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# Economic Aspects of Some Groundwater Disposal Options for Irrigated Dairy Farms: A Preliminary Evaluation<sup>1</sup>

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Net annual costs for disposal by pumping to the Murray River, an on-farm evaporation basin, conjunctive use with surface water to irrigate dairy pasture, and undiluted irrigation of a salt tolerant grass were estimated and compared. Total conjunctive use (TCU) is the cheapest option below 10dS/m groundwater salinity. TCU becomes more expensive than river disposal above 10 dS/m and than total evaporation above 15 dS/m. Above 10 dS/m, partial conjunctive use with disposal of some groundwater by irrigating salt tolerant forage is similar in cost to river disposal and less expensive than total on-farm evaporation. Farm and regional perspectives for optimising sustainable salt management are discussed.

*Key words:- salinity, groundwater, Murray River, evaporation basin, conjunctive use*

## 1. INTRODUCTION

Large masses of salt are on the move in the catchments of the Murray-Darling Basin.

Where mobilised salts accumulate in the rootzone, increasing salinity reduces plant productivity. It has been estimated that agricultural losses due to salinity may rise to 30-40% of potential unaffected production over the next 30-50 years if no remedial measures are implemented.

The installation of sub-surface drainage is an effective remedy for waterlogging and salinity. This establishes a percolative hydrological regime which leaches excessive levels of salts from the rootzone, rapidly restores productivity and protects against further degradation.

However drainage produces saline effluent which must be disposed in a manner acceptable to local, downstream and wider communities. There is only limited scope for disposal of saline effluent via the Murray River and alternative disposal options are needed. Conjunctive use with rainfall and surface irrigation water, evaporation and marine outfall<sup>3</sup> are other technically feasible options.

The purpose of this preliminary evaluation is to consider some economic aspects of groundwater disposal options for an irrigated dairy farm. The hypothetical 100 hectare farm has a perennial pasture based production system and is located in a region where groundwater must be pumped to provide sub-surface drainage. This situation obtains in the Shepparton Irrigation Region in northern Victoria which is underlain by an extensive system of shallow aquifers of varying groundwater salinity (Bethune and Prendergast 1994).

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<sup>3</sup> A recent review (Gyles, 1998) found this option still uneconomic.

## **2. GROUNDWATER MANAGEMENT FOR SALINITY CONTROL**

The groundwater management policy assumed for all options is a moderate aquifer pumping rate of 1 ML/ha sufficient to provide leaching for salinity control. Pumped groundwater may contribute to crop water budget, depending on disposal option.

## **3. ESTIMATED IMPACT OF IRRIGATION DEPTH AND GROUNDWATER SALINITY ON THE PASTURE BASED COMPONENT OF PRODUCTION**

### ***3.1 Irrigation requirement***

10ML/ha (1.0m depth) is taken as the annual irrigation requirement for well watered perennial pasture. This is consistent with district recommendations for maximum yield established at sites with low groundwater salinity. This irrigation supplements an estimated 400mm (4 ML/ha) effective rainfall making total water use 14 ML/ha. The study farm is assumed to have a water right of 6ML/ha and the system allocation to be water right plus 50% sales allocation. Thus no transfer of water entitlement is required.

