of the fresh groundwater resource in the area is confined to a N-S aeolianitic-filled valley in granitic basement.

The Basin is bound to the south, east and west by basement highs, and to the north by saline groundwater (Sibenaler, 1980). Recharge to the unconfined limestone aquifer is estimated at 26 mm/yr or 650 ML/yr by direct infiltration (Sibenaler, 1980). The nearest town is Warooka, which is reliant on the Basin for its town water supply. Groundwater salinity is between 600 and 1000 mg/L, with higher salinities in the north due to shallowing of water tables and evaporitic effect. Average rainfall at Warooka is 448 mm/yr (Bureau of Meteorology, 2000).

Between 1977-1979 work was done by the Department of Mines to quantify the sustainable yield of the limestone aquifer and define the basin limits. This was triggered by increasing demands on the Warooka water supply system, which at the time was pumping close to 200 ML/yr. Four investigation wells were drilled into the basin and geophysical work was done to determine basin configuration, salinity and aquifer thickness (Sibenaler, 1980). Results from the investigations upgraded the safe yield from 200 ML/yr to 400 ML/yr. Findings of hydrogeological investigations can be found in Sibenaler, (1980) and the unpublished geophysical report by Pilkington (1977).

Review of Drilling Activity

Currently there are 74 wells in the Para-Wurlie Basin. Fifty-one are operational, 10 have been abandoned and the remainder are not in use or their status is unknown. Nine wells have been drilled into the basin since 1990. Of these, three were classed as having their primary use for irrigation while there were two TWS wells drilled during the period 1995-1999. Table 13 below is a summary of drilling activity over the past 15 years.

Table 13. Summary of Drilling Activity in Para-Wurlie Basin since 1990.

Period	Total	Stock	Domestic	Irrigation	Other	Comments
1990-1994	0	0	0	0	0	No new wells
1995-1999	6	2	2 (TWS)	3*	1	2 IRR wells since abandoned.
2000-2003	3	1	0	0	2	
Total	**9**	**3**	**2**	**3**	**3**	

Estimated water use

IRRIGATION ACTIVITY

Landsat 5 and ESI show that landuse is primarily for pasture and stock grazing, with sections of uncleared scrub. No irrigation activity was seen on Landsat 5 images for years 1995, 2000 and 2004, nor from field inspections.

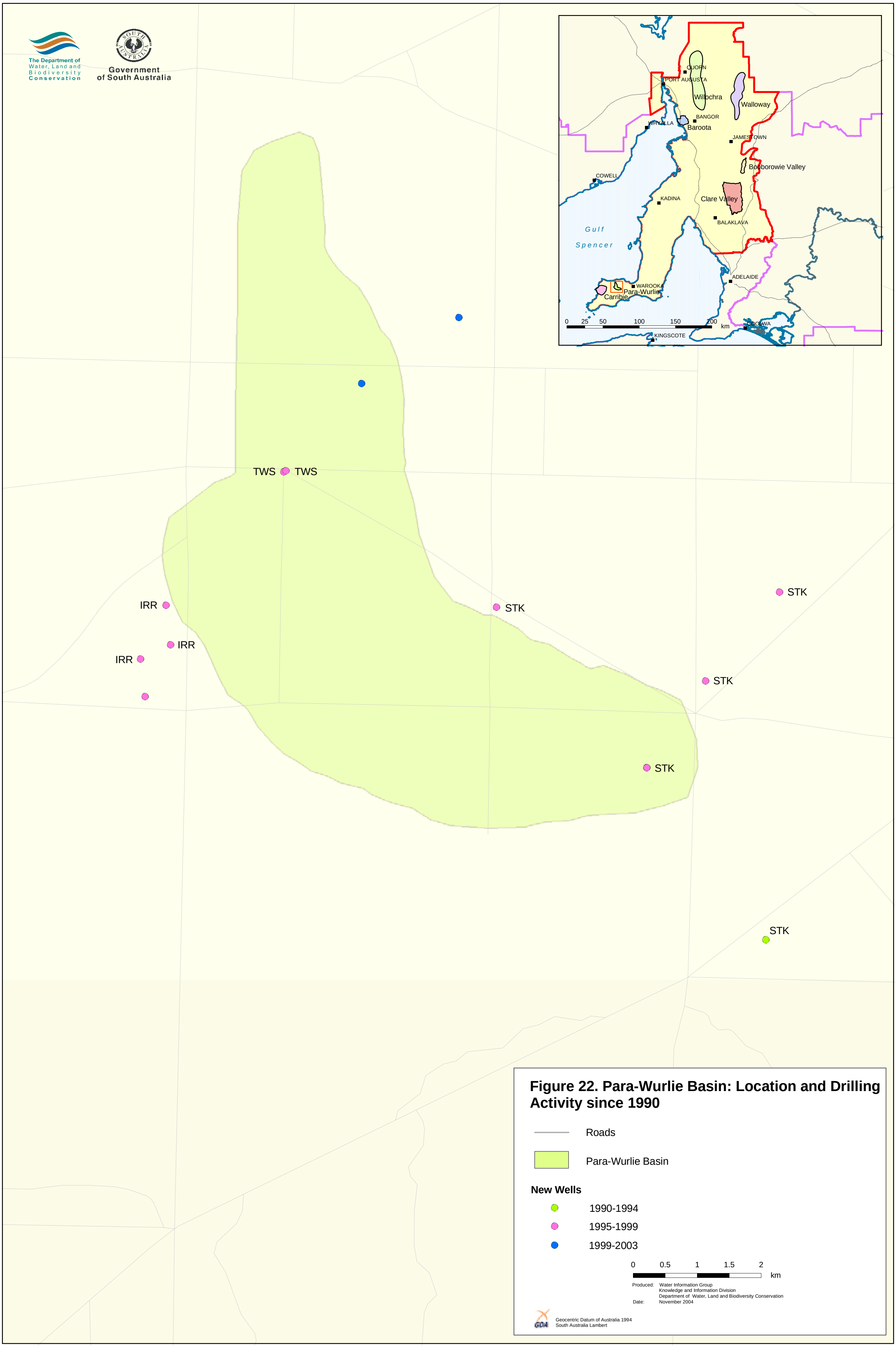
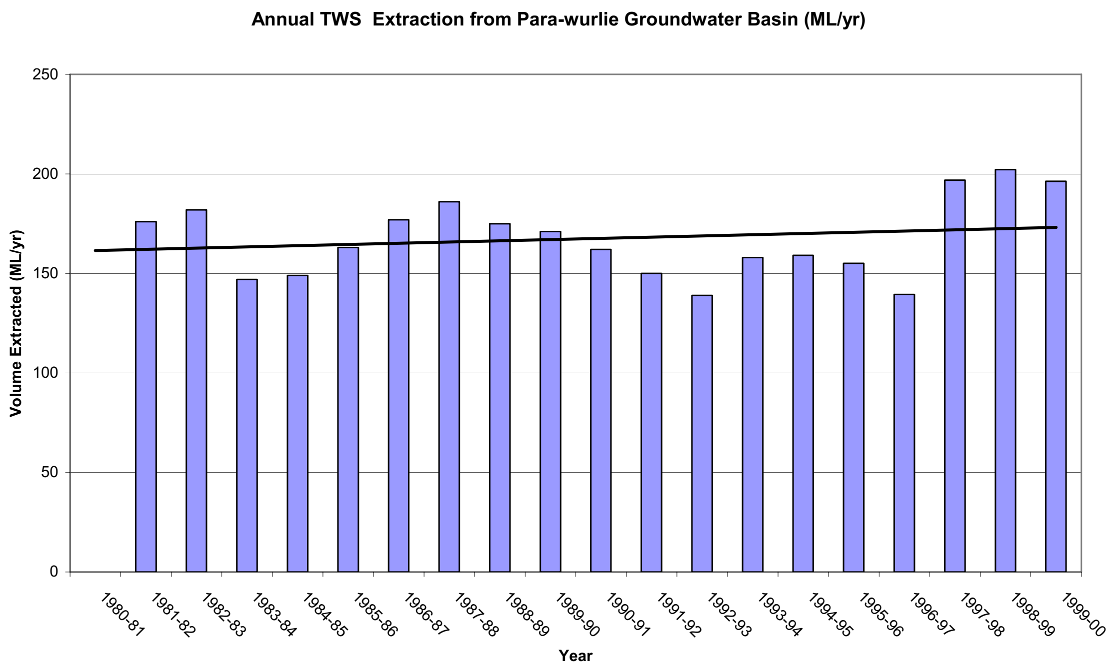


Figure 22. Para-Wurlie Basin: Location and Drilling Activity since 1990

TOWN WATER SUPPLY

The Para-Wurlie Basin is the chief source of water that supplies the townships of Warooka and Point Turton, with the River Murray pipeline extending only to Yorketown. SA Water currently has four operational bores in the basin: Warooka 1, Warooka 2, Warooka 4 and Warooka 5. Warooka 5 is the main bore that yields up to 7.75 L/s. Warooka 2 contributes 2.5-3 L/s (Kobelt pers.comm., 2004). Warooka 1 and 4 are backup bores, and are only used at peak times. Together these wells contribute an additional 2 L/s to the supply.



Source: SA Water Crystal Brook

Figure 23. Warooka TWS Extractions; Period 1980-2000.

