Background papers to WAWA's south-west irrigation district strategy study

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Background Papers to Water Authority of Western Australia’s South-West Irrigation District Strategy Study


Resource Management Technical Report 106
Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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1. Introduction

The Water Authority of Western Australia established a study in 1990, aimed at assisting the Government in developing policies for the rehabilitation and/or modernisation of the irrigation systems serving the Waroona, Harvey and Collie River Irrigation Districts.

The Study was guided by a consultative committee with wide industry representation, including membership from the Western Australian Department of Agriculture. The first phase of the study involved background data gathering and issue identification. As part of that process various officers of the Department of Agriculture were asked to write papers addressing the issues.

This Technical Report is a reproduction of those papers. They are presented in the same format as they appear in the Background Papers to the South West Irrigation Strategy Study, published by the Water Authority of WA. The section numbers therefore refer to the position of the papers in the Water Authority document. The table of contents from each background paper is also reproduced in this Technical Report so that the context in which these papers were prepared can be seen.
2. Acknowledgements

3. Background Paper No 3 – The Economics of Irrigated Agriculture

Ian Loh – Water Authority
Ian Longson – ACIL Australia
John Abbott – Kinhill Engineers
Peter Arkell – Department of Agriculture (Pers Comm only)
George Olney – Department of Agriculture
David Morrison – Department of Agriculture (Pers Comm only)

4. Background Paper No 4 – Engineering Cost Estimates for the Continued Operation and maintenance of the South West Irrigation Services

Ian Laing – Department of Agriculture

5. Background Paper No. 5 – Potential Changes in Irrigated Agriculture

Peter Arkell – Department of Agriculture
R Taylor and I Wilkinson – Department of Agriculture
I Longson – ACIL Australia
3. Background Paper No 3
The Economics Of Irrigated Agriculture

Prepared by Peter Jacob - ACIL Australia

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* Not prepared by Department of Agriculture

+ By G Olney
3.2.5 Dairy Farm Model

(a) Background

The Western Australian Dairy Farm Model (the Model) has been developed by George Olney to assist in assessing the impact which changes in farming practices and/or policy might have on dairy farm profit. The Model takes into account a wide range of variables such as calving periods, lactation patterns, nutritional requirements, pasture production, supplementary feed, stock selling strategies and irrigation practices. Management options can be fixed in the Model, enabling comparison of farm profit generated under different management options.

In terms of the Irrigation Strategy Study, the Model has been used to determine likely changes in farm profit that might result if irrigation was no longer possible - as would be the case if the irrigation systems in each of the three Districts were shut down. Additionally, the effect on farm profit of changes in the price of irrigation water have also been assessed.

(b) Model Data

The Model has been based on data obtained from 15 specialist dairy properties surveyed as part of the 1990 farm survey. The 15 farms were chosen because they did not operate any other enterprise, that is, they were all specialist dairy properties. The data on which the Model is based are as follows:

- Total area of irrigation farm: 194 ha
- Total irrigated area: 48 ha
- Area of irrigated permanent pasture: 37 ha
- Area of early germinated pasture: 11 ha
- Area of run-off property (no irrigation): 170 ha
- Total number of cows: 150 cows
- Total milk production: 617 kL
- Total market milk quota: 438 kL
- Average milk production per cow: 4387 L
- Total water use: 359 ML
- Area cut for hay: 60 Ha
- Concentrates purchased and feed: 84 tonne
The dairying prices used in the model are those applying in 1988-89, which are slightly lower than those which applied for 1989-90.

(c) Results

Three separate runs of the Model were made, each involving a different set of assumptions regarding dairy production levels and management strategies. The three runs were:

Where production and management strategies remain at current levels. Management refers to the mix and level of irrigated pasture production, the level of hay production undertaken on the home and run-off properties, and the amount of concentrate feeding undertaken. It is considered that existing management strategies are not the optimum and improvements can be made, especially in the area of increasing the productivity of irrigated pastures. (Refer Background Paper 5 for a detailed discussion on the costs and benefits associated with increasing irrigated pasture productivity).

Where current production levels are maintained, but management strategies are allowed to be optimised; and

Where production is unconstrained and management strategies are optimised. This scenario provides an indication of the gains which could theoretically be achieved by dairy farms within the South West Irrigation Region under optimal management strategies. It therefore provides an estimate of the upper bound of achievable dairy output.

For each scenario described above, the Model was run for four different water prices as well as for the no irrigation option. The four pricing options were existing (1989-90) price, and price increases of 1.5, 2 and 3 times the 1989-90 price.

The reduction in annual farm profit estimated to occur with increases in the price of water and with no irrigation are presented in Table 3.7 for each of the three production / management scenarios.

### Table 3.7 Change in Estimated Farm Profit With Increases in Water Price and Under the No Irrigation Option

<table>
<thead>
<tr>
<th>Water Price</th>
<th>Current Production And Management $</th>
<th>Current Production Optimum Management</th>
<th>Optimum Production And Management $</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989-1990</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1989-1990 x 1.5</td>
<td>-5,164</td>
<td>-6,742</td>
<td>-6,402</td>
</tr>
<tr>
<td>1989-1990 x 2.0</td>
<td>-10,327</td>
<td>-12,226</td>
<td>-12,008</td>
</tr>
<tr>
<td>No Irrigation</td>
<td>-15,478</td>
<td>-6,828</td>
<td>-15,700</td>
</tr>
</tbody>
</table>
Assuming current production and management, an irrigated dairy farm is estimated to be around $15,500 more profitable than a dryland property. The main reason for the higher cost of the dryland property (ie. lower profit) is the greater need for purchased concentrate feed (219 tonnes compared with 84 tonnes on the irrigated property). However, if water prices increased by more than 2.5 times, dryland dairy production would become more profitable than irrigated dairy production.

These general conclusions hold true if production and management are both unconstrained. However, there would be substantial changes in the management structure of the properties. Under the unconstrained management and production option, both the area irrigated and amount of concentrate feed purchased would increase. At existing water prices, the total farm profit would increase by an estimated $35,000 from $99,350 to $134,350, with total milk production increasing from 617 kL to 877 kL. With increases in the price of water, the area irrigated would reduce with this being offset by increased hay production from the run-off property.

In the case where production is assumed to remain at existing levels but management is optimised, the reduction in profit resulting from switching from irrigated to dryland dairy production is estimated to be around $6,800. By comparison with existing management practices, the optimum management strategy places greater emphasis on hay production from both the main and run-off properties, enabling the volume of concentrate feed to be reduced substantially from 219 tonnes to 77 tonnes. Prima facie, the results indicate that there are greater benefits to be achieved from improving dryland management than irrigation management. However, it should be realised that under this scenario production is constrained to existing levels which, in turn, also limits the benefits able to be achieved from improving irrigation management.

In summary, the results of the analyses indicate that a move from irrigated to dryland dairy production brought about by a close down of the irrigation system is likely to decrease farm profit by around $15,000. Feed normally generated from irrigated pastures would be replaced by greater use of hay and concentrate feeds. Additionally, water prices would need to increase by between 2 and 3 times the existing price before it would be more profitable for specialist dairy farmers to switch from irrigated to dryland production.
4. Background Paper No 4

Engineering Cost Estimates For The Continued Operation
And Maintenance Of The South West Irrigation Services.

Prepared By Ian Loh - Water Authority

(Appendix C. On-Farm Water Supply For Livestock And Domestic Purposes On Farms
In The Waroona, Harvey And Collie Irrigation Districts.) By I.A.F. Laing, Western
Australian Department of Agriculture

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1. General

The study area can be subdivided into hydrological land types based on:

i) Salinity of groundwater at the top of the superficial aquifer (i.e. the shallow watertable);

ii) Salinity of groundwater at the base of the superficial aquifer; and

iii) Salinity of groundwater in the Leederville formation.

The superficial aquifer consists of an assortment of clays in the 0 to 15 m depth range, with more sandy material encountered between 15 and 35 in. The top of the aquifer is from 0 to 3 m, and the base of the aquifer from 15 to 35 m (average depth of bores, 25 in).

The Leederville formation is a sub-artesian aquifer and the average depth of bores required to utilize this water was assumed to be 60m. It was also assumed that the height of pumping water from these bores would be approximately double that required from bores into the base of the superficial aquifer and that the annual running costs (electric power) for pumping would also be double.

2. Hydrological Land Types

Shown in figure 1: Land types are defined as follows

Type 1: Groundwater salinity is less than 1,000 mg/L TSS in either:

a) top of superficial aquifer; or

b) base of superficial aquifer; or

c) Leederville formation.

Type 2: In any area outside Type 1, where groundwater salinity is greater than 1,000 mg/L TSS in both the base of the superficial - in the Leederville formation: and less than 4,000 mg/L TSS in either the base of the superficial or the Leederville formation.

Type 3: Any area outside Types 1 and 2, where groundwater salinity is greater than 4,000 mg/L TSS in both the base of the superficial aquifer and in the Leederville formation.
3. Water Quality And Quantity For Dairy Farms

Water quality classes assumed and average daily and annual amounts used per 100 cow dairy are as follows:

**Class 1 Water: < 1,000 mg/L TSS**

<table>
<thead>
<tr>
<th>Use</th>
<th>kL/d</th>
<th>kL/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>For (1) homestead garden use</td>
<td>2</td>
<td>700</td>
</tr>
<tr>
<td>and for (ii) milking machine washing</td>
<td>2</td>
<td>700</td>
</tr>
<tr>
<td>Class 1 sub totals</td>
<td>4</td>
<td>1,400</td>
</tr>
</tbody>
</table>

**Class 2 water: 1,000 to 4,000 mg/L TSS**

<table>
<thead>
<tr>
<th>Use</th>
<th>kL/d</th>
<th>kL/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>For (iii) milk cooling</td>
<td>6</td>
<td>2,100</td>
</tr>
<tr>
<td>(iv) cattle drinking</td>
<td>6</td>
<td>2,100</td>
</tr>
<tr>
<td>(v) wash down</td>
<td>2</td>
<td>700</td>
</tr>
<tr>
<td>Class 2 sub totals</td>
<td>14</td>
<td>4,900</td>
</tr>
<tr>
<td>Totals</td>
<td>18</td>
<td>6,300</td>
</tr>
</tbody>
</table>

4. Water Supply Options

4.1 Domestic

In-house water requirements throughout the Study Area can be fully satisfied by collecting and storing roof run-off in covered tanks, providing minimum roof areas of 400m² are available per farm. The minimum storage tank capacity required would be 100 kL and would cost approximately $8,500.

4.2 Livestock and Garden

It was assumed that sufficient quantity of on-farm water could be developed (either dams or bores) on each farm of average size to cater for the proposed farm enterprise.

4.2.1 Land Type 1

On-farm supply of water of appropriate quality for all farm uses listed in Section 3 could be developed from groundwater bores to 25 in or 60 m, or from farm dams or soak-dams.
4.2.2  Land Type 2

Although water supplies for sheep and for beef cattle may be readily obtained in Land Type 2, it seems unlikely that secure supplies of appropriate salinity for dairy farming will be available.

It is assumed that approximately 8 to 10 kL/d of Class 1 water (<1000 mg/L TSS) would be required for milking machine washing and homestead garden use on each farm of average size, and that it would not be possible to develop water supplies (using normal on-farm methods) to provide water of less than 1000 mg/L TSS in this Land Type.

Despite the above pessimistic view it should be noted that reverse osmosis desalination units of appropriate size are commercially available in Perth.

A tentative estimate of the installed cost of a desalinator, on an average-sized farm, would be $25,000, and the estimated annual running costs would be approximately $5,000.

With the desalination option applied to 20 per cent of the water requirement, and the remaining water requirement being available by normal on-farm methods, Land Type 2 could be suitable for dairy production.

4.2.3  Land Type 3

Water supplies for dairy farming could not be developed with normal on-farm methods.

5. Costs Of Water Supply

The estimated costs per average farm of 260 ha (carrying 300 cattle equivalents) and requiring an average of 50 kL of water per day or 16,000 kL per year for livestock and homestead garden watering, are as follows:

Costs in 1990 dollars per average farm of 260 ha (carrying 300 cattle equivalents)

<table>
<thead>
<tr>
<th></th>
<th>Bores Into Superficial Aquifer</th>
<th>Bores Into Leederville Formation</th>
<th>Farm Dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average capital cost ($)</td>
<td>40,000</td>
<td>60,000</td>
<td>48,000</td>
</tr>
<tr>
<td>Average annual cost ($)</td>
<td>1,000</td>
<td>2,000</td>
<td>1,200</td>
</tr>
<tr>
<td>Area taken out of production (ha)</td>
<td>Nil</td>
<td>Nil</td>
<td>3.0</td>
</tr>
</tbody>
</table>
6. Estimated Proportions Of Study Area In Each Land Type

Estimated areas of the three hydrological land types, as hectares and percentages, in the three major irrigation districts.

<table>
<thead>
<tr>
<th>Hydrological Land Types/ Irrigation Districts</th>
<th>Waroona</th>
<th>Harvey</th>
<th>Collie</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ha</td>
<td>%</td>
<td>ha</td>
</tr>
<tr>
<td>Type 1</td>
<td>3,100</td>
<td>68</td>
<td>4,300</td>
</tr>
<tr>
<td>Type 2</td>
<td>1,400</td>
<td>32</td>
<td>10,600</td>
</tr>
<tr>
<td>Type 3</td>
<td>0</td>
<td>0</td>
<td>1,100</td>
</tr>
<tr>
<td>Totals</td>
<td>4,500</td>
<td>100</td>
<td>16,000</td>
</tr>
</tbody>
</table>

7. Existing On-Farm Water Supply

ACIL survey data indicates that a significant proportion of water for livestock use is currently supplied from sources other than irrigation supplies. On-farm supplies such as bores, creeks, dams and soaks constitute these water sources.