### ***3.2 Effect of conjunctively used groundwater salinity and depth of irrigation on productivity***

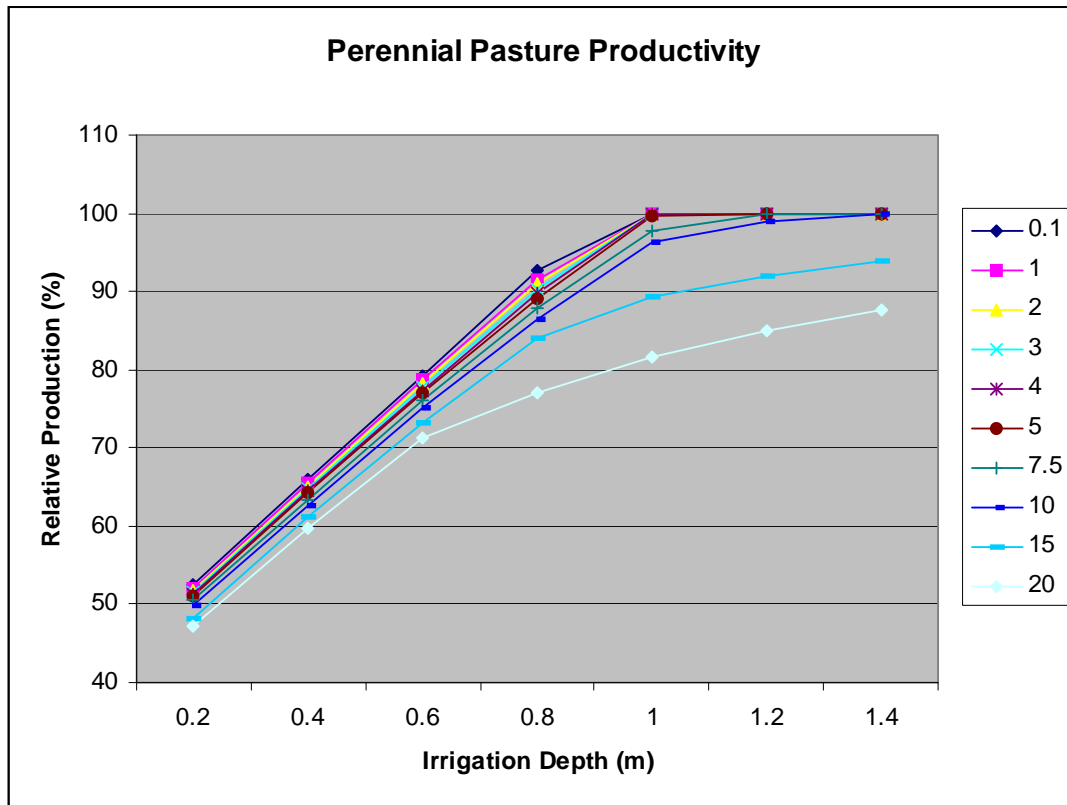
Production functions implicit in the modelling by Bethune (2000) relating depth of irrigation and groundwater salinity are shown in Figure 1. The functions exhibit diminishing marginal productivity. Maximum production level is attained at 1.0 m depth of irrigation for groundwater salinities of 0.1, 1, 2, 3, 4 and 5 dS/m, at 1.2 m depth of irrigation for 7.5 dS/m and 1.4 m depth of irrigation for 10 dS/m. Relative production is still rising at 1.4 m depth of irrigation for groundwater salinities of 15 and 20 dS/m.

The production response for 0.1 dS/m groundwater salinity is analogous to that obtained from irrigation solely with surface channel supply of low salinity

### ***3.3 Water use efficiency of pasture based dairy production***

Water use efficiency for 0.1 dS/m groundwater salinity and 1.0 m depth of irrigation is assumed to be the average found by Armstrong *et al* (1998). This is 867 litres/ML of total water use (effective rainfall plus irrigation).

No adjustment is made for variation in quality or utilisation of forage produced at different salinities or irrigation intensities.



**Figure 1: Relationship between relative yield of perennial pasture and irrigation intensity for a range of groundwater salinities**

### **3.4 Irrigation costs**

Given the assumed water right, an increase in irrigation intensity will incur additional costs for transfer of water entitlement and delivery of supply. The annualised cost of district surface supply system water “in the farm channel” is estimated at \$62/ML (Gyles, 1999). Conversely a reduction in irrigation intensity should similarly reduce production costs. No allowance is made for changes in irrigation labour requirement.

### **3.5 Other pasture management costs**

It is assumed that there will be reduced fertiliser/pasture maintenance costs for the lower water use intensities. These reductions range from \$10-100/ha depending on irrigation depth.

### **3.6 Estimate of gross margins**

Based on the assumed water use efficiency, a pasture based production gross margin of \$157/ML total water use is derived by assuming a milk price of 27.1 cents/litre, and the pasture variable costs estimated by Knee (Armstrong *et al* 1998), together with an allowance for shed, herd and repairs/maintenance costs. This estimate falls to \$113/ML total water use for a milk price of 22 cents/litre.

### 3.7 Change in gross margin

The irrigation cost and fertiliser adjustments outlined above were included the calculation of the gross margin using the relative productivities already derived for the range of irrigation intensities and groundwater salinities shown in Figure 1. The change in gross margin relative to the base case (\$2198/ha @ 1 m irrigation depth, 0.1 dS/m) is shown in Figure 2. No scope for use of supplements to offset pasture dry matter losses is assumed.