Figure 23 shows the volumetric extractions from the Warooka well field between the period 1980 and 2000. The mean trendline shows a slight rise in the volume of groundwater used over the 20 year period. The average extraction over the period was 177 ML/yr. Figure 24 below shows the present town water supply wells and pipeline to Warooka.

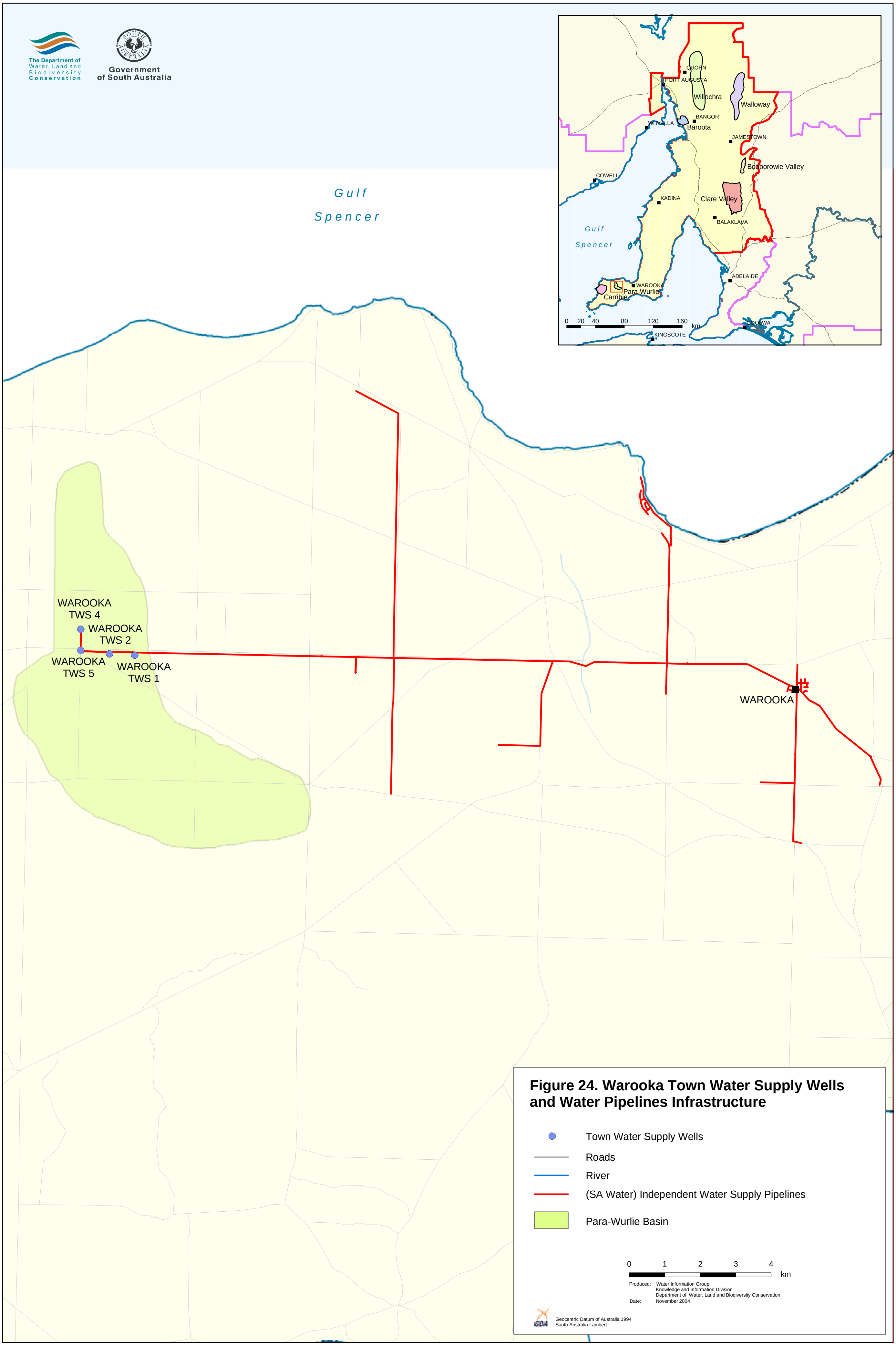


Figure 24. Warooka Town Water Supply Wells and Water Pipelines Infrastructure

Monitoring

The Para-Wurlie monitoring network currently has 6 observation wells monitored by DWLBC staff. These include four government observation wells, one operating TWS (PWL 13) well and a private windmill (PWL 14). The network covers the deepest section of the basin and is centred on the Warooka extraction wells. Table 14 shows well statistics for the current obswells, while Figure 25 shows the Para-Wurlie observation network.

Table 14. Well statistics of Observation Wells: Para-Wurlie Basin

OBS Number	Unit Number	Total Depth (m)	Sample (Y/N)	SWL (Y/N)	Comments
PWL 003	6328 00132	5.63	Na	Y	Government Obswell
PWL 004	6328 00141	7.87	Na	Y	Government Obswell
PWL 006	632800140	14.24	Na	Y	Government Obswell
PWL 007	632800148	12.78	Na	Y	Government Obswell
PWL 013	632800400	17	Y	?	Sample when pumping
PWL 014	632800124	2.7	Y	Y	Open stock well.

(Source, SA Geodata, 2004).

PWL 6 is located toward the northern end of the Basin and was constructed to monitor for saltwater intrusion (Sibenaler, 1980). PWL 14 is an open well outside the western boundary of the basin and is suitable for a standing water level measurement and water quality sample when pumping. The four Government Obswells are in relatively good condition, and are used to monitor the standing water levels around the town water supply wells. A salinity sample is available from the PWL 13 (well 6328-00400).

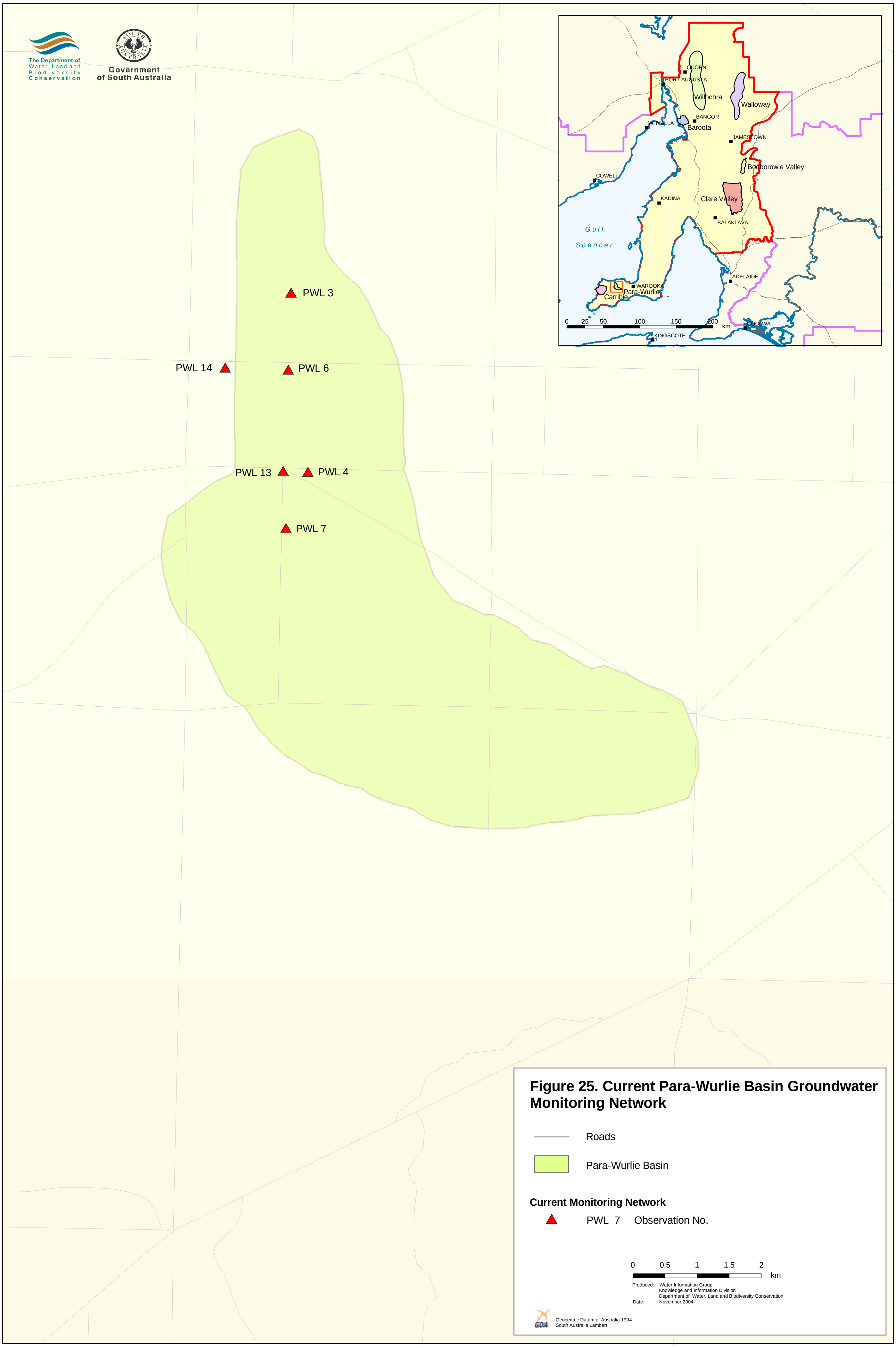


Figure 25. Current Para-Wurlie Basin Groundwater Monitoring Network

Discussion

The Para-Wurlie Basin is an unconfined to semi confined limestone aquifer located in the mid-section of the foot of Yorke Peninsula. The Basin supplies the towns of Warooka and Point Turton with domestic water supplies. Current landuse on the basin is for pasture and stock, with no irrigation identified from desktop and field assessments.

