Groundwater resource management in the Angas-Bremer irrigation area of South Australia

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ABSTRACT

The Angas-Bremer irrigation area is one of the premier grape growing areas of South Australia and is currently undergoing rapid development due to the booming wine industry. Historically, much of the water used for irrigation of vines and other crops was extracted from the underlying confined limestone aquifer. However, in recent years, both surface and groundwater supply irrigation demands.

Over-development of the aquifer has been responsible for considerable rises in salinity over the last 30 years. A regional drawdown allowed saline waters to infiltrate from the margins of the basin and also induced leakage, of generally more saline water, from the overlying unconfined aquifer.

Following the proclamation of the area, under the Water Resources Act in 1981, management policy has been developed by a joint committee of both local irrigators and scientific officers from government departments. Policy is aimed at containing the problem and possibly reversing it with time. Extraction has been reduced from a maximum level of 16 000 ML annually to a current level of approximately 4 000 ML during the 1992-93 irrigation period (following a wet 1992 winter).

Additional to management by policy, artificial recharge using low salinity river water has proved effective for individual irrigators. This has been successfully implemented since 1987. Currently 1 000 to 2 000 ML are recharged annually via approximately 30 gravity drainage wells.

KEYWORDS

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SUMMARY

The Angas-Bremer irrigation area is one of the premier grape growing areas of South Australia, and is currently undergoing rapid development due to the booming wine industry. Historically, much of the water used for irrigation of vines and other crops was extracted from the underlying confined limestone aquifer. However, in recent years, both surface and groundwater supply irrigation demands.

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INTRODUCTION

The Angas-Bremer irrigation area is situated 80 km southeast of Adelaide (Fig 1 a ,b). It is bounded by the southern Mount Lofty Ranges to the northwest, and by Lake Alexandrina (freshwater) to the southeast. The area has an average rainfall of 392 mm annually, at Langhorne Creek, and an average annual pan evaporation of 1 100 mm.

The Angas and Bremer Rivers cross the area from the northwest to the southeast and flow into Lake Alexandrina. The area has a well-developed irrigation industry, primarily producing lucerne and grapes, centered around the town of Langhorne Creek. The Bremer River is used by riparian irrigators to flood irrigate vineyards and orchards in periods of high flow and low salinity. Water is extracted in part from the rivers and lake, but historically, underground water has been the most widely used source.