Introducing costs to the evaluation alters the analytical perspective from physical productivity to production economics. Optimum input levels are not necessarily those needed for maximum yield. The relationship between milk price and input costs must also be considered. Once the marginal increase in revenue falls below the cost of the additional inputs required, gross margin will fall even though production may still be rising. Thus Figure 2 indicates the optimum depth of irrigation is 1.0 m for systems using 7.5 and 10 dS/m groundwater even though Figure 1 shows production would rise with 1.2 m depth of irrigation. Similarly, costs of increased production exceed increased income beyond 0.8m and 0.6m depth of irrigation for the 15 and 20 dS/m systems respectively.

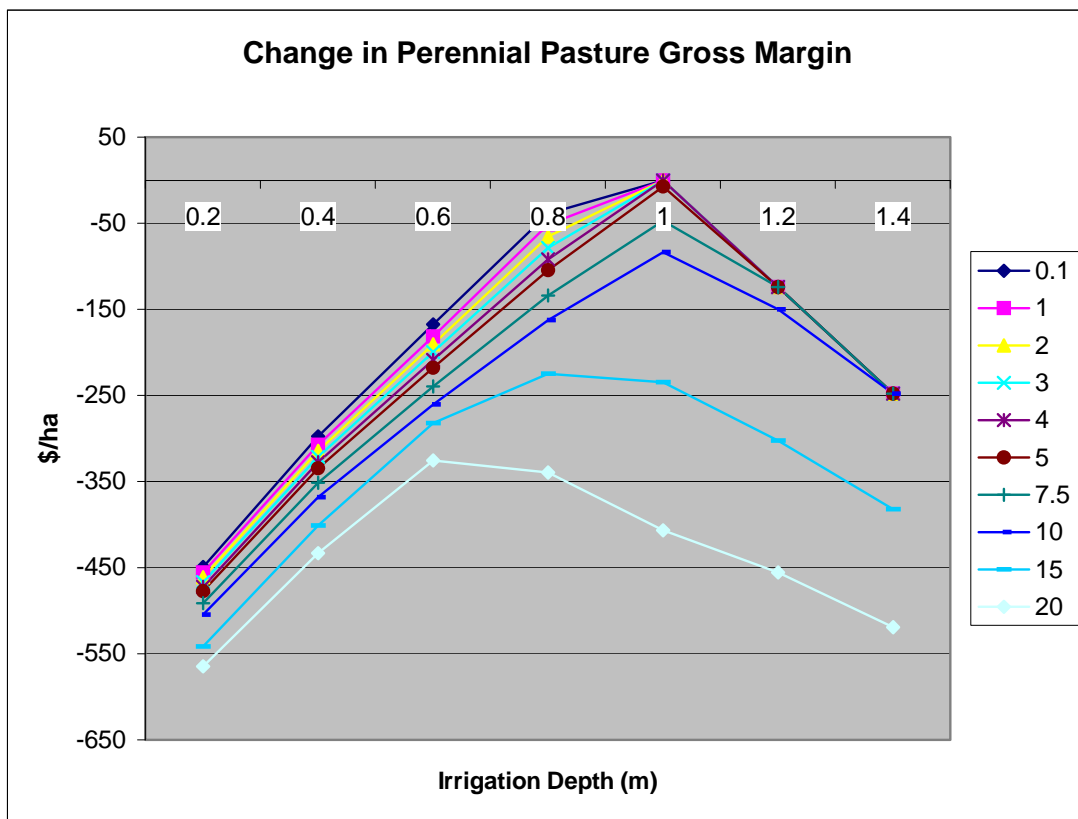


Figure 2: Change in gross margin relative to base case.

This relationship is sensitive to changes in factors affecting gross margin. For example, at a lower milk price of 22 cents/litre, the optimum depth of irrigation for production over the two lowest salinity groundwater categories would fall to 0.8m.

## **4. DESCRIPTION OF OPTIONS FOR DISPOSAL OF GROUNDWATER**

A number of disposal options are considered:-

### **4.1 Complete disposal to river**

Pump effluent is disposed to the river system. Downstream impacts result from increased river salinity.

### **4.2 Total disposal to an on-farm evaporation basin**

The area of perennial pasture is reduced. Surface supplies previously used on the disposal area are released for transfer to areas on or beyond the farm.

