Groundwater investigations in the Jerramungup shire

S B. Martin

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GROUNDWATER INVESTIGATIONS
IN THE
JERRAMUNGUP SHIRE

Stephen Martin

TECHNICAL REPORT 122
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GROUNDWATER INVESTIGATIONS

IN THE

JERRAMUNGUP SHIRE

STEPHEN MARTIN
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GROUNDWATER INVESTIGATIONS IN THE JERRAMUNGUP SHIRE

Stephen Martin

Abstract

The Jerramungup Land Conservation District Committee (JLCDC) received National Soil Conservation Program (NSCP) and State Government funding in 1988 to employ a technical officer for 12 months. During this time 100 piezometers were planned to be constructed, with the aim of raising farmers’ awareness of the current and potential land salinization. Measuring the increase in farmers’ awareness is basically a qualitative index and is not to be the main topic of this report, though it was one of the main aims of this project. Therefore farmer involvement was an essential part of the programme, to ensure farmers’ were aware of their salinity problem.

The aim of this report is to report the results obtained while installing piezometers and monitoring groundwater levels in the Jerramungup Shire.

Drilling was carried out with a dry rotary auger rig, with a depth limit of 31 m for the first 28 piezometers and 40 m thereafter. Farmers assisted in the site selection and construction of the piezometers in most cases and will in the future be responsible for monitoring their piezometer(s) regularly. The average depth to bedrock was 18 m and the average depth to groundwater was 9 m, with an average salinity level of 3600 mS/m. The average total salt storage was approximately 2800 tonnes per hectare.

Most farming land has been cleared for almost 30 years. With present management strategies, the water-table has risen 0.3 m per annum in the Jerramungup Shire since clearing.

1. Introduction

Land salinization as a result of land clearing has been recognized in south-western Australia since the turn of the century, but was not fully acknowledged until the 1960s (Schofield et al., 1988). During this time, however, extensive clearing was still being carried out in the Jerramungup Shire in conjunction with the War Service Land Settlement scheme and the Government decision to release Crown Land on the condition that a certain percentage was cleared. Little regard was given to the problem that clearing would have on the fragile environment. Indiscriminate clearing was the norm (Twigg, 1989), with some lakes, major waterways and the Fitzgerald National Park being the exception.

The natural vegetation before clearing, used up most of the rainfall, before it had a chance to recharge the groundwater systems (Nulsen et al., 1986). However, salts which fell with the rain, have accumulated over thousands of years (Hillman, 1981). The traditional practice of rotating annual pastures with cereal crops has caused an imbalance in the groundwater system. The increase in recharge has mobilized huge quantities of salts, to create a highly saline groundwater (Hillman, 1981).

The aim of the project was to construct between 80 and 100 piezometers in an attempt to raise farmers’ awareness of dryland salinity.

The aim of this report is to report on the results from the installation and monitoring of piezometers.

One hundred and ten piezometers were constructed throughout the Jerramungup Shire in an attempt to show farmers what effect their management strategies are having on groundwater levels. In the long term this will aid farmers in management decisions with regard to manipulating the ground water levels.

2. Background

2.1 Climate

The Jerramungup Shire covers an area of diverse climate, soils and landforms.

From Bremer Bay to Fitzgerald, the conditions vary considerably (Figure 1). However, the climatic conditions at the Jerramungup townsite are indicative of the general climatic regime for the Shire.
Figure 1. a) Rainfall map; b) Bioclimatic map. (Source: Beard, 1976)

Jerramungup receives an average of 400 mm annual rainfall, approximately 70 per cent of that falling over the months of May to October. Temperatures are affected by coastal influences, with no frosts occurring south of the townsite and minimal frosts to the north. The July temperature variation is 14°C maximum to 6°C minimum. Over January/February 28°C is the average maximum temperature and the average minimum is 14°C (Figure 2).

Figure 2. Ombrothermic diagram.
2.2 Geology

The Jerramungup Shire can be divided into two major geological provinces, the Yilgarn Block and the Albany-Fraser Orogen (Newby, 1985). Approximately 70 per cent of the Jerramungup Shire is on the Yilgarn Block, characterized by its undulating plains and exposed granites and gneissic rock along creek lines. The Albany-Fraser Orogen basically consists of Proterozoic basement rocks (principally gneisses) overlain by sediments of Proterozoic and Eocene ages (Newbey, 1985).

The major geological feature in the Jerramungup region is the Jarrahwood Axis. The Jarrahwood Axis divides the north and south flowing rivers (Thom et al., 1984). It is presently used to mark the northern boundary of the Fitzgerald Biosphere Project area, running in a NE/SW direction approximately 110 km from the coastline (Figure 3).