Initial investigations by Bowering (1972) estimated the sustainable yield at 200 ML/yr. This was subsequently upgraded to 400 ML/yr by Sibenaler (1980). Current use of the basin is primarily for the Warooka/Pt Turton town water supply, which is 200 ML/yr (SA Water, 2004). Although the current use is less than the sustainable yield of 400 ML/yr calculated by Sibenaler, there is concern that new development in the area – in particular Pt Turton – may be causing additional stress to the system. An immediate course of action is to examine hydrograph data from the monitored observation wells to determine current groundwater level trends and obtain up to date groundwater extraction records from SA Water.

The current observation network adequately monitors the sensitive parts of the basin where major extraction takes place. Wells are located to the north, west and south of the town water supply well field and monitor any intrusion of poorer quality groundwater. The network is currently monitored every 6 months.

Based on the above information and current level of demand, the Para-Wurlie resource is considered to be at a moderate to high level of risk. If continued development occurs at Pt Turton, increased demand may cause groundwater levels to fall, and result in deterioration of groundwater quality.

Recommendations

- Groundwater monitoring continue at 6 monthly intervals.
- An evaluation of groundwater monitoring data to determine trends in groundwater levels and quality.
- Currently monitored observation wells are up to date in SA Geodata and the obswell database.

OTHER GROUNDWATER USE IDENTIFIED

The following section is a summary of other small groundwater resources in the NYAD that have been identified as having importance for particular areas. Some of the resources are capable of sustaining limited quantities of irrigation, while others are at or already above a sustainable level of use.

Quorn

Quorn mostly relies on groundwater to meet domestic requirements as the Mt Arden Reservoir has experienced problems with contamination (Osei-Bonsu and Evans, 2002). There are currently three operating wells drilled into fractured rock northwest of the town (Quorn 1, Quorn 2 and Quorn 3). The bores are located below the Mt Arden Reservoir and follow the stream line of the Mt Arden Creek (see Figure 3). None of the bores are currently monitored. Table 15 below shows well statistics for the three production wells, while Figure 26 shows surface and groundwater extractions from the Quorn TWS production wells for the period 1980-2000.

Table 15. Well statistics for Quorn TWS wells.

Name	Unit No	Drill date	Latest Yield (L/s)	Yield Date	Latest Salinity (mg/L)	Salinity Date
Quorn 1	6533-174	8/5/1948	3.54	5/08/1948	1183	7/11/1983
Quorn 2	6533-177	4/12/1969	6.32	12/04/1969	1149	7/11/1988
Quorn 3	6533-179	3/31/1978	4	31/03/1978	1289	6/17/1997

Extractions from water bore Quorn 1 rose from 21.6 ML in 1987 to 169.3 ML in 2001, and in 2002, DWLBC was contracted by SA Water to explore the possibility of finding more potable groundwater from the current well field (Osei-Bonsu and Evans, 2002). Two investigation holes were drilled to 80 m and 120 m respectively (unit numbers 6533-00864 and 6533-00865). Drillhole 6533-00864 was found to be dry, but groundwater of sufficient quality was intercepted between depths of 82 and 108 m in drillhole 6533-00865. Conclusions from the investigation suggest that there may be groundwater of sufficient quality and yield available at depths of up to 150 m adjacent to existing TWS well Quorn 1 (Osei-bonsu and Evans, 2002).

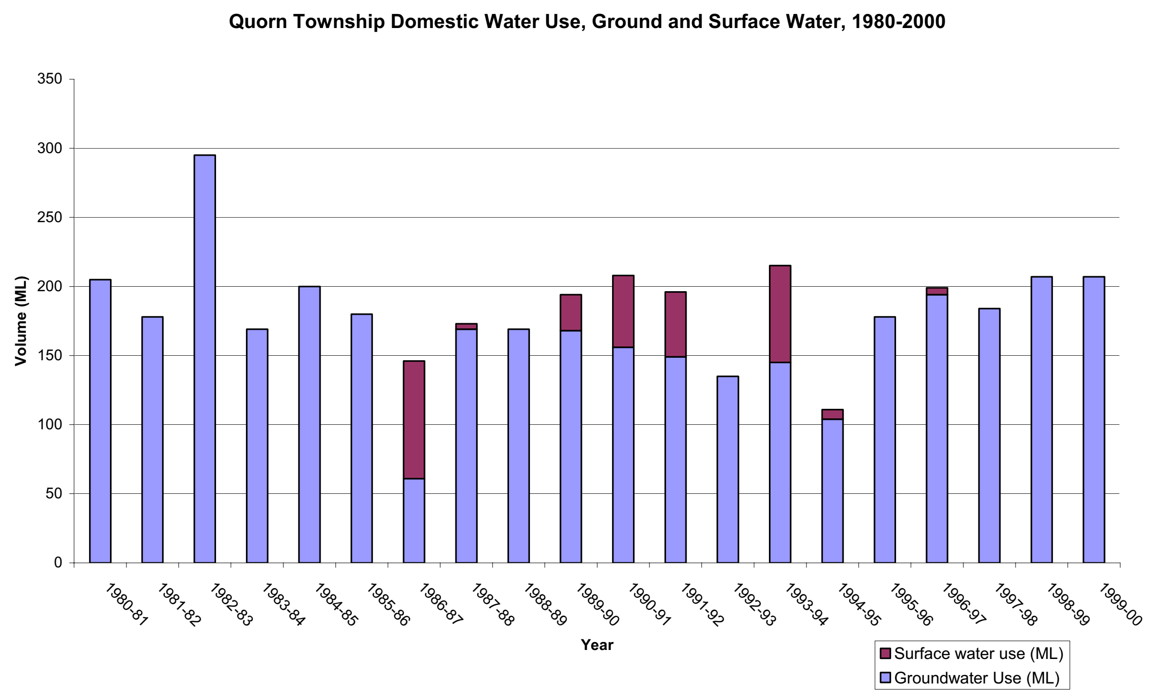
Drilling Activity

Records from SA Geodata indicate that 36 wells have been drilled in the Quorn area since 1990. Of these wells, 8 were for stock, 10 were for domestic and 14 were for irrigation purposes. Table 16 below is a breakdown of drilling activity since 1990.

Salinity of groundwater generally ranges between 1500 and 2500 mg/L, with most yields less than 5 L/s. Little is known about the capacity of the resource, or whether continued use will result in depletion to the aquifer.

Table 16. New wells drilled in the Quorn area since 1990.

Period	Total	Stock	Domestic	Irrigation	Other	Comments
1990-1994	12	6	2	3	1	
1995-1999	11	0	2	9	0	
2000-2003	13	2	6	2	3	2 investigation wells
Total	**36**	**8**	**10**	**14**	**4**	



(Source: SA Water, Crystal Brook).

Figure 26. Town water supply use for Quorn township – surface and groundwater (all wells); Period 1980-2000.

Irrigation Activity

During field inspection in December 2004, a number of irrigated olive, pistachio and saltbush plots were located on the outer fringes of the town. At present it is unclear whether water for these developments is pumping from private wells or from the Quorn town water supply. Consultations with local irrigators would help to clarify this.

At present there is not enough information to determine whether this resource is at risk, however the nature of low rainfall environment and dependency of Quorn on groundwater for domestic supplies warrants closer attention be paid to this area.

Rocky River

The Rocky River area – extending from north of Wirrabara to slightly south of Laura – appears to have shifted towards increased irrigated horticultural development in the last 5-10 years. The area has experienced significant drilling activity since 1990, as reflected by the number of irrigation bores drilled into the fractured rock adjacent to Rocky River. Table 17 below is a summary of the drilling activity that has occurred in the vicinity of Laura since 1990. Upon field inspection (December 2004) there was evidence of irrigated vineyards, olives, lucerne and figs.

The irrigation activity tends to follow the line of the Rocky River, suggesting that best quality groundwater is available where there is connection and recharge from surface flows. Whether the volume of groundwater and seasonal recharge to the fractured rock aquifers is sufficient to sustain long term use is presently not known, and requires further investigation. This region should be considered a high priority area.

Table 17. Well statistics for Laura Township and surrounds, 1990-2003.

Period	Total	Stock	Domestic	Irrigation	Other	Comments
1990-1994	7	0	0	4	1*	1 irrigation well abandoned
1995-1999	4	1	2	3	0	2 IRR wells since abandoned.
2000-2003	7	1	0	5	1	
Total	**18**	**2**	**2**	**12**	**2**	

Bangor

This in an area located off the Pt Germain Gorge Road, approximately halfway between Pt Germain and Murraytown where small quantities of groundwater are available from a fractured rock aquifer. Information from SA Geodata indicates that there are 46 wells located within a 5 km radius of the settlement.

Of the 46 wells, two were listed as having a yield greater than 10 L/s. Most remaining wells had yields less than 1.5 L/s. Salinity in the region is variable, with average salinity greater than 2000 mg/L. There is currently one irrigation well (6532-01372) that pumps water for a vineyard located on the White Park Road near the Wirrabara State Forest. This is drilled to a depth of 109 m and has a salinity of 866 mg/L (SA Geodata, 2004). Its yield is unknown.