### **4.3 Total conjunctive use**

All pumped groundwater is mixed with channel supplies and used for irrigation on the farm. The volume of water resources available for irrigation is increased by 1ML/ha. Increased irrigation salinity may reduce plant production.

### **4.4 Partial conjunctive use**

Conjunctive use is restricted to limit the impact of salinity on pasture productivity as set out under the sub-surface drainage policy for the Shepparton Irrigation Region Land and Water Salinity Management Plan (SIRLWSMP) (Anon, 1989). The surplus volume of groundwater is disposed away from the conventional pasture area. There are several options for disposal of the surplus groundwater.

#### **4.4.1 River disposal**

Similar but proportionally reduced downstream impacts result from increased river salinity as in the complete disposal to river option.

#### **4.4.2 On-farm disposal**

The area of conventional perennial pasture is reduced and part of the farm is used for disposal of groundwater surplus to the volume required for partial conjunctive use. Surface supplies previously used on the disposal area are released for transfer to areas on or beyond the farm. Two on-farm options are considered.

##### **4.4.2.1 “Salt tolerant forage”**

Surplus undiluted groundwater is used for irrigation of salt tolerant species. Bermudagrass (couch) is grown for utilisation in the dairy production system in this case. Effective rainfall contributes to production (beneficial use).

##### **4.4.2.2 Evaporation basin**

Surplus groundwater is evaporated in a basin constructed on the farm.

## **5. COSTS OF GROUNDWATER DISPOSAL OPTIONS**

### **5.1 Costs of groundwater pumping**

As the assumed groundwater management policy is the same for all options, groundwater pumping costs are not included in this analysis. Nor is any allowance

made for possible differences between options for delivery of groundwater to disposal points.

### **5.2 Total disposal of groundwater to river**

Cost is calculated taking the impact on river salinity as 1 EC unit/6500 tonnes of salt. The cost of a 1 EC increase is assumed to be \$100,000.

### **5.3 Total disposal to an on-farm evaporation basin.**

Basin construction cost is assumed to be \$6250/ha. Capital cost amortised over 50 years. No additional operating and maintenance costs are assumed.

Effluent disposal capacity of basin is assumed to be 8 ML/ha.

The 4 ML/ha effective rainfall evaporated in the basin is lost from the production system.

Surface supplies previously used on the disposal area are released for transfer to areas on or beyond the farm.

### **5.4 Total conjunctive use**

Reduced gross margins will result from lower plant productivity due to the impact of the increased salinity of irrigation as illustrated in Figure 2.

Assuming a direct relationship between pasture yield and milk production and that variable costs remain the same, a 10% reduction in pasture production will result in a fall in milk production of 1214 litres/ha valued at \$329.

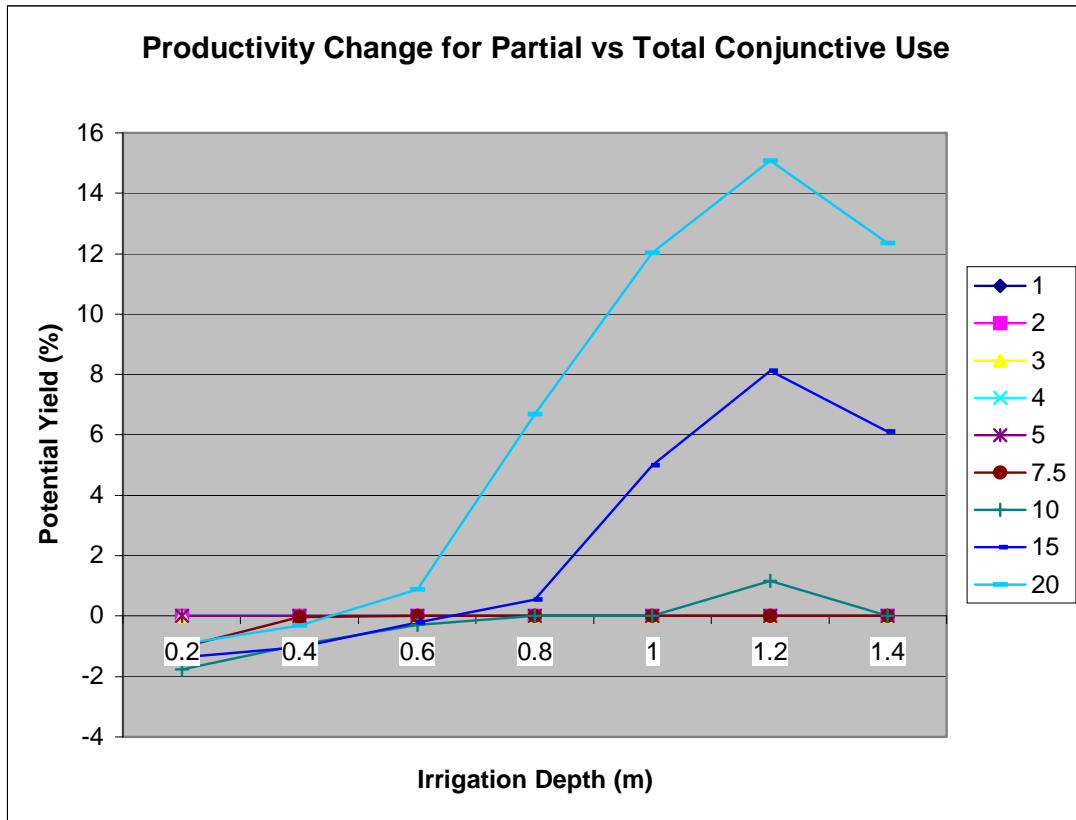
### **5.5 Partial conjunctive use to SIRLWSMP irrigation shandy limit and disposal of surplus groundwater.**

