

# **1. INTRODUCTION AND AIM**

## **1.1 Environmental Problems of Southern Murray-Darling Basin Irrigation Areas**

The Murray-Darling Basin (MDB) contains most of the irrigation areas in Australia. Of 1.6 million hectares of irrigated land in Australia, 1.2 million are located within the MDB (Haskew 1996). The Basin itself covers 1.06 million square kilometres which is 14 per cent of the total land area of Australia.

The irrigation areas in the Southern MDB face a number of environmental and agricultural production problems. Two of the major internal environmental concerns for farmers in irrigated areas of the Southern MDB are waterlogging and soil salinisation. Both waterlogging and soil salinity are exacerbated by the presence of watertables within two metres of the soil surface. Prior to irrigation, the watertable under these areas was 20 to 30 metres below the surface. The incidence of high watertables within the region has increased with the advent of clearing and irrigation.

There are two aspects of environmental degradation caused by rising watertables:

1. internal effects in the irrigation district relating to sustainable productivity and,
2. potential negative off-site effects from water discharge and wastes (McDermott 1993).

Undesirable external impacts are a consequence of natural conditions and inappropriate agricultural practices in the Southern MDB. The soils of the area are saline and the onset of irrigation has caused the mobilisation of this salt as watertables rise. Any salt discharged from pumping or drainage runoff cannot simply be returned to the river system because of lack of rainfall and river flows in these semi-arid regions. The salt is not diluted and causes environmental and agricultural productivity problems for downstream users.

The policies examined in this dissertation are evaluated within the context of minimising adverse internal impacts in the irrigation area and thus moving closer to the ultimate goal of a financially viable sustainable production system.

### **1.1.1 Waterlogging**

Waterlogging can be defined as reduced oxygen concentration in the root-zone of the soil resulting from soil becoming saturated. In the field there are two types of waterlogging. First, transient waterlogging from low soil permeability and, second, a long term effect which occurs because of a consistently high watertable.

### **1.1.2 Salinity**

Salinisation is defined as increased concentration of soluble salts within the root zone of the soil. There are two processes that cause salinisation. First, irrigation water carries small amounts of dissolved salt into the rootzone and, after evaporation, the salt is left behind. The second process occurs when watertable rise is sufficiently high to cause water to evaporate from the soil surface. The soils of the Riverine Plain are naturally rich in soluble salts and the rise in watertables causes capillary rise of saline water to the rootzone where the water evaporates and deposits salt. The high watertable also means that leaching salt from the rootzone is difficult. Increased salt levels have an effect on soil chemistry, soil physical structure, soil and rootzone biology, root growth and function, and ultimately crop growth and yield.

### **1.1.3 Sustainability of Irrigation Areas**

It is possible that areas currently irrigated in the Southern MDB will eventually become unproductive due to high soil salinity levels. The economic viability of irrigation systems has been questioned previously (Davidson 1969). McDermott (1993) states that the question of financial and economic viability of irrigation schemes over the long term is a key issue facing both Government and local management boards. Economic sustainability of irrigation schemes is defined as the ability of a scheme to meet its full economic costs and asset renewal without subsidy (McDermott 1993). This broader question of long term sustainability is addressed, in part, by local irrigation community Land and Water Management Plans (LWMPs) and it is not the question addressed in this dissertation. The dissertation concentrates on policy options available to irrigation communities to achieve productive and environmental sustainability rather than financial sustainability on a wider scale.

The abandonment of irrigated agriculture is a possible solution to the environmental problems facing the MDB. Comments such as 'we should get rid of most of our sheep, cattle and rice' by renowned botanist Mary White highlight the problems faced by irrigated agriculture (Norwood 1997).

#### **1.1.4 Current Policy and Framework of the Dissertation**

In NSW and Victoria government administered irrigation areas are either being privatised (Murray areas) or corporatised (Murrumbidgee Irrigation Areas and the Coleambally Irrigation Area). This process has included the development of local Land and Water Management Plans (LWMPs). These are community based strategies that aim to combat the problems of waterlogging and salinity by focusing on a range of options, on-farm, engineering and policy, that can be economically implemented. Following moves towards local autonomy through privatisation and corporatisation it is policy of the NSW Environmental Protection Agency that Areas and Districts will be issued drainage licenses (McDermott 1993).

At a national scale, the Council of Australian Governments (COAG), through their Water Resources Policy of February 1994, have made a number of recommendations to reform the irrigation sector including full cost recovery in water charging, provisions for environmental flows and fully tradeable water entitlements. These reforms are expected to be fully implemented by the year 2001.

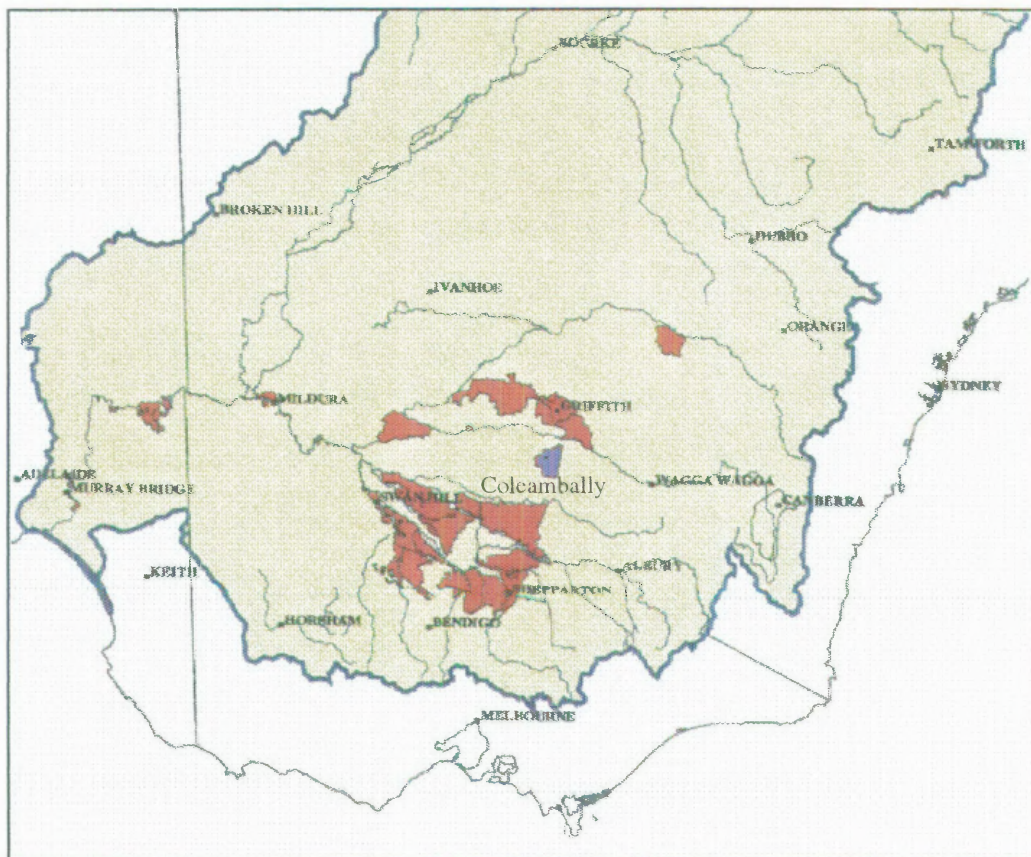
The policy options available at a local irrigation area level to encourage improved efficiency of irrigation water application will be effected by the broader policy background. The larger question of whether the policies achieve global economic efficiency is not addressed. It is assumed that the policy goal is to achieve sustainability of Southern MDB irrigation areas with options that maintain financial viability of irrigation farms while minimising the effect of farm practices on waterlogging and salinisation.