The region came to the attention of DWLBC in late 1999 when concerns were raised by local landowners with regard to falling groundwater levels. A field assessment by Clarke in 2000 suggested that falling water levels were not inconsistent with the regional fall in water levels experienced in other parts of the NYAD at the time. Furthermore Clarke nominated 18 wells to form the Bangor network. The network was last monitored in March 2003.

Most of the wells in the network are for stock and domestic purposes. There appears to be limited scope for further development of irrigation and groundwater resources in this region.

Mambray Coast

Groundwater in the Pirie Basin between Spencer Gulf and the Southern Flinders Ranges is typically high, between 4000-5000 mg/L in the Quaternary and Tertiary Aquifers. The Baroota Notice of Intent to Prescribe Region has the best quality groundwater in the region due to leakage from the Baroota Reservoir. Extensive horticultural developments have occurred here in recent years and there is limited scope for further development.

There are currently 5-6 bores listed in SA Geodata as having their primary purpose for irrigation along the Mambray Creek, although three of these have been abandoned. It is unlikely that economic quantities of fresh groundwater would be available from this source.

Fractured rock aquifers in the adjacent ranges supply small but important sources of groundwater for properties near Spear Creek, Horrocks Creek and Nectar Brook Creek (Herde, pers. comm., 2005). Springs in the Hills are heavily reliant upon seasonal rainfall for continuous flow, and periods of low rainfall have seen Springs in the upper part of Horrocks creek become dry (Herde, pers. comm., 2005). Mapping of groundwater resources in this area, including permanent waterholes, springs and associated groundwater dependent ecosystems is recommended. Further understanding of local geology, including fault systems, joints and fractures would help to aid in the understanding of these resources.

Given the nature of the semi-arid/low rainfall environment, and restrictions on groundwater use in the Baroota Notice of Intent to Prescribe Region, there is limited scope for further horticulture development along the Mambray Coast.

Nelshaby / Napperby

Located slightly to the west of the Southern Flinders Range, this area has had a long history of market gardening. The industry has shown a gradual decline over recent years due to two factors: groundwater salinity which is more saline than the ideal for horticulture; and, the high cost of drilling due to local conditions (Clarke, 1996).

For historical reasons, the main area in which irrigation has taken place is not the optimal area for groundwater quality and minimum drilling costs (Clarke, 1996). Evidence suggests that the best quality water is to be obtained at the foot of the Flinders Range, while the irrigation area is several kilometres to the west.

There is currently a small amount of irrigation occurring in the district. Evidence from field inspection (4/8/2004) revealed a number of small olive plots.

This region is presently monitored by observation wells TEL 4 and TEL 5, which contribute to the Baroota observation network.

East Coast Yorke Peninsula – Pine Point to Edithburg

Along a small coastal strip on the east coast between Pine Point and Edithburg, is the western margin of the St Vincent Basin, comprising Tertiary Sandstones, Limestones and Marls. They reach a maximum thickness of 40 m and rest of Permian Sands, Cambrian or Adelaidian rocks (Martin et al, 1998). The region between Port Vincent and Stansbury was identified by Clarke (1996) as having sufficient quantity of good quality groundwater for irrigation, but is restricted by low yields and the shallow depth and quality of soils. Information from SA Geodata suggests that there are a number of irrigation wells between Pine Point and Stansbury, but recorded salinities are generally greater than 2500 mg/L.

There was no irrigation identified by Landsat 5 imagery for this area, although a small irrigated vineyard was located south of Edithburgh (27/01/05) that could be utilising groundwater.

Marion Bay

At Marion Bay, local residents rely on captured rainwater as the principal supply of drinking and domestic water. Marion Bay Caravan Park and Foul Bay both use groundwater from the unconfined limestone aquifer.

The existing network of bores, storage tanks and pipeworks was installed by the Waratah Gypsum Company in 1958-59 for use in the mining of Gypsum at Stenhouse Bay. In 1973 the Mine closed down and the Government took over the installation as part of the Innes National Park (Parello, 1993). The bores are located on private land about 11 kilometres north east of Stenhouse Bay (3½ km northeast of Marion Bay).

The bores supply water to the Marion Bay Caravan Park operated by the Local Council, the Innes National Park staff and visitor centre located at Stenhouse Bay, and Mr Mark Bennett, the landowner on whose land the bores are located. The Caravan Park uses approximately two thirds of the water and the rest split between the Innes National Park and the landowner (Parello, 1993). The CFS also uses the water for fire fighting.

The amount of water currently being extracted from the bores is above the replenishment value to enable the current quality to be maintained. Ever since the bores were sunk the water quality has continually deteriorated (Parello, 1993). The salinity of extracted groundwater from the current operational Bores 5 and 10 (6227-00092 and 6327-00410) was measured at 2783 mg/L and 2267 mg/L in 1991. At the time of construction (1958-59) salinity in Bore 5 and Bore 10 was 1554 mg/L and 1770 mg/L respectively (Parello, 1993).

With expansion of tourism and increasing development in the area, further water supplies will be needed to meet higher demands for the Marion Bay region. Already the current domestic water supply system is showing signs of stress. Investigations are occurring into the establishment of a desalinator for the Caravan Park, utilising the brackish groundwater from local aquifers. Good quality groundwater is available at the Carribie Basin (approximately 21 km to the north), but infrastructure costs appear to be the limiting factor to the development of this resource (Hoffrichter pers comm., 2004).

The Marion Bay groundwater resource is considered to be at a high level of risk, and should be considered as a priority for further action.

Minlaton and Jamestown Dryland Salinity Catchments

There are two small groundwater monitoring networks that were established by Primary Industries and Resources of South Australia (PIRSA) in the early 1990s for investigations into dryland salinity. These are currently being monitored on a 6 monthly basis by DWLBC. Studies are continuing in the catchment by Rural Solutions (SA), and it is requested that the networks continue to be monitored on a half yearly basis, preferably in the autumn and spring (Henschke pers comm., 2004). Further information on the catchments can be obtained by contacting Chris Henschke, Rural Solutions, South Australia.

CONCLUSIONS

The importance of groundwater resources throughout the Northern and Yorke Agricultural District INRM Region has been outlined in this study. There are some significant knowledge gaps that exist with regard to most of the smaller resources covered by this study.

The most serious gaps in technical information are in relation to the allied topics of sustainable yield and recharge processes. The resources are, in general, poorly understood and this increases the risk of inappropriate management practice. Three areas – Parawurlie Basin, Marion Bay and Rocky River – have also been identified that require further work to establish the level of risk currently imposed. This can be done by analysing existing groundwater monitoring data for the Parawurlie Basin and undertaking further field assessments in the Marion Bay and Rocky River areas.

Notable exceptions to the general paucity of knowledge are the highly developed areas such as the Clare Valley and Baroota. These areas have not been included in this study as they are, or have already been, the subject of significant investigative work. High level technical investigations are required to develop a good level of confidence in the sustainable use limits determined.

This level of investment may not be appropriate for small resources and adaptive management capable of a rapid response to perceived threats is required. Effective monitoring and timely evaluation of monitoring data for indications of resource condition become increasingly important in the context of poorly understood resources.

Studies such as this are somewhat restricted by the available information, and in considering the findings there is a need to recognise the limitations of information contained within the State database SA Geodata. Assumptions made on bore information from the State database, in particular bore status should be treated with caution. On-ground evidence is the best way to confirm the presence of irrigation and the volume of water use.

The ability to determine the pressure being exerted on groundwater reserves under irrigation use is reliant on determining accurate application rates, which is also affected by surface water usage. Although historically surface water and groundwater are managed individually, they are effectively part of a single inter-related resource. There is evidence in areas throughout the NYAD region, that the two resources are in very direct connection and future management needs to avoid the possibility of double allocation.

It is apparent that future investigations to further refine risk levels in key areas will need to focus on an intensive community consultation phase to:

- differentiate between the use of surface and groundwater in irrigation and other extractive uses.

- determine accurate data on application rates.
- document and interpret landholder observations of resource behaviour.
- raise awareness within the community of the concept of Environmental Water Requirements.

Irrigation activity is clearly subject to a range of influences including market forces and climatic patterns. It is therefore difficult to make a definitive statements regarding the risk to a resource posed by the activity. Qualitative assessments of risk made within this report have taken into account existing information and knowledge, current levels of use and likelihood for future increases in usage pressure.

From a regional perspective it appears that there is little scope for expansion on existing groundwater use. For some areas, however, it has been identified that the current use is already at, or near, the sustainable limit. To develop a high degree of confidence that resources are being used within sustainable limits will require a significant investment in time and resources.

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GLOSSARY

Aeolianite General term for the sedimentary products of wind deposition.

Alluvial Applied to the environments, actions and products of rivers or streams.

Aquifer A body of permeable rock, for example unconsolidated gravel or sand stratum, that is capable of storing significant quantities of water, is underlain by impermeable material and through which groundwater moves.

Archaean One of the three subdivisions of the Precambrian lasting from about 4000 to 2500 million years ago.

Artesian Groundwater Groundwater that overflows on to the land surface via artificial boreholes or naturally by springs because of high hydraulic head that may have developed in a confined aquifer.