Figure 3. Fitzgerald biosphere project zone.

In the geological past the granites and gneisses in the region have been intruded by dolerite dykes. These dykes, or their weathering products, form effective barriers to ground water flow and saline seeps often break out upslope of them (R.A. Nulsen, pers. comm.). Dykes can be found throughout the Jerramungup region, most consisting of dolerite. Together with bedrock highs, they are thought to be responsible for causing over 80 per cent of the salinity problems in the Shire. However, it may be possible to solve many of these seeps with strategic planting of trees and/or perennials (George and Nulsen, 1985).

2.3 Soils

The soils in the Jerramungup region are extremely diverse; from the moort clays in the north, to the deep sands of Bremer Bay; from the duplex soils of Gairdner, to the clay loams of Corackerup. These variations can also exist on the one farm, creating problems for both farm management and soil mapping. However, for general purposes, Northcote et al. (1975) divided the soils of Jerramungup into eight basic soil types (Figure 4).
<table>
<thead>
<tr>
<th>Soil number</th>
<th>Principal soil</th>
<th>Description</th>
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<tr>
<td>72c</td>
<td>Dr 2.43 (alkaline)</td>
<td>Solodized solonet and solodic soils.</td>
</tr>
<tr>
<td>93b</td>
<td>Dy 3.82 (neutral)</td>
<td>Lateritic podolic soils.</td>
</tr>
<tr>
<td>94b</td>
<td>Dy 5.42 (neutral)</td>
<td>Yellow podzolic soils.</td>
</tr>
<tr>
<td>96a &amp; 8a</td>
<td>Dy 5.81 and Uc 4.11 (brown-grey)</td>
<td>Humic soils.</td>
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<tr>
<td>2 &amp; 9a</td>
<td>Uc 1.2</td>
<td>Siliceous sands.</td>
</tr>
<tr>
<td></td>
<td>Uc 4.21</td>
<td>Firm siliceous sands.</td>
</tr>
<tr>
<td>4</td>
<td>Uc 1.4</td>
<td>Bleached sands.</td>
</tr>
<tr>
<td>5</td>
<td>Uc 2.1</td>
<td>Bleached sands.</td>
</tr>
<tr>
<td>6</td>
<td>Uc 2.2</td>
<td>Bleached sands with coloured B horizon.</td>
</tr>
</tbody>
</table>

Figure 4. Map of main Jerramungup soil types. (Source: Northcote et al., 1975)

2.4 Vegetation

The Jerramungup Shire has within its boundaries some of the most diverse natural vegetation in the world, found in the Fitzgerald National Park (Thomas, 1989). The major vegetation types are: heath, mallee heath, broombush thicket, *Eucalyptus platypus* "thicket", *E. occidentalis*, *E. wandoor* and *Casuarina obesa* woodlands (Beard, 1976).

Development for farming has seen the diverse, deep rooted natural vegetation replaced by shallow rooted annual pastures and crops. This has increased recharge of the water-table, causing secondary salinity.

2.5 Farming practices

In general farmers still maintain the traditional practice of an annual pasture/cereal rotation. There has been a swing to earlier sowing of cereal crops and the use of a cleaning crop, such as lupins, to ensure crops are healthy, which should use more water (W.L. Crabtree, pers. comm.).

Perennial pastures and fodder shrubs are still being researched and developed, but more farmers are experimenting every year. Planting of trees for shelter belts and to limit recharge is also growing amongst farmers in the district. Current farm planning being carried out by Simon Abbott will see
approximately 3000 trees planted on every property planned in the next ten years (S. Abbott, pers. comm.).

The farmers in the Jerramungup Shire are known throughout Australia for their concern and early adoption of conservation strategies. John Hamblin (1989) has made an accurate assessment of the farmers in the area:

"I believe our farmers are remarkably flexible. If you asked the car industry to change the way our farmers have changed ... they would tell you it was utterly impossible, so I have great confidence in our farmers changing to meet the challenges that are coming up." (Hamblin, 1989: 5.)

2.6 Previous ground water investigations

The nature of this project does not allow long term estimates in the movement of ground water levels to be obtained. For this reason, data from previous drilling which has been carried out in the area was used to supply this information. The Department of Agriculture's investigations into the Mallee Road Sump (Siewert and Abbott, unpublished), and drought relief drilling carried out by the Department of Mines in 1969-1970, were used to determine ground water levels over time (see Results).