For the purposes of this dissertation, a case study irrigation district, the Coleambally Irrigation Area (CIA) is examined. Many of the problems facing the CIA are shared by other irrigation areas in the region. It has been estimated that by the year 2023 Coleambally will have 60,000 ha of a total 89,000 ha with a shallow watertable less than two metres from the surface (Coleambally LWMP 1996).

## 1.2 The Coleambally Irrigation Area

The Coleambally Irrigation Area (CIA) is located in the Riverina region of NSW. It was developed for irrigation between 1960 and 1970 making it the newest irrigation area in NSW. The CIA is located 60 km south of the city of Griffith on the southern side of the Murrumbidgee River. Irrigation water is diverted from the Murrumbidgee River at Gogeldrie Weir and drainage is sent to the Murray River via the Yanco and Billabong Creeks.

The CIA covers an area of 79 160 hectares. There are 311 'large area' farms in the region and 22 horticultural farms. The area measures 40 kms from north to south and 25 kms east to west (Coleambally LWMP 1996).



**Figure 1** Location of the CIA and other irrigation areas within the Southern Murray Darling Basin.

### 1.2.1 Estimated Costs of Salinity and Waterlogging in the CIA

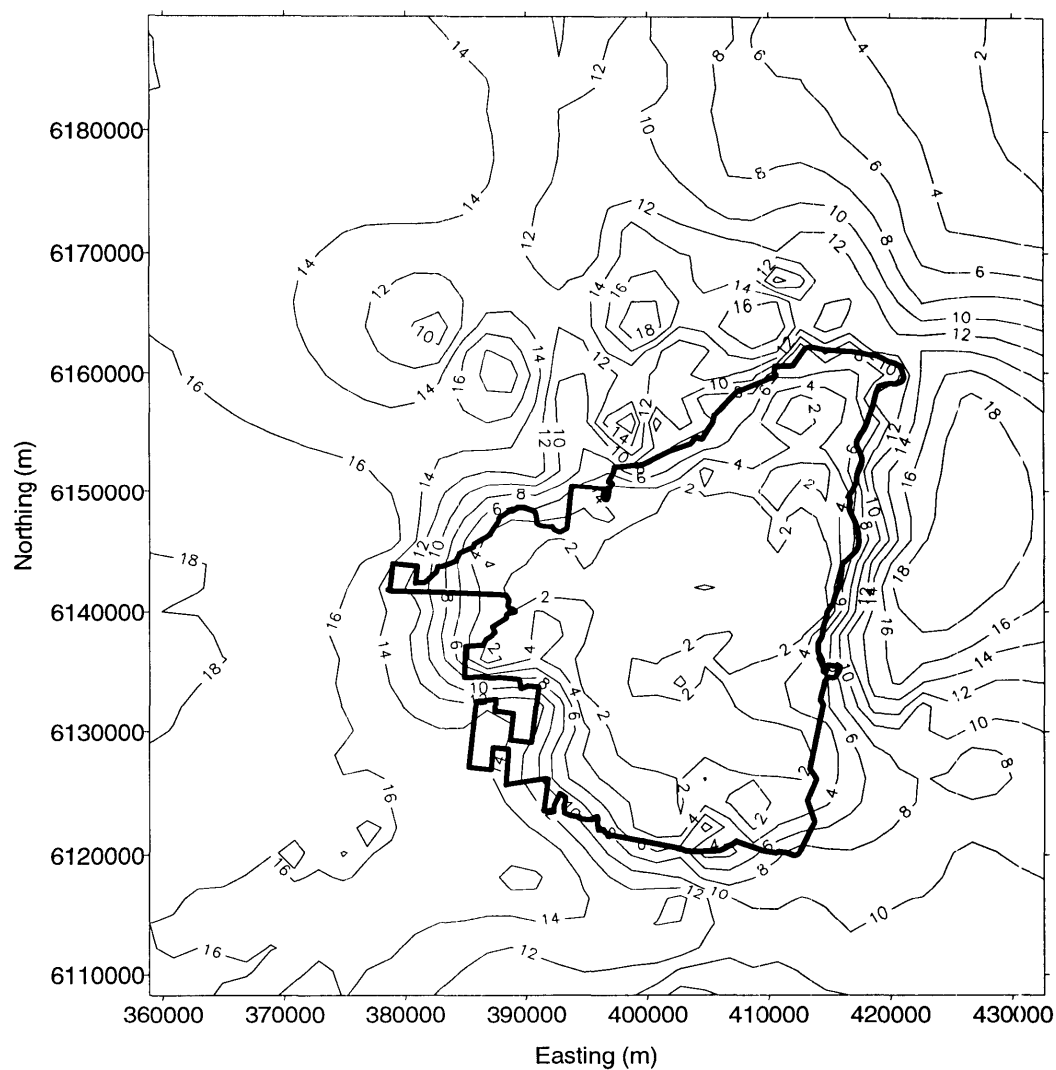
A 'current trends' scenario has been undertaken in the Coleambally LWMP to examine the likely economic impact on agricultural production of an increased area of shallow watertables. A value of \$15.55 million over a 30 year period has been placed on decreased farm gate revenue from impacts of waterlogging and salinity. This figure does not include flow-on effects to the general community and downstream users or damage to infrastructure.

The major contributing factor to waterlogging and salinisation is depth to the watertable. The watertable is high throughout most of the area (Figure 2). The groundwater contours show large areas where the watertable is within two metres of the soil surface.

To control waterlogging and salinity, the depth to the watertable is critical and needs to be managed. If the watertable depth is greater than approximately two metres there may be adequate capacity in the soil to allow a leaching fraction from irrigation to wash salts past the rootzone thereby maintaining productivity. Irrigation water from the Murrumbidgee River is not the major cause of salinity though it does have a minimal effect. Van der Lely (1994) has estimated that some 630 kg ha<sup>-1</sup> yr<sup>-1</sup> of salt is added to the CIA through irrigation water which is very minor when compared to the amount of salt stored in the soil.

The CIA community recognises the problems it faces from rising watertables. One of the objectives of the community LWMP is:

*'to control net recharge to the groundwater so that the area of land affected by salinity (defined as rootzone soil salinity not greater than 2 dS m<sup>-1</sup>) does not exceed more than 15% of the total land area.'* (Coleambally LWMP 1996).