Basement Highly folded metamorphic or plutonic rocks often overlain by undeformed sedimentary beds.

Calcareous Refers to a rock or sediment which comprises up to 50% calcium carbonate.

Confined Aquifer A confined aquifer is an aquifer that is sealed above and below by impermeable material (for example sealed above by clay and below by basement rock). A confined aquifer contains groundwater that is under sufficient pressure that it rises above the level encountered originally in a well.

Depth to Water The depth to groundwater as measured from a fixed reference point at the land surface.

Drawdown The reduction in piezometric head due to pumping or gravitational drainage.

Ephemeral short lived.

Fractured Rock Aquifer An aquifer which stores and transmits groundwater through fractures and cracks in rock material. As distinct from sedimentary aquifers.

Groundwater Basin A depressed area, usually of considerable size that may be erosional or structural in origin, which is capable of storing large quantities of groundwater.

Hydraulic Conductivity In general, the ability for a rock, sediment or soil to permit fluids to flow through it.

Lenticular Resembling in shape the cross section of a convex lens.

Logs Sedimentological logs are vertically measured records of sedimentary successions, illustrating with symbols the vertical sequence of lithology, grain size, sedimentary structure and fossil content.

Observation Well A groundwater well used for the purpose of measuring standing water levels, depth to water or used to retrieve groundwater for a salinity sample.

Piedmont The tract of country at the foot of a mountain range.

Pleistocene The first of two epochs of the Quaternary Period, conventionally thought to have lasted from 1.64 Ma to 10, 000 years ago at the beginning of the Holocene.

Proterozoic The most recent (2500-575 Ma ago) of the three subdivisions of the Precambrian.

Quaternary A sub era of the Cainozoic Era that covers the last 1.64 million years. The Quaternary comprises of the Pleistocene and Holocene Epochs.

Quartzite A metamorphic rock composed mainly of quartz and usually formed by the metamorphism of quartz sandstones.

Recharge Infiltration/Percolation into an aquifer – which may be natural or induced. The process of replenishment of an aquifer, by lateral or vertical (or combined) water transfer.

Standing Water Level A relatively static point groundwater level, as opposed to dynamic or recovering water level.

Sub-Artesian Groundwater Groundwater under sufficient pressure from a confined aquifer that it rises above the level in which it is first encountered (in an artificial well), but does not reach the land surface.

Sustainable Yield Sustainable yield is the groundwater extraction regime, measured over a specified planning time frame, that allows acceptable levels of stress and protects the higher value uses that have a dependency on water.

Tertiary First sub era of the Cainozoic Era, which began about 65 million years ago and lasted until 1.64 Million years ago.

Transmissivity The rate at which groundwater is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Unconfined Aquifer An aquifer in which the water table defines the upper water limit.

Water Point A site on the land surface where surface water is collected for monitoring purposes. An example would be a creek bed or rock pool.

Water Table The level below which an unconfined aquifer is permanently saturated with water.

SI UNITS COMMONLY USED WITHIN TEXT

Table 18. SI Units Commonly Used Within Text

Name of unit	Symbol	Definition in terms of other metric units	
Millimetre	mm	10^{-3} m	length
Metre	m		length
Kilometre	km	10^{3} m	length
Hectare	ha	10^{4} m^2	area
Megalitre	ML	10^{3} m^3	volume
Gigalitres	GL	10^{6} m^3	volume
Milligram	mg	10^{-3} g	mass

ABBREVIATIONS COMMONLY USED WITHIN TEXT

Table 19. Abbreviations / Acronyms Commonly Used Within Text

Abbreviation	Name	Units of measure
TDS	Total Dissolved Solids *(milligrams per litre)*	mg/L
EC	Electrical Conductivity *(micro Siemens per centimetre)*	μS/cm
pH	Acidity	
ppm	Parts per million	
Ppb	Parts per billion	
ML/yr	Megalitres per year	
mg/L	Milligrams per litre (see TDS above)	
CL	Crown Lease (refers to land parcel identify)	
CT	Certificate of title volume	
DEH	Department for Environment and Heritage	
DTW	Depth to water (in a water well)	
DWLBC	Department of Water, Land and Biodiversity Conservation	
ESI	Enhanced satellite imagery	
GIS	Geographic information systems	
INRM	Integrated natural resource management (NRM) (Committee)	
NDVI	Normalised difference vegetation index	
NYAD	Northern and Yorke Agricultural District	
Obswell	Groundwater monitoring observation well	
PIRSA	Primary Industries and Resources SA	
SWL	Standing Water Level (of a water well)	
SA Water	South Australian Water Corporation	
TWS	Town water supply	

APPENDIX A - WILLOCHRA BASIN MONITORING NETWORK: FIELD NOTES AUGUST 2004

4 August 2004

Obs No	Unit Number	DTW (m)	Total Depth (m)	Easting*	Northing*	Sample (Y/N)	Comment Obswell	Comment Other
APP 002	6531 01528	4.18	10.8				In middle of Wilsons Paddock. Old windmill	Wilsons vineyard. Used to irrigate for Lucerne with centre pivot
APP 003	6531 01156	2.55	N/a				Irrigation bore; Could not take total depth reading	Planted vines in 1996
GRG 011	6532 00571	24.57	44.25	239809	6367608		Abandoned well. Good access for observation measurements.	located just off road
GRG 018	6532 01383	14.15					Melrose TWS 3	In from paddock
GRG 014	6532 00568?	14.35		241134	6368784		Melrose TWS. Next to gum tree. Reference point 25cm above GL	Need to confirm unit no
GRG 008	6532 01010	14.76		235239	6376865		Walfords property. Wells spaced ~ 4m apart.	
GRG 009	6532 01011	22.46		235251	6376848		Probably monitoring 2 different aquifers	
GRG 007	6532 01007	Blocked					No good	
GRG 012	6532 01355						Government Obs bore - requires key.	
GRG 006	6532 01017			236977	6379325		Well was being pumped at the time. Low yielding well.	a lot of obswell are from windmills and if pumping is occurring SWL has no meaning.
GRG 005	6532 00983	7.82					Sample taken but probably not representative of aquifer salinity. Overflow pumps back into well	
GRG	6532						Good quality groundwater in this region - close to	Recommendation from Dave is to have a tight

010	08185						spring creek. Important to have a tight network (DC)	network in this area.
WLR 007	6532 01165	Dry					Dry and shallow. Well probably no use to observation network.	
WLR 005	6532 01133	11.37	25.41	233406	6386187		A new well was on this property (6532 01395). Sample taken from new well. Existing well could not be accessed.	Fox Terriers present.
WLR 006	6532 01150	10.12					Sample taken. Obswell near Wilmington.	
TWS	Unknown	21.95		228435	6384497		Wilmington TWS. Obsnumber and unit no unknown.	
WLR 004	6532 01120	19.14						Windmill was pumping at the time. Sample taken from tank
WLR 012	6532 01296	1.62					Sub artesian bore. Located on slight rise so water does not come to surface.	H2S smell and taste. Typical of artesian water.
WLR 018	6532 01346			238026	6392298		An abandoned artesian well. Leaking - needs fixing.	Approximately 100m from previous well. On roadside.
WLR 024	6532 01286						Irrigation well so could not obtain DTW measurement. Sample taken from shed	Lucerne paddock with some of the best quality artesian water in the district. Drip irrigation.
WLR 015	6532 01128	8.9					Windmill with green tank. Group of cows followed us over to try and get some food. Sorry cows.	Sample was taken. Windmill was operating at the time however.
WLR 013	6532 01143	10.3					Windmill and storage tank. In a green field.	
PDA 001	6532 00931	13.4					DC - "fairly saline well, TDS > 13000mg/L"	DTW was referenced to top of beams.

* Zone 54H UTM

APPENDIX B - WALLOWAY BASIN MONITORING NETWORK: FIELD NOTES AUGUST 2004

5 August 2004

OBS No.	Unit No.	DTW (m)	Total Depth (m)	Easting	Northing	Sample (Y/N)	Comment Obswell	Comment Other
WAW 015	6632 00647	0.15				Y	Pekina Spring. Natural outflow of groundwater into small creek. Creek runs into Pekina Creek reservoir.	Lowest level Dave Clarke had seen in the spring. Flowing at < 0.5L/s. Sample taken from spring outflow.
WAW 006	6632 00963	N/a				N	Water hole downstream from Pekina Creek reservoir. Appears to be fairly permanent. Next to pumping station.	Sample not taken. Water exposed to atmospheric conditions. DC thought salinity would be around 1400mg/L.
WAW 008	6632 00602	16.29	16.54				~ 2km east of the town. Next to a tank and gum trees.	Well is abandoned. Adjacent land used for pasture.
WAW 010	6632 00798	23.96	24.25			N	Disused bore, good access but need to remove stone.	Abandoned well. Original depth was 83ft (in 1926). Small diameter well.
WAW ???	6632 01140			278157	6378125	Y	Orroroo TWS. Relatively new well since November 2001. Sample taken from valve.	Has not been issued with an obswell no yet - still quite a new well.
WAW 005	6632 00631			278187	6378165	N	Old TWS. No DTW or sample. Abandoned? GIS coverage does not indicate.	Unclear of this wells status. Probably not in use and not suitable for monitoring purposes.
WAW 004	6632 00884	8.06		278260	6378273	N	Ex TWS 2. Ok obswell. Appears not to have been monitored since 1989. Previous SWL (1989) was 9.74m. 12" casing.	Obswell located north of TWS 1. Waypoint 014.
WAW 013	6632 00970	7.71				N	TWS 2. Present Obswell. Linburgh rd. (not Johnburgh rd as initially thought).	Water level dropped 30cm since previous monitoring (10/6/04).
WAW 003	6632 00673	N/a	N/a	278317	6378349	N	Old leaky artesian well as indicated by the reeds (bulrushes) next to the well. Well depth 126m.	No access for monitoring. Probably can remove from network.
WAW 009	6632 00700	14.4				N	Disused windmill. No sample available.	Reference point for DTW is hole in casing.