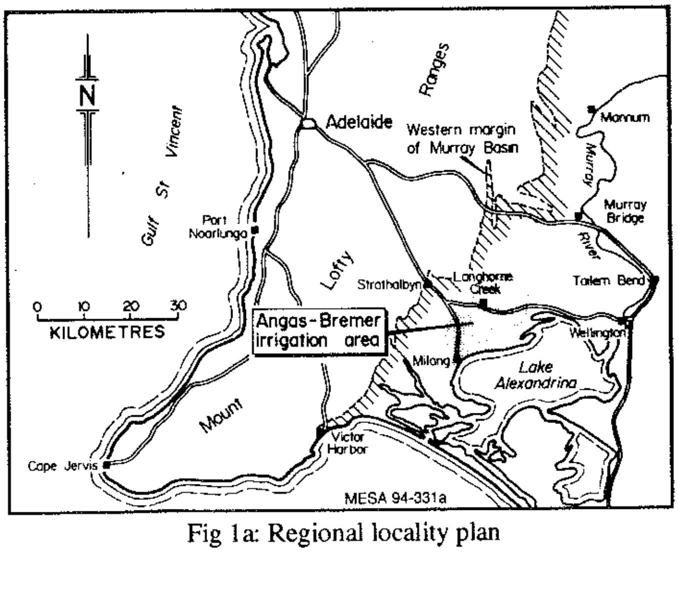

Fig 1a: Regional locality plan

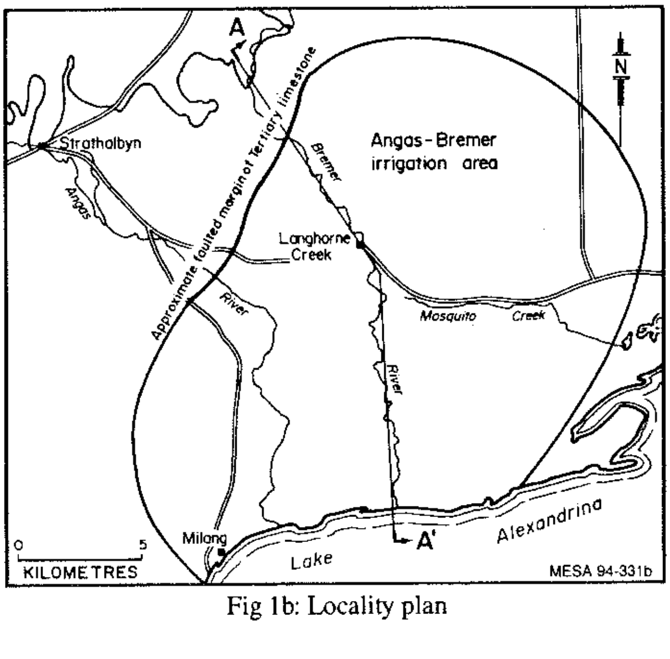

Fig 1b: Locality plan

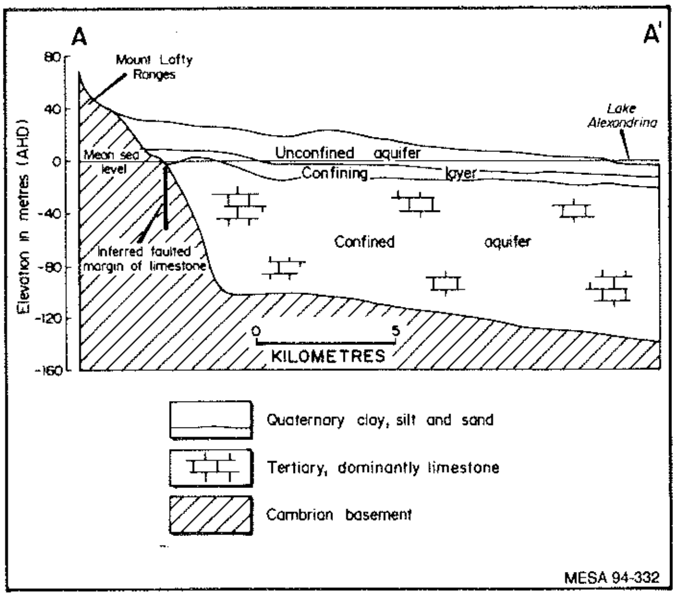

Fig 2: Aquifer sequence

HYDROGEOLOGY

General

The irrigation area is a sub-basin on the southwestern extremity of the Murray Basin. The sedimentary pile superposes the Cambrian Kanmantoo Group metasediments which act as a floor to the basin. The area is underlain by the aquifer sequence shown in Fig 2, a cross section through the basin along the Bremer River.

The basin well represents the classic text book example of the two aquifer system separated by a confining layer. The hydrogeology of the basin has been investigated in detail by the Department of Mines and Energy, South Australia (MESA) for many years. A summary of the hydrogeology follows.

The unconfined aquifer comprises 10-35 m of sands, silts and clays of the Quaternary Blanchetown Clay and Chowilla Sand equivalents. Pliocene Parilla Sand and Northwest Bend Formation may also occur. The sands form discontinuous and inter-lensing aquifers within the region. Part of the sequence forms a thin confining layer between the unconfined and confined aquifers. This is variable in its effectiveness and is considered to be poor in the south of the area. Groundwater salinity ranges from 1 000 mg/L in some areas along the rivers, up to 30 000 mg/L at some distance from the rivers. This aquifer, with its generally poor quality water and low yields (up to 5 L/s), was developed primarily for stock water supply.