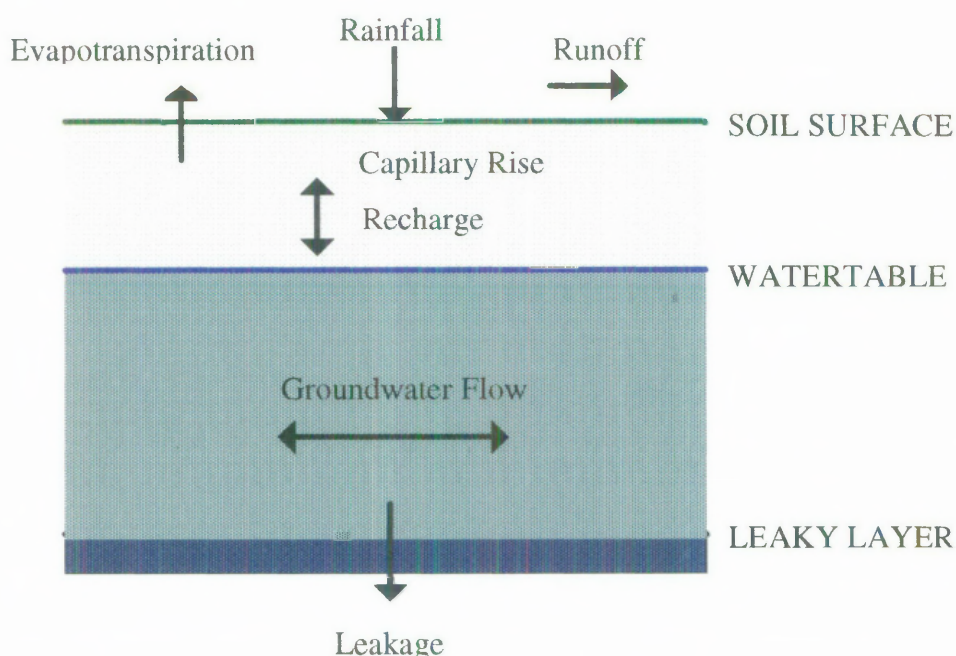
**Figure 2** Contour map of the depth (m) to the watertable from soil surface in the Coleambally Irrigation Area for 1995

### 1.3 Net Recharge

Salinity and waterlogging of irrigation areas on the Southern MDB are caused by net recharge to the watertable. The control of net recharge through a range of options is critical to the productive sustainability of irrigation areas in these semi-arid regions.

### 1.3.1 The Net Recharge Process

The rise in the watertable is caused by an increase in net recharge. Net recharge is defined as recharge minus discharge and is dependent upon three factors: recharge from irrigation and rainfall, capillary upflow from the watertable and leakage to deeper aquifers.



**Figure 3** The determinants of net recharge

There are two options to prevent further watertable rise available to the irrigation area as a whole. Given that lateral movement of groundwater is extremely slow and downward leakage rates are small, either (1) the amount of water entering the watertable must decrease or (2) the amount of water leaving the watertable must increase.

### 1.3.2 Net Recharge Management (NRM)

There is no single solution to the problem of net recharge rather, a number of cost-effective partial solutions must be considered (Prathapar 1994). Three models have been developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land and Water to evaluate options to control salinity through net recharge management.

The first model can be used to evaluate solutions to manage net recharge at an individual farm level.

The second group of models (the subject of this dissertation) can be used to assess various policy approaches to manage net recharge in terms of their likely impact on farm viability and effect on cropping patterns. This work provides information that will enable informed decision making on water usage policy by the resource managers in the CIA. The approach can be transferred to other irrigation areas within the Southern MDB by changing input data.

The third model concentrates on engineering options at a regional level and incorporates a groundwater simulation model.

### 1.3.3 The Scope for Improvement

The aim of the CIA LWMP and the NRM project is to improve water use efficiency (WUE). The scope for improvement in WUE in the CIA is indicated by the standard deviation of water ordered for rice from 1987-1994 (Table 1).

**Table 1** Summary statistics of water ordered for rice (ML ha<sup>-1</sup>)

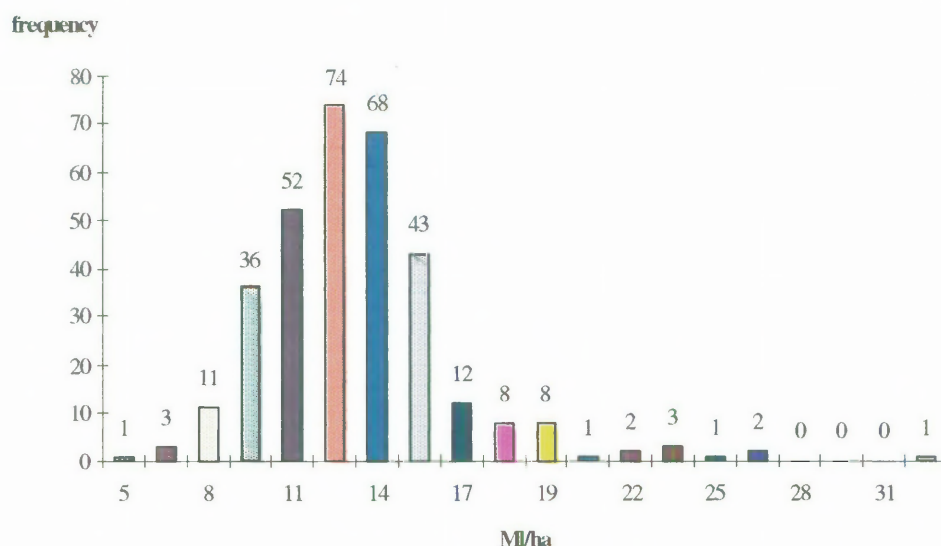
|                  | 87/88 | 88/89 | 89/90 | 90/91 | 91/92* | 93/94 |
|------------------|-------|-------|-------|-------|--------|-------|
| <b>Count</b>     | 289   | 296   | 309   | 313   | 323    | 326   |
| <b>Mean</b>      | 17.4  | 15.0  | 14.5  | 15.3  | 14.8   | 12.3  |
| <b>Std. Dev.</b> | 3.4   | 2.7   | 2.8   | 3.0   | 3.0    | 3.3   |
| <b>Minimum</b>   | 10.9  | 9.6   | 6.7   | 2.2   | 5.0    | 5.1   |
| <b>Maximum</b>   | 51.6  | 30.6  | 25.7  | 31.7  | 34.4   | 32.4  |

\*Data not available for the 1992/93 season

Currently only rice water use in the CIA is monitored by the local irrigation authority, Coleambally Irrigation. Recent shifts towards row cropping, the presence of winter cereals and pastures and the adoption of on farm recycling mean that data on rice water usage for some farms is unclear or incomplete. The CIA LWMP aims to introduce monitoring of all crop water usage to resolve this problem.

A histogram of rice water application per ha for the year 1993/4 (Figure 4) shows the variation in the amount of water applied by farmers. The range may be

caused by differences in soils, watertable depth or management. The histogram demonstrates that there is likely to be room for improvement in WUE on some farms.



**Figure 4 Histogram of 1993/94 rice water use**

In an average year the evapotranspiration requirement for rice is  $12 \text{ ML ha}^{-1}$  (Humphreys and Meyer 1996). The Department of Land and Water Conservation presently has a  $16 \text{ ML ha}^{-1}$  target rice water consumption for the CIA. If particular paddocks cannot meet this level of WUE the local irrigation authority, Coleambally Irrigation should remove the paddock approval for rice growing.

#### 1.4 Policy Options Identified to Reduce Net Recharge

Policy as defined by Reichelderfer and Kramer (1993) is 'any intervention of the government in the economy'. A number of policies are identified in the Coleambally LWMP which could help alleviate the problem of rapidly rising watertables and increasing soil salinity. These policy measures have been listed as:

- water allocations
- internal water transfers
- water pricing
- drainage charges
- subsidy schemes
- taxation incentives.

Other policy options include:

- reduction in off-allocation water allowances
- setting farm development and operation guidelines for water entitlements
- rescinding of unused entitlements
- property amalgamation policies
- reduction in rice growing areas
- drainage quotas

Policies can be categorised into ‘command and control’ policies such as the reduction of rice growing areas, or economic instruments such as pricing. Economic instruments in principle improve the efficiency and effectiveness of policy in three ways: (1) reduce the cost of achieving a given level of environmental protection by allowing greater flexibility, (2) stimulate more rapid innovation in pollution abatement and (3) some economic instruments may raise revenue that can be used for reclamation.