WAW 012	6632 00875	11.15	>96			N	Dept of Mines obswell. Deep well monitoring artesian aquifer. Well is probably leaking. Needs to be pressure cemented.	Artesian water is probably leaking into non-pressure aquifers. Water sample would be a mixture of the waters.
WAW 007	6632 00551	20.02				Y	Obswell is a windmill. Sample taken from watering trough.	Opposite well is a brick structure that had pigeons in it. Looks like an upside down cup.

APPENDIX C – BOOBOROWIE VALLEY MONITORING NETWORK: FIELD NOTES AUGUST / OCTOBER 2004

9 August 2004.

Obs Number	Unit Number	DTW (m)	Total Depth (m)	Easting*	Northing*	Sample (Y/N)	Comment Obswell	Comment Other
AYS 028	6630 00782	3.04				Y	Windmill located in unirrigated lucerne paddock. 1st stop of day.	Sample taken from feed trough using float pump. Drove through gate and over paddock.
AYS 029	6630 00772	N/a				Y	Windmill. Located next to fenceline. No access for SWL reading.	No DTW taken. Clamp is too tight to fit probes.
AYS 034	6630 01121	26.13				N	Windmill not pumping at time - no sample	DTW ok. Crop has not been planted for a few years. Sheep grazing.
AYS 031	6630 01203	8.87		291471	6279505	N	Abandoned well. Rusted casing, not appropriate for sampling without risking pump.	Quite hard to find. Hole is under a rock. General area is clump of native gums. 1 large one near by.
AYS 024	6630 01113	14.07				N	Old windmill, head missing. 5" inch casing.	Well on slight rise.
AYS 023	6630 01117	25.42				Y	On LHS of bitumen rd facing west? Yellow rudder on windmill, green tank.	Water did not taste too bad. DTW taken to top of casing.
AYS 026	6630 00816	5.35				Y	Opposite sign saying 'ANAMA', through gate.	Sample taken from floatation device in feed trough.
AYS 050	6630 02273	N/a				Y?	New windmill in last 5 years or so. No access for DTW probes.	Might have to wait for a few years before obswell can be used for DTW. Presently no good.
AYS 027	6630 00802	8.34		289075	6281695	N	Old abandoned well with wide diameter. Exposed to air and hard to pump.	Sample not available for this well.
AYS 032	6630 00778	N/a				N	Located next to rusted out tank. Blocked at 3.56m.	A wet winter may cause groundwater to rise above blockage.

AYS 019	6630 00818	28.7					Close to line of pine trees. Had to jump fence and walk approx 30m.	In a field of chickpeas and grass.
AYS 020	6630 00811	13.91				?	Windmill and tanks. ~20m from road.	
AYS 036	6630 00812	6.4					Government obswell with data logger. On side of road.	Possibly monitoring irrigation well that is located ~ 150 in from road.

10 August 2004.

AYS 037	6630 01120	15.58	26.27			N	Government Obswell on side of single laned road. 5 or 6" casing.	First well back after rain delay (Wednesday).
AYS 016	6630 01086					N	DTW ok for this well but it was wet at the time. Did not want to chew up farmers crop.	
AYS 044	6630 01197					N	Irrigation well that was not pumping. No sample available.	
AYS 047	6630 01192					N	Irrigation well that was not pumping. No sample available.	
AYS 035	6630 01189	5.45				N	Government Obswell. Followed North Booborowie Rd for approx 1.5km. Near a gate.	Used to have a datalogger on it.
AYS 012	6630 00832	28.12				N	Took a bit to get the sinkers down the hole.	
AYS 011	6630 00828						Windmill is blocked. No DTW.	Sample taken from tank overflow.
AYS 009	6630 00846	N/a					Usually dry.	
AYS 010	6630 00847						Did not check. Probably can leave for now.	Did not check. Have to open and close gates.
AYS 006	6630 01052	18.84	N/a				Not sure if windmill is pumping at time.	Windmill so cannot do total depth.

AYS 048	6630 00856	9.28					Irrigation well amongst lucerne patch. Carob plantation close by.	Irrigation pipes were over the ground. Pump needs to be started if sample required.
AYS 049	6630 00855	9.55					DTW at top of clamp.	Well located close to irrigation well. Probably a good observation well if located in same aquifer. Check well logs/depths.
AYS 045	6631 00420					Y	No space to fit probe for DTW sample.	Sample taken from tap at front of Andrew McInness house. Well is located a reasonable way away in paddock.
AYS 046	6630 00841					Y	No space for DTW probe.	Sample taken from top of tank. Exposed to atmosphere. Check windmill next time to see if windmill has been adjusted for DTW.
AYS 001	6630 00419						Ok for DTW and sample. Windmill often is pumping so treat DTW accordingly.	
AYS 022	6630 01232	21.4					Stock watering point. Windmill located in sheep paddock.	Good coverage of clover in paddock although grazed heavily.
AYS 038	6631 00162	6.79					Government obswell.	AYS 038 and AYS 039 are the same well with 2 sets of casing (PVC inside steel)
AYS 039	6631 00771	7.49					Government obswell.	

Notes:

*Zone 54 H UTM

Hundred of AYERS complete. 95% of wells were inspected and samples/DTW was taken.

The hundred of AYERS finishes where the bitumen stops.

The obswells in the hundred of ANNE did not have DTW and samples taken at the time of inspection. Dave Clarke gave information/recommendations on whether each of the wells were adequate for monitoring purposes.

10 August 2004

ANN 024	6631 00381	Potential irrigation bore in small pumping shed. SWL only, Unequipt.	Near small farmhouse that is collapsing.
ANN 014	6631 00349	Small windmill and tank in gully. SWL and sample available	
ANN 015	6631 00384	Windmill, have not been able to get SWL for a while. Salinity only.	
ANN 034	6631 00859		
ANN 026	6631 00773	Hard to get too, so probably remove from network.	
ANN 004	6631 00332	Disused and abandoned windmill. Rusted casing. SWL available	Make self known if going in there.
ANN 027	6631 00318	In pumping shed. Unused irrigation bore. No access for DTW. Not a current obswell.	
ANN 003	6631 00316	Disused windmill. Dug well, close to road	Good access.
ANN 020	6631 00337	Mines department well. Start of Booborowie Creek and Near Heysen Trail.	
ANN 007	6631 00336	Windmill in sheep paddock. Same property as ANN 20	
ANN 023	6631 00343	Sample and SWL from windmill. Often overflowing	
ANN 032	6631 00886		
ANN 031	6631 00849	Collapsed, dry. Not longer current.	
ANN 008	6631 00256	Little windmill and tank. Hard to get too. Tight clamp.	Remove off network.
ANN 010	6631 00258	Unequipt windmill, small.	
ANN 002	6631 00250	Windmill and tank. Sample only	
ANN 030	6631 00854	Water point from natural spring when flowing. Has not been flowing for a few years.	Sample taken out of reed bed - former bulrushes. Opportunistic sample.

ANN 029	6631 00853	Spring that no longer flows. Give flick.	
ANN 009	6631 00406	Old obswell. Dave could not get water level so gave up.	
ANN 025	6631 00356	Concrete wells in paddock. Northern most well unequipt. SWL reading available.	
ANN 033	6631 00949	Unequipt, SWL only.	
ANN 021	6631 00362	Sample only. Back behind house yard. Another part of Collinsville.	

APPENDIX D - BALAKLAVA MONITORING NETWORK: FIELD NOTES AUGUST 2004

25 August 2004

OBS No.	Unit No.	DTW(m)	Total Depth (m)	Comment Obswell	Comment Other
BAL 008	6529 00172		15.24	SWL. Windmill	Did not stop at time. Also owned by Tillers. Quaternary, unconfined.
BAL 007	6529 00540	?	73	SWL from pumping well.	Formally lucerne irrigator (Tillers property). Stopped due to high Fe in water that burnt leaves.
BAL 005	6529 00544				
BAL 002	6529 00219	13.55		Old hand dug well. Not in use.	Sleepers over well.
BAL 003	6529 00897	14.85		ARISA investigation well.	Small green well next to white stake.
BAL 004	6529 00887	13.32		SWL. ARISA well put down for investigation purpose.	Key required. See folder.
BAL 006	6529 00206	13.5		Windmill not operational. Pumps now used. Opportunistic sample.	In Balaklava township. Domestic well. Windmill out the back of house near granny flat.
BAL 001	6529 00221			Backfilled hand dug well. Not updated on database (permit??).	
BAL 009	6529 01061			Irrigation bore on eastern side of race track	Bore may not be correctly placed on database. Too far south. Check
BAL 010	6529 00898	13.35		Irrigation shed. Undo bolts to measure SWL.	Irrigation well. Balaklava racecourse. Northwest corner.
BAL 011	6529 00222	15.11		SWL, windmill. Replacement well for BAL 1.	Add to network.
DAE 002	6529 00466	19.32		Well is in a corrugated shed.	Farm house with grain holders.
DAE	6529	20.67		SWL	Windmill on side of road next to peppercorn tree.