The 75-100 m thick confined aquifer is Tertiary Mannum and Ettrick Formation limestone. It has been primarily the uppermost Mannum Formation limestone that has been developed for irrigation. This limestone is far from homogenous, varying in character between a clayey soft limestone, a hard sandy limestone and a soft bryozoal limestone. In some areas solution features are evident. MESA has conducted a number of aquifer tests over the years and results indicate a transmissivity of less that 100 m^2/day north of Langhorne Creek, 500 m^2/day in the central area, and possibly as high as 1 500 m^2/day in the southern area. Groundwater salinity ranges from 1 500 to 3 000 mg/L near the rivers. Salinity increases rapidly towards the basin margins and between the rivers up to 10 000 mg/L. Yields are high, and range from 10 to 40 L/s, depending on aquifer hydraulic properties and well penetration.

Pre- and Post-Development Flow Mechanisms, Head and Salinity

Prior to irrigation development the groundwater system operated as shown in Fig 3. Recharge occurred to both the confined and unconfined aquifers where the rivers cross the northern faulted basin margin. Further recharge to the confined aquifer occurred by vertical leakage from the unconfined aquifer. Infiltration from rainfall to the unconfined aquifer is considered to be insignificant. Discharge from both aquifers allowed a continual flushing action preventing the buildup of salt in the system. In the unconfined aquifer this occurred through springs and by lateral flow into Lake Alexandrina. Major evaporation losses may also have occurred in the south of the area. Discharge from the confined aquifer occurred by lateral flow into the aquifer beneath the lake and by vertical leakage to the unconfined aquifer in the south of the area (where the aquifer was artesian).