For the purposes of this study, analysis will focus on reduced water allocations, increased water prices and the introduction of a tiered water price structure. The framework and models developed for this purpose can be used to analyse other policies.

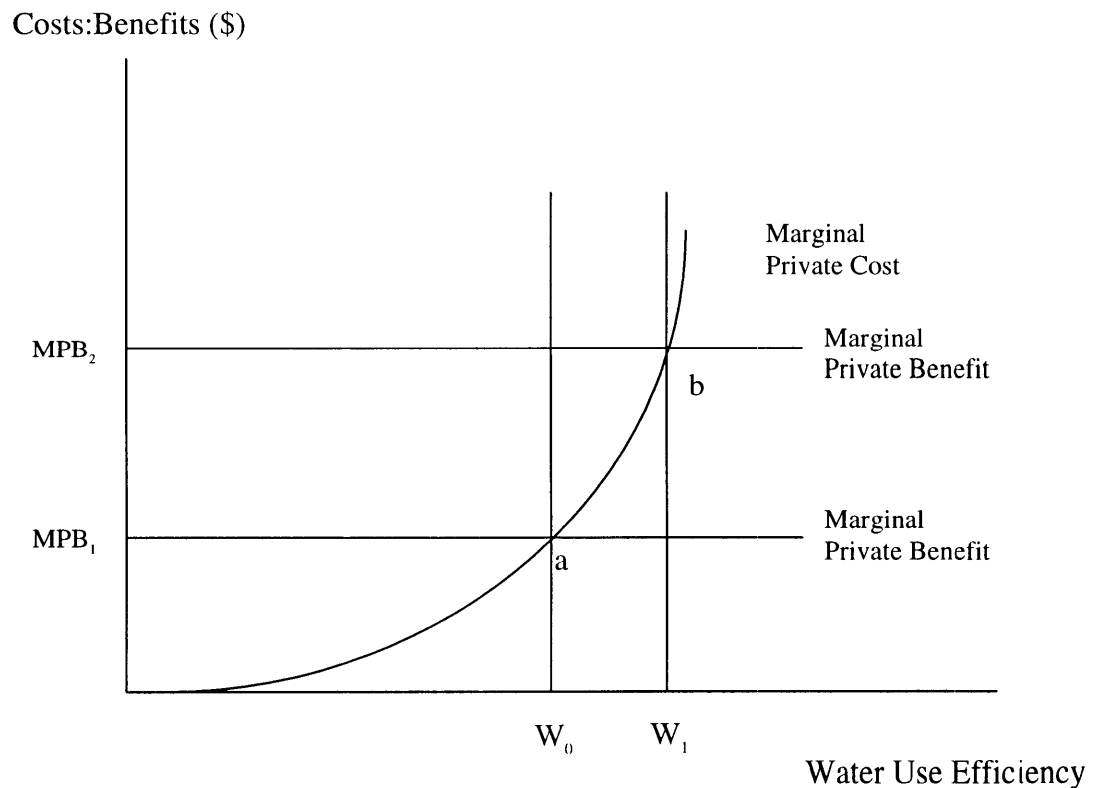
## **1.5 Water Use Efficiency as an Economic Goal and Protection of the Natural Resource**

Water use efficiency (WUE) can be defined a number of ways. WUE is usually defined by scientists as ‘yield per unit of water applied or transpired’ (Dinar 1993). There has been considerable scientific work carried out on WUE and on how to increase WUE in irrigated agriculture.

As this dissertation is concerned with the problems of salinity and waterlogging, the concept of WUE is modified to emphasise efficiency in terms of minimising the impact of irrigation on the watertable net recharge. Thus irrigation efficiency is defined in terms of excess water applied to a hectare of land in excess of the evapotranspiration ( $E_t$ ) rate associated with the land use of that hectare. Increasing the WUE of farms in the CIA using this definition will also lead to increased WUE as defined by Dinar above.

The economic considerations that must be accounted for when farmers address the question of WUE are complex. Improved WUE will achieve direct and indirect benefits to the farmer. As farmers tend not to account for externalities and the full cost of water is not currently charged to irrigators (Industry Commission 1992) the value of WUE differs from private and public viewpoints.

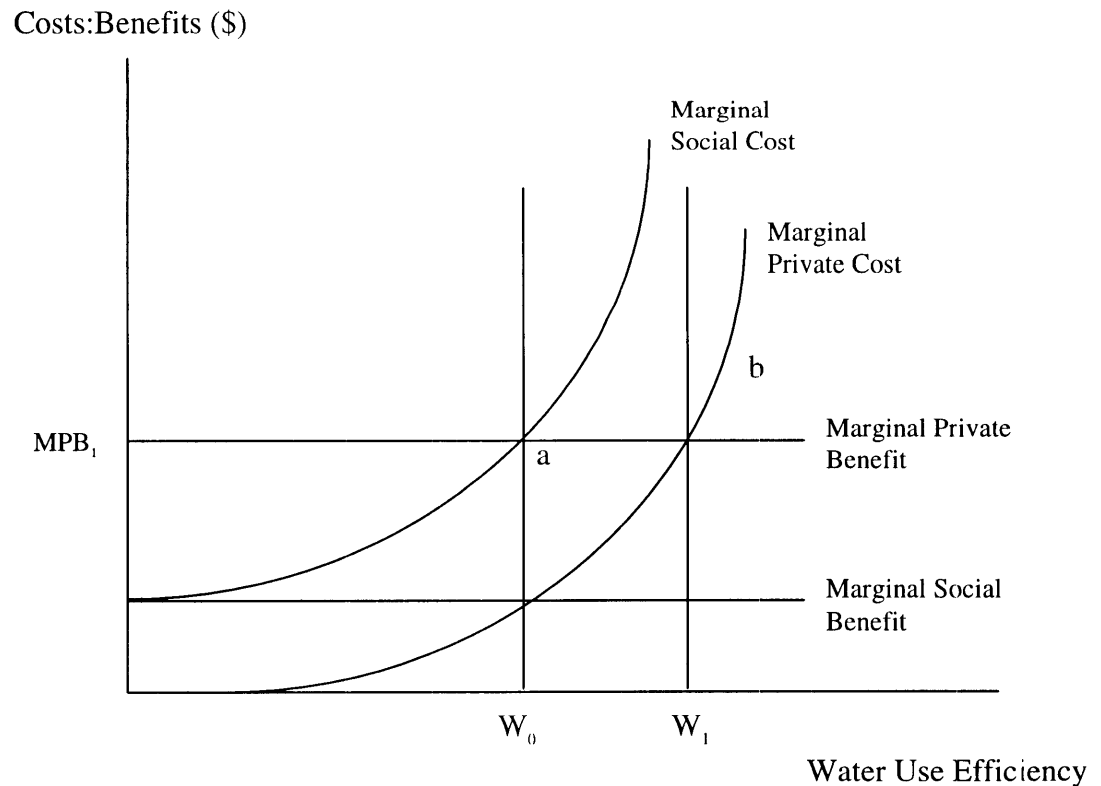
Costs from increasing WUE can be weighed against benefits such as the increased opportunity to crop or the ability to sell part of the water allocation. Dinar (1993) plots the Marginal Private Costs (MPC) and Marginal Private Benefits (MPB) as shown in Figure 5. The optimal level of WUE is found when  $MPB = MPC$ . The optimal private solution for WUE is found at  $W_0$ .