3. Materials and methods

3.1 Site selection

The first 70 sites were selected by Dr. R.A. Nulsen, ensuring that rock outcrops, major waterways and discharge areas (salt scalds) were generally avoided. Transects were taken along selected watercourses, ensuring at least one piezometer was located at the headwaters and one near the assumed discharge point. Depending on the size of the catchment and the number of farmers involved, further piezometers were located at varying positions in the landscape, top, bottom and mid-slope. The use of 1:50 000 topographic maps and 1:250 000 geological maps and visual assessment were used in determining site locations; farmers' comments were also taken into consideration. I selected the remaining 40 sites, on a similar basis as Dr. R.A. Nulsen, but with more farmer involvement. The location of the piezometers is given in Appendix A, Figure A1.

3.2 Drilling and construction of piezometers

A GEMCO HM7 rotary drilling rig, using 3 1/2" (dry) rotary augers was used to drill the holes; drilling to bedrock whenever possible and installing a shallow well on top of any hard layers (e.g. hardpans or 'floater' rock). Soil samples were taken with a hand auger for the first metre, at 0, 0.5 and 1.0 metres. Samples were then taken at 2,3,4,5,6,8,10,12,15,20,25,30,35 and 40 metres from the dry rotary augers and/or at any distinct colour, texture, or moisture change until bedrock. Initially there was a limit of 31 metres of augers for the first 28 bores and 40 metres thereafter.

The bores were cased with 50 mm, class 9 PVC, capped on top and bottom and slotted for 1 m if less than or equal to 10 m in depth and 2 m if greater than 10 m (except with some observation bores where they were slotted to the surface). Four litres of coarse sand was then added for every 1 m of slotting and bentonite added until the remainder of the bore was full. A concrete seal was then constructed on a grade to ensure little or no surface water interfered with the piezometric head readings. The piezometer was then allocated a number preceded by a "J" (e.g. J73) and a "B" proceeding this if an observation bore was constructed (e.g. J73B). The number was placed on the inside of the cap and on the concrete surface. Farmers were then asked to fence approximately 1 square metre around the bore to minimize damage to their piezometer(s).

An initial reading of the groundwater level was taken six weeks after construction. A water sample was then taken with a sludge pump, and the remaining water blown out with a compressor to ensure the slots were not blocked, and a true reading would be recorded by farmers. A cross check with field notes at what level water was found during drilling provided a guide as to how correct the initial reading was, and the need for continued development.

3.3 Analysis of samples

Soil samples were oven dried, sieved (2 mm) and a subsample made into a 1:5 solution in distilled water. Soil and water samples were analysed for chloride (Cl), electrical conductivity (EC) and pH. Cl levels were determined by titration with silver nitrate. EC was measured with a 1 cm conductivity
bridge. pH was measured using a pH meter. Hand textures of the soils were carried out using the method described by McDonald et al. (1988). Munsel colour charts were used to determine soil colour.

Salt storage of the soil in the area surrounding the piezometer was estimated using the following formula:

\[ 2 \times \% \text{Cl} \times \text{BD} \times \text{DS} \times 100 = \text{TSS} \]

TSS being the total salt storage (t/ha).
2 being the conversion from %Cl to TSS
%Cl being the average percentage of chloride in the soil.
BD being the estimated average bulk density of the soil (t/m³).
DS being the depth of the soil.
100 to convert to tonnes per hectare.

3.4 Monitoring and recording

After the initial water level recording, farmers are responsible for monitoring their own piezometer(s). A sheet to record the measurements was provided to each farmer with an accompanying letter recording the results of drilling, soil and water analyses and an interpretation of the results. It is intended that monitoring will be carried out every three months and the results sent into the Jerramungup Department of Agriculture every six months, to be recorded onto a computer data base.

4. Results

The depth to bedrock varied from 5 metres to over 40 metres. The depth to the groundwater table varied from ground level to being nonexistent. There was one site with water fresh enough for human consumption (90 mS/m). The most saline was three times more saline than the sea (9400 mS/m). The lowest salt storage of all of the Jerramungup soils held approximately 15 tonnes of salt for every hectare of land. The highest was 9500 tonnes of salt per hectare.

The median depth to the water table was -4.14 metres, with a median conductivity of 3000 mS/m. The median depth to bedrock was -15.10 metres and the median salt storage was of 1417 tonnes of salt per hectare.

A complete record of site locations is given in Appendix A and piezometer details and soil analyses in Appendix B. Some general features of the Jerramungup Shire are presented in the case studies in Appendix C.

4.1 Time of clearing

![Time of Clearing and Height of Groundwater Above Bedrock](image)

Figure 5. Multiple regression of time of clearing and height of groundwater above bedrock.
By assuming that the natural vegetation before clearing, used up most of the water before it added to the recharge, and that recharge after clearing resulted in groundwaters building up on the bedrock; a hypothesis could be formed which suggests that the time of clearing should effect the water-table significantly.

Figure 5 shows that there is no significant relationship (p > 0.05) between the time of clearing and the height above bedrock the water-table has risen.