OBS No.	Unit No.	DTW(m)	Total Depth (m)	Comment Obswell	Comment Other
004	00122				
DAE 008	6529 00112				
DAE 009	6529 00543	17.5		SWL level. Behind shed near olive tree. Fox terrier.	Farmer indicated that creek yet to flow in 04. Flowed for 24-36 hours in previous year.
DAE 010	6529 00991			Water point at creekline.	Not flowing. No sample.
HAL 001	6529 00408	18.39		Golf course. More south-westerly of observation bores. SWL and sample when pumping	Sample available when pumping.
HAL 002	6529 00892	18.16		More north-westerly of the 2 wells. SWL reading.	New wells has been recently installed that could be added to network. Located near present wells.
DAE 012	6529 00480				
DAE 003	6529 00492	20.98		Fiegerts piggery. PVC casing to top. 15m north of Piggery.	latest depth 42.2m
DAE 013	6529 00517				
DAE 001	6529 00124	24.42		SWL	Well with sleepers and disused pump. Cage around outside.
DAE 007	6529 00127	26.2		SWL. Deepish hand dug well with brick walls.	Windmill lying on side.
DAE 006	6529 00481	20.36	39	SWL. Next to settling ponds.	Pumping shed on side of road entrance road.
DAE 005	6529 00119	20.81	26.4	Pumping well next to piggery. Near power box. SWL	Reference point ground level
HAL 004	6529 00584			SWL. Could not fit probe into hole. Discontinue monitoring.	Supplementary irrigation bore. Down side of hill.

OBS No.	Unit No.	DTW(m)	Total Depth (m)	Comment Obswell	Comment Other
HAL 003	6529 00317	15.29		Main irrigation bore. SWL and sample when available	Graham Wilson Property. Piggery and Olives. Has an irrigation bore.
HAL 008	6529 00313	20.67		Windmill in fairly large diameter well.	Near sheep pens. Muddy when wet.
HAL 007	6529 00478			SWL. Not operational. Has not been monitored recently	Dave stopped monitoring this well. 35m deep.
DAE 011	6529 00495				
HAL 006	6529 00311	22.6		Windmill. SWL	Occasional sample available.
HAL 009	6529 00479	20.78		SWL. Not pumping.	Windmill on RHS of road heading down towards creek. Electric fence
HAL 005	6529 01063			Water point. Opportunistic sample available from creek.	Dry at the time of visit. Only flows in wet periods.
DAE ??	6529 00493	21.37		SWL. PVC casing.	latest depth 42.2m. Needs adding to network?

APPENDIX E - YORKE PENINSULA MONITORING NETWORK: FIELD NOTES AUGUST 2004

Para-Wurlie

10 August 2004

OBS NUM	Unit No.	DTW (m)	Total Depth (m)	Sample (Y/N)	Comment Obswell	Comment other
PWL 003	6328 00132	1	5.63		Government obswell. Good well for monitoring purposes.	Had to drive through low lying swampy ground to get to this obswell. Cattle present and limestone rubble in paddocks.
PWL 004	6328 00141	5.23	7.87	N	Department obswell. Located on RHS of (main bitumen) road heading west. (see photo).	Spanner required to access well. DTW measurement ok. Pump required for sample.
PWL 005	6328 00123					
PWL 006	6328 00140	1.67	14.24	N	Department obswell.	Good well for monitoring purposes.
PWL 007	6328 00148	7.8	12.78	N	Department obswell. Turn left off main Rd onto dirt rd. Approx 800m from previous well.	2" hole. No sample taken. Previous SWL (16/2/04) was 7.72m.
PWL 011	6328 00136				Close to PWL 011. TWS well.	
PWL 012	6328 00139					
PWL 013	6328 00400			N	Warooka TWS well. Installed in 1996. Padlocked at the time of visit. No sample or DTW.	Could have jumped fence for sample if really keen. Contact SA water for details. See photo.
PWL 014	6328 00124			Y	Set of 3 windmills. No depth to water taken due to pumping at the time. Overflow fed back into the well.	Last recorded monitoring was 31/03/2003. Probably a sampling well only unless windmill is turned off.
					Not all previous TWS wells are being monitored. Some are current and some are historical.	Old wells were probably cut to save costs.

Carribie

10 August 2004

OBS NUM	Unit No.	DTW (m)	Total Depth (m)	Sample (Y/N)	Comment Obswell	Comment other
CRB 002	6328 00028	6.29	21.35	N	Government obswell. Slightly rusted. Located on RHS of road facing west.	Small healthy shrubs in vicinity.
CRB 005	6327 00308	3.88	15.89	N	Government obswell. Located on Marion Bay to Corney Point rd which has recently been sealed.	Fine for monitoring purposes. Might have been used recently for road dampening.
CRB 007	6327 00306	4.22	17.03	N	Government obswell. Located on Marion Bay to Corney Point rd.	Located ~ 15m north of CRB 005
CRB 008	6227 00011	3.5	18.43	N	Government obswell. Located behind shed, close to a pile of old fencing material.	Required to open gate and follow fence line to get to the well.
CRB 009	6227 00013	2.63	16.78	N	Government obswell. Showing signs of age. Casing is rusty and has a hole in the top 3-4cm.	Good obswell but is getting old. Located on side of road.
CRB 010	6327 00334	7.58	12.25		Gov obswell. Near diverted track slightly lower in elevation than main sealed road.	Located off the road approx 100m on from Daly heads turnoff (Heading towards Marion Bay).
CRB 011	6227 00017	2.88	12.25	N	Government obswell. On rd to Daly Heads, on LHS. Turn off Marion Bay to Corney Pt road.	Well is located near yellow sign indicating a bend in the road.
CRB 012	6227 00018					
CRB 013	6327 00356	6.74	11.95	N	Government obswell. Good well for SWL.	Road that leads to well is opposite Denise Lehmanns Driveway.
CRB 014	6227 00021	2.89			Government obswell. On LHS of road heading to Corney Pt.	
CRB 015	6327 00314	10.55	15.4		Government obswell	Near corner of Lower White Hut rd and unnamed rd on LHS side, in amongst thickish scrub.
CRB	6327	N/a	N/a		Windmill and tank. Turn right when heading to Corney	Hand dug well. ~ 200m in from fenceline. Only a useful well

016	00312				Pt from Marion Bay.	when pumping (for sampling). Casing prevents access for DTW.
CRB 017	6327 00321					
CRB 018	6327 00311	2.24	2.67	N	Private windmill pumping from a well. Diameter of well ~ 1.0m	Sample taken from tap at back of house.
CRB 019	6327 00357	N/a		Y	Private windmill. No access	Sample taken from tank overflow.
CRB 020	6327 00358	13.1			Private windmill. Small trickle is coming from tank. Solar panel close by.	
CRB 021	6327 00022	10.98	N/a		Private windmill on Denise Lehmann's property. One of Dave Clarke's friends. On slight rise.	No space for a Total depth probe. Large dunal system in background looking west.
CRB 022	6227 00023	1.76				
CRB 023	6327 00309	2.53	3.53	N	Windmill on private property. Not on current obswell system.	Dave C indicated that he had contacted the owners of this property around 18 months ago.
WRB 003	6227 00028					

APPENDIX F - REMOTE SENSING ANALYSIS REPORT

NORTHERN AND YORKE AGRICULTURAL DISTRICTS (NYAD)

Remote Sensing Change Analysis of Irrigation Usage between 1995 to 2004

Executive Summary

Landsat 5 Thematic Mapper imagery was used to map and quantify irrigation change within the Northern and Yorke Agricultural Districts (NYAD). The change analysis was concentrated over a 10 year period between 1995 and 2004. Summer scenes were acquired to remove effects due to seasonality as well as offering the maximum amount of contrast for land cover classification.

The study provided the following results regarding the increase and decrease of irrigation areas within the NYAD between 1995 and 2004:-

Area of irrigation 1994/5: 1773ha

Area of irrigation 2004: 1006ha

Therefore there has been a 56% reduction in the amount of irrigated areas in the NYAD between 1994/5 and 2004.

This figure has not been ground verified, and is an overestimate of the amount of change. The above figures can include healthy non-irrigated vegetation that cannot be differentiated spectrally.