**Figure 5** Private benefits and costs of improving water use efficiency

If the benefit from increased WUE increases from  $a$  to  $b$  due to a higher water price, or the introduction of a water market, then  $MPB_1$  increases to  $MPB_2$ . The optimal WUE is then  $W_1$ . Social costs are not included in this analysis. Social costs may include the lost value of water from alternative uses or damage caused by salt downstream.

If social costs are included in this analysis and assumed to be linearly related to WUE then the total marginal cost curve shifts upwards (Figure 6). The optimal private WUE for the irrigator ( $W_1$ ) will be different to that for society ( $W_0$ ). From an economic efficiency standpoint, private and socially optimal WUE values should be equal at the socially optimal value.



**Figure 6 Private and social benefits and costs of improving water use efficiency**

The social costs that are evident in the CIA can be identified as recharge to the watertable and external drainage. That is, water applied in excess of the  $E_i$  requirements of the crop. This is easily identified but quantifying and costing the amount of net recharge and drainage can be very difficult since these are hard to measure and the impact is in the form of environmental degradation which varies chronologically and spatially. These effects are currently ignored in the cost of

water. The planned levy for the funding of the LWMP initiatives is a charge that accounts for some of the degradation caused.

This internalisation of the social costs of low WUE is the goal of policies identified by the CIA LWMP Committee. The policies outlined in this dissertation aim to bring actual WUE as close as possible to the best potential WUE (here defined as  $E_t$  requirement) at both paddock and farm levels. It is assumed that implementation of new technologies and better cultural practices will improve WUE. This step may be economically feasible, though other factors will effect the overall feasibility of a policy aimed at encouraging the uptake of improved technologies and practices.

## 1.6 Aim of Dissertation

The study aims to provide a framework to evaluate various policy instruments in terms of increased WUE and therefore, net recharge reduction in the CIA, and the resulting financial effects on farms. Three options will be considered in the investigation. These are reduced water allocations, flat water price increases and tiered water pricing.

These policy reforms would impose pressures on the farmers of Coleambally. The level of financial performance and the ability to adapt is important information that will impact both on the community and on the adoption of environmentally sound practice. Farmers will also face different opportunities and constraints in adjusting to policy reforms, depending on their individual resources and financial situations.

There are a number approaches that can be taken to analyse farmers' responses to rising watertables and policy instruments. These include gross margin budgeting, benefit cost analysis, static simulation modelling and dynamic programming modelling (Hall *et al.*, 1995). In this study, representative farms will be specified to evaluate the three policy options. A combination of whole farm budgeting and a linear programming model is used to analyse the impact of policies on total water costs, farm incomes and enterprise mixes on the representative farms.

Water should be treated as an economic resource as recommended by COAG. However, a number of criteria should be used to evaluate any water policies (FAO 1995). These are listed below and will be used as a guide to assess the policies:

1. Effectiveness: Reform is not a costless exercise and it is therefore necessary that any policy will have a 'pay-off' in terms, of achieving its goals.
2. Economic Efficiency: This criterion requires that benefits of policies exceed their costs.
3. Equity and distributional effects: Policies should be seen as fair in their effect on different groups.
4. Fiscal Impact: The impact on revenue for the irrigation authority is of crucial importance.
5. Political and public acceptability: There are generally winners and losers in any policy change and policies need to be judged with this in mind.
6. Sustainability of effect: Some policies have a one-off impact while others affect long term water use and may increase in their impact over time because they provide incentives for continuing and cumulative effects.
7. Administrative feasibility: Monitoring and enforcement is necessary for any policies.
8. 'Soft effect': Refers to various possible effects of policies in terms of changes in attitude, generation and diffusion of information. These impacts are impossible to quantify but can be important.
9. Policy mix: What is the cost of a do-nothing scenario and what is the best balance between 'command and control' measures and economic instruments relying on incentives.

## 1.7 Hypothesis of the Dissertation

The main hypothesis of the dissertation is that:

*Tiered water pricing will have a less deleterious impact on irrigation farm incomes in the CIA than will a flat price increase or reduced allocations. Further, that tiered pricing will have a positive effect on reducing net recharge in the Irrigation Areas of Southern NSW.*

## **1.8 Outline of Dissertation**

The first step in evaluation of proposed policy options for the management of net recharge in the CIA is the specification of policy detail. These options are explained in Chapter 2 and the advantages and disadvantages of each are discussed.

Chapter 3 specifies a whole farm financial model for the CIA and provides a review previous work based on this type of model to analyse the impact of policy on farms. The Coleambally Farm Financial Model (CFFM) is based on four representative farms that are typical for the area. The CFFM uses @Risk simulation techniques to provide a short run analysis of the effect of policies on farm viability.

Chapter 4 provides a specification of a linear programming model for a representative farm for the CIA. A review of programming models developed to analyse the performance of irrigation farms and the impact of policies on farm viability and enterprise mix is provided. This model will provide a preliminary analysis of the impact of policy options on the enterprise mix within the CIA.

Chapter 5 reports the results of the financial and linear programming model for each of the policy options described. A range of farm types and policy scenarios are examined.

Chapter 6 uses the results to draw conclusions as to how the policy options will effect farm incomes in the Coleambally Irrigation Area. Some discussion as to which option is acceptable to the community and it's likely impact on net recharge will also be provided.

## 2. SELECTED POLICY OPTIONS TO REDUCE NET RECHARGE

### 2.1 Reduction of Farm Irrigated Water Allocation

#### 2.1.1 Introduction

In NSW, the Department of Land and Water Conservation (DLWC) confers rights to take and use water through an allocation system on regulated rivers where 'regulated rivers' are those waterways controlled by a dam. The entitlement is to a specified number of megalitres of 'allocation water'. Users are also permitted access to 'off-allocation' flows when critical flow conditions are met. These off-allocation flows are charged to the user and are only available to license holders.

Holders of normal security licenses may receive their entitlement depending on the availability of water in storage. In the south of NSW it is unusual for license holders not to receive their full allocation while in the north it is uncommon for a license holder to receive a full entitlement volume.

The present volumetric allocation scheme for the Murrumbidgee Valley is based on historical precedent of unknown origin rather than seasonal crop usages. In the CIA the allocation is based on farm area as described in Table 2.

**Table 2      Formula used to calculate the volumetric allocation for CIA Farms**

| Farm Type               | Criteria and allocation MI ha <sup>-1</sup> |    |
|-------------------------|---------------------------------------------|----|
| For Large Area Farms    | 1. First 120 ha                             | 6  |
|                         | 2. Next 60 ha                               | 10 |
|                         | 3. Subsequent 160 ha                        | 2  |
| For Horticulture Farms  |                                             | 12 |
| For Miscellaneous Farms |                                             | 6  |

Source: Coleambally LWMP Committee (1996)

The average area of broadacre farms in the CIA is 242 ha (A. Rzeszkowski 1994, pers. comm.). From Table 2, the irrigation water allocation based on this area for a single farm is 1444 MI.

The total allocation for the CIA amounts to 481 383 Ml yr<sup>-1</sup> and annual consumption has ranged from 380 000 Ml yr<sup>-1</sup> to 600 000 Ml yr<sup>-1</sup>. Off allocation flows are available in 9 out of 10 years.

Water sales in 1994/95 were low because of the extreme drought restricting the initial announced allocation. Coleambally Irrigation sold a total of 443 388 Ml which was made up of 433 686 Ml sold to Coleambally farmers and 9,702 Ml delivered as transfers into the area for the Kerarbury Channel (Coleambally Management Board 1995). Water usage by CIA landholders amounted to 89.6 per cent of total allocation. Total income from water charges in 1994/95 was \$4 3678 000.