The nineteen sites selected were all at mid-slope, but cleared at different points in time.

Confounding variables to this relationship would include: the position in the catchment, geological structures, soil types, existing vegetation, rainfall and management practices in the catchment.

The graph, however, does not mean that time of clearing is not a significant factor affecting groundwater levels. While by itself it is not significant, connected with rainfall events, soil type and other variables which would affect the rate of recharge, it may be a significant contributing factor in conjunction with these.

Groundwaters may not build up continually at a particular site after clearing, but flow to areas where the basement is deeper or to discharge areas such as creeklines and sumps.

4.2 Management practices

Results from North Jacup show the effect of confounding variables on groundwater levels.

In all cases the land was cleared approximately twenty-five years ago, but different management practices were adopted. At site A, one crop was put in and then regrowth of natural vegetation was allowed to occur after four years.

At site B, a rotation of annual pastures and cereal crops was adopted in the area downslope of the piezometer. However, some regrowth of the natural vegetation occurred in the area surrounding the piezometer, although it has been grazed since.

Site C is located on land with annual pastures, with a fresh water lake surrounded by natural vegetation fifty metres away.

Site D has no deep rooted natural vegetation nearby, and has been under a rotation of annual pastures, cereal and legume crops since clearing.

This may illustrate the impact management practices can have on a catchment. The water-table is deeper at sites where more deep rooted pastures are present. This may indicate that their presence will decrease the rise of the water-table. From site A to site D the water-table rises from 19 metres in depth to 4 metres.

![Soil Profile of North Jacup](image)

Figure 6. Cross-section through four North Jacup piezometers sites.
However, this could be an example of horizontal movement of groundwater. Water entering the system predominantly at site C may be flowing north and south. Further investigations would be required to confirm which or if both are occurring.

Assuming that the aquifer was dry before clearing occurred (Nulsen et al., 1986), the water-table in this area has risen at an average rate of almost 0.7 m per annum since clearing.

Both the soil type and the situation in the landscape vary considerably between sites. This could affect the amount of recharge, and whether or not a site was a discharge area. At site C the soil profile consists of sandy loams to a depth of six metres. Together with its position in the landscape and the soil type it is likely that this area is a recharge zone.

4.3 Soil characteristics

![Graphs showing soil characteristics](image)

a) Low chloride level profile  b) High chloride level profile

Figure 7. Patterns in the salt distribution in the soil profile.

The pH (measured in water) of the surface soils in the Jerramungup area ranged from 4.5 to 7.5. The average EC (1:5) and %Cl in the surface soils (0 to 0.1 m) were 42 mS/m and 6.2 %Cl respectively (see Appendix B for individual details).

There were two distinct patterns of salt storage in the soil profiles in the region (Figure 7). The water-table would typically be at twelve metres in case (a), and the groundwater would have low EC readings. In case (b) the water-table would be at six metres and the water would have high EC readings.

![Map showing soil types](image)

1 olive, coarse-sandy clay loam
2 grey, coarse-sandy clay loam
3 brown, clay loam

Figure 8. Approximate distribution of main saprolite types.
There were three main types of saprolite found in the area. An olive, coarse-sandy clay loam was the most common; a grey, coarse-sandy clay loam and a brown clay loam were less common. Their approximate distribution is shown in Figure 8.

![Diagram showing soil distribution](image)

- Deep soils
- Shallow soils

**Figure 9.** Approximate distribution of deep and shallow soil profiles.

The different types of saprolite may correspond with the types of bedrock found in the Jerramungup Shire. For example, granite - olive saprolite, granitic gneiss - grey saprolite and dolerite - brown saprolite. The soils developed on granite and granitic gneiss bedrock tended to be deeper than those developed on the dolerite. Bedrock samples from the drilling program supported this general trend in most cases.

The defined areas of deep and shallow soils in the Jerramungup area are depicted in Figure 9; deep being > 20 metres and shallow being < 20 metres in depth.

The deeper soils, have high salt storages, in comparison to the shallow soils. This, however, was usually a function of the total depth, rather than a higher average salt content. The shallow soils also tend to be better drained in most cases, but dolerite dykes, bedrock highs and poor subsurface drainage caused land salinization problems within this region particularly.

Hardpans and silcretes overlying the bedrock tended to occur mainly in the areas with shallow soils. The hardpans appeared to follow a line running North-West to South-East around Jacup (Figure 10). In this area there was little sign of moisture below the hardpan layer. In areas surrounding this strip, the watertable was within a few metres of the surface in the lower parts of the landscape.