Livestock water supply presently derived from given sources

<table>
<thead>
<tr>
<th></th>
<th>Irrigation Supplies</th>
<th>On-Farm Sources Such As Bores, Creed, Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Waroona</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td>Harvey</td>
<td>59</td>
<td>41</td>
</tr>
<tr>
<td>Collie</td>
<td>66</td>
<td>31</td>
</tr>
</tbody>
</table>

This information suggests that if the irrigation supplies were not available the demand for extra water supplies would be less than the estimates in Section 5. It is not clear as to whether the term “livestock water supply” in the above table relates to all uses listed in Section 3, or only to some of those uses.
8. In-House Water Requirements

Water for use in the house can generally be provided by collecting and storing roof run-off in covered tanks, provided it is possible to maintain roofs in a reasonably clean state for most of the year.

The study area has a mean annual rainfall in the range 900 to 1,100 mm. The following RAINTANK data is derived from modelling different tank capacities, roof areas and household water use with thirty years of Perth daily rainfall as input data. The mean annual rainfall for that data set was 880 mm.

Perth RAINTANK data is as follows.

**To supply 600 L/d or 220 kL/yr with 98 per cent reliability.**

<table>
<thead>
<tr>
<th>Minimum Tank Capacity (KL)</th>
<th>Minimum Roof Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>100</td>
</tr>
<tr>
<td>Option 2</td>
<td>90</td>
</tr>
<tr>
<td>Option 3</td>
<td>80</td>
</tr>
</tbody>
</table>

Increasingly the tank capacity by 50 per cent will increase reliability of supply to 100 per cent and in most years the water demand could then be substantially greater than 600 L/d.

The majority of farms would have more than 400 in² of roof area on buildings. For example: an average sized house, 200 m²; a double carport, 40 m²; a hay shed, 160 m² and a general purpose shed, 200 m². This particular example would allow a continuous water demand of 600 L/d with 98 per cent reliability, provided a covered storage tank of 88 kL was available.

Rainwater Tanks - Costs

- 1 x 88 kL concrete tank with galvanised iron roof $5,000
- 1 x 54 kL concrete tank with galvanised iron roof $3,500
9. Groundwater Bores

9.1 Into Superficial Aquifer - To Supply 50 kL/d

Average yields per bore of 5 kL/hr are achievable. Theoretically, 10 hours pumping per day at 5 kL/hr would provide 50 kL/day.

It is suggested that a practical and cautious approach would be to construct three bores which would all feed into a storage and reticulation system. In case of bore failure or maintenance, two others are available. With three bores in service, pumping would be required for 3.3 hours per day.

Each bore - construction costs

<table>
<thead>
<tr>
<th>Average depth: 25m</th>
<th>Estimated construction cost - drilling, casing and development and $80/m</th>
<th>$2,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pump and power supply</td>
<td>$3,000</td>
</tr>
<tr>
<td></td>
<td>Total per bore</td>
<td>$5,000</td>
</tr>
<tr>
<td>Per farm</td>
<td>Three bores</td>
<td>$15,000</td>
</tr>
<tr>
<td></td>
<td>Reticulation costs - including concrete tanks and drinking troughs</td>
<td>$20,000</td>
</tr>
<tr>
<td></td>
<td>Total capital costs per farm</td>
<td>$35,000</td>
</tr>
</tbody>
</table>

9.2 Into L.eederville Formation - To Supply 50 kL/d

Average yields per bore 5 kL/hr - assumed three bores required.

Each bore - Construction costs

| Average depth: 60m | Estimated construction cost - drilling, casing, cement grouting, development, etc at $140 per metre | $8,400 |
|                   | Pump and power supply                                                    | $5,000 |
|                   | Total per bore                                                           | $13,400|
| Per farm          | Three bores                                                              | $40,200|
|                   | Reticulation costs                                                        | $20,000|
|                   | Total capital cost per farm                                              | $60,200|
10. Farm Dams - To Supply 50 kL/d

Because of assured winter rainfall and relatively clayey soils throughout the study area, it is assumed that regular annual dam filling will occur. Evaporation loss is assumed to be 1.6 m per year.

It is assumed that average dam sizes and depth will be 2,000 m³, ~ in deep, and provided these dams are full at the end of August each year, each will provide sufficient total water requirements for 25 cattle.

Larger and deeper dams will be more efficient and it should be possible to construct such dams throughout much of the study area.

Each dam - to water 25 cattle
2,000 m³ capacity, 4m deep
Dam construction - $1.30/m³ $2,600
Each dam to be fenced and a pump and trough installed $1,400
Total per dam $4,000

Per farm
12 dams (to water 300 cattle) $48,000

11. Water Supply Operating Costs

11.1 Bores Pumping From 20m

Per bore
Electric submersible pump (Capital cost $1,500)
Assumed pumping rate 5 kL/hr (= 1.4 L/s) for 3.33 hrs (= 16.7 kL/day).

Requires a 0.68 KW electric motor (40 per cent efficiency). Running cost is therefore 0.68 x 12 cents = 8.16 0/hr (assumed electricity available at 12 cents per KW hr).

Running cost per farm
3 bores x 365 x 3.33 hrs x 8.16 0/hr = $300 per year
Replace pumps and motors every 10 years? (= $700 per year)

11.2 Bores, Pumping From 40m

Assumed annual pumping costs would be double the amount estimated in previous section.
11.3 Dams
Require desilting every 10 years @ $50 per year per dam = $600 per year for 12 dams.
Upkeep on 12 pumps and troughs @ $50 per year = $600 per year.

12. Area Taken Out Of Production By Farm Dams
Each dam, 2,000 m$^2$, top dimensions 50 m x 50 m = 0.25 ha.
Per farm, 12 dams = 3.0 ha.
5. Background Paper No 5

Potential Changes in Irrigated Agriculture

Prepared by Greg Luke - Department of Agriculture

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* By G Luke

** By P Arkell

+ By R Taylor and I Wilkinson

++ Not prepared by Department of Agriculture and not reproduced here
1. Introduction

There is no doubt that the irrigation industry in the south west has undergone substantial changes since its inception early this century. That process of change will continue. It is the purpose of this paper to include a brief description of how the irrigation enterprises have changed in the past, to describe the industry today, and to indicate some possible future developments.

Water Authority records show that the areas under irrigation have changed quite dramatically through the years. In 1936 there were some 3,000 ha under irrigation. This expanded to a peak of about 15,000 ha in 1976, and declined to nearly 12,000 ha in 1988.

The areas of irrigation devoted to horticultural crops have been even more variable, fluctuating annually. There has, however, been a fairly steady decline in the area of potatoes, other vegetables and orchards since 1936.

2. Existing Irrigation Enterprises

Paper 3 summarises the currently available statistics on Farm Enterprises in the district.

Individual enterprises vary greatly and full knowledge of farm enterprises is not available. As discussed in Paper 3 the process of describing properties is made even more difficult as the statistics available generally refer to a whole farm, which usually includes some land outside the irrigation districts. However, there are a few generalisations which can be made about the types of irrigation enterprises being pursued.

1. Commodities Produced Using Irrigation: Although there is a wide range of commodities produced within the irrigation area, the vast majority of the water goes to produce pasture for dairying. Other uses include fruit crops, and vegetables such as potatoes, pumpkins, beans, broccoli, cucumbers, rockmelons, watermelons, and tomatoes. The water is also used to produce pasture for horses, beef cattle, sheep and goats. The amenity and tourist value of the resource should also be remembered.

2. Areas Under Irrigation: Water Authority data suggests that in 1988/89 there were approximately 12,000 ha of pasture being irrigated within the Waroona, Harvey and Collie Irrigation Districts. Added to this there were a further 150 ha devoted to fruit or vegetable production. Australian Bureau of Statistics returns do not detail the areas of irrigated pasture but put an estimate of 196 ha on horticulture in the district.

3. Types of Irrigation Utilised: The predominant form of irrigation practiced in the area is flood. Smaller areas, mainly on fruit and vegetables, are watered through either overhead or micro sprinklers, or by trickle irrigation.
4. Preferred Soil Types: The soils in the districts have been described on a number of occasions. In most cases the scale of the soil mapping is too broad to be useful in accurately classifying the types of soil upon which irrigation is carried out. The System 6 descriptions broadly classify the soils into three main types. They are the Guildford, Dardanup and Serpentine River Associations. Of these, the Dardanup Soils (for example those in the Harvey No. 1 Area) are the most favoured for horticulture. The Serpentine River soils along the western margins of the districts are heavy clays prone to salinity, and are the least favoured. Smaller areas of other soil units also exist. Full details on all these soils along with discussions on their suitability for different uses are found in Section 4 of this paper.

5. Limitations to the Districts: There are several major factors apart from water, which limit the possible extent of the irrigation districts. The soils along the western margins are heavy clays prone to salinization. Further to the west are a range of sandy soils, similar to those which have been implicated in the eutrophication problems in the Peel-Harvey Inlet. The majority of the soils in the area are generally poorly drained. While this problem has been overcome to a large extent, any further expansion of the districts would require a similar expansion to the drainage system. Full details on the possible offsite effects of the irrigation industry are given in Paper 6.

3. Potential Changes To Irrigation Enterprises

There are a number of possible changes which could be made to the irrigation industry. It has been shown that the industry is a dynamic one, changing in size and in enterprise mix through the years. It is possible that further changes will occur. These changes will be in response to the ever-increasing need for farmers to become more efficient, and to the need for the resource to be put to its most economically valuable and environmentally sustainable use. There are two main ways in which the industry may change and thereby become more efficient:

1. Possible Improvements to Existing Enterprises.

These are discussed in the following sub-sections.

3.1 More Profit From Better Managed Pastures

Achieving greater levels of plant and animal production from irrigated pastures requires improvements in pasture management, water management and land management. This article attempts to assess some of the improvements that can be made and with the assistance of the Western Australian Dairy Farm Model (G.R. Olney and G.J. Kirk, 1989), their effect on dairy farm profitability.
In a study with the WADFM of a hypothetical farm, better pasture, water and land management increase the profitability of a 150 cow herd by $19,608. The better management cost $9,873 a year so the net extra profit due to better management was $9,735. Two hundred and twenty tonnes of extra pasture dry matter was produced so the net extra profit due to better management was $44/tonne of dry matter. Summer fodder crops did not appear in the final solution.

**Pasture production**

Data on irrigated pasture production levels in Western Australia has been collected in association with animal production trials, nitrogen fertilizer trials, drainage trials and water management trials. This data collection has been collected intermittently over at least three decades and is difficult to use to obtain a clear picture of current pasture production levels. However, it is estimated that under average good management an irrigated pasture produces 10 to 12 tonnes of dry matter per ha per year of which 60 percent to 70 percent is utilized by the stock grazing it. Poorly managed Kikuyu dominant pastures may produce only 8 tonnes dry matter per ha per year or even less in those areas severely affected by saline groundwater.

These production levels are much less than those measured over a seven year period at Kyambram Research Institute in northern Victoria (C.R. Stockdale, 1983). The mean annual production of Paspalum dominant pasture, white clover/ryegrass dominant pasture and annual pasture was 18.3, 18.3 and 11.0 tonnes dry matter per ha respectively over a seven year period. Mid-spring to mid-autumn temperature and day light lengths at Kyambram are similar to Harvey so similar irrigated pasture production levels are probably achievable in the Western Australian irrigation areas. However, this has yet to be established and may take considerable management skills to achieve.

One factor limiting pasture and animal production in Western Australia that does not occur in North Victoria is the presence of Kikuyu in Western Australian irrigated pastures.

Kikuyu has a low to moderate nutritional quality, tolerates moisture stress and salinity much better than White Clover and competes aggressively with White Clover when lightly grazed. Long irrigation intervals and lax grazing encourages Kikuyu and discourages Clover. Animals produce poorly on Kikuyu dominant pasture.

In the following sections the cost of better pasture, water and land management is assessed.

**Pasture management**

The objective of pasture management is to have a short leafy Paspalum/White Clover/Ryegrass pasture containing a substantial proportion of White Clover and little Kikuyu. White Clover has a high nutritional value so it plays a valuable role in achieving high animal production from irrigated pastures.

Good pasture management requires a high stocking rate, a flexible system of rotational grazing, slashing or mulching to control Paspalum and Kikuyu maturation and a regular
programme of reseeding. A technique developed at Wokalup Research Station of spraying with glyphosate, burning the dead pasture and direct drilling a mixture of White Clover and perennial Ryegrass shows good promise as a practical method of reseeding.

In the case study the cost of reseeding more frequently than is the current practice, is included as a cost of better management.

*Water management*

White Clover tolerates high temperatures. Its growth rate is relatively independent of temperature over the range 15°C to 35°C. However, White Clover needs more frequent watering than perennial Ryegrass and Paspalum. Thus research at Wokalup (P. Scott) on a White Clover/Ryegrass pasture shows that for high production, irrigated pastures need watering every 6 to 8 days in summer during the November to February period, applying 50 mm of water at evaporation deficits of 50 to 70 mm.