There were 101 water transfers out of the CIA which totaled 17 193 Ml or 3.6 per cent of the total allocation.

### **2.1.2 Policy Background**

The Council of Australian Governments (COAG) addressed issues concerning irrigation allocations and pricing through their Water Resources Policy at their February 1994 meeting. All Australian Governments at the Federal and State level endorsed a number of principles that relate to the issues discussed in this dissertation. Pertinent principles for the issue of farm irrigation water allocation are that governments implement comprehensive systems and water allocations to use water by:

- separating user entitlements from land title,
- clearly specifying entitlements in terms of ownership, volume, reliability, transferability and quality,
- formally determining water allocations to the environment,
- making substantial progress by 1998 towards providing a better balance in water resource use where river systems have been over allocated.

The Independent Pricing and Regulatory Tribunal of NSW (IPART) also recognised the role that allocation will have in policy by stating 'Non-price mechanisms are likely to be the most effective way of achieving environmental improvements' (IPART 1996).

In July 1995 a cap was placed on water extraction from the MDB. This policy was set by the Murray-Darling Basin Ministerial Council and prevents the member states from extracting water above 1993/94 levels after allowing for seasonal conditions. The aim of the policy is to arrest the decline in river 'health' within the MDB. The cap is administered by the DLWC in NSW. The cap is interim in nature and at the time of writing is under review.

A number of agencies are also involved in providing specific water entitlements for the environment and obtaining water quality objectives. Currently a number of discussions regarding River Flow Objectives and Water Quality are nearing completion. Both the NSW Environmental Protection Agency (EPA) and the DLWC are involved in this process and the recommendations stemming from these deliberations are likely to have a significant impact on the allocations to existing water users.

The DLWC have floated a methodology for calculating CAP diversions based on net evapotranspiration ( $E_t$ ) requirements and historical diversions. The CAP may be determined by the formula:

$$CAP = 1.18 * (NetE_t) + 470$$

where  $NetE_t$  is annual net evapotranspiration in gigalitres (Gl) with error bands of +/- 150 Gl around this figure.

Irrigators in the CIA have seen a reduction in their normal announced allocation over the past two years as a result of drought and changes in government policy. The cap has seen the apportionments in the CIA reduced from 120 per cent to 100 per cent of allocation under the interim cap (Area News 1997). In addition to these reductions, formalised volumetric extraction limits have been placed on 'off-allocation' water where none existed previously.

### **2.1.3 Advantages of Reducing Irrigation Allocations**

The introduction of reduced water allocations has a number of effects which may be advantageous to certain groups. The following lists some of the effects of introducing a policy of reduced allocations and the likely reaction from various sections of the water industry:

- reducing allocations is easy to implement by irrigation authorities,
- farmers can easily understand the concept of reduced allocations,
- likely to be equal in impact on farm allocations and

- may encourage a more active water trading market, possibly leading to increased efficiency on a catchment scale.

#### **2.1.4 Disadvantages of Reducing Irrigation Allocations**

As well as any perceived advantages, a reduction in allocations may have negative effects. These include:

- unpopular with irrigators,
- will impact upon farmers who are not causing environmental damage,
- likely to reduce incomes and increase levels of farm debt and
- will impact upon the value of property and not be compatible with levels of investment based on a higher allocation.

## **2.2 Flat Water Price Increase**

### **2.2.1 Introduction**

The DLWC is responsible for allocating the States water supplies. On regulated rivers it also has the responsibility of delivering bulk water to irrigators. The DLWC has sought to recover some costs through license fees, metering charges and volumetric charges. Volumetric charges only partly covered the costs of managing the rivers. Roughly 70 per cent of costs are recovered from users through volumetric charges (Government Pricing Tribunal 1995).

Increased water prices should lead to an increase in the efficiency of water use. However, the current discussion about water pricing is not aimed at controlling watertable rise and salinity specifically, rather, the focus is on cost recovery and provision of environmental flows.

At present CIA irrigators pay for their water on a mainly volumetric basis with a small fixed component under a water pricing matrix that provides a stable revenue base for Coleambally Irrigation. The matrix ensures that water prices do not need to be increased to offset reduced sales in high rainfall years.

### 2.2.2 Policy Background

An interim review of bulk water prices by the Independent Pricing and Regulatory Tribunal (IPART) was released in October 1996. This review is part of a larger reform process driven in part by COAG. Important COAG principles that impact on irrigation water pricing are;

- adopt pricing regimes based on the principle of consumption based pricing, full-cost recovery and removal of subsidies. Where cross-subsidies continue to exist, they should be made transparent.
- agree that charges and costs for rural water users be reviewed progressively so that they comply with the principle of full cost recovery with any cross subsidies made transparent and achieve positive real rates of return on the written-down replacement costs of assets in rural water supply by 2000, where practicable.

Price has played a limited role in the allocation of water resources. Traditionally, NSW water authorities allocated water at prices that did not cover the operating and maintenance costs of water services or the capital costs of the infrastructure. The pricing objective of IPART is to have charges that recover the efficient costs incurred by the DLWC in delivering water and administering the associated resource management and licensing activities (IPART 1996). In practice, IPART is to set maximum prices for those government-owned monopoly enterprises referred to it by the Premier. DLWC has the role of resource management, regulation and supply to six privatised or corporatised irrigation areas and many other irrigation districts.

IPART recognises that environmental costs associated with the irrigation practices are not well understood and suggests that non-price measures are likely to provide a more appropriate response than price mechanisms alone. One of the key recommendations from the IPART report was that charges should be based on a two part tariff composed of an access charge based on fixed costs and a usage charge based on variable costs (IPART 1996).

The NSW Irrigators Council have said that in the MIA water costs represent 20-25 per cent of farm variable costs which implies that a large water price increase will have a major effect on farm viability. This reduction in viability may actually decrease the ability of farmers in the irrigation area as a whole to implement the LWMP options identified to increase WUE. It is important to

know what effect increases in prices will have on the incomes and investment options of farmers within the CIA.

### **2.2.3 Advantages of Increasing Irrigation Water Prices**

Arguments for implementing increased water prices include:

- attractive to water administrators because it is easy to introduce,
- farmers can easily understand the concept of higher water prices,
- equal in likely impact and
- will increase revenue for the Government which could be use for environmental projects.

### **2.2.4 Disadvantages of Increasing Irrigation Water Prices**

Any introduction of increased water prices will also have adverse effects on various sections of the irrigation water industry, in particular on the irrigators. Negative aspects of a prices increase are:

- will impact upon farmers who may not be causing environmental damage,
- if the elasticity of demand for water is high a price increase may reduce farm income and increase farm debt and
- political considerations will have to take into account that any price increase will be unpopular with irrigators.

The MIA Horticulture Council (1996) argue that increased water prices are not the appropriate mechanism to improve WUE and encourage environmental reform. The Council quote a paper presented by Ian Carruthers at a FAO Conference in Rome (1986) 'Furthermore, waste will be minimised if farmers have high value-in-use for irrigation water. It is high value water not high cost water that prevents waste. Farmer profitability is thus the first criterion of success'.

## **2.3 A Tiered Block Pricing Structure**

### **2.3.1 Introduction**

As part of the Water Resources Policy, COAG also endorsed the National Strategy for Ecological Sustainable Development. An objective of this strategy is to develop 'functional' water resource management mechanisms. Two of the Government undertakings were to:

- examine and determine within their own jurisdiction, the most effective mix of water resources management mechanisms, including appropriate pricing policies, regulatory measures, long-term monitoring strategies, adequate research support, and a better use of the existing infrastructure.
- continue to develop methodologies by which the environmental externalities can be reflected in water pricing.