The modelling indicates that there is no significant improvement in pasture productivity with partial conjunctive use, except for systems underlain by 15 and 20 dS/m groundwater at high irrigation water use intensity (Figure 3).

Reduced gross margins will result from lower plant productivity. There will also be distinct costs for the various options for disposal of surplus groundwater.

#### **5.5.1 Disposal to river**

This is calculated as in section 5.1 although the volume for disposal is considerably reduced by partial conjunctive use.



**Figure 3: Change in productivity of perennial pasture: Partial vs total conjunctive use.**

**5.5.2 On farm disposal of groundwater surplus to partial conjunctive use.**

Perennial pasture production is lost on the disposal area. The cost will be the product of the area used for disposal by the difference in net cost of the disposal activity per hectare relative to perennial pasture.

**5.5.2.1 “Salt tolerant forage”**

Maximum potential production of Bermudagrass is assumed to be 70% that of perennial pasture (Kimbrough, 1998).

The effectiveness of the utilisation Bermudagrass dry matter by the dairy production system is assumed to be 70% of that for perennial pasture.

The combined effect of these reductions is that the dairy productivity of Bermudagrass in the base case low salinity situation is assumed to be 49% of that for perennial pasture. The higher salinity tolerance of Bermudagrass will reduce this difference in more saline situations. Variable costs are assumed to be identical with those for perennial pasture in each situation. The relationship between gross margins derived from these assumptions and the productivity estimated by the modelling are shown in Figure 4. Gross margins are still rising with increasing irrigation intensity for all groundwater salinities at 1.4 m depth of irrigation. The potential for high leaching fractions resulting from irrigation with high salinity water imposes limits on the depth of irrigation. The area required for disposal of groundwater surplus to



partial conjunctive use is thus calculated on the basis that 10 ML can be disposed by evapo-transpiration per hectare of Bermudagrass.

Surface supplies previously used on the disposal area are released for transfer to areas on or beyond the farm.