Most farmers water every 12 to 16 days, though some farmers water as frequently as 9 to 10 days. Two developments appear to have encouraged farmers to water more frequently.

The provision of daily evaporation figures by Wokalup Research Station through the media.

The adoption of laser levelling. Laser levelling improves the ease and efficiency of irrigation enabling more frequent watering. The process of laser levelling destroys organic matter thus reducing soil moisture holding capacity. The new pasture, being based on White Clover/perennial Ryegrass, requires more frequent watering than Kikuyu/Paspalum pastures do.

Irrigation is an irksome task and more frequent watering may be impossible without automation of bay outlets and/or channel checks. But Victorian experience (Department of Agriculture and Rural Affairs and the Rural Water Commission) is that it is more important to have a well designed irrigation system than to have automation. In northern Victoria a whole farm irrigation plan is considered to be a blueprint for future farm development. A 50 percent subsidy is available for a survey, for design and computational work and the cost of a development budget (DARA, 1988). The Victorians consider that automation is only the “icing on the cake” and that irrigating every 6 to 8 days is feasible without automation if the irrigation system is well designed. This may well be true, but it must require more effort from the farmer.

Western Australian dairy farmers already work long hours, and automation has become more reliable. So Western Australian advisers believe that automating that part of the farm watered at night (25-35 percent) is a sound objective. Day time irrigation can be assisted by using the “Water Baby” alarm made by Gian Electrics which alerts the farmer when it is time to change bays or sections.

Western Australian irrigation systems need designing and constructing so that farmers can water every 6 to 8 days and to water each area quickly. Current design parameters will need modifying when data on infiltration rates for Western Australian soils has been
obtained. But farmers need to look beyond the design of the laser levelled area itself. The ideal is a whole farm irrigation plan based on a grid survey. At the very least the head ditch and the tail drain need including in the design. The Victorians favour the flat-bottomed head ditch (Figure 1) which is larger than most Western Australian head ditches. This bigger volume head ditch means that water can move around the farm quicker and with minimized erosive force. Culverts too, should be designed so that they do not restrict water flow.

![Fig. 1. Flat-bottomed channel (head ditch)](image)

Tail drains are an important part of the drainage system having a role to play in summer and winter. Like head ditches they need to be of good design and have regular maintenance, so that run-off water and winter drainage water is quickly removed from the bay.

Laser levelling costs above $500 per ha and the associated costs of fencing, reseeding, pasture seed, fertilizer and channel construction, costs another $500 per ha. The extra costs of larger channels and better designed culverts is estimated to cost $100 per ha (M. Green, 1990).

However, many farmers have already laser levelled most of their land. These farmers may need to improve the design of head ditches, tail drains and culverts to improve water flow around the farm. The cost would vary between $100 and $300 per ha, depending on what changes need to be made to fences and farm roads.

**Land Management**

Land management aspects that need improving to increase pasture production include:

1. Top soiling
2. Ripping or mole draining
3. Head ditch and tail drain maintenance
4. Tile drainage where salinity is a major problem

Top soiling, i.e. storing the top 50 to 75 mm of soil when laser levelling could add an extra $200 per ha to the laser levelling costs. But, in Victorian experience, top soiling is only needed when cutting more than 5 cm deep. It may not be needed on the whole area laser graded. The advantage of top soiling is a quick return to full productivity. Top soiling is becoming a more common procedure in Western Australia.
**Mole draining and ripping**

Soils of low permeability and poor internal drainage need regular mole draining or ripping. While some farmers rip their land every two or three years to improve water penetration, others use a mole drain, which appears more useful because it improves drainage as well as water penetration.

Mole draining costs $50 per hour (contract rates) at 1.4 ha per hour with 1.5 metre spacing 45 cm deep. One farmer (Mr G. Edwards) mole drains most irrigation paddocks every year putting the mole in between the previous year’s mole drains. This ensures that the land is maintained in a good ripped and mole drained state and that difficult land regularly grows good quality pastures. Overall costs are $36/ha per year.

**Tile drainage**

Where salinity is a major problem mole drainage may not be sufficient. Construction of tile drains in addition to mole drainage will be required in many cases. The degree of tile drainage required will vary greatly from farm to farm. Cost estimates for tile drainage vary from $1000 to $2000 per hectare.

**The benefits of increased production**

The whole dairy farm model was used to assess the profitability of increasing irrigated pasture production from 12 to 18 tonnes dry matter per ha per annum, i.e. from the estimated current level of production on a well managed Western Australian dairy farm to the level measured by research officers at Kyambram Institute. Early germination pasture production was increased from 2.8 to 3.6 tonnes dry matter per ha per year.

On the case study farm (Table 1) 150 cows calve each year, and increasing irrigated pasture production by 6 tonnes dry matter per ha produces an extra $19,608 profit. The extra profit was produced by reducing grain purchased from 200 tonnes to 149 tonnes and by increasing the proportion of steers sold at three years old instead of at two years old (Table 2). Milk production per cow was hardly altered (Table 3). Cow herd size was restricted to 150. A greater increase in profit would have occurred if cow numbers were allowed to increase.
Table 1 Case study farm in brief,

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Actual At 12 Tonnes Dm/Ha</th>
<th>Actual At 18 Tonnes Dm/Ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market milk quota (L)</td>
<td>845</td>
<td>845</td>
</tr>
<tr>
<td>Irrigated farm area (ha)</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Run off area (ha)</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Maximum number of cows</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Calving pattern</td>
<td>Uniform</td>
<td></td>
</tr>
<tr>
<td>Max. total area irrigated (ha)</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Actual permanent pasture (ha)</td>
<td>43.9</td>
<td>38.5</td>
</tr>
<tr>
<td>Actual early germination pasture (ha)</td>
<td>31.1</td>
<td>36.6</td>
</tr>
</tbody>
</table>

Maximum area for hay
- home farm                         | 60                        | 60                        |
- run off block (ha)                | 54                        | 54                        |
Grain fed tonnes                    | 200                       | 149                       |
Profit ($)                          | 136,775                   | 156,383                   |

Overall, due to better management, an extra 220 tonnes of pasture dry matter was produced from the permanent pasture and the early germination pasture.

Table 2 Steer sales

<table>
<thead>
<tr>
<th>12 Tonnes Dry Matter Per Ha/A</th>
<th>18 Tonnes Dry Matter Per Ha/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers sold at:</td>
<td></td>
</tr>
<tr>
<td>1-2 years</td>
<td>0</td>
</tr>
<tr>
<td>2-3 years</td>
<td>44</td>
</tr>
<tr>
<td>3 years</td>
<td>22</td>
</tr>
<tr>
<td>Quota L/day</td>
<td>12 Tones Dry Matter</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>845</td>
<td>845</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manufactured milk L/year</th>
<th>12 Tones Dry Matter</th>
<th>18 Tonnes Dry Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>646,188</td>
<td>642,837</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total milk L/year</th>
<th>12 Tones Dry Matter</th>
<th>18 Tonnes Dry Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>954,613</td>
<td>951,262</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No cows</th>
<th>12 Tones Dry Matter</th>
<th>18 Tonnes Dry Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yield/cow L</th>
<th>12 Tones Dry Matter</th>
<th>18 Tonnes Dry Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.364</td>
<td>6,342</td>
<td></td>
</tr>
</tbody>
</table>

**Financial return from increased production**

To assess the extra financial returns that might be gained from better management, the cost of better management must be subtracted from the expected profit. The following cost assumptions might be made.

<table>
<thead>
<tr>
<th>Extra Cost</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td></td>
</tr>
</tbody>
</table>

**Pasture management**

- Re-Seed every 5 instead of 10 years, i.e. 15 ha instead of 7.5 ha each year
  - $113/ha (15 – 7.5) ha
  - 848 Yearly

**Automation of 33% of irrigated area**

- One auto unit per 1 ha bay
  - 310
- Sensor
  - 20
- Air Tube
  - 40
- Installation cost
  - 100
- Insurance
  - 12

<table>
<thead>
<tr>
<th>Cost for 25 ha</th>
<th>$11,800</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 yearly</td>
<td></td>
</tr>
</tbody>
</table>

- Better system design (head ditching, tail drain, culverts)
  - 7,500
  - 20 years

- Top soilng 50% or irrigation area
  - 7,500
  - 20 years

- Mole draining $36 x 75ha
  - 2,250
  - Yearly

- Tile drainage of 20% of area $1500 x 15
  - 22,500
  - 20 Yearly
Considering cash flows over a 20 year period at a real interest rate of 10%, the equivalent annual cost is $9,873.

The net financial benefit each year from improved pasture production is therefore $19,608 - $9,873 = $9,735 per year.

The study reported above was of a hypothetical farm. The study needs repeating with real farms.

The study, however, clearly shows that it is profitable to actively pursue improved management techniques. The results are sensitive to the amount of the drainage required. Much of the profitability would be eroded if all the irrigated areas required both tile and mole drainage to control salinity. This is discussed further in Paper 6.

*Summer fodder crops*

A few farmers grow summer fodder crops, mainly millet on newly lasered land. An expansion of this practice has often been proposed, particularly of maize for silage, because high yields are possible (20 to 40 tonnes dry matter per ha). In a study with the whole dairy farm model maize was at first included in the programme when digestibility was set at 70 percent (10.2 MJ/kg DM) but when dropped to a more realistic 62 percent (9.0 MJ/kg DM) maize was no longer included in the programme. Fodder crops are a more costly feed than pasture (Table 4) and so unlikely to be fed unless pasture is very limited or pasture quality is very high as in the Kyabram Dairy System. Further work with the model may identify situations in which maize is a viable consideration. For farmers like the case study farm (2 cows per ha of irrigation) it seems more profitable for farmers to improve their pasture management than to grow maize for silage on a substantial scale.

Millet looks promising as a grazing crop on salt affected land, on newly lasered land and in pasture renovation. But yield of 8 t per ha is probably not high enough for it to be used on large areas of the farm.

| Table 4 |
|---|---|---|---|
| Crop | Yield t/ha | Cost $/ha | Cost $/t DM |
| Millet - Sudax | 8.0 | 337 | 42.12 |
| Maize - Growing | 24.4 | 672 |  |
| - Silage (20% loss) | 19.6 | 318 |  |
| - Total cost | 19.6 | 990 | 50.5 |
| Irrigated pasture | 11.6 | 348 | 30.0 |
| Maize silage at Kyabram | 20.2 | 80 - 100 |  |
Costs include water costs at $16.50/ML and assumes 4.5 ML/ha for fodder crops and 9.1 ML/ha for permanent pasture.

The Kyabram Research Institute is developing the Kyabram Dairy System based on maize silage and pure legume pastures. Maize silage at $80 to $100 per tonne DM and 9.5 MJ/kg DM is high in fibre and combines well with legume pastures in a feeding programme. Maize is cheaper than grain and uses land, water and solar energy much more efficiently than pasture. Kyabram researchers see the Kyabram Dairy System as a good replacement for the hay and Paspalum dominant pasture system commonly found in the Shepparton region and a more profitable way of increasing the size of farm businesses than buying land. But its place on a substantial scale on Western Australian dairy farms has yet to be proved.

3.2 Potential For Alternative Land Uses

If it becomes economically unviable for existing users of water to continue, there are a number of agricultural alternatives for the use of water which may be considered. Most of the alternatives to the traditional dairy farm already exist in the region. These include fruit and vegetable growing, floriculture, viticulture, horses and other agricultural enterprises. The potential for these alternatives along with any major problems are discussed in the context of suitable soils, water quality considerations and potential demand for horticultural land.

3.2.1 Suitability of Soils

Determining the suitability of soils for various uses is usually based on landform mapping. The best available for the irrigation areas is that of Churchward and McArthur (1980). These landforms contain a mixture of soil types which have been identified in later work, e.g. Wells (1989) for Pinjarra. Eventually this process will include the irrigation districts.

Until that time the “System 6” mapping of Churchward and McArthur (1980) must be used. Unfortunately it is not possible to predict the proportions of different soil types within each landform, for the purpose of identifying the most suitable irrigation soils.

The following are the landforms identified, with a description of the unit, its horticultural capability rating and notes as to limitations to use. The capability rating is a five class system, with Class I being most suitable.

**Forrestfield** - “Laterised foothills of the Darling Scarp dominated by gravelly and sandy soils”. Rating = II - V for fruit and vegetables. This wide capability range reflects the fact that the unit varies from deep gravelly sands to lateritic slopes up to 10%. There are many areas suitable for horticulture.

**Guildford** - “Flat plain with medium textured deposits; yellow duplex soils”.

Rating: III - IV for fruit, IV - V for vegetables
Wells (1989) separated this unit into 12 soil types ranging from deep sands with capability rating of II to cracking clays with a rating of V. The limitation is generally poor internal and external drainage, which can be overcome for tree cropping. In the Guildford Association there are areas suited to irrigated horticulture.

*Dardanup* - “Alluvial fans with dark brown loamy sands”. Rating III - IV for fruit and vegetables.

This is the soil used in the Harvey No. 1 area. The major limitation is drainage, which in general is overcome by the Water Authority system of drains. The units then become Classes II - III with the major limitation being low fertility. They are well suited to pastures and horticulture.

*Serpentine River* - “poorly drained plain with fine textured alluvial soils”.