IPART recommends that:

- pricing policy should promote ecologically sustainable use of water and of the resources used to store, manage and deliver that water (IPART 1996).

IPART (1996) also suggests that the appropriate role of pricing policy in achieving ecologically sustainable development is to complement non-price mechanisms such as restricting water extractions and discharges to specific water bodies. It argues that the development of better ways to include external costs in water prices should also be a goal of pricing policy development. The tiered block pricing structure is an attempt to provide a direct link between environmental damage and the pricing system.

### **2.3.2 Outline of a Tiered Block Pricing Structure**

A tiered pricing scheme involves having a number of prices or tiers linked directly to WUE. The tiers are related to the water needed to meet crop evapotranspiration ( $E_t$ ) demand. Tiered pricing therefore uses scientific principles to link prices to environmental damage from the use of water for irrigation.  $E_t$  is comprised of evaporation from the soil surface ( $E_s$ ) and transpiration from crop foliage ( $E_p$ ). The rate of  $E_t$  when soil water is not limiting depends on (1) the energy available, (2) the crop type and (3) the crop foliage development (Meyer 1985). Different species vary in the rate at which they lose water.

If there are three tiers in a pricing structure, the first tier will be on water applied to meet the  $E_i$  requirements of a crop, the second tier will be levied on an acceptable level of irrigation over this  $E_i$  requirement. This level of 'inefficiency' is necessary to provide a leaching fraction which washes salts through the rootzone and to recognise physical limitations on the concept of best management practice. This addition to the watertable should be set at a level that provides a suitable leaching fraction and also falls within the bounds of natural dissipation mechanisms. This principle is an element of net recharge management concept. Tier 2 can be specifically determined for individual farms using tools such as SWAGMAN<sup>®</sup> Farm developed by CSIRO in conjunction with Coleambally Irrigation as part of the Net Recharge Management Program.

Water that is applied to a crop in excess of the first and second tiers either drains or causes the watertable to rise. This water will be levied at a price sufficient to recover the costs associated with the damage caused by a rise in the watertable. This cost could be approximated through a salinity loss production function or by calculating the costs of alleviating the problem through pumping and using this figure as an opportunity cost of damage controls. The pricing structure has  $P_1 < P_2 < P_3$ . The setting of tiers and their associated price levels is a question of balancing the level of economic and non-price controls to achieve an effective and equitable set of incentives to improve WUE.

A tiered price structure is an alternative to a general flat price increase per megalitre. The tiered pricing scheme is designed to focus on WUE and to provide incentives for farmers to be more efficient.

The following example illustrates the proposed tiered pricing structure.

Mr and Mrs Smith own 200 ha of land in the CIA. They grew 69 ha of rice and 40 ha of soybeans in 1994/95. Studies show that for most years in the CIA, the evaporative requirement of rice and soybeans is in the order of 11 ML ha<sup>-1</sup> and 8 ML ha<sup>-1</sup> respectively.

The irrigation water required to meet the evaporative demand of rice and soybeans will be 1079 ML ( $69 \times 11 + 40 \times 8 = 1079$  ML). This amount will be at the first tier of water price for this farm.

If the acceptable level of loss from farm channels, surface drainage and soil evaporation is 20 per cent of the evaporative requirement of this farm, then the

acceptable excess water use in this farm is 216 MI ( $1079 \times 0.2 = 216$ ). This water will be priced at the second tier rate.

If Mr and Mrs Smith have used 1400 MI, then 105 MI of water (1400-1295) will either cause watertables to rise, or will be drained from the farm. This is referred to as the third tier.

In summary, Mr and Mrs Smiths' water use could be divided into three tiers. Tier one of 1079 MI for evaporative demand, tier two of 216 MI, which is the acceptable level of excess water and tier three of 105 MI which is the unacceptable level of excess water.

The proposed tiered pricing structure will have three prices,  $P_1$ ,  $P_2$  and  $P_3$  corresponding to the three tiers such that  $P_3 > P_2 > P_1$ . This pricing structure is likely to provide long-term effects on irrigators by providing incentives to continuously improve WUE.

The tiered pricing scheme can be thought of as a type of indirect pollution tax. The pollution in this instance is the recharge of water to the watertable.

### **2.3.3 Advantages of a Tiered Block Pricing Structure**

The introduction of a tiered pricing structure has a number of advantages. It is a less blunt instrument than the previously discussed policies as it:

- provides a clear incentive to save water and therefore has potential to decrease farmers total water costs,
- provides a WUE target for farmers to aim for and aids education,
- equity is achieved as those contributing most to external costs pay extra for their water and
- increases the opportunity to bring environmental and production benefits through WUE increases.

### 2.3.4 Disadvantages of a Tiered Pricing Structure

Any new policy will have negative effects on some sections of the industry. The introduction of tiered pricing may:

- negatively impact on farmers who cannot improve WUE either because of financial constraints or physical constraints on the farm,
- initially confuse farmers as it is a more complex pricing structure,
- involve a higher level of monitoring and enforcement costs and
- result in a transfer of income from water use inefficient farmers to water use efficient farmers. The setting of price is currently post season and is based on a charge to meet the budget of Coleambally Irrigation. If this funding is to be maintained a tiered pricing scheme, without transfers, will be a transfer from inefficient farmers to more efficient farmers.

### 2.3.5 Additional Data Requirements

There are additional information requirements with the tiered pricing scheme. The information requirements are the area of crops grown on each farm, the water applied to these crops and the  $E_i$  requirements of these crops.

Bryant *et al.* (1996) have examined the feasibility of introducing drainage water quotas into for the Murrumbidgee Irrigation Area. Their proposal uses the same basis for determining excess water use as the tiered pricing example outlined above. Bryant outlines a method for introducing such a scheme into an irrigation area. The tiered pricing scheme can be considered as an extension of the drainage quota proposal as it deals with the question of the penalty to be imposed if a farmer exceeds the drainage quota for the farm.

Coleambally Irrigation have introduced a water ordering system which requires the farmer to specify what crop is being irrigated. It is proposed that the amount of crops grown can be ascertained by existing aerial photography techniques or satellite procedures developed by the CSIRO. This process involves a statement sent to growers for confirmation and any discrepancies would be ground 'truthed'. Given current data availability and resources it is considered that costs of data collection and manipulation would not be an excessive.

### 2.3.6 Overseas Experience

Tiered pricing was introduced in the Broadview Water District within the San Joaquin Valley, California in 1989 (Wichelns and Cone 1992, Cone and Wichelns 1994). The Broadview Water District is a small, highly intensive irrigation area. The scheme charges a higher price for water applied in excess of crop specific tiers.

Selection of tiering levels and prices was carried out by the board of the irrigation district. A two block structure was implemented. The board maintained the current price of U.S. \$16 per acre-foot (\$23.6 per MI) for the first tier and U.S. \$40 per acre-foot (\$59.3 per MI) for the second tier<sup>1</sup>.

The board considered two methods to fix the crop specific tiers. The  $E_i$  rate of particular crops was considered as a benchmark but a second option of reducing the current average volume of irrigation application by ten per cent was implemented. This was thought to be more relevant to local conditions and gave a recognisable goal to farmers.