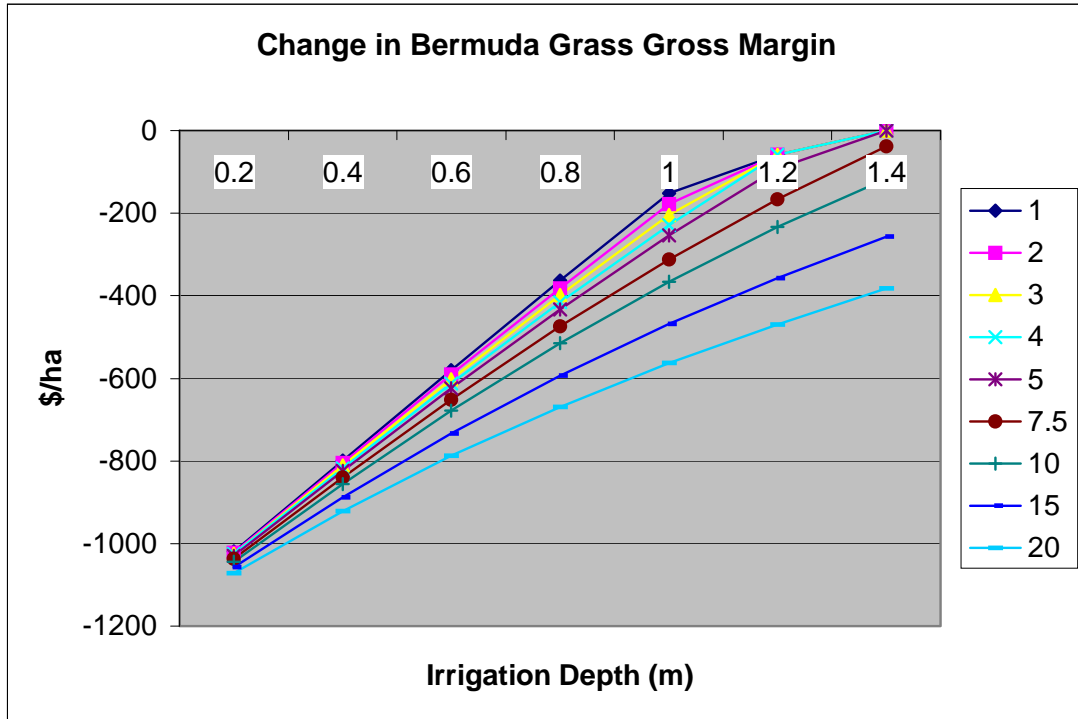


Figure 4: Change in Bermudas grass gross margin with irrigation depth and salinity.

#### 5.5.2.2 Evaporation basin

The capital cost is assumed to be \$6250/ha and disposal capacity 8 ML/ha

## 6. ESTIMATES FOR EACH STRATEGY

A matrix of annualised costs and benefits for the range of groundwater disposal options is shown in Table 1. The estimates shown in Table 1 are based for an irrigation depth of 1m and groundwater salinity of 20dS/m.

Table 2 sets out the total (net) annual cost for each option for the full range of groundwater salinities considered. The change in cost of disposal with groundwater salinity is shown in Figure 5.

The cost of Total Evaporative Disposal is the same for all groundwater salinities and is estimated at \$25,846 per annum. It is the most expensive option for all groundwater salinities except 20dS/m where the estimated annual productivity loss for the Total Conjunctive Water Use (TCWU) option rises to \$40,563.

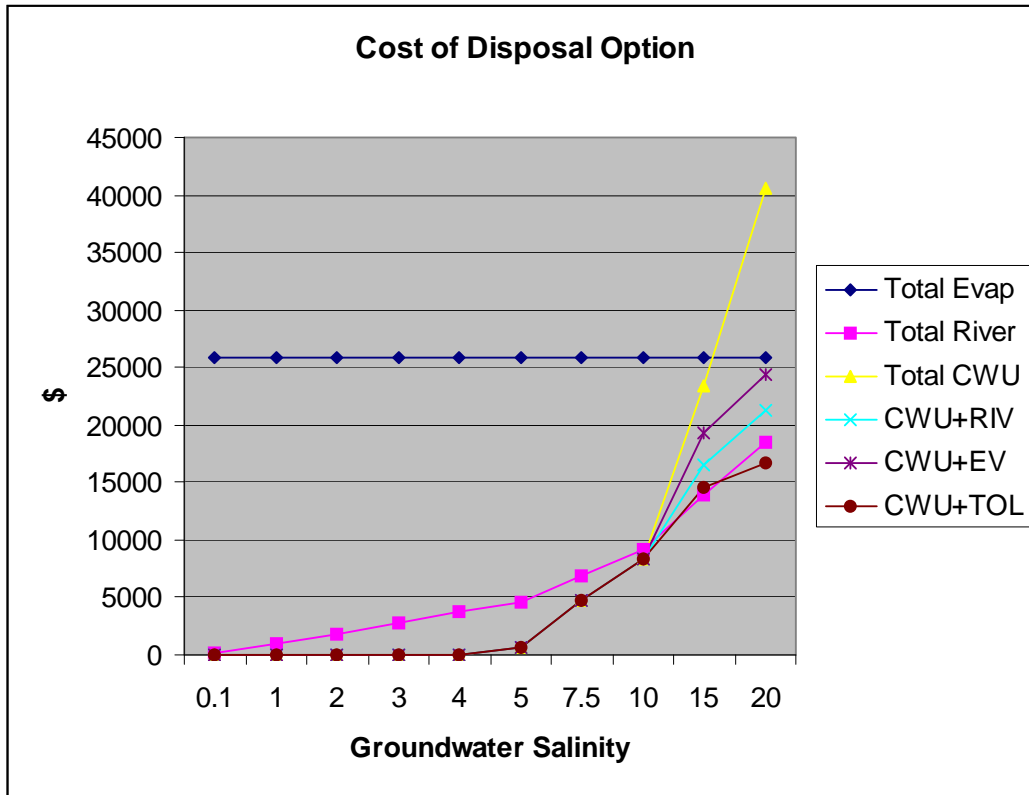
**Table 1: Matrix of costs and (benefits) for the range of disposal options.**