Rated IV - V for fruit and vegetables. This unit, apart from poor drainage, has high susceptibility to salinization and is difficult for crops’ roots to penetrate. It is seen along the western margin of the existing irrigation districts at Harvey and Waroona. In general it cannot be modified economically for horticultural crops and requires careful management for pastures.

*Cannington* – “Poorly drained plains with calcareous substrate, yellow duplex soils with minor areas of red and black clays over limestone”.

Rated V for fruit and vegetables.

This occurs next to, and has the same problems as the Serpentine River landform.

*Southern River* - “Sandplain with low dunes and many intervening swamps: iron and humus podzols, peat and clays.

Rated IV - V for fruit, II - V for vegetables

This unit is widely varying from sands to clays. It has problems ranging from poor moisture retention (sands) to poor internal drainage (clays).

*Bassendean* - “Sand plain with low dunes and occasional swamps: iron or humus podzols”.

Rated III - IV for fruit, III for vegetables

This unit has poor water and nutrient retention capacity and is unsuited for horticulture or pastures due to potential adverse off-side effects.

*Karrakatta* - “Undulating landscape with deep yellow sands over limestone.

Rated I-II for fruit, I - II for vegetables
This unit does not suffer from the same detrimental offsite effects found on the Bassendean Sands. It is suited to horticulture (sprinklers or trickle irrigated) and pasture or lucerne (sprinkler irrigated).

*Cottesloe* - “Low hilly landscape with shallow brown sands over limestone; much exposed limestone:

Rated II - V for fruit, I - V for vegetables

The need to modify the soil by removing limestone is the major problem with this unit. Similar to the Karrakatta sands.

*Vasse* - “Poorly drained plains with variable and differentiated estuarine and marine deposits”.

Rated V for fruit and vegetables

This unit has poor drainage and is prone to salinization. It is also of limited value for irrigated pasture.

*Swan* – “Alluvial terraces with red earths and duplex soils”.

Rated II - V for fruit and vegetables.

The unit is flood prone and is a difficult soil to work. It is suited to pastures and horticulture away from high risk flood areas.

*Preston* - “Major valleys with sandy and gravelly slopes; red earths and duplex soils on valley floor.

Rated I - IV for fruit, II - IV for vegetables

This unit is in places prone to flooding and in parts has poor drainage. There are, however, areas very suitable for horticulture or pasture.

*Cartis* - “Gently sloping fringe to the Blackwood Plateau; grey or yellow sands with some gravels.

Rated II - IV for fruit, II - IV for vegetables

This unit is also quite variable. The major limitation is poor moisture and nutrient retention ability. Care would be needed in developing these areas for horticulture due to the possible off-site effects. This is especially true for the grey sand areas.

A summary of the capability ratings for the different land units, and the areas of each found within and adjacent to the irrigation districts is found on Tables 5 to 8.
### Table 5 Land Capability Areas - Waroona District

<table>
<thead>
<tr>
<th>Land Unit</th>
<th>Areas Inside District</th>
<th>Areas Adjacent</th>
<th>Capability Rating Fruit</th>
<th>Capability Rating Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forrestfield</td>
<td>12</td>
<td>1,695</td>
<td>II - V</td>
<td>II - V</td>
</tr>
<tr>
<td>Guildford</td>
<td>1,924</td>
<td>9,572</td>
<td>III - IV</td>
<td>IV - V</td>
</tr>
<tr>
<td>Dardanup</td>
<td>2,018</td>
<td>2,293</td>
<td>III - IV</td>
<td>III - V</td>
</tr>
<tr>
<td>Serpentine River</td>
<td>646</td>
<td>6,859</td>
<td>IV - V</td>
<td>IV - V</td>
</tr>
<tr>
<td>Cannington</td>
<td></td>
<td>6,345</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>Southern River</td>
<td></td>
<td>4,605</td>
<td>IV - V</td>
<td>IV - V</td>
</tr>
<tr>
<td>Bassendean</td>
<td></td>
<td>1,455</td>
<td>III - V</td>
<td>III</td>
</tr>
<tr>
<td>Karrakatta</td>
<td></td>
<td></td>
<td>III</td>
<td>I - II</td>
</tr>
<tr>
<td>Cottesloe</td>
<td></td>
<td></td>
<td>II - V</td>
<td>IV</td>
</tr>
<tr>
<td>Vasse</td>
<td></td>
<td></td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>Swan</td>
<td></td>
<td>796</td>
<td>II - V</td>
<td>II - V</td>
</tr>
<tr>
<td>Preston</td>
<td></td>
<td></td>
<td>I - IV</td>
<td>II - IV</td>
</tr>
<tr>
<td>Cartis</td>
<td></td>
<td></td>
<td>II - IV</td>
<td>II - IV</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,600</strong></td>
<td><strong>33,620</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 6 Land Capability Areas - Harvey District

<table>
<thead>
<tr>
<th>Land Unit</th>
<th>Areas Inside District</th>
<th>Areas Adjacent</th>
<th>Capability Rating Fruit</th>
<th>Capability Rating Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forrestfield</td>
<td>863</td>
<td>2,234</td>
<td>II - V</td>
<td>II - V</td>
</tr>
<tr>
<td>Guildford</td>
<td>9,653</td>
<td>10,795</td>
<td>III - IV</td>
<td>IV - V</td>
</tr>
<tr>
<td>Dardanup</td>
<td>2,018</td>
<td>4,263</td>
<td>III - IV</td>
<td>III - V</td>
</tr>
<tr>
<td>Serpentine River</td>
<td>2,125</td>
<td>7,281</td>
<td>IV - V</td>
<td>IV - V</td>
</tr>
<tr>
<td>Cannington</td>
<td></td>
<td>744</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>Southern River</td>
<td></td>
<td>9</td>
<td>IV - V</td>
<td>IV - V</td>
</tr>
<tr>
<td>Bassendean</td>
<td>161</td>
<td>13,984</td>
<td>III - V</td>
<td>III</td>
</tr>
<tr>
<td>Karrakatta</td>
<td></td>
<td>1,016</td>
<td>III</td>
<td>I - II</td>
</tr>
<tr>
<td>Cottesloe</td>
<td></td>
<td>196</td>
<td>II - V</td>
<td>IV</td>
</tr>
<tr>
<td>Vasse</td>
<td></td>
<td>1,032</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>Swan</td>
<td></td>
<td></td>
<td>II - V</td>
<td>II - V</td>
</tr>
<tr>
<td>Preston</td>
<td></td>
<td></td>
<td>I - IV</td>
<td>II - IV</td>
</tr>
<tr>
<td>Cartis</td>
<td></td>
<td></td>
<td>II - V</td>
<td>II - IV</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14,820</strong></td>
<td><strong>41,554</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 7  Land Capability Areas - Collie District

<table>
<thead>
<tr>
<th>Land Unit</th>
<th>Areas Inside District</th>
<th>Areas Adjacent</th>
<th>Capability Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forrestfield</td>
<td></td>
<td></td>
<td>II - V</td>
</tr>
<tr>
<td>Guildford</td>
<td>12,548</td>
<td>17,336</td>
<td>III - IV</td>
</tr>
<tr>
<td>Dardanup</td>
<td>526</td>
<td>993</td>
<td>III - IV</td>
</tr>
<tr>
<td>Serpentine River</td>
<td>349</td>
<td>5,571</td>
<td>IV - V</td>
</tr>
<tr>
<td>Cannington</td>
<td>137</td>
<td>730</td>
<td>V</td>
</tr>
<tr>
<td>Southern River</td>
<td>399</td>
<td>5,203</td>
<td>IV - V</td>
</tr>
<tr>
<td>Bassendean</td>
<td>1,961</td>
<td></td>
<td>III - V</td>
</tr>
<tr>
<td>Karrakatta</td>
<td>889</td>
<td></td>
<td>III</td>
</tr>
<tr>
<td>Cottesloe</td>
<td></td>
<td></td>
<td>II - V</td>
</tr>
<tr>
<td>Vasse</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Swan</td>
<td>2,029</td>
<td>4,194</td>
<td>II - V</td>
</tr>
<tr>
<td>Preston</td>
<td>3,786</td>
<td>3,786</td>
<td>I - IV</td>
</tr>
<tr>
<td>Cartis</td>
<td>2</td>
<td>862</td>
<td>II - IV</td>
</tr>
<tr>
<td>Total</td>
<td>15,990</td>
<td>41,525</td>
<td></td>
</tr>
</tbody>
</table>

NB: Numbers are only approximate as District Boundaries are not exact.

### Table 8  Land Capability Areas - Total Region

<table>
<thead>
<tr>
<th>Land Unit</th>
<th>Areas Inside District</th>
<th>Areas Adjacent</th>
<th>Capability Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forrestfield</td>
<td>875</td>
<td>3,939</td>
<td>II - V</td>
</tr>
<tr>
<td>Guildford</td>
<td>29,125</td>
<td>37,703</td>
<td>III - IV</td>
</tr>
<tr>
<td>Dardanup</td>
<td>4,562</td>
<td>7,549</td>
<td>III - IV</td>
</tr>
<tr>
<td>Serpentine River</td>
<td>3,120</td>
<td>19,711</td>
<td>IV - V</td>
</tr>
<tr>
<td>Cannington</td>
<td>137</td>
<td>7,819</td>
<td>V</td>
</tr>
<tr>
<td>Southern River</td>
<td>399</td>
<td>9,817</td>
<td>IV - V</td>
</tr>
<tr>
<td>Bassendean</td>
<td>161</td>
<td>17,400</td>
<td>III - V</td>
</tr>
<tr>
<td>Karrakatta</td>
<td>1,905</td>
<td></td>
<td>III</td>
</tr>
<tr>
<td>Cottesloe</td>
<td>196</td>
<td></td>
<td>II - V</td>
</tr>
<tr>
<td>Vasse</td>
<td>1,032</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Swan</td>
<td>2,029</td>
<td>4,990</td>
<td>II - V</td>
</tr>
<tr>
<td>Preston</td>
<td>3,786</td>
<td>3,786</td>
<td>I - IV</td>
</tr>
<tr>
<td>Cartis</td>
<td>2</td>
<td>862</td>
<td>II - IV</td>
</tr>
<tr>
<td>Total</td>
<td>35,410</td>
<td>11,6699</td>
<td></td>
</tr>
</tbody>
</table>

NB: Numbers are only approximate as District Boundaries are not exact.
Discussion

The land units described by Churchward and McArthur (1980) are not homogeneous soil types. As can be seen from the descriptions and ratings, they range from areas suitable for horticulture or pastures to those unsuited.

In general terms they can be classed as:

Suitable: Forrestfield (in parts) Guildford (with drainage)
Dardanup

Unsuitable: Serpentine River
Cannington
Southern River
Bassendean
Vasse
Swan

Immediately outside the area are four units which contain some suitable soils.
    Karrakatta
    Cottesloe
    Preston
    Cartis

It is virtually impossible to predict how much of the “suitable” units are in fact suitable for horticulture. It is, however, safe to conclude that the majority of the “unsuitable” units should not be considered for horticultural developments. In fact, a case could be made that the Serpentine River, Cannington and Southern River units are generally less suited for pasture production due to pressures of rising watertables, poor drainage and salinity. Careful management is required to ensure good productivity is maintained.

As the objective of this background paper was to act as a discussion starter, and to try to indicate where the most suitable soils for horticulture were, I shall draw some bold conclusions.

Bear in mind, however, 2 facts:

1. These conclusions are based on a very crude data base and may need considerable revision when the current soil/land capability assessment of the district is completed.

2. The current review of economic alternatives and returns from each unit may also result in a revision of these conclusions.
Conclusions

1. Consideration could be given to excluding the “unsuitable” units (Serpentine River, Cannington, Southern River, Bassendean and perhaps Vasse and Swan) from any proposed upgrading of the irrigation supply system. This may result in a concentration of irrigation with the more suitable areas. A system of TWE may be important in this process. The environmental and social consequences of taking these areas out of production would need careful review.

2. Not all of the “suitable” units (Forrestfield, Guildford and Dardanup) may be suited to irrigated horticulture. However, there should be sufficient land in these areas, for horticulture and pasture, to take up the water currently used on “unsuitable” units. This will of course result in higher than 3. in 3 irrigations and will require either sale of water or land between farmers.

3. It would seem to be economically rational for this transfer to occur. The returns per hectare and per megalitre should increase. Water Authority costs of restructuring and maintaining a more compact district should decrease.

4. The social and environmental aspects of any such changes need careful consideration.

5. Some restructuring of the irrigation districts to include valuable soils in the Dardanup and Forrestfield units may be warranted. Alternatively, farmers could be encouraged to pump water to areas outside the district. An example of this could be to pump water to the Forrestfield soils which are immediately adjacent to but above the supply channels. These soils, which are gravelly and sandy-surfaced, are suited to horticulture, but would require sprinkler irrigation rather than flood.

6. These conclusions are drawn on the basis of available data. The results of current studies may necessitate revision.
3.2.2 Water Quality Considerations

The water in the Waroona and Stirling Dams is of sufficiently high quality that no problems are envisaged if crops less tolerant than the existing pastures were to be grown. There may, however, be problems in the Collie Irrigation District.