![Diagram showing hardpan area](image)

**Figure 10.** Hardpan area of the Jacup region.

---
While all bores drilled in the area, marked in Figure 10, had some hardpan layer, surrounding dams did not show signs of this in some areas. This could mean that the hardpan layer was deeper in this area, or that it occurred in patches in the area. More extensive drilling would need to be carried out to define the extent of the hardpans.

4.4 Groundwater levels under cleared and uncleared land

![Graphs showing groundwater levels](image)

Figure 11. Water-table depth under native bush and developed farmland.

Several piezometers were constructed in native bush and a corresponding one on neighbouring farming land to compare the differences. In all cases the water table under the native bush was deeper than under nearby farming land (Figure 11).

The groundwater levels under the uncleared land in both of these cases is approximately 6 m lower than under the neighbouring farming land. In case (a) there was no water-table present under the native bush. However, in case (b) there were considerable amounts of saline groundwater present under the native vegetation. It is likely that the water-table under the 'island' of native vegetation has been affected by the surrounding farming land. However, for this volume of water to be present there also may have been some groundwater prior to clearing.

4.5 Perennial pastures

Perennial pastures have shown promise in lowering the water-table and at the same time providing summer and autumn feed. Monitoring of established perennial pastures, to see how effective they are in lowering the water-table, has been a major interest of the Department of Agriculture at Jerramungup.

Water-table levels under established perennial pastures have been monitored for some time at Rob and Ann Smart's at Mallee Road and Rob Purvis' at Jerdacuttup. In both instances the groundwater table has been lowered under perennial pastures, in comparison with the level under annual pastures.
a) Rob and Ann Smart's lucerne pastures.

b) Rob Purvis' mixed perennial pastures vs neighbouring annual pastures.

Figure 12. Perennial pastures lower the water-table.

Farmers have been experimenting with lucerne and tagasaste which both offer promise in providing protein rich feed over late summer and autumn, as well as using more water than annuals (Nulsen, 1985).

4.6 Rising water-table

While the average rise in the water-table is 0.3 m per annum based on past records, they have shown varying rates of increase at different areas.

The Department of Agriculture has carried out extensive groundwater investigations in the north Fitzgerald area, known as the Mallee Road Sump (Stewart and Abbott, unpublished). From this work it was found that the bedrock formed a barrier, preventing groundwater from escaping the basin (Figure 13).

John Moody has monitored the fluctuations of the groundwater table since the Departmental work finished. From this monitoring it is known that on average the groundwater table is rising about 0.2 m per annum.

Figure 13. Cross-section of the Mallee Road Sump.
The only other record of how far the water-table is rising each year is at Gairdner. In 1969 drought relief drilling by the Department of Mines was carried out (Mines Department Records, unpublished). At this time the groundwater table was 10 m from the surface. By 1989 the groundwater table had risen to a depth of 2 m, averaging 0.4 m rise per annum over this time.

5. Discussion

5.1 General

The clearing of the native vegetation and its replacement with shallow-rooted annual pastures and crops in the Jerramungup Shire has been the major cause for the increase in secondary salinity. Before clearing, the amount of recharge to the water-table would have been minimal (Nulsen, et al., 1986). However, now that the native vegetation has been cleared, there is a need to use as much water as possible to minimize recharge. Perennial pastures appear to be the most practical alternative from research carried out so far. This will be discussed further in this report.

Considering there is no significant relationship (p > 0.05) between the length of time an area had been cleared and the distance the water-table was above bedrock, I will look at the many variables which combine to effect the rate of rise.

The management practices adopted since clearing is the only variable which farmers have a control over (provided the economic climate allows farmers to have a choice). Knowing this, the clearing of further land in the area should be carried out with great care, and thought should be given to what is sustainable land use once cleared. Present restrictions on clearing, through the Department of Agriculture, should ensure that these two important factors are considered when further development is carried out.

Areas with unusual characteristics, such as hardpans and dykes, should also be considered in land use management options. Farmers need to adopt a catchment mentality, rather than considering their property as an 'island' in the landscape. For instance, the farmers in the area of hardpans may not have problems with salinization themselves, but the excess water entering into the soil profile could be creating a problem somewhere else in the catchment. Therefore, to solve the problem it would require the involvement of all landholders in the catchment, including those without a salinity problem.

Areas with deep soils need to be managed differently than those with shallow soils, particularly with regard to soil salinity. The salinity problem in the areas with shallow soils tended to be from dykes and bedrock rock highs interfering with groundwater flow. In the areas with deep soils, salinity problems tended to be more from a rise in the regional water-table. Farmers with deep soils then would have to plant more high water-using plants than those with shallow soils to solve their problems (planting in recharge and/or discharge areas).