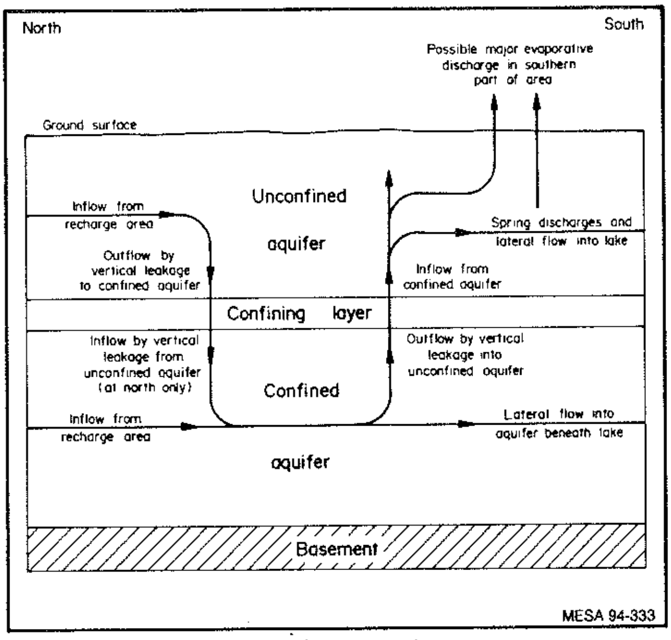

Fig 3: Pre-irrigation groundwater system

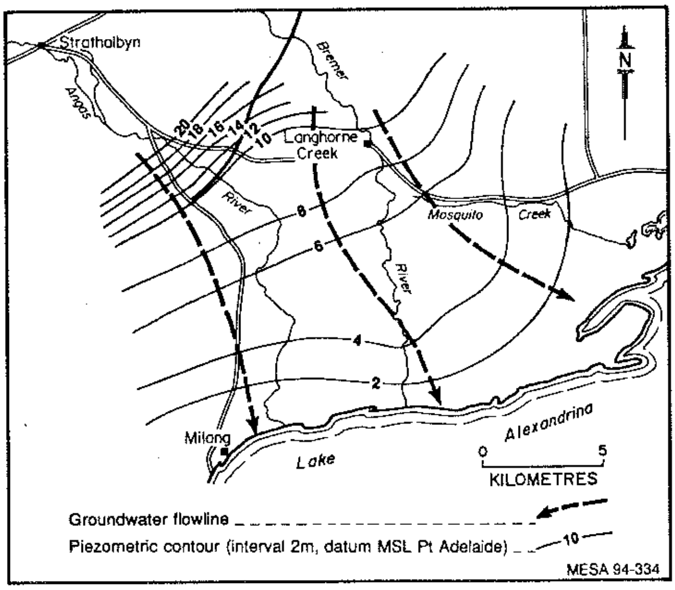

Fig 4: Pre-irrigation confined aquifer piezometric surface 1950

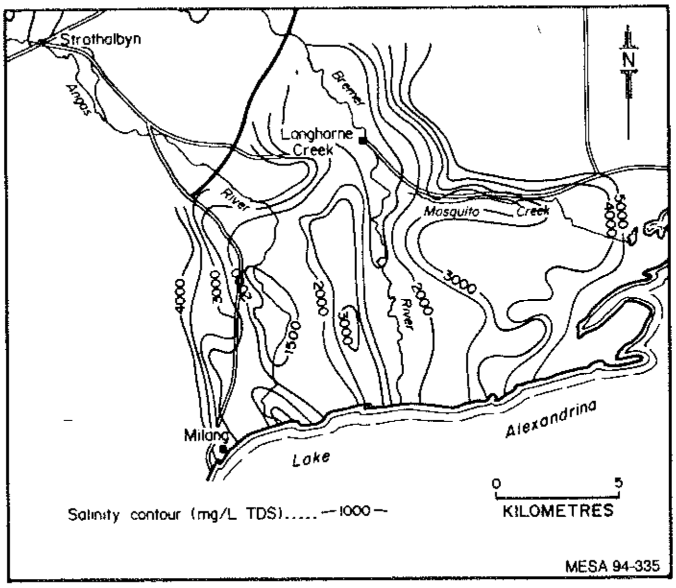

Fig 5: Pre-irrigation confined aquifer salinity contour plan 1950

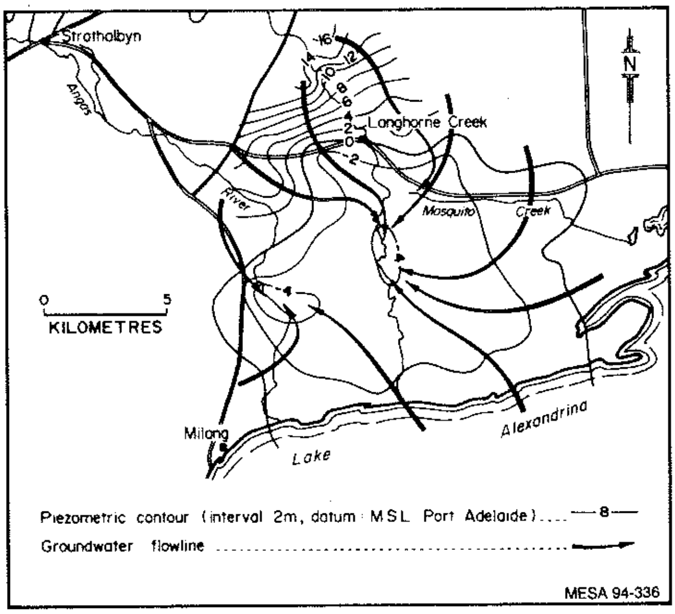

Fig 6: Confined aquifer piezometric surface March 1977

The pre-irrigation piezometric surface and salinity contour plans are given in Figs 4 and 5 respectively.