The water from Wellington Dam contains around 1000 mg/L TSS. Water of this quality is described as being “Class 3” (AWRC, 1974) or water of high salinity which cannot be used on soils with restricted drainage. In the Collie District the drainage system which exists is sufficient to enable the production of relatively salt tolerant pasture species, but for more sensitive crops such as many of the vegetables, special management, such as “tile” drainage, may be needed.

With good management the following yield losses could be expected:

- 0% Broccoli
- 0 - 10% Cabbages, cucumbers, tomatoes
- 10 - 25% Beans (broad and runner), radish, lettuce, capsicums, sweet potatoes, sweet corn, potatoes, citrus (orange, lemon, grapefruit), stone fruit (peach, apricot, plus), berryfruit, grapes, almonds and avocados.
- > 25% Carrots, onions and strawberries.

(after Bernstein, 1967 and Awad. 1984)

Added to those problems is the fact that many of our crops are particularly sensitive to chloride. The water from Wellington contains approximately 500 mg/L chloride. Even though some of the crops listed above might be grown in the area albeit with a yield reduction, the chloride in the water will exclude some. These include some citrus, avocados, plus sensitive grape varieties, and the berryfruit.

For these reasons the potential usefulness of the Collie Irrigation Area for the production of horticultural crops is limited. Only the more salt tolerant vegetable and fruit crops could be considered, and then only with careful management.

3.2.3 Estimated Future Horticultural Land Requirement

In order to determine likely future demand for horticultural land and water requirements in Western Australia, an analysis is required of current production and likely trends in market demand. Horticulture, like most agricultural crops, has been in the past, production-orientated rather than market-driven. While some of the ‘newer’ crops are being established based on market prospects, in the main, horticulture will rely on established markets.

In an earlier report, ‘Future Demand, Value and Transfer Methods of Irrigation Water’, 1986, the Marketing and Economics Branch of the Western Australian Department of Agriculture (WADA) looked at prospects for horticulture exports in Western Australia’s major markets. Its prediction then was for a growth rate of 6.2 percent per annum over
the 20 years from 1986. Export performance has declined in recent years, however, with total exports in 1989 declining 33 percent below the 1986 level. In this analysis, medium-term projections are based on a growth in exports of 9.5 percent per annum.

This study also uses total State horticultural statistics for analysis of future horticultural land required. This differs from the previous report, which attempted to derive statistics for the study area. However, to attempt comparison by extrapolation, this analysis arrives at a figure of 3-5.5 percent per annum growth in area of land required from 1988/89. The previous study estimated that demand for horticultural land would increase by 4.4 percent per annum from 1984/85. Both these estimates include floriculture but this area is fairly stable.

According to the Australian Bureau of Statistics the total area under horticultural crops (excluding floriculture) in Western Australia during 1988/89 was 15,889 hectares. The area of vegetables cropped was 8141 hectares. However, assuming each hectare is cropped 2.0 times each year, then the actual physical area planted to vegetables was 4070 hectares. This assumption could be increased to 2.5 crops per hectare per annum if only vegetable production on the coastal plain were considered.

Table 9 shows the area of fruit and vegetables and the changes in area over two periods leading to 1988/89. It is not possible to obtain an accurate picture of the change in area of the total period due to a change in statistical collection method in 1985/86. The table therefore shows two distinct periods. Most of the decline in fruit area prior to 1985/86 was due to removal of apples and citrus and, to a lesser extent, gravevines. However, a recovery in vineyard area due to recent winegrape plantings, increased interest in stonefruit because of new varieties, and plantings of ‘newer’ fruits, have begun to reverse the decline in the State’s fruit area.

The area of vegetables planted has shown strong growth and has mainly occurred in varieties in demand for export. The area of potatoes has also increased slightly in recent years but the expected large growth in the next two years to meet processing requirements is likely to be met at the expense of alternative vegetable crops, rather than additional land. A recovery in the area of peas used for processing has also occurred.
Table 9 Area of fruit and vegetables (hectares)

<table>
<thead>
<tr>
<th></th>
<th>5 Years</th>
<th></th>
<th>3 Years</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a)</td>
<td>(b)</td>
<td></td>
<td>(a)</td>
</tr>
<tr>
<td>Fruit</td>
<td>9254</td>
<td>9058</td>
<td>-2.1</td>
<td>7082</td>
</tr>
<tr>
<td>Vegetables (planted areas)</td>
<td>5758</td>
<td>6958</td>
<td>+20.8</td>
<td>6461</td>
</tr>
<tr>
<td>Total area planted</td>
<td>15012</td>
<td>16016</td>
<td></td>
<td>13543</td>
</tr>
<tr>
<td>Total (physical area)</td>
<td>12133</td>
<td>12537</td>
<td>+3.3</td>
<td>10313</td>
</tr>
</tbody>
</table>

Source: ABS

a) Establishments with gross value agric. operations >52,500

b) Establishments with gross value agric. operations >$20,000

The Agricultural Economics and Marketing Division of the WADA has attempted to predict future land requirements for horticulture based on current production and estimating growth factors for domestic population, and imports and exports of horticultural produce. Table 10 summarises the outcomes for a range of estimated growth rates for both 5 and 10 year periods from 1988/89. These are based on highly, medium and low projections of population growth, demand for imports and exports and land productivity.

Table 10 Predicted future area of fruit and vegetables (hectares)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>7748</td>
<td>12538</td>
<td>62%</td>
<td>15523</td>
<td>100%</td>
</tr>
<tr>
<td>Medium</td>
<td>7748</td>
<td>9370</td>
<td>21%</td>
<td>11090</td>
<td>43%</td>
</tr>
<tr>
<td>Low</td>
<td>7748</td>
<td>6274</td>
<td>-19%</td>
<td>6840</td>
<td>-12%</td>
</tr>
<tr>
<td>Vegetables (physical area)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>4070</td>
<td>7957</td>
<td>95%</td>
<td>10163</td>
<td>150%</td>
</tr>
<tr>
<td>Medium</td>
<td>4070</td>
<td>4972</td>
<td>22%</td>
<td>6086</td>
<td>50%</td>
</tr>
<tr>
<td>Low</td>
<td>4070</td>
<td>3217</td>
<td>-21%</td>
<td>3707</td>
<td>-9%</td>
</tr>
</tbody>
</table>

Using the “medium” projections would indicate an area of 14,342 hectares of land will be required for horticulture by
1993/94 (9370 ha fruit and 4,972 ha vegetables), an increase of 2524 ha, or 21 percent on the amount of land estimated to be used for horticulture in 1988/89. By 1998/99, the total area required is projected to be 17,176 ha (11,090 ha fruit and 6,086 ha vegetables), an increase of 5358 ha, or 45 percent on 1988/89. These figures ignore the area of land required for floriculture.

The major driving forces behind increasing demand for horticultural land are likely to be population growth and overseas exports. While exports to the Eastern States may be significant in some years, they are likely to be spasmodic, depending on shortages caused by adverse weather.

Imports of fruit and vegetables into Western Australia from both the Eastern States and overseas are likely to be linked to growth in our population. This is because imports consist mostly of fruits and vegetables which cannot be economically grown in Western Australia, or processed foods which we have difficulty producing competitively because of our small population. Quarantine restrictions apply to some fruits. Some import replacement could occur however, if ventures such as the frozen potato chip plant at Manjimup are successful. Production from this plant is expected to be 50,000 tonnes when full production is reached.

Population growth in Western Australia is predicted to be fairly constant at around 2.5 percent per annum for the next ten years. Consumption of fruit and vegetables per head of population has fluctuated from year to year for Australia as a whole, but there is no definite trend towards increased or decreased consumption. In the future there is the prospect for per capita consumption of fruit and vegetables to increase, but this will be dependent on improved market promotion and/or an increasing awareness by the public of the health benefit of eating fresh fruit and vegetables.

The biggest variable when trying to estimate future horticultural area in Western Australia is the likely level of exports. For most Australian horticultural industries, the domestic market has determined what quantities are available for export. Western Australia is an exception to this in that certain vegetable crops are grown specifically for export. Three commodities, carrots, cauliflowers and apples, dominate exports, comprising 60 percent of total exports in 1989. About 80 percent of vegetables grown locally are consumed fresh within the State and 20 percent exported, mainly overseas.

Western Australia’s export performance in overseas markets has suffered in recent years due to a number of factors such as a high Australian dollar, high domestic prices in Eastern Australia and strong overseas competition on some fruits. While a return to normal seasonal conditions should again see an emphasis on overseas markets, growth in exports is expected to be only moderate.

**Floriculture**

Because of the difficulty in obtaining accurate data and the varying plant densities per hectare, it is difficult to predict the area of land used by the floriculture industry. However, based on surveys of plant numbers by the WADA, an estimate of the likely area involved and predictions for change in the next 5 to 10 years have been made in Table 11.
Table 11 Estimated area of floriculture (hectares)

<table>
<thead>
<tr>
<th></th>
<th>1989</th>
<th>1994</th>
<th>1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivated wildflowers</td>
<td>1000</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Cultivated proteaceae</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Exotics - greenhouse grown</td>
<td>22</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>Exotics - field grown</td>
<td>28</td>
<td>32</td>
<td>36</td>
</tr>
<tr>
<td>Nurseries</td>
<td>300</td>
<td>339</td>
<td>384</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1550</strong></td>
<td><strong>1396</strong></td>
<td><strong>1448</strong></td>
</tr>
</tbody>
</table>

After rapid growth in the 1980s from a low base, it appears prospects for future production, particularly for wildflowers, have diminished due to the limited domestic market, transport problems, over-production and quality problems. It is likely that the growth area for floriculture in the future, based on export market prospects, is for exotic plants but the areas of land required will be minimal. Growth in nursery areas will match population growth, being centred mainly in the Perth region. Total area required for floriculture is expected to remain fairly static.

**Conclusion**

From the calculations made by Taylor and Wilkinson, from the Department of Agriculture’s Division of Agricultural Economics and Marketing, it can be seen that if the current rate of growth in demand is maintained, then the State will require a further 5,256 ha of horticultural land by 1999. This does not take into account the loss of any existing land taken over by urban development.

Another study currently under way in the Department of Agriculture is looking at identifying the area of land in the State which is suitable for horticulture, without damaging the environment, and for which water resources are available. While that study is not yet completed, the indications are that on the Swan Coastal Plain, from Lancelin to Dunsborough, there are only about 3000 ha of suitable land, which groundwater resources allocated to agriculture. It is possible that some reallocation of the groundwater resource may occur and that the land available may increase. Similar studies are under way to determine the amount of land available outside that study area.

Clearly, however, since the realisation of the effect that irrigated horticulture has on the environment around coastal wetlands, there has been a dramatic downward re-estimation of the State’s available horticultural land. For that reason it is quite possible that in years to come horticulturalists will find the heavier soils of the irrigation areas far more attractive than they have in the past. Any restructuring of the irrigation districts should consider including those soil units which are more suited to horticulture, such as the Forrestfield or Dardanup soils.
4. Aspects Requiring More Data

1. *Land Capability*: This study is aimed at determining the future of the South West Irrigation Districts. It is inappropriate therefore to make far reaching decisions with less than satisfactory data. The discussion on land capability clearly shows that there is insufficient information available on the potential of the area for alternative agricultural land uses. Work by Wells and Van Gool shows that the earlier System 6 mapping, has grouped together extremely variable land units into Soil Associations. While it would appear that there may be sufficient land suitable for other uses such as horticulture, verification of this is needed before any decisions on the long term structure of the industry are made. These decisions should not be made until the results of a land capability assessment which is currently underway are available. These results should be available by late 1990.

2. *Soil Salinity Survey*: Soil salinisation due to rising water-tables is a major problem along the western margins of the districts. Soil salinity surveys carried out in 1980 and in 1985 showed that the area affected by salt increased from 5 percent to 17 percent. An additional 15 percent was shown to be marginally affected in 1985. A further survey should be commissioned to determine whether the affected area has increased since 1985. This study should include an assessment of the regional hydrogeology and the likely consequences of any major relocation of the area being watered. These studies could have a significant impact on the discussions.

3. *Economic Potential of Land Units*: The land capability survey currently underway includes an assessment of the economic potential of the different land units for a range of uses. This work should be completed by the end of 1990. Once again the information from this study should be invaluable to the planners, in their decision making process. The discussions should not be completed before that data is available.
5. References


Green, M. (pers. comm.).


Scott, P. (pers. comm.).


6. Background Paper No 6

Environmental Effects of Past & Possible Future Public Irrigated Agriculture in the Region

Prepared by Ross George - Department of Agriculture of WA

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1. Introduction

This position paper considers only salinity and eutrophication (nutrient enrichment) under the heading of ‘environmental effects’.

Salinity is widespread on the Swan Coastal Plain (SCP). The commonly held view that high rainfall will save the SCP from salinity is a myth. Much of the coastal plain is flat and poorly drained and it receives 200-250 kg/ha of salts in the rainfall each year. Groundwater beneath the Plain occurs in clayey subsoils close to the surface and frequently contains more than 7,000 mg/L, total soluble salts (the top of the groundwater or saturated layer in the subsoil is the watertable). These groundwater conditions ensure that considerable soil salinity will arise under the disturbance to the water balance caused by clearing and draining for agriculture. Irrigation which introduces even greater changes to the water and salt balance has exacerbated the situation, leading to extensive salinization of the irrigated areas.