The deep soils are possibly associated with two major geological features, the Jarrahwood Axis to the north and the Stirling Fault to the south. The shallow soils are younger, associated with the area between these two features (Thom and Chin, 1984; Thom et al., 1984).

The patterns in salt stored in the soil profile may also provide farmers with information on how to better manage their land. It is likely that the two patterns of salt storage indicates recharge and discharge areas. The less salts stored in the soil profile, the more likely that water is percolating through the soil, taking salts with it, to a discharge area somewhere else in the catchment. Planting such recharge areas with high water-usage plants would help solve many secondary salinity problems in the Shire.

5.2 Management options

With groundwater levels rising an average of 0.3 m per annum, farmers must act now. There are numerous management changes farmers can choose. I will cover three which appear to be the best options.

While all these strategies are likely to reduce the problems of secondary salinity and increase the productivity of saltland, not enough is known to be sure of how successful they would be in the Jerramungup area. For this reason, continued monitoring of piezometers is essential to gain the full benefit from this work. Furthermore, changes in management techniques should also be recorded, to record the success of various methods in lowering the water-table.
5.2.1 Perennial pastures

Perennial pastures, at this stage, show the greatest potential in lowering the water-table, while retaining productivity on farming land. If district recharge and discharge areas can be defined, then the water-table could be lowered significantly if they were planted to perennials. However, if there is no defined area of recharge, then the majority of the catchment area would have to be sown to perennials (Nulsen, 1985).

The advantage perennials have over other techniques, is that they not only lower the water-table, but also provide feed for stock over late summer and autumn: the time when farmers usually have to buy feed for their stock in this Shire (W.L. Crabtree pers. comm.). Lucerne is one of the most promising of the perennial pastures. While there are still problems in establishing lucerne in the Shire, such as time of sowing, control of pests and disease, there are several good, established stands in the area.

5.2.2 Agroforestry

Agroforestry is another avenue which farmers could decide to take. This would involve planting trees in strips in conjunction with traditional farming practices. Little is known about the economics of such an enterprise in areas with rainfall < 500 mm per annum. However, from research carried out in areas with > 500 mm of rainfall per annum (Anderson 1982), there may be some limitations in adopting agroforestry techniques in the Jerramungup area.

The major limitation would be the cost of fencing such large areas of trees, particularly during the first few years when seedlings are most vulnerable to damage from stock. The cheapest solution is the use of electric fencing (Maughan, 1988). This would enable farmers to relocate the fences once the trees were large enough to withstand stocking pressures.

The benefits of agroforestry are far more numerous than the disadvantages. Apart from using more water, the trees provide shelter belts for stock. This alone can provide enough added income to justify its adoption (D. Bicknell, pers. comm.): increasing pasture and crop growth directly behind the shelter belt; increasing lamb survival rates; decreased losses of shorn sheep; decreases in wind erosion and salinity; increases in the amount of wildlife and aesthetic appeal. After twenty to thirty years, trees can be harvested to provide farmers with fencing material or firewood.

Tagasaste (Chamaecytisus palmensis) is a perennial tree which has been successfully grown in the Jerramungup Shire, and elsewhere on the South Coast. Like lucerne, it can provide feed rich in protein over the months farmers usually buy feed in the Jerramungup Shire. However, as yet there are no confirmed results on the effect tagasaste has on the water-table in the area, but being a deep rooted perennial it is reasonable to assume it would use more water than annuals.

5.2.3 Saltland Agronomy

Saltland can be productive if salt tolerant pastures are grown. Saltbush (Atriplex spp.) have given good results in trials carried out in the Jerramungup area. They have the potential of being as productive as existing annual pastures (Malcolm and Swaan, 1989). Fencing off salt affected land, for stock management, is essential, but is the limiting factor with this option. However, the potential returns from the feed supplied during autumn from this should cover the costs incurred. Also, it is now recognised as a good management practice to fence off salt affected areas, even if planting of salt tolerant pastures does not occur (Malcolm and Swaan, 1989).

River saltbush (Atriplex amnicola) has proven to be the most palatable for stock as well as being able to withstand stocking pressures. Some varieties of River saltbush volunteer successfully in non-waterlogged areas, and once established can withstand waterlogging and survive flooding over a period of several weeks. However, most vigor occurs when the site is not waterlogged. Leaf material contains 10 per cent crude protein and 13 per cent crude fibre. A good stand can support up to 16 dry sheep equivalents per hectare over autumn, but most stands would more likely support 12 (Runciman and Malcolm, 1989).

6. Recommendations

With the current management techniques and the rise of 0.3 m per annum in the saline water-table, it is likely most discharge areas will be salt affected within the next ten to fifteen years.
Continued monitoring of the water-table and the effect of various management techniques is essential.