Following irrigation development since the 1950s (leading to the extraction of 21 000 ML annually between the late 1970s and mid 1980s) a significant regional drawdown developed in the piezometric surface of the confined aquifer (Fig 6), which did not recover even during the winter months. A corresponding depression occurred in the watertable induced by leakage.

The result of development has been to modify the groundwater system to that shown in Fig 7. Recharge occurs in a similar manner to that of the pre-irrigation system, but has additional components. These include lateral flow from beneath the lake and from marginal areas of the basin for both aquifers, and major induced leakage of recirculated irrigation water from the unconfined to the confined aquifer. Discharge is now dominated by extraction.

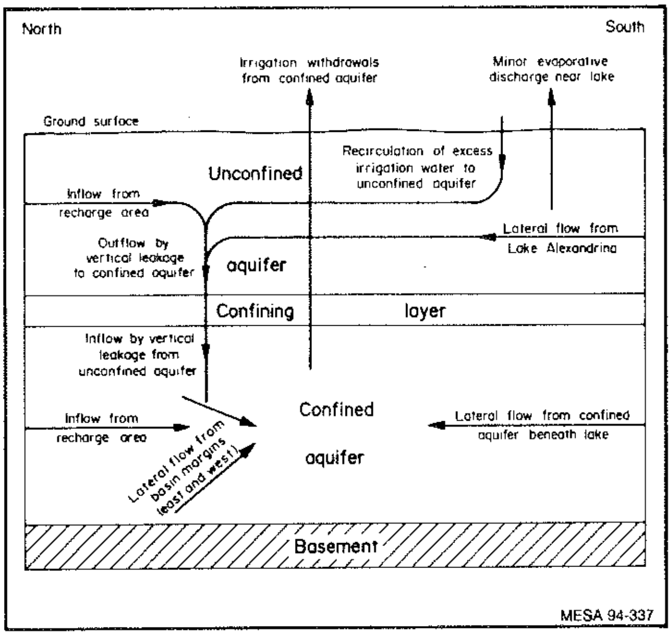

Fig 7: Post-irrigation development groundwater system

Irrigation withdrawals of 21 000 ML annually were thought to be balanced as follows:

- downward leakage of generally saline water 50% 10 500 ML
- natural recharge from rivers in the north 25% 5 250 ML
- lateral inflow of saline water 15% 3 150 ML
- possible recharge from lake 10% 2 100 ML

The most serious result of the modification to the system is the induced leakage of saline water from the unconfined to confined aquifer, and loss of flushing mechanism from the system. This means irrigation water cycles from the confined aquifer to the unsaturated zone, where evaporation concentrates salts. The water then percolates to the unconfined aquifer and eventually back to the confined aquifer. The induced salinisation of the confined aquifer, with respect to that prior to irrigation development, is evident in the salinity contour plan (Fig 8).