Eutrophication is of concern because drainage waters from the irrigated areas (apart from the small area served by the Myalup Diversion Drain) discharge eventually to either the Harvey Estuary or the Leschenault Inlet. Irrigated land-use is of particular concern because it generally has high inputs of fertilizer and an increased potential for the loss of nitrogen and phosphorus from the land. Associated activities such as processing and the disposal of animal wastes from dairies, piggeries and feedlots increase the risk of nutrient loads.

This paper will discuss separately salinity and nutrient loss problems and endeavour to make some predictions with regard to the likely changes to the irrigation system.

2. Irrigation Salinity

2.1 Background

The Harvey, Waroona and Collie Irrigation Areas comprise about 12,000 to 13,000 ha of irrigated land using about 120,000 ML/year of water from reservoirs in the Darling Scarp. Gross production from the area is approximately $20 mn/annum and the total value of irrigated land is about $300 mn. The prime form of irrigated agriculture is growing pastures for market milk production.

Irrigated pasture production currently shows poor economic returns for the water used. Pasture production over the irrigation season is only around 8-10 t (dry matter), and quality in January, February and March is poor because of low digestible energy levels caused principally by the loss of clovers from pastures at that time. It is postulated that poor water management (too much, too infrequently) and salinity are prime factors in this poor productivity.

Whole-farm economic analysis (Morrison et al. 1981) has emphasized the low returns to water by estimating the (low) marginal value to an irrigation farmer of an extra megalitre of water. Because of this, increases in water charges result in reduced demand for
water, but at the same time profits can be maintained because of the ready substitution of feed grain for pasture (another pull on the rope!).

In practical terms I believe the outcomes of this situation are:

- Little incentive to invest management or capital into on-farm improved water management with consequent water wastage leading to high watertables and soil salinity.

- Under an irrigation water pricing policy of strict recovery of annual operating costs, reduced consumption tends to induce higher prices and a consequent further decline in consumption.

- Proposals to increase water prices or perceived reductions in water value or quality (e.g. increased salinity) result in intense consumer (political) pressure to maintain the status quo.

- Provision for infrastructure replacement does not come from water sales revenue but from general taxation revenue resulting in funding delays or rejections (the current crisis).

Improved water use efficiency and reduced salinity problems are thus contingent on increased productivity from water used. In the short term this will entail improved productivity from pasture systems and be assisted by the proposed introduction of transferable water entitlements. In the longer term, however, it will be changes to more productive cropping systems on the better soils that will most likely guarantee the future viability of the irrigation industry.

2.2 How Extensive is Salinity in the Irrigation Areas?

The extent of soil salinity overall the irrigation areas has never been properly quantified. The problem has, however, been observed to be extensive but variable in its severity.

Quantification is difficult because salinity effects are frequently manifest as poor pasture production and quality rather than obvious bare and scalded areas. Additionally, waterlogging is a confounding effect.

The extent of the problem can be gauged through surveys and by watertable levels throughout the irrigation areas.
Surveys

Two recent surveys provide some measure of the extent of soil salinity:

- A visual assessment, in 1986, by experienced advisers (Middlemas, pers. comm.) from the area concluded that 35% of the irrigation areas were affected by salinity. The occurrence of the main saline areas were also mapped (see Figure 2.3 of Summary of Background Papers).

  The soil salinity detected by this survey was worst along the western margins of the irrigation areas and coincides with the clayey soils of the Serpentine and Guildford Associations (known locally as “bungum clay”). These fine textured, poorly drained soils have considerable stores of sub-soil salts (McArthur and Bettenay 1974), which can be brought to the surface by clearing and irrigation.

  The western edges of the irrigation areas frequently intersect the discharge zones of the Leederville aquifer. Here, upward seepage of water and salts constitute an additional salinity hazard. This aspect will be returned to in later sections.

- A grid survey of soil salinity and watertable depth was carried out of the Waterloo District of the Collie Irrigation Area in 1988. About 1,000 ha were surveyed containing approximately 300 ha of irrigation land. Results are summarized in Figure 1 and Table 1.

<table>
<thead>
<tr>
<th>Salinity Range Ec (1:5) Ms/M</th>
<th>Percentage Of Area</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>40</td>
<td>Non-saline</td>
</tr>
<tr>
<td>20-50</td>
<td>35</td>
<td>Clover yield reduced by 25% to 50%</td>
</tr>
<tr>
<td>&gt;50</td>
<td>25</td>
<td>Clover yield reduced by 50% to 100%</td>
</tr>
</tbody>
</table>

Watertable levels

Numerous studies and investigations (George (1980b), George & Furness (1979), George (1979), Sanders (1974), Deeney (1989), P.R. George (unpublished data), P.R. Scott (unpublished data), George and Dyer (in prep.)) confirmed the universal occurrence of shallow watertables throughout the irrigated areas. Depths lie within the range of 0 and 1.5 m below ground level and watertable salinities vary between 500 mg/L and 15,000 mg/L total soluble salts. These groundwater conditions thus predispose the whole of the irrigated areas to soil salinity, though the severity depends on the salinity of groundwater. Deeney (1989) shows the watertable salinity increasing in the direction of groundwater flow (westward) causing salinity to be more severe on the western margins of the irrigation areas.
Figure 2 shows watertable depths determined during the grid survey of the Waterloo area. In much of the area watertables are less than 1.0 m from the surface (November 1987).

2.3 How Fast is Salinity Spreading?

I believe irrigation farming has been living with salinity for many years. There are references in Agriculture Department files to salinity investigations on irrigation pastures in Brunswick in 1938 and to problems in potato crops in Dardanup in the early 1960’s.

Early saltland surveys (see Figure 2.2 Summary of Background Papers) mapped mainly obviously saline areas rather than areas where, though supporting irrigated pastures, yields were impaired.

It is my impression from around 15 years experience in the areas that the 1986 estimates of saltland represent a fairly stable situation and that noticeable increases in soil salinity are restricted mainly to non irrigated areas.

![Figure 1. Salinity contours (EC 1:5 mS/m) of the surface (0-150 mm) layer of soil for the Waterloo area (sampled Nov. 1985).](image)
Figure 2. Watertable depths for the same area as in Figure 1.

Watertable levels in the Harvey Irrigation Area have been stable showing if anything a slight downards trend because of a period of dry winters. This contrasts with the Collie Irrigation Areas where watertable levels through the 1970’s and early 1980’s showed a tendency to increase by about 0.10 to 0.15m/year. This would tend to expand groundwater discharge areas and worsen salinity as was observed to be the case in the Waterloo area. The period also coincided with a deterioration in Wellington Dam water quality which increased salt loads on irrigated land and perhaps led to increased watertable salinities.

In the Waterloo area, however, where salinity of the Leederville aquifer is less than 1,000 mg/L, soil salinity is not as severe as it is in the discharge areas west of Harvey where the Leederville aquifer contains around 5,000 mg/L and leads to higher watertable salinities (Figure 5).

Laser levelling, which involves baring the soil surface and a fallow period when irrigated water is not applied, has been observed to increase soil salinity and delay pasture re-establishment. These areas generally recover once leaching by rainfall and irrigation water, aided by the slow return of pasture cover, takes place. This could explain the observation by some farmers in the Collie Irrigation Area that salinity is increasing and by others that it is decreasing.
2.4 What are the Changes to the Water and Salt Balances that lead to Salinity in Irrigation Areas?

Groundwater accessions from irrigation:

In Table 2 (George, 1988) channel seepage and field percolation losses have been used to estimate groundwater accessions from irrigation.

Table 2. Groundwater accession estimates for the Harvey, Waroona and Collie Irrigation Area (volumes expressed as x $10^3$ ML)

<table>
<thead>
<tr>
<th>Year</th>
<th>Pasture Irrigated (Ha)</th>
<th>Total Water Supplied</th>
<th>Water Used On Farm</th>
<th>Channel Seepage</th>
<th>Field Percolation</th>
<th>Total Groundwater Accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983/84</td>
<td>13,000</td>
<td>158</td>
<td>122</td>
<td>36</td>
<td>18</td>
<td>54</td>
</tr>
<tr>
<td>1984/85</td>
<td>12,250</td>
<td>127</td>
<td>97</td>
<td>30</td>
<td>15</td>
<td>45</td>
</tr>
</tbody>
</table>

Though this type of crude analysis cannot allow for all the intricacies of irrigated land use and management that occur, it provides a reasonable first order approximation of the groundwater accessions that occur due to irrigation practice. The estimates are a ‘gross’ accession figure because they take no account of losses due to natural groundwater flow out of the irrigation areas. On the other hand they do not include unknown accessions from unlined drainage channels. Accessions to the groundwater of 50,000 ML/year (twice the volume of the Waroona Dam) represents an equivalent recharge over the total irrigation districts of 140 mm/year, a similar figure to that quoted by Lyle (1984) for the Shepparton Region of Victoria. If it is assumed that groundwater recharge beneath the Pinjarra Plain increased from 0.5% of annual rainfall (~4 mm/year) to 5% of annual rainfall (~40 mm/year) following clearing, this and the additional recharge from irrigation constitutes a major disturbance to the water balance.

Water balance of irrigated land:

At a more detailed level Table 3 (George, 1979) shows the annual water balance for a 200 ha area near Dardanup within which about 60 ha was permanent pasture. Because data are averaged over the whole study area, the irrigation water applied per hectare appears low and should be multiplied by three to obtain the approximate amount of water applied to the irrigated land. The seasons referred to run from May to April.

Evapotranspiration has been estimated from an on-site, Class A pan evaporimeter and used in the water balance equation to estimate the amount of excess water percolating beyond the root zone. Evapotranspiration estimates allow for the fact that only the irrigated one-third of the area will be active during summer, but do not include potentially significant amounts of evaporation from swamps and fringing vegetation.
Table 3. Annual water balance of a 200 ha, mixed dryland and irrigated area near Dardanup

<table>
<thead>
<tr>
<th>Season</th>
<th>Rain (P) mm</th>
<th>Irrigation (I) mm</th>
<th>Run-off (R) mm</th>
<th>Evaporation (Ep) mm</th>
<th>Groundwater recharge (U) mm</th>
<th>Percentage of water entering soil recharging groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975/76</td>
<td>856</td>
<td>454</td>
<td>340</td>
<td>662</td>
<td>308</td>
<td>31</td>
</tr>
<tr>
<td>1976/77</td>
<td>628</td>
<td>420</td>
<td>275</td>
<td>625</td>
<td>148</td>
<td>19</td>
</tr>
<tr>
<td>1977/78</td>
<td>636</td>
<td>439</td>
<td>336</td>
<td>679</td>
<td>57</td>
<td>8</td>
</tr>
<tr>
<td>Mean</td>
<td>706</td>
<td>437</td>
<td>317</td>
<td>655</td>
<td>171</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 3 shows a wide seasonally dependent range in groundwater recharge but indicates on average that about 20% (170 mm) of the water entering the soil percolate beyond the root zone of the pastures. In relation to Table 2, estimates of field percolation losses (U) in Table 3 are considerably higher due to high irrigation application rates (up to 14 mL/year) during the period of measurement.

Table 4 estimates water deficits over the November to April irrigation season for the same area and relates these to actual irrigation applications. Note that run-off applies only to that estimated to have occurred due to rainfall.

On average about 25% of the irrigation water applied is unaccounted for and assumed to leach beyond the root zone.

Table 4. Seasonal water deficits from irrigated land at Dardenup in relation to water application and water requirement

<table>
<thead>
<tr>
<th>Season</th>
<th>Rain (P) mm</th>
<th>Run-off (R) mm</th>
<th>Evapn.¹ (Ep) mm</th>
<th>Water deficit (P - (R + Ep)) mm</th>
<th>Irrigation Requirement² (Ir) mm</th>
<th>Irrigation application (Ia) mm</th>
<th>Ia/Ir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov 1975 – Mar 1976</td>
<td>130</td>
<td>10</td>
<td>830</td>
<td>-710</td>
<td>1,020</td>
<td>1,446</td>
<td>1.41</td>
</tr>
<tr>
<td>Nov 1976 – Mar 1977</td>
<td>158</td>
<td>16</td>
<td>772</td>
<td>-630</td>
<td>900</td>
<td>1,128</td>
<td>1.25</td>
</tr>
<tr>
<td>Nov 1977 – Mar 1978</td>
<td>48</td>
<td>-</td>
<td>845</td>
<td>-797</td>
<td>1,135</td>
<td>1,310</td>
<td>1.15</td>
</tr>
<tr>
<td>Nov 1978 - Mar 1979</td>
<td>57</td>
<td>2</td>
<td>788</td>
<td>-733</td>
<td>1,050</td>
<td>1,251</td>
<td>1.19</td>
</tr>
<tr>
<td>Mean</td>
<td>98</td>
<td>7</td>
<td>808</td>
<td>-717</td>
<td>1,024</td>
<td>1,284</td>
<td>1.25</td>
</tr>
</tbody>
</table>

¹ Evaporation
² Irrigation Requirement
1 Ep = 0.8 Epan (Class A).

2 Ir = Water deficit + 0.7 (allows for 30% run-off of applied water).

Salt balance of irrigated land:

Based on a 12 ML application of water, about 3 t and 12 t of total salts per hectare are applied to irrigated land in the Harvey and Collie Irrigation Areas. These loads reflect the differences in water quality between the two areas. In general to avoid build-up these amounts of salt need to be leached out of the soil.

Table 5 (George, 1979) shows the salt balance for irrigated land in the Collie Irrigation Area.