More trials measuring the effect of perennial pastures, agroforestry and saltbush on the water-table are needed to prove their value in the Jerramungup area. The establishment of a productive and reliable perennial pasture would be an innovation which would be adopted by numerous farmers in the Jerramungup area. The worth of agroforestry and saltbush, beyond their aesthetic value, will take longer to be adopted by most farmers.

7. Post Script

This has been the most extensive drilling program carried out by the Western Australian Department of Agriculture. Consequently the Jerramungup Shire has the best monitoring network in the State. There has been a large amount of data collected, which, to be really useful, requires the continued monitoring of piezometers and observation bores.

There are many aspects of this research which have not been covered in this report, such as, the relationship between pH and EC; and the relationship between soil texture and EC / %Cl levels. However, the data is provided in the appendices and are available for further analyses.

Planned clearing of the native vegetation does not mean secondary salinity will eventuate. The problem that needs to be addressed is the management after clearing. Current farm planning will hopefully provide farmers with the blueprint to adopt sustainable land use techniques.

The aim of this project was to increase farmers awareness of the salinization in the area. However, most of the farmers were not only aware of the problem, but are either adopting the appropriate management techniques, or are contemplating which techniques best suits their management program. But no matter how good the intentions of the Jerramungup farmers, economic pressures will always be a major limiting factor.

My involvement in the project is now finished and it is up to the Jerramungup farmers to use, to the fullest, the piezometers and observation bores I have installed.

8. Conclusions

With water-tables rising an average of 0.3 m per year at an average depth of 9 metres at present, management needs to change. Even though the groundwater supplies have high salt contents, with an average conductivity higher than sea-water (3600 mS/m), it does not have to be looked upon as a threat, provided action can be taken soon.

Using the information from this program and continued monitoring, a management strategy could be formulated to use the groundwater in a productive way. Knowing that perennial pastures and other deep rooted species can lower groundwater levels, some management options have already been identified.

Land management will need to vary depending on the characteristics of the area, many of which have been identified in this program.

Changes in soil depth, %Cl and saprolite, hardpan areas and vegetation have all been identified in this report.

Areas with different soil depth were associated with varying salinity problems.

Changes in the %Cl stored in the soil profile appeared to be associated with the depth to the water-table and possibly whether the area was a significant recharge or discharge area.

Areas with hardpans had little groundwater which was at depth.

Groundwater levels were noticeably lower under land with perennial pastures or other deep rooted vegetation than annual pastures or crops.

Changes in saprolite colour were associated with changes in parent material.

Provided the management changes are made soon salinity does not have to mean losses to production. The groundwater supplies can be an asset, provided it can be used before it reaches the surface. Monitoring the effect of changes in management needs to continue, otherwise salinity may become the problem it is in other areas of South-West Western Australia.
In no way would I suggest that a complete ban on clearing of remaining native vegetation, due to the findings in this report. Native vegetation would be unlikely to use the volumes of water that are presently entering groundwater aquifers, as is possibly the case at Tom Fishers'. More efficient pumps are now required, which will still allow agricultural production.

9. Acknowledgement

Special thanks to: Ed Solin, for his education in the art of drilling and work in preparing soils for analysis; Bob Nulsen, for his aid in selecting sites and guidance throughout the program; Don McFarlane and Richard George, for their help with editing drafts of this technical report; numerous officers of the Resource Management Division for assisting at various stages of this program; the Jerramungup Land Conservation District Committee; NSCP for the funding to carry out this program; and all the farmers who assisted with drilling.

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APPENDIX B.  SOIL/WATER ANALYSES

The full listing of these analyses has not been included here because of their quantity. Instead, they are contained in "Jerramungup Drilling Report 1989/90", copies of which are held in the Department of Agriculture's library at South Perth and at the Jerramungup and Albany District Offices.
APPENDIX C. CASE STUDIES

1. North Jacup
The average depth to bedrock was 20.04 m. The average depth to the water-table was 9.13 m, with an average conductivity level of 2154 mS/m. Salt storage in the soil profile averaged 1896 tonnes of salt per hectare.
There were two main features discovered from the drilling at North Jacup, the existence of hardpans and the possible effect of deep rooted plants on the water-table, both of which were discussed earlier in this report.

2. South Jacup
The average depth to bedrock was 17.18 m. The average depth of the water-table was 11.09 m, with a conductivity of 2034 mS/m. Salt storage averaged 1586 tonnes of salt per hectare.
The Fitzgerald National Park is the major feature affecting groundwater levels in South Jacup. Combined with the presence of silcrete overlying the bedrock on two properties, and the extension of the hardpan area from North Jacup, groundwater levels were reasonably deep. There were, however, some naturally saline areas, and in the eastern part of the catchment, signs of secondary salinity.
There was one unusual site, where there was no sign of bedrock at a depth of 40 m. This was in a cultivated sandplain area, south of the Jacup grain bins.