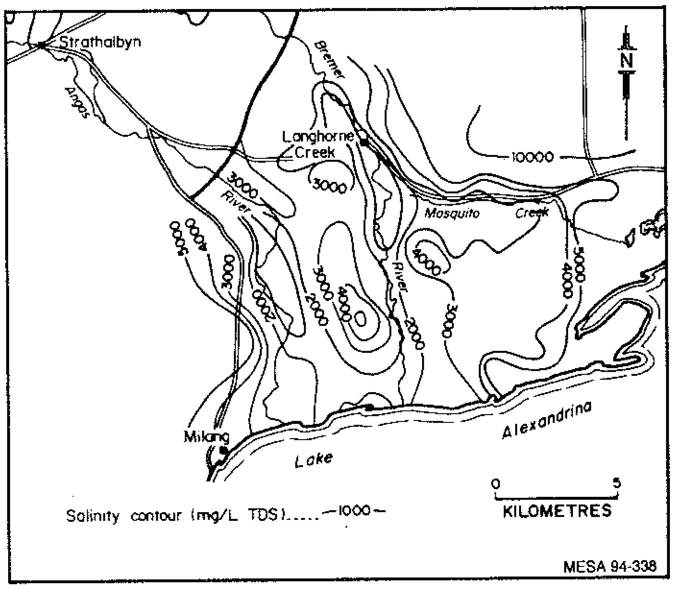

Fig 8: Post-irrigation development confined aquifer salinity contour plan 1986

This plan indicates a significant contraction of the 3 000 mg/L contour in the east and west of the area and expansion of the 3 000 mg/L isohaline between the rivers. In the northeast of the area salinity has risen above 10 000 mg/L, marginal even for stock water. Since the 1950s, groundwater salinity has been rising at an average rate of 40 mg/L per year.

MANAGEMENT

Due to the severity of the problems being experienced by irrigators, the Angas-Bremer irrigation area was proclaimed under the Water Resources Act in 1981. This paved the way for management policy to be developed by a joint committee of both local irrigators and government scientific officers.

Proposed Management Policies August 1981

The proposed management policies were defined in August 1981. At this time irrigators were issued with an Underground Waters Licence. The total groundwater allocation was 29 000 ML, individual licence values being based on historical use. The land use survey results (Table 1) from 1985-86 indicate the problem is exacerbated by lucerne production. If this low value water hungry crop were to be replaced with a high value crop (such as grapes) the problem would be alleviated.

crop	irrigated area(Ha)	water use(ML)
lucerne	1 835	29 695
vines	220	883
other	512	2 266

Table 1: Land use survey 1985-86

The management policies comprised the following simple terms.

- No increase of a Licence would be allowed unless special circumstances were demonstrated.
- On transfer, or subdivision of property, the licence issued to the prior owner would expire. A new licence would be issued dependant on the policy at the time of transfer.
- Licences were not to be transferred to other blocks of land unless special circumstances were demonstrated.
- A permit to drill a replacement well would be issued on condition that the old well be correctly backfilled.

Management Plan July 1987

The first management plan was set in place in July 1987. The management strategy objective was to maintain the viability of the groundwater resources of the area for sustainable use by existing users as far as was practical. The 'do nothing' option was unacceptable to the community. Due to the fact that the quantity of water committed to licences (29 000 ML) now exceeded the quantities actually being used (an estimated 14 000 to 16 000 ML), the excess on the licences was to be removed (before it was utilised) during the life of the plan, with the allocated volume being reduced to 20 000 ML. The management plan comprised the following important terms.

- Reduction in licences of 15-30%, based on the allocated volume during the life of the plan.
- On sale of property (outside family), licences were to be cut by 5%.
- Due to the fact that the Angas and Bremer Rivers contribute approximately 15 000 ML annually to Lake Alexandrina (ie River Murray), the Minister of Water Resources approved 15 000 ML of River Murray water be made available to the Angas-Bremer licencees. This would operate by allowing transferal of groundwater licences to River Murray licences. On transferal, the value of the licence would be returned to the original pre-cut level, thus increasing the incentive.
- Substantially increase artificial recharge to the groundwater basin and allow 50% to be accredited to the groundwater licence, which would be available for use during the following three successive years. Credits were not to be saleable or transferable.

Gravity drainage recharge wells have been used on a small scale by irrigators in the Angas-Bremer area since approximately 1970, with water being sourced from the rivers during winter flows. At this time, salinty levels may fall below the nominal 1 500 mg/L required for grape vines and may fall as low as 500 mg/L for short periods. Irrigators are well aware of the water quality benefits obtained. In 1987, MESA supervised the drilling of the first hydraulically efficient recharge well south of Langhorne Creek and shortly afterwards, constructed an experimental (salinty, clogging and redevelopment) recharge well of its own at Langhorne Creek. Following these successes there are now approximately 30 recharge wells in operation recharging between 1 000 and 2 000 ML annually. Most of the wells are partially penetrating irrigation wells, however a number of more efficient fully penetrating (Mannum Formation) wells have been constructed to depths of 80 m. These have drainage rates up to 40 L/s and are capable of recharging up to 200 ML in a good year, a significant volume when irrigation of grape vines is considered.