Table 5. Salt balance over the irrigation season of irrigated land within the Collie Irrigation Area

<table>
<thead>
<tr>
<th>Season</th>
<th>Rain chloride kg/ha</th>
<th>Irrigation chloride kg/ha</th>
<th>Run-off chloride kg/ha</th>
<th>Excess chloride kg/ha</th>
<th>Excess total salt kg/ha</th>
<th>Salt input Salt output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975/76</td>
<td>50</td>
<td>5,300</td>
<td>2,110</td>
<td>3,240</td>
<td>5,590</td>
<td>2.5</td>
</tr>
<tr>
<td>1976/77</td>
<td>0</td>
<td>5,520</td>
<td>1,790</td>
<td>3,460</td>
<td>5,960</td>
<td>2.9</td>
</tr>
<tr>
<td>1977/78</td>
<td>25</td>
<td>7,750</td>
<td>2,720</td>
<td>5,050</td>
<td>8,700</td>
<td>2.8</td>
</tr>
</tbody>
</table>

About 2.5 to 3.0 times as much salt is added to the land as is lost by run-off and excess salt added to the land was up to 8.7 t/ha. The sharp increase in 1977/78 was a direct reflection of a deterioration of water quality.

Over winter a net (of saltfall) loss of total salts in the run-off water of 100-500 kg/ha occurs, but this is insufficient to balance the salt inputs in the irrigation water in summer. On an annual basis, averaged over the whole 200 ha study area, the excess total salts applied to the soil were 1,600 kg/ha in 1975/76, 1,300 kg/ha in 1976/77 and 2,150 kg/ha in 1977/78. To maintain a salt balance natural drainage must be sufficient to remove these amounts of salt.

2.5 How do Groundwater Conditions Affect Salinity in the Irrigation Areas?

Two aspects of groundwater are relevant here:

- the occurrence of shallow, possibly perched, watertables beneath irrigated soils. This aspect has been discussed in earlier sections and will be discussed further in later sections.
- regional groundwater flows in relation to watertables and salt leaching. This aspect is discussed further below.
Regional groundwater hydrology and salinity:

Bore monitoring programmes in the Harvey (George, 1979b) and Collie Irrigation Areas (P.R. George, unpub. data) show that the badly saline or salt prone soils lie on groundwater discharge areas. These are areas where groundwater is tending to seep upwards maintaining high watertables and preventing leaching of salts.

They are natural discharge areas, but irrigation and other land-use changes have probably expanded their area. Irrigation on groundwater discharge areas causes or worsens waterlogging and salinity problems.

Figures 3a and 3b show watertable (Bores H1.5A and D6.5) and deep groundwater pressure levels in the saline discharge areas of west of Harvey and at Waterloo.

Figure 4a and 4b are cross-sections through the Pinjarra Plain near Cookernup, north of Harvey, showing groundwater movement within the superficial (near surface) sediments and the top of the Leederville formation. Recharge (addition of water) to the latter occurs mainly on the foothills (Ridge Hill Shelf) and discharge (loss of water) occurs around bores 1.5 and 1.6 which are severely salinized areas.

Beneath the less saline soils (bores 1.4, 1.10, 1.11), groundwater flow is away from these areas allowing some natural salt leaching.

For the same cross-sections, groundwater salinities are shown in Figures 5a and 5b.

Groundwater salinities in the superficial deposits east of the Darling Fault are less than 1,000 mg/L, TSS with, as expected in recharged areas, salinity increasing slowly with depth. On the Pinjarra Plain salinities generally decrease with depth indicating near surface concentration by evapotranspiration.

Beneath the better irrigated land (bores 1.4, 1.10, 1.11), though groundwater movement allows some salt leaching, the eastward extension of brackish watertables is probably due to the salt load applied in the irrigation water and localized evaporation from watertables increased, over summer, by irrigation.

In the discharge areas around bores 1.6 and 1.5 salt has accumulated, markedly increasing groundwater salinity. As a consequence groundwaters have salinities in excess of 15,000 mg/L. Note that groundwater near the top of the Leederville aquifer contains around 5,000 mg/L, TSS compared to 1,000 mg/L, TSS found in the Waterloo area.
Figure 3. Groundwater levels in the saline discharge areas: (a) west of Harvey and (b) Waterloo. Bores HL5C and D6.5A are measuring groundwater pressure levels in the top of the Leederville Formation. Bores HL.5A and D6.5 show watertable levels.
Figure 4. Cross-sections through part of the Coastal Plain near Cookernup, 10 km north of Harvey, showing groundwater flow.

Figure 5. The same cross-sections as in Figure 4 showing groundwater salinities.
Concluding remarks on regional groundwater and salinity:

The regional discharge areas are characteristically heavy, clay soil areas which carried a dense cover of Melaleuca spp before clearing. The native vegetation maintained deep watertables through high transpiration and this together with the regime of annual flooding caused soluble salts to accumulate in the sub-soil. Removal of the natural vegetation and its replacement with annual pastures has reduced discharge via transpiration and watertables have risen to compensate. This has allowed the movement of salts to the surface by capillary action to cause dryland salinity. Irrigation, which adds further salt and water, adds considerably to the problem.

Other problems have beset these discharge areas. Irrigation appears to have added slightly to groundwater flow to the discharge area, but the main flow is from water leaking upwards from the Leederville aquifers. Pressures in these aquifers have probably increased because of increased recharge following clearing of intake areas. In the Harvey Irrigation Area, groundwater levels (Figure 3) show no rising trends and appear to be in hydrologic equilibrium. In the Collie Irrigation Area, however, monitoring bores within the Waterloo District have shown a rising trend in watertables and groundwater pressures of about 0.1 m/year. In this area, recharge to the Leederville aquifer occurs on the Blackwood Plateau to the east of the irrigated soils. Clearing on the Plateau over the last 10-20 years has undoubtedly increased recharge and the hydrologic impact of this is still being felt. Rising watertable levels imply the expansion of discharge areas and hence saline soils and this together with the salinity of Wellington Dam water is responsible for the great concern about salinity in the Collie Irrigation Area.

2.6 What is the Nature of Soil Salinity in the Irrigation Areas?

The changes in soil salinity through the year:

Figure 6 shows soil salinity levels with depth for a Dardanup loam soil at different times of the year. At the time of sampling (1972/73) irrigation water (Wellington Dam) salinity was 500 mg/L., TSS.

Initial profiles at the end of the rainy period show a well leached, fairly uniform salinity profile with the electrical conductivity of the saturation extract (ECe) uniformly in the vicinity of 150 to 200 mS/m. Salinities increase to a maximum, usually in the hot January-February period, and as conditions cool and evaporative demand falls, leaching increases avid ECe’s decrease. This pattern is consistent, though salinity levels will vary with season and location.

The following winter rainfall usually restores the soil salinity to its initial state. Dry, late spring weather, because it coincides with periods of high watertables and poor pasture cover, can however rapidly cause resalination of the surface even before irrigation resumes.

Figure 7 shows for the same sites, surface (0-15 cm) salinities (ECe) over the course of an irrigation season and compares these with published salt tolerance data for white clover and paspalum.
Figure 6. Soil salinity profiles for a Dardanup loam soil at different times of the year (Collie Irrigation Area).

Figure 7. Annual fluctuations of surface soil salinities compared to salt tolerance of common pasture plants. (Dardanup loam, irrigation water salinity 500 mg/L, groundwater salinity 1,000-1,500 mg/L).
The changes in soil salinity over an irrigation cycle:

Figure 8 shows salinity changes for a site at Benger over a 14 day irrigation cycle. The samples were taken from plots being watered with Stirling Dam water (150-200 mg/L, TSS) and where the groundwater contained 2,500-3,000 mg/L, TSS.

Initial leaching following irrigation is evident but salt levels show a steady increase up to the next irrigation due to capillary rise. As no salt has been added over the period of sampling the only source of this salt can be the shallow groundwater beneath the site.

The distribution of salts in the soil profile:

In the undisturbed state surface soil salinities are generally low. The subsoil salinities of the heavy textured soils are however high (> 0.3% TSS below 0.2 to 0.3 m); higher than in the better drained Dardanup and Coolup soil types and lighter phases of the Boyanup soil types (Bettenay et al. 1960, McArthur & Bettenay, 1974).

Under irrigated conditions sampling consistently shows that soil salinities are highest at the surface and decrease with depth; the reverse of the soils in the virgin state.

This characteristic distribution of salts with depth is shown in Figures 6, 8 and 9 and is due to upwards capillary flow of water and salt from the watertable.

High salinity in the surface layer has important consequences for plant growth. As it is the zone of most active water uptake, plant growth is more sensitive to salinity in the upper root zone than in the subsoil (Ayers & Westcott, 1976).

Further, it means that the soil salt level is not so much governed by irrigation water salinity, as by the factors governing the rate of capillary water flow to the soil surface and by the salinity of the groundwater (which is the source of the capillary water).

The effect of groundwater salinity on soil salinity:

In a recent survey (George & Dyer, in prep.) soil and groundwater salinities were compared. Some of these data are summarized in Figure 9. As groundwater salinity increases, a consistent trend to increased soil salinity is shown. With high groundwater salinity, capillary flow transports greater amounts of salt into the root zone.

2.7 What is the Effect of Irrigation Water Salinity on Soil Salinity?

As stated previously, capillary rise of salts from shallow groundwater causes salinity and plant growth problems to be insensitive to water quality.

To test this directly, adjacent plots on a site at Benger were watered with Wellington Dam and Stirling Dam waters and pasture growth and soil salinity compared.
Figure 8. Variation over an irrigation cycle of salinity (measured as chloride levels) profiles for a soil near Benger (Boyanup loam). Figures on curves are days after irrigation.

Figure 9. The effect of groundwater salinity on soil salinity levels.

Table 6 shows the aggregated yield data for all years that the trial was carried out. No significant treatment differences are apparent and daily growth rates are similar within and between years.
Table 6. Pasture production (D.M.) over irrigation season when irrigated with waters of different salinity

<table>
<thead>
<tr>
<th>Year And Treatment</th>
<th>Clover kg/ha (%)</th>
<th>Grasses kg/ha</th>
<th>Total kg/ha</th>
<th>Growth Rate kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1975/1976</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stirling</td>
<td>1,072 (17)</td>
<td>5,449</td>
<td>6,521</td>
<td>50.2</td>
</tr>
<tr>
<td>Wellington</td>
<td>1,168 (19)</td>
<td>5,238</td>
<td>6,406</td>
<td>49.3</td>
</tr>
<tr>
<td><strong>1976/1977</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stirling</td>
<td>4,132 (48)</td>
<td>4,548</td>
<td>8,680</td>
<td>56.4</td>
</tr>
<tr>
<td>Wellington</td>
<td>4,539 (55)</td>
<td>3,736</td>
<td>8,275</td>
<td>53.7</td>
</tr>
<tr>
<td><strong>1988/1989</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stirling</td>
<td>735 (9)</td>
<td>7,617</td>
<td>8,352</td>
<td>74.6</td>
</tr>
<tr>
<td>Wellington</td>
<td>463 (6)</td>
<td>7,747</td>
<td>8,238</td>
<td>73.5</td>
</tr>
<tr>
<td><strong>1978/1979</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stirling</td>
<td>470 (5)</td>
<td>8,187</td>
<td>8,657</td>
<td>56.6</td>
</tr>
<tr>
<td>Wellington</td>
<td>354 (4)</td>
<td>7,948</td>
<td>8,302</td>
<td>54.2</td>
</tr>
</tbody>
</table>

* Stirling 150-200 mg/L, TSS.
   Wellington 750-1,000 mg/L, TSS.

Soil salinities measured at this site (Figure 10) show no consistent differences that can be related to irrigation water salinity.

The decline in clover levels on both treatments in 1977/78 coincided with the increase in the salinity of Wellington Dam water from 770 mg/L TSS to 1,000 mg/L, TSS. This could indicate cross contamination of adjacent plots and invalidation of the results. However care was taken to ensure no lateral surface water flow during irrigation and low soil hydraulic conductivity (permeability) (0.05 m/day) coupled with low groundwater gradients at right angles to the plots would indicate only minor sideways underground flow. Pasture samples were taken in the centre of bays to minimize such effects.

Though this trial showed no differences over the period it was conducted, the high salinity of Wellington Dam water must be expected to have an effect on soil salinity specially over the long term as salt builds up in the groundwater. Certainly, however, the predominant effect on soil salinity is the shallow groundwater and salt problems due to the salinity of the irrigation water could be better managed.
2.8 What is On-farm Water Management Like at the Moment?

Recently, seven fields, three in the Harvey Irrigation Area and four in the Collie Irrigation Area, were surveyed to:

- Evaluate on-farm water management.
- Demonstrate the impact of watering on watertable levels and salinity.
- See if laser levelling was improving water management and soil salinity.

In general it was found that:

- Watering practices were leading to excessive groundwater recharge.
- Watertable levels beneath irrigated land were very shallow and as a consequence salinity occurred in both irrigation areas with the severity depending on groundwater salinity.
- Watertable is beneath adjacent unirrigated land were deeper than those beneath irrigated land.
- With one exception laser levelled land was as bad as unlasered land because water was staying on the paddock too long.