3. North Jerramungup
The average depth to bedrock was 19.59 m. The average depth of the water-table was 8.11 m, with a conductivity of 3702 mS/m. Salt storage averaged 2741 tonnes of salt per hectare.
There were many interesting discoveries made from drilling in this area. The main regions were (Figure C1):
1. The *Eucalyptus occidentalis* (flat-topped Yates) and type had shallow bedrock and groundwater levels within a few metres of the surface in drainage lines.
2. Sandplains generally had deep soil profiles and deep water-tables.
3. An area with a highly saline water-table (over 6000 mS/m). The groundwater was only a few metres from the surface throughout the area, even at some distance from the drainage lines.
4. The only site with groundwater fresh enough for human consumption was in the North Jerramungup area. The conductivity was 90 mS/m and there were no clay layers in the soil profile.

![Figure C1. Major Features of North Jerramungup.](image-url)
4. **South Jerramungup**

The average depth to bedrock was 8.69 m. The water-table was 2.41 m from the surface on average, with an average conductivity of 1624 mS/m. The average total salt storage was 973 tonnes per hectare.

![Diagram showing cross sections of dykes and bedrock highs](image)

**Figure C2. Cross Sections of Dykes and Bedrock Highs.**

South Jerramungup was characterized by shallow bedrock levels and saline seeps caused by dykes and bedrock highs. For this reason, piezometers were usually located in areas of concern to the farmer. Therefore, the above figures would not be representative of the entire catchment, rather a worst case scenario.

5. **Corackerup**

The average depth to bedrock was 14.41 m. On average, the water-table was 2.97 m from the surface, with an average conductivity of 3990 mS/m. Salt storage averaged 1558 tonnes of salt per hectare.

The Corackerup Catchment Group chose to have one area in particular drilled, the "high country" in their catchment. This area posed the greatest risk of becoming saline and would cause large scale problems if it did occur.

![Diagram showing soil profile of the Corackerup High Country](image)

**Figure C3. Soil Profile of the Corackerup High Country.**

-20-
From this information it appears that the bedrock on Tim Marwick's property may be acting as a bedrock high, with groundwater flowing towards Jerramungup. Obviously groundwater is moving to an unknown discharge area or is filling a low point in the bedrock or an unknown aquifer.

Towards Jerramungup from this area the watertable is fairly deep (> 10 m). However, towards Ongerup the water-table is fairly high (< 5 m). This could make this area a good site for future research on the horizontal of the groundwater.

The remainder of the Corackerup Catchment area was similar to that of South Jerramungup.

6. **Gairdner**

The average depth to bedrock was 16.50 m. On average the depth of the water-table was 5.71 m, with an average conductivity of 2847 mS/m. Salt storage averaged 1983 tonnes of salt per hectare.

Dykes and bedrock highs have caused more problems for Gairdner farmers than anywhere else in the Jerramungup area. Frank Lynch's farm is an example of the problem facing many of the Gairdner farmers.

![Soil Profile of Frank Lynch's Farm](image)

**Figure C4.** Soil Profile of Frank Lynch's Farm.

The dykes and bedrock highs on Lynch's farm have resulted in 80 ha of land becoming saline. This is representative of most of the farmers surrounding the town site of Gairdner. Fortunately most of the farmers are trying to use the available saline water to produce feed for stock over autumn, either in the form of saltbush in the discharge areas and/or lucerne upslope from the seepage.

7. **Bremer Bay**

Averages for the Bremer Bay Catchment Group have been drawn from BHP and EUCLA mining records (unpublished). The average bedrock depth was 28.50 m. The groundwater had an average salinity content of 3216 mS/m, at an average depth of 11.77 m.

In this program five piezometers were placed along a drainage line of a freshwater lake. While the lake is at the moment fresh, if the water-table were to rise at the average 0.3 m per annum, then it could be salt affected in only thirty-five years.
Figure C5.  Soil Profile of a Freshwater Lake Drainage Line, Bremer Bay.

Table C1.  Summary of average catchment figures.

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<th>Catchment</th>
<th>Avg. depth bedrock (m)</th>
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<td>9.13</td>
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<td>S. Jacup</td>
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<td>N. Jerra</td>
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<td>1624</td>
<td>7</td>
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<td>Corack</td>
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<td>2.97</td>
<td>3990</td>
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<td>Gairdner</td>
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<td>5.71</td>
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<td>28.50</td>
<td>11.77</td>
<td>3126</td>
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TOTAL      | 18.00                  | 9.00                      | 3600                                | 110       |
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