As a result of these policies, the groundwater allocations and use were reduced as shown in Table 2. During this period 2 172 ML were transferred to River Murray licence. The previously discussed and discarded idea of irrigators funding their own pipelines to the lake was suddenly seen as a very viable option to obtain good quality water and stay in business. At April 1994, 15 irrigators have spent an average of $200 000 (and a maximum of $400 000) to install pipelines.

Year	Allocation(ML)	Use(ML)
1987-88	24 000	12 000
1988-89	22 000	15 000
1989-90	21 000	11 000
1990-91	19 000	10 000
1991-92	17 000	9 000

Table 2: Groundwater allocation and use 1987-1992

Management Plan July 1992

The current management plan was set in place in July 1992. The total groundwater allocation was 16 000 ML. The central focus of the management plan was to reduce extraction to the level of the natural recharge plus artificial recharge (approximately 5 000-6 000 ML annually) by reducing extraction and/or increasing artificial recharge. It was hoped that the return of the natural flushing mechanisms of the basin would slowly impact on the salinity problems. It was recognised that areas along the lake front may be adversely affected by rising water tables. The importance of the quality of the surface water flowing into the area was for the first time formally recognised. A proposed investigation into the Bremer catchment management was suggested in order to reduce the salinity of the water available for natural and artificial recharge. The management plan comprised the following important terms endorsed by the local community.

- Reduce the risk of an increase in water use (due to the fact that use was still lower than the allocated volumes) by further reducing the allocations by 15%.
- On sale of property (outside family), licences were to be cut on a sliding scale from 5% at 0 ML, to 15% at greater than 400 ML.
- An agreement was made with the River Murray Water Resources Committee that the groundwater licence could be converted to a surface water licence for use within the basin, or for use at another location on the River Murray Proclaimed Watercourse within South Australia. This allowed for sale of the licence outside the area.
- Encourage the licencees to increase the amount of artificial recharge, possibly with pipelines from the lake during winter months when they were not normally in use.
- Promote water conservation through improved irrigation practice with the use of drippers and centre pivot irrigation systems.
- Promote land management techniques to minimise the impact of rising watertables in the area near Lake Alexandrina.
- Promote research into the sources of salinity affecting the Bremer catchment, and methods to minimise the salinity of winter runoff.
- Promote moves towards the locally based management of the resource.

The predicted impact of the policies was a usage of 7 500 ML by 1995-96. At April 1994, 1 340 ML transferred to River Murray licence had been sold outside the area. A further 1 267 ML were transferred to River Murray licence and kept within the area. During the 1992-93 irrigation period only 4 000 ML were used. This low figure is partly due to the extremely wet year of 1992 (wettest on record) which reduced the extraction considerably. A slightly higher figure is expected to have been extracted during the 1993-94 irrigation period.