OPTION	RIVER IMPACT	BASIN COST	REDUCED PRODUCTIVITY	CHANNEL WATER SAVING	REDUCED AREA PERENN PAST	GM FROM BERMUDA GRASS	TOTAL
Total river disposal	18462	0	0	0	0	0	18462
Total evaporation	0	3641	0	(5270)	27475	0	25846
Total Conjunctive Use	0	0	40653	0	0	0	40653
Partial Conjunctive use	River	8046	0	13188	0	0	21234
	Evaporation	0	1585	13188	(2295)	11963	24441
	Tolerant For	0	0	13188	(1836)	9570	16628

**Table 2 : Estimated annual cost of groundwater disposal options for a range of groundwater salinities**

GROUNDWATER SALINITY (DS/M)	TOTAL EVAP	TOTAL RIVER	TOTAL CWU	CWU +RIV	CWU +EV	CWU +TOL
0.1	25846	92	0	0	0	0
1	25846	923	0	0	0	0
2	25846	1846	0	0	0	0
3	25846	2769	0	0	0	0
4	25846	3692	0	0	0	0
5	25846	4615	714	714 <sup>4</sup>	714 <sup>4</sup>	714 <sup>4</sup>
7.5	25846	6923	4744	4744 <sup>4</sup>	4744 <sup>4</sup>	4744 <sup>4</sup>
10	25846	9231	8331	8331 <sup>4</sup>	8331 <sup>4</sup>	8331 <sup>4</sup>
15	25846	13846	23438	16465	19304	14586
20	25846	18462	40653	21234	24441	16628

<sup>4</sup> See comments under section 5.5



**Figure 5: Change in cost with groundwater salinity for the range of disposal options (1 m depth of irrigation)**

The lowest cost options at each groundwater salinity form the lower bound of the graph in Figure 5. Reference to Table 2 shows that there are several lowest cost options at low groundwater salinity. For 0.1 to 10 dS/m groundwater, Conjunctive Water Use is the cheapest option. Below 4 dS/m, TCWU and Partial Conjunctive Water Use (PCWU) are equivalent as the irrigation salinity limit of the SIRLWSMP is not reached. Above 10 dS/m groundwater salinity, PCWU is cheaper than TCWU, with the disposal of the surplus groundwater to salt tolerant pasture being the cheapest sub option. For the options using total non-pasture disposal of groundwater, evaporation is a more expensive option than outfall to the river.

## 7. DISCUSSION

### 7.1 Farm and regional perspectives for optimising sustainable salt management

There are industry issues and resource management constraints affecting the widespread adoption of options for conjunctive water use. While these were extensively considered during the preparation of Land and Water Management Plans, it is appropriate to incorporate both new insights from hydrological research and recent trends observed in aquifer pressure and salinity into reviews of sub-surface drainage programs.

For this purpose, a number of points would warrant further consideration.

### 7.1.1 Channel water availability relative to land resources

The average water right for the Goulburn-Murray irrigation region is approximately 3 ML/ha. There is a wide range in water entitlement and water use intensity across farms and enterprises in the region.

Table 3 shows that less than 10% of dairy farms have water rights greater than 6 ML/effective ha<sup>5</sup> (Farmanco *et al*, 1999).