Deliverables

NYAD Report.doc

NYAD_IrrigationAreas_1995_2004_LCC_RGB	+.bil, .ers, .hdr
NYAD_IrrigationAreas_1995_LCC	+.bil, .ers, .hdr
NYAD_IrrigationAreas_2004_LCC	+.bil, .ers, .hdr
NYAD_Landcover_Change_1995_2004_LCC	+.bil, .ers, .hdr
NYAD_Landcover_Change_1995_2004_LCC_RGB	+.bil, .ers, .hdr

NYAD_ESI1995_LCC	+.ecw, .ers
NYAD_ESI2000_LCC	+.ecw, .ers
NYAD_ESI2004_LCC	+.ecw, .ers

Deliverable Information

Datum: GDA94

Projection: Lambert Conic Conformal (SA Lamberts Projection)

Dates: 2/12/1994, 3/1/1995, 14/3/1994, 14/3/1994

1/3/2004, 10/3/2004, 7/2/2004

Satellite: Landsat 5

Sensor: Thematic Mapper (TM)

Pixel size: 25m

Satellite Imagery

Satellite imagery used in this study was from Landsat 5. Details as follows:-

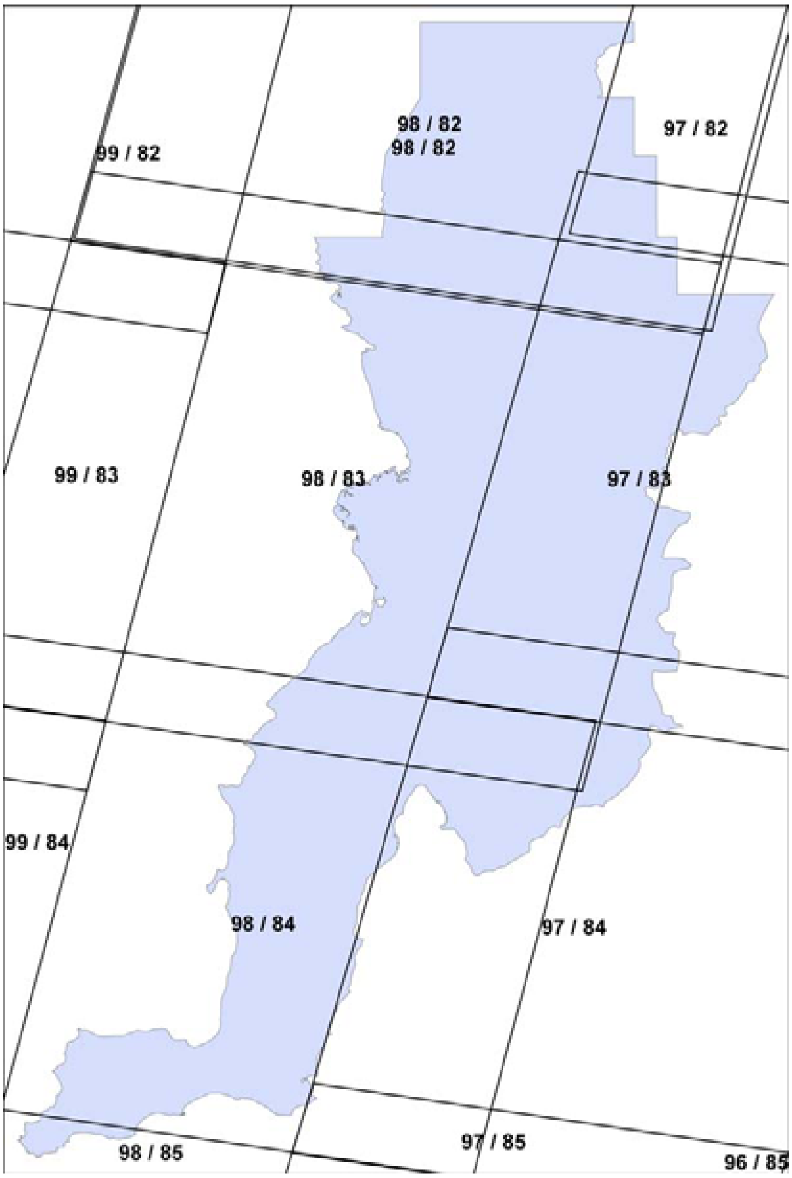
- **Epoch 1 – 1994/1995**

Path	*Row*	*Date*
97	***83***	***14/3/1994***
98	***82***	***2/12/1994***
98	***83***	***3/1/1995***
98	***84***	***3/1/1995***

- ***Epoch 2 – 2004***

Path	*Row*	*Date*
97	***83***	***10/3/2004***
98	***82***	***1/3/2004***
98	***83***	***1/3/2004***
98	***84***	***1/3/2004***

Location of Paths and Rows are shown in the following figure:-



Methodology & Results

Georectification

Each image was georectified to an in-house product called ESI2000 which was derived from Landsat 7 data in summer 2000. The ESI2000 was originally georectified to 1:50000 mapping standards using a combination of photogrammetrically derived control and differential/non-differential GPS points.

The difference in error between the two epochs is on average 41 metres. The greatest error was observed to occur on southern Yorke Peninsula, however as no irrigation (past or present) was observed here, this error was acceptable.

Once the imagery had been georectified the images making up each epoch were balanced and mosaicked together, and cut to the supplied vector file of the NYAD region.

Analysis

Bands 1 to 5 and 7 of each epoch dataset were combined into a single 12 band dataset. A normalised digital vegetation index (NDVI) of each epoch dataset was also included into a final 14 band/layer dataset to enhance the vegetation response, and to increase the probability of finding change in the region based on the increase of vegetation health due to irrigation. Two types of analysis were performed to extract the change in irrigation levels over ten years:-

1. Unsupervised Classification
2. NDVI Threshold

Unsupervised Classification

The 14 band/layer dataset was classified to 100 classes using an ISOCLASS unsupervised classification method. Each class was attributed to 1 of 13 land cover themes, each with its own corresponding digital number (DN), as can be seen in the following table:-

DN / Class	*Colour*	*Class Description*
1	***Blue***	***Health decrease (healthy 2004, not as healthy 1995)***
2	***Yellow***	***Health increase (healthy 1994/5, not as healthy 2004)***
3	***Black***	***Water***
4	***Grey***	***Shallow water / salt lakes***
5	***White***	***Bare ground***
6	***Cream***	***Pasture (includes grasses, cropping, small shrubs)***
7	***Light green***	***Scattered vegetation / some vineyards***
8	***Tan***	***Shrublands (dense)***
9	***Dark green***	***Vegetation (trees, plantations etc)***
10	***Cyan***	***Plantation to pasture 1995 – 2004***
11	***Magenta***	***Vegetation regrowth***
12	***Pink***	***Bare ground to pasture 1995 – 2004***
13	***Brown***	***Pasture to bare ground 1995 - 2004***

Due to spectral inseparability between healthy non-irrigated vegetation and irrigated vegetation, these two types were often classed as “healthy”. Therefore there has been an overestimate in the amount of detected irrigated areas. This can be solved with ground verification to ***remove those areas*** that are naturally healthy. Increases and decreases of healthy vegetation may not be due solely to changes in irrigation practises, but could be attributed to a wetter/drier winter and spring. Due to the failure to separate irrigated vegetation from healthy vegetation, the quantified amounts of irrigation for each epoch were not extracted from this dataset as they were unrealistically high. The land cover change map ***should be used as an indicator of*** healthy vegetation change only.

This method has produced the following deliverables that can be found on the DVD:-

- NYAD_Landcover_Change_1995_2004_LCC +.bil, .ers, .hdr
- NYAD_Landcover_Change_1995_2004_LCC_RGB +.bil, .ers, .hdr

NDVI Threshold

The NDVI uses the proportions of reflected red and near infrared light as an indicator of health. The more near-infrared and less red reflectance is indicative of a healthy plant. Conversely, as the proportions reverse, the response is due to less healthy, drier, senescing vegetation.

An NDVI for each epoch was calculated and thresholded to show only those areas with a high index value indicating extreme health. These areas were assumed to be the result of irrigation practices. Erroneous areas of healthy mallee, younger plantations, and creek bed vegetation were removed from the images based on visual inspection of the two epochs of satellite imagery. The remaining information still contains some vegetation that was not artificially irrigated, but provides a more realistic assessment of irrigation areas. The number of pixels that resided in these mapped areas were counted and used to provide an area of irrigation for both epochs. These values are as follows:-

- ***Area of irrigation 1994/5: 1773ha***
- ***Area of irrigation 2004: 1006ha***

Therefore there has been a 56% reduction in the amount of irrigated areas in the NYAD between 1994/5 and 2004.

This method has produced the following deliverables that can be found on the DVD:

- NYAD_Irrigation_Decrease_1995_2004_LCC +.bil, .ers, .hdr
- NYAD_Irrigation_Increase_1995_2004_LCC +.bil, .ers, .hdr

Enhanced Satellite Images (ESI)

ESI versions of each epoch, including the reference 2000 dataset, can be found on the CDROM. They have been enhanced to pseudo-natural ***colours*** using the green, red, near-infrared, and mid-infrared parts of the electromagnetic spectrum to aid in image interpretation. Both the 1995 and

2004 versions have 25 m pixels, while the ESI2000 has a spatial resolution of 12.5 m. All images are in GDA94/LCC.

Recommendations/Conclusions

The methodology described in this report did detect changes in vegetation health over the study period between 1994/1995 and 2004.

Due to the difficulty of separating irrigated vegetation from vegetation that is naturally very healthy, the amount of increased and decreased irrigation has been overestimated, but to different degrees. The Land Change Classification significantly overestimated the amounts of irrigated vegetation due to its inability to spectrally separate irrigated vegetation from healthy non-irrigated vegetation.

The method of thresholding the NDVI of each epoch provided a more effective method to provide a more accurate assessment of irrigated areas.

To increase the detection and separation of irrigated vegetation for naturally healthy vegetation, hyperspectral data may be required. Possible sources of this data include Hyperion satellite data and Hymap airborne data. However, Hyperion data would be the most suitable as the problem appears to be spectral rather than spatial, and is a significantly cheaper prospect.

Report prepared for DWLBC by

James Cameron

Image Data Section

Environmental Information Directorate

Department for Environment and Heritage

13/8/2004