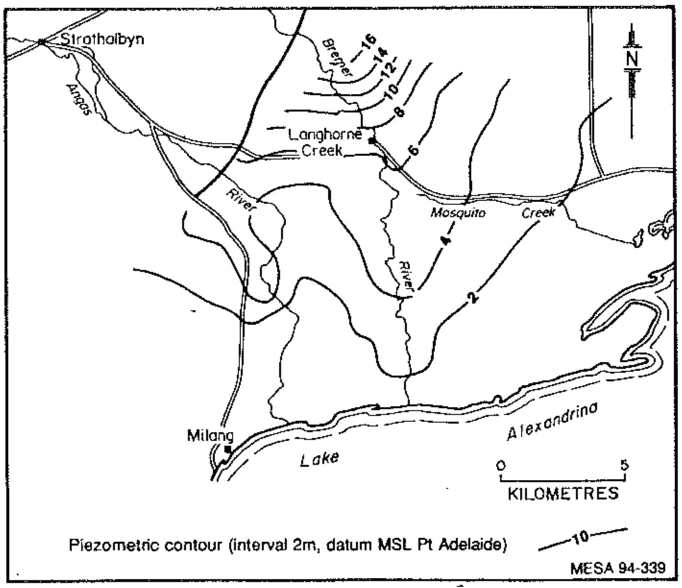

Fig 9: Confined aquifer piezometric surface August 1993

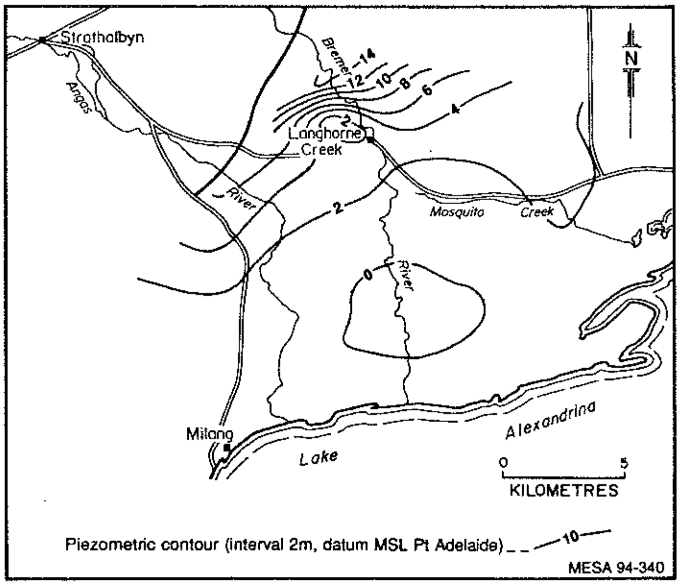

Fig 10: Confined aquifer piezometric surface March 1994

The piezometric surface of the confined aquifer rose rapidly. Contour plans for August 1993 and March 1994 are shown in Figs 9 and 10 respectively. The winter surface indicates recovery in winter towards a head regime not seen since the 1950s. The summer surface indicates a situation similar to the best recovery during the winter 17 years ago. The current situation indicates that flow has been restored through the area for more than 6 months of the year. If these heads are maintained, the salinity rises may be expected to stabilise.

THE FUTURE

The Angas-Bremer Water Resources Advisory Committee is widely recognised as being one of the leaders in South Australia in developing innovative groundwater management policy. The policy is aimed at containing the problems and possibly reversing them with time. Actual extraction has been reduced from a maximum level of 21 000 ML annually to a current level of an estimated 6 000 ML annually.

The long term sustainability of the Angas-Bremer basin depends on a significant shift in community attitude to farming — and there is clear evidence that this is happening. For long term sustainability, the basin can only support low water use crops with water applied by effective irrigation practice such as drippers. This makes vines an ideal crop. Unless these changes occur, irrigation will be reduced to areas where natural recharge ensures low salinity water, where artificial recharge can be effectively conducted, or where lake water can be used.

It is recognised that as a result of the changes occurring new problems may develop. It is apparent that flow through the system has been restored for the greater part of the year and will increase as more groundwater licences are converted to lake water. Obviously the rising piezometric levels due to reduced extraction, increased artificial recharge and importing of lakewater will slow leakage from the unconfined aquifer, the process which has so far prevented a waterlogging problem. It is expected that waterlogging will only become a major problem adjacent to the lake, an area which was saline in its natural state. Leakage of lake water, being less saline than groundwater, is expected to cause less of a salinity problem than the cycling of groundwater. The real question is whether continued build up of salts in the system will occur at a rate greater than the rate the flushing can eventually overcome.

It is hoped, however, that the surface and groundwater resources can, in the long term, be conjunctively manipulated to provide a sustainable resource and therefore viticultural irrigation industry in the area. The future introduction of a water resource management charge may allow these problems to be addressed with comprehensive engineering solutions.