**Table 3: Distribution of water right intensity on dairy farms in the Goulburn Murray irrigation region (after Farmanco *et al* 1999)**

WR/EFF HA	GOULBURN	MURRAY VALLEY	TORRUMBARRY	GMID
0-3	29%	31%	29%	30%
3-4	28%	35%	30%	29%
4-5	27%	23%	25%	25%
5-6	10%	6%	11%	10%
>6	5%	7%	6%	6%

Thus most dairy farms would need to purchase transfer water to operate at the irrigation intensity used for this case study. As water, rather than land, is the limiting resource for dairy production based on irrigated perennial pastures, there is an opportunity to consider the economic implications of the interaction of other forage production systems and different water use intensities with the regional hydrology. The case study farm evaluation needs to be carried out for a range of farms and enterprises before the options can be fully viewed in a regional perspective.

This wider range would also allow consideration of the impact of seasonal variations in water allocations on the relative merits of the different disposal options.

A regional integration of land and water resources with disposal options and crop productivity should significantly reduce the estimated cost of evaporative disposal, since this study assumed that land was limiting and perennial pasture production was lost by construction of a basin (see Table 1). In the regional context, the opportunity cost of land would more likely be the value of dryland production foregone plus the transaction and other costs of the transfer of resources.

### 7.1.2 Trends in aquifer salinity

Increasing aquifer salinity will reduce the potential for conjunctive water use. Practices which accelerate rising trends will impose costs on groundwater disposal options. The benefits of groundwater pumping for water resources or exporting salt must be offset by the cost of earlier losses in pasture productivity and/or adoption of more expensive disposal options (Gyles *et al*, 1994)

### 7.1.3 Channel water salinity

Increasing channel water salinity will reduce the potential for conjunctive water use. The external costs of disposal of public groundwater pump effluent to irrigation channels must be fully considered.

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<sup>5</sup> 1 ha perennial pasture = 1 effective ha and 1 ha annual pasture = 0.5 effective ha

#### **7.1.4 Availability of Salt Disposal Credits**

It has been estimated <sup>6</sup> that there are only sufficient allocated salt disposal credits to continue the implementation of the SIRLWSMP until June 2001.

#### **7.1.5 Changing enterprise composition within catchments**

Disposal requirements will markedly increase as horticultural development continues. Given the scarcity of salt disposal credits, non-river disposal options will be required to handle the effluent produced by providing water table control to 2m depth for expanded permanent horticultural plantings.

#### **7.1.6 Sodicty implications of increasing conjunctive use.**

The costs of managing any deleterious effects of increasing soil sodicity arising from conjunctive use would need to be included in a more comprehensive evaluation, particularly if large productivity impacts were to occur well into the future.

### **8. CONCLUSION**

The costs of groundwater pump effluent disposal options for a 100 hectare perennial pasture dairy farm in the SIR have been estimated and compared.

On the basis of the assumptions used in this study, total conjunctive use with surface channel supplies is the cheapest disposal option for groundwater up to 10dS/m salinity. Given the restrictions on implementing river disposal, annual savings are around \$25,000 p.a. with conjunctive water use rather than on-farm evaporative disposal for groundwater salinity up to 5 dS/m. Savings decrease at higher groundwater salinity as the productivity of forage production under conjunctive use declines. While total conjunctive use becomes more expensive than total evaporation above 15 dS/m, partial conjunctive use with disposal of excess groundwater to salt tolerant forage is approximately \$9,000 p.a. less expensive than total on-farm evaporation. Beneficial use irrigating salt tolerant forage can be a profitable stage in the continuum of disposal options

There is considerable scope to rethink salinity management options for both sustainable agriculture and in strategies for managing the distribution of salt in the landscape to meet end of catchment river salinity targets. The biophysical modelling indicates potential solutions exist for both irrigated and dryland catchments.

Where the bounds of the study exaggerate the regional opportunity cost of the land required for construction of an evaporation basin, the relative merits of the on-farm disposal options should be evaluated using a modelling perspective integrating regional land and water resources with disposal options and crop type and productivity. The GIS based analytical tool "ASESS" developed by Kularatne and Abuzar (Gyles *et al*, 1999) would provide a spatial perspective at a regional scale for the analysis. This could be supplemented with sensitivity testing for changes in enterprise composition and the required standards of groundwater management due to trends in commodity prices, costs and water resource constraints using the inter-temporal model constructed by Montecillo (Gyles and Montecillo, 1998). This work should substantially contribute to the strategic review of sub-surface drainage programs by regional communities supported by resource management agencies.

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<sup>6</sup> Critchell S (2000) 'Allocation of Salt Credits' Draft discussion paper, CMSA, DNRE

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