Table 7. Observed opportunity times for infiltration of irrigation water (hours)

<table>
<thead>
<tr>
<th>Site</th>
<th>Section Of Bay</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>E-lasered</td>
<td>12.1</td>
<td>11.5</td>
</tr>
<tr>
<td>T-lasered</td>
<td>8.0</td>
<td>7.4</td>
</tr>
<tr>
<td>G-lasered</td>
<td>7.5</td>
<td>6.8</td>
</tr>
<tr>
<td>E-lasered</td>
<td>3.4</td>
<td>3.6</td>
</tr>
<tr>
<td>E-unlasered</td>
<td>11.2</td>
<td>10.1</td>
</tr>
<tr>
<td>B-unlasered</td>
<td>7.6</td>
<td>7.9</td>
</tr>
</tbody>
</table>
Figure 10. Soil salinities compared on adjacent plots being watered with Stirling or Wellington Dam waters for a site near Benger.

Figure 11. Advance-recession curves for a site west of Harvey showing the "ideal" recession curve based on a 70 mm irrigation and measured infiltration. The ideal opportunity time for intake of irrigation water is shown by 4.
How long is water staying on the paddock?

Figure 11 shows the common advance-recession curve found by the survey. In this case for a single watering on a site at Harvey.

The advance curve shows the time that water takes to move down the bay. The recession curve shows for the various points along the bay the time that water stops flowing (i.e. has receded from that section of the bay). The difference between the two lines at any distance along the bay is the time water has had the opportunity to infiltrate into the soil.

Also shown on Figure 11 is the “ideal” recession line; that is the line that given the amount of water required to replace that used by the pasture and the infiltration capacity of the soil, gives the ideal length of time (4) for infiltration that avoids wastage. Any time above that line represents excessive infiltration.

Table 7 summarizes the findings of the advance-recession surveys. Apart from the Site, E-lasered, infiltration times were excessive and this was reflected in the findings on watertable levels.

What were the effects on watertable levels?

For the same site as shown in Figure 11, the response of watertable to watering is clearly shown by Figure 12. Four irrigation cycles are shown, with the watertable rising to the surface each time and remaining there for 2-4 days before falling to about 1 m before the next watering. Table 8 summarizes groundwater levels and salinities for each site in the survey.

Did laser levelling help?

The answer is yes and no. Table 7 shows that generally, even watering was achieved on lasered paddocks, however, Table 8 shows that with one exception (E-lasered) watertable levels are no better than for unlasered paddocks.

Examining the site E-lasered further, Table 7 shows even and rapid watering with opportunity times less than one-half the other sites. This site had been recently lasered and as a consequence had low infiltration and could be watered quickly. Table 8 shows that watertable levels, in contrast to the adjacent paddock (Site E-unlasered), were maintained about 1.3 m below ground level. A continuous plot of these levels is shown by Figure 14. Only minor rises in the watertable are observed following waterings on December 29 and January 11.
Figure 12. Continuous watertable levels for the same site as Figure 11, showing fluctuations over four irrigation cycles.

Figure 13. Continuous watertable levels for a Site E-Lased where times for infiltration were close to \( t_f \). Slight responses to irrigation on December 29 and January 11 can be seen.
Figure 14. Salinity profiles at Site E. The difference between lasered and unlasered is due to greater watertable depth beneath the lasered plot (cf. Figure 3).

Figure 15. Watertable levels and salinity beneath a dryland paddock (Site G-dryland) at Waterloo. Groundwater salinity is about 6,000 mg/L.
Table 8. Groundwater levels and salinities

<table>
<thead>
<tr>
<th>Site</th>
<th>Groundwater Salinity Mg/L</th>
<th>Watertable Depth (m)</th>
<th>Irrigation Water Salinity mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>Average</td>
</tr>
<tr>
<td>E-lasered</td>
<td>8,651</td>
<td>1,650</td>
<td>3,663</td>
</tr>
<tr>
<td></td>
<td>3,993</td>
<td>1,749</td>
<td>3,209</td>
</tr>
<tr>
<td>E-dryland</td>
<td>7,150</td>
<td>6,655</td>
<td>6,966</td>
</tr>
<tr>
<td></td>
<td>7,271</td>
<td>2,832</td>
<td>5,022</td>
</tr>
<tr>
<td>G-dryland</td>
<td>6,220</td>
<td>5,467</td>
<td>5,922</td>
</tr>
<tr>
<td>R-unlasered</td>
<td>3,147</td>
<td>1,562</td>
<td>2,514</td>
</tr>
<tr>
<td>B-unlasered</td>
<td>5,206</td>
<td>1,046</td>
<td>3,245</td>
</tr>
<tr>
<td>T-lasered</td>
<td>7,540</td>
<td>5,740</td>
<td>3,031</td>
</tr>
<tr>
<td>E-lasered</td>
<td>410</td>
<td>319</td>
<td>366</td>
</tr>
</tbody>
</table>

The effect of a lowered watertable on salinity:

Figure 14 compares salinity profiles taken from the lasered and unlasered paddocks at Site E. Not only are surface salinities lower for the lasered site but the profile form is different. The unlasered site shows the typical “capillary rise” form while the other is showing a leaching form; with the main salt accumulation below 0.5 m. Salinity levels at the lasered site are still relatively high though leaching and freshening will continue as long as watertable conditions allow.

It is important to realize in Figure 14 the key effect is the difference between watertable levels induced by efficient watering not the lasering per se.

There is some evidence in Figure 14 that a “critical depth” for the watertable to avoid salt accumulation at the surface is less than 1.2-1.3 in on this heavy clay soil under irrigation pasture. This is thus a useful objective for water management or drainage to achieve salinity control, and is in accord with Victorian experience with similar soils.

What are watertable depths on dry paddocks next to irrigated paddocks?

Figure 15 shows a continuous plot of watertable depth over an irrigation season beneath dryland at Site G-dryland. Table 8 allows a comparison of watertable fluctuations at this site with the adjacent irrigated site (Site G-lasered).
2.9 What are the Options for Salinity Management?

What follows is a general discussion of management options. A more specific discussion prepared by John Abbott is attached as Appendix I.

On-farm options:

Careful water management is needed to obtain the benefits of irrigation without the adverse effects of increased salinity and waterlogging. Good water control ensures that the required amount of water can be uniformly applied when it is needed, without large losses of water to the groundwater. For maximum grass production it is generally desirable to avoid water stress by watering frequently to maintain low soil moisture deficits. Gravity irrigation systems offer less scope than sprinkler or trickle irrigation systems for close control of water applications. Gravity systems can, however, be modified to allow better water control through the use of laser controlled precision land-levelling and automated water inlet gates. The move to laser levelling and re-layout of irrigation paddocks has progressed rapidly (Green and Middlemas 1985), however, automated water controls have not been adopted.

The full benefits of laser levelling are currently not being realized because water is staying on the bay too long. However, very little local information exists on required bay dimensions and water application rates to achieve uniform water distribution with a minimum of water loss. Moreover there are no precise local experimental data that enable the determination of the optimum watering frequency or the amount of water required to “re-fill” the soil at each irrigation, though these are now being obtained.

With gravity irrigation systems labour and operating costs are minimized by decreasing the irrigation frequency (resulting in higher application rates per irrigation) but yields and water use efficiency are in general increased by increasing irrigation frequency (Morrison et al. 1981). There is thus a trade-off between production (frequency of irrigation) and profitability. At current levels of irrigated pasture production and quality it is doubtful that the incentive is there to increase irrigation frequency. Only by improving the overall production of the farming system will farmers be able to make the necessary investments in water management systems that will improve water-use efficiency and reduce groundwater levels.

Off-farm distribution system:

A restraint to improved on-farm water use and reduced groundwater accessions is the irrigation water distribution system.

The current open channel distribution system was designed to supply water on a fixed rotation basis, but a few years ago this was changed and farmers can now receive water on demand within three days of notification. Efficient on-farm water use requires that water be delivered on demand and if an effective water scheduling system causes a concentration of water demand there are some doubts about the capacity of current supply channels to deliver. Introducing greater flexibility into the water supply system inevitably reduces conveyance efficiency. Improved and better maintained channel liners will reduce, but not eliminate channel seepage, and are very expensive. A pipe
conveyance system, as installed in the Harvey Irrigation Area, virtually eliminates seepage losses and because the gravitational potential of the supply is harnessed provides more options for distribution management, on-off controls and irrigation methods. Modernization of the distribution system to this degree, though tremendous from a water efficiency point of view, is expensive. The Harvey scheme completed in 1987, after nine years of construction, cost $9.2 m or $7,500 per hectare serviced. A feasibility study prior to commencement of the project indicated that channel relining was more expensive (Doubikin 1987).

The injection of such levels of capital into the other irrigation areas can probably only be economically justified if it is applied to the best soils, allows transfer of water rights to these areas and results in more water efficient and productive farming systems. It is unlikely that this scenario could apply to irrigated grass production.

*Land drainage:*

To control root-zone salinity levels a sufficient downward flow of water is required to leach salts added in the irrigation water. Heavy winter rainfall assists this process, however, beneath permanent pastures, watertables need to be maintained between 1.0- to 1.2m below the surface (Lyle 1984) to prevent salination of the surface over the summer. With cropping systems, where greater soil evaporation can occur, greater watertable depths are needed.

Where efficient water management cannot maintain a salt balance and reduce groundwater accessions sufficiently, for example, where “foreign” water from channel seepage or groundwater discharge impinges on an area, groundwater drainage will be required. Tube drainage will require spacings of about 10-15 m (George, unpublished data) to be effective and is currently uneconomic.

Pumped drainage is also feasible, but initial tests in the Waterloo District (Hirschberg, 1985) and subsequent testing were not encouraging. Pumped drainage offers the prospect, in areas of fresh groundwater, of conjunctive use of groundwater and channel irrigation water. Pumping would however involve the dewatering of the Leederville aquifer, a valuable groundwater resource, causing salinity management and groundwater resource management to be in conflict.

*Transferable water entitlements:*

The establishment of an open market in irrigation water, should in theory result in overall improved productivity of the irrigated areas by shifting water use to the more efficient managers and the more productive and less salt prone soils. Transferable water entitlements would lead to a greater concentration of irrigation on the better soils and possibly exacerbate salinity and waterlogging problems unless excellent water control can be achieved at the same time.

At present the over concentration of irrigation activity is prevented by the even geographic spread of water allocations throughout the irrigation areas and the restricting of irrigation ratings to one-third of the farm.
3. Eutrophication

3.1 Background

All of the Waroona Irrigation Area and 92% of the Harvey Irrigation Area drain into the Harvey Estuary. All of the Collie Irrigation Area drains to the Leschenault Inlet. The Peel-Harvey estuarine system is currently under active management to reduce nutrient inputs (mainly phosphorus) to its waters. The condition of the Leschenault Inlet is delicately balanced such that increased nutrient inputs would cause a severe deterioration of its condition. Clearly proposals that would increase nutrients inputs for either system cannot be sanctioned.

Increased problems could arise due to:

- Further intensification of land-use leading to higher nutrient usage on the land (e.g. horticulture).
- Development of processing works or intensive animal industries as a consequence of more intensive agricultural systems.
- Intensification of horticulture on sandy soils west of the current irrigation areas if the transfer of water to these areas to augment groundwater supplies proved justifiable in the future.

3.2 What is the Current Situation?

The irrigation soils have high phosphorus fixing capacities and should not readily leach phosphorus. Irrigated dairying is, however, expected to use more fertilizer than other grazing enterprises and irrigation is expected to increase run-off (which carries the nutrients) by about 100 mm/year. In addition poor handling of milking shed washings by, for example, disposing directly to drains will increase nutrient levels.

Measurements at the Vindictive Drain gauging site at Waterloo indicated low phosphorus export levels of around 0.6 kg/ha/year(?). Recent data, however, from the Samson Brook North Catchment (preliminary data of G. Bott, E.P.A.) indicate phosphorus export levels in excess of 2 kg/ha/year, which is higher than export rates from non-irrigated Bassendean sand soils (see Table 8).
Table 8. Phosphorus export rates from different land-use and soil types (prelim. data of G. Bott, E.P.A.)

<table>
<thead>
<tr>
<th>Year</th>
<th>Meredith Catchment¹ (kg P/Cleared Ha)</th>
<th>Sampson Brook North² Catchment (kg P/Cleared Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>1984</td>
<td>1.2</td>
<td>3.1</td>
</tr>
<tr>
<td>1985</td>
<td>1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>1986</td>
<td>0.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Mean</td>
<td>1.5</td>
<td>2.2</td>
</tr>
</tbody>
</table>

¹. Meredith - Bassendean sands, non irrigated, low drainage density.

². Sampson Brook North - clay soils, irrigated, high drainage density.

The data for Sampson Brook North must be considered as preliminary only as there are doubts as to the catchment size and the possible inputs via the interlocking drainage network, of water from outside the catchment.

3.3  The Future?

The current irrigated areas are likely to be more closely scrutinized than in the past. In addition any redevelopment leading to increased fertilization and increased drainage will need to be closely evaluated as to its nutrient export potential. Horticulture is a possible alternative use for the better Harvey and Dardanup loam type soils and there is already a trend towards this in the Harvey No. 1 Area. Horticulture watered by micro irrigation methods has however the potential to halve the water application rates used by irrigated pasture. This should result in less run-off and a reduction of nutrient losses as long as winter rains do not wash silt into drains. Increased groundwater (tile) drainage is not expected to pose a great phosphorus hazard on the high phosphorus fixing soils.
4. References