The tiered pricing was favoured by the board as it allowed farmers to maintain current levels of flexibility when making cropping decisions. The introduction of tiered pricing within the region was considered a success by Cone and Wilchens (1994) as average irrigation depths and drainage volumes declined in the two subsequent years after the introduction of the scheme.

### 2.3.7 Initial Community Response to a Tiered Pricing Structure

A discussion group meeting was held at Coleambally during 1996. A group of thirteen farmers and agency staff discussed drainage quotas and tiered pricing. A number of concerns and ideas were raised within the group. These points are summarise below.

A number of advantages of the scheme were raised;

- provides a clear incentive to save water and therefore has potential to decrease farmers total water costs.

---

<sup>1</sup> Converted from acre-feet to MI by multiplying by 1.234. Converted to A\$ using a exchange rate of 0.8.

- provides the opportunity to achieve environmental and production benefits through WUE increases.
- provides the opportunity for community ownership through the design of the pricing scheme
- farmer education will be raised.
- the scheme allows flexibility as tiers can be easily changed as monitoring of the watertable depths indicate the success or otherwise of the scheme.

Disadvantages identified included;

- farmers may be initially confused by a new pricing structure.
- involves a higher level of monitoring and enforcement costs.
- the setting of price is currently post season and is based on a charge to meet the budget of Coleambally Irrigation. Given a set funding target a tiered pricing scheme will be a transfer from inefficient farmers to more efficient farmers.

A number of concerns were raised that will have to be addressed if a tiered pricing structure were to be introduced in to the CIA and other MDB irrigation areas. The measurement of the  $E_i$  requirement that accurately reflects conditions within the irrigation area was thought to be crucial to the credibility of the scheme. Bryant *et al.* (1996) suggest using local weather stations within the area and finding an average through the area for  $E_i$  calculations. Local landholders, in the interests of equity, wish to include local farm conditions such as soil type, depth to watertables and farm layout in the structure of the tiers and prices.

The question of the  $E_i$  requirements of pasture was raised as it was thought that pastures would vary greatly in terms of  $E_i$ . Further work is currently being carried out in the Murray Valley on this question.

The greatest concern was that the tiered pricing scheme may heavily impact on farmers that cannot improve efficiencies significantly, either because of financial constraints or physical constraints on farm. This is a contentious issue. One suggestion to deal with this was to use funds raised through tiered pricing in activities to improve the efficiency of these farmers.

### 3. THE COLEAMBALLY FARM FINANCIAL MODEL (CFFM)

#### 3.1 Introduction

The policy reforms outlined in the previous section will impose economic pressures on the farmers of Coleambally. The level of financial performance and ability to adapt will impact on the community and the success of the policies. Farmers will also face different opportunities and constraints in adjusting to water policy reforms depending on their individual resource and financial characteristics.

There are a number approaches that can be taken to analyse farmers' responses to the policies. They include gross margin budgeting, benefit cost analysis, and static and dynamic simulation modelling (Hall *et al.* 1993).

There are two approaches to regional simulation. Representative farms can be used and then aggregated or alternatively, a region such as Coleambally can be treated as one 'farm'. It was decided to undertake a whole farm budgeting spreadsheet model with four representative farms to evaluate the effect on total water costs, and therefore income, of a reduction in irrigation water allocation, a flat water price increase and the introduction of a tiered pricing structure. This approach enables closer examination of effects on heterogeneous farm types within the CIA.

Linear programming is a commonly used method in answering these questions. A linear programming model is presented in the following chapter. However, linear programming models are generally dependent on the assumption of maximising returns and as such they can sometimes misrepresent a system. A programming model can also be hard for lay people to comprehend. Therefore a spreadsheet model has been developed to use in conjunction with a linear programming model.

A spreadsheet model is included in this dissertation because, (1) it is simple, (2) the results can be easily interpreted by non-technical people, (3) stochastic analysis is possible in this framework, (4) the model can be used as an educational tool with 'hands on' use by policy makers and (5) a spreadsheet model allows analysis to be easily updated with new information as it becomes available.

### 3.2 Literature Review of Previous Financial Studies

There have been many farm financial models developed for analysis of farm performance and viability. Their application to irrigation farms specifically and irrigation policy is less common. Giesler *et al.* (1996) have developed a Rice Farm Financial-Policy Simulation Model (RFPM) using spreadsheets which simulates the financial structure of a farm with rice as the predominant crop over a five year period. The model aims to analyse the changes in asset and liability structure of farms as variables such as crop prices, land values and interest rates change.

The RFPM uses cash flow, balance sheets, breakdown of receipts and expenses and a set of financial ratios. The emphasis in the model is on determining financial performance given changes in government policy rather than enterprise mixes.

A number of survey studies have been conducted within the southern irrigation areas of the MDB. ABARE included a survey of irrigation farms within the Murrumbidgee region as part of their Farm Surveys Report (1996, 1997). The survey covered horticulture and broadacre farms for the 1994/95 year. This survey reported that 31 per cent of broadacre respondents had a negative farm business profit for the period.

The 1997 farm surveys report (ABARE, 1997) surveyed farms in the Murrumbidgee Irrigation Area (MIA) and northern Victoria for the 1995/96 season. It found that irrigation water expenditure in the MIA comprised 13 per cent of total cash costs on cropping farms, that is, farms with over 75 per cent of their income derived from cropping activities.

A number of the LWMPs have financial surveys associated with their assessment of options to control salinity (Naunton and Co. 1994,1995; Fisher Dowell Associates 1992).

Fisher Dowell and Associates (1992) carried out a study in the Berriquin Irrigation District (BID) in the Murray Valley NSW, based on farm financial performance. Berriquin is faced with similar environmental problems to the CIA. Their objective was to obtain a measure of the financial viability of farms in the BID so that the ability to pay for options identified within the LWMP could be gauged.

The Fisher Dowell Financial Study (1992) calculated net cash surplus (NCS) which was defined as:

$$NCS = TGM - OH - FC - CP$$

adjusted for inventory change, depreciation and off-farm income, where

|     |                              |
|-----|------------------------------|
| TGM | Total farm gross margin (\$) |
| OH  | Overhead costs (\$)          |
| FC  | Finance costs (\$)           |
| CP  | Capital payments (\$).       |

Analysis was carried out to assess the impact on NCS of the sample farms of changing debt levels, interest charges, water charges, fuel costs and labour costs. The effect of increases of 25, 50 and 100 per cent in total water charges was examined for four sample farms chosen on enterprise type. The report found that a 100 per cent increase in water prices caused rice farms to undergo an average decline of 82 per cent in NCS (Fisher Dowell Associates 1992).

A similar financial survey was carried out by Naunton and Co. (1994) for the CIA. The survey was commissioned to ascertain the financial status of the Coleambally area and examined the farming community's ability to contribute to works identified in the CIA LWMP to ensure the sustainability of production from the area.

The Naunton and Co. Financial Survey (1994) calculated a family cash surplus (FCS) which was defined as:

$$FCS = Y - OE - Dep - IC$$

where,

|     |                                    |
|-----|------------------------------------|
| Y   | Total farm income (\$)             |
| OE  | Operating expenses (\$)            |
| Dep | Depreciation (\$)                  |
| IC  | Interest and finance charges (\$). |

The FCS excludes the amount spent for development and also personal drawings including tax. The study found that the average FCS for the 'composite' farm in

the CIA was \$61 900 per farm in 1991/92. The composite farm was derived from the survey by combining results for single and multiple farm holdings in a ratio of four to one.

The Naunton and Co. (1994) report also conducted a sensitivity analysis that examined the effect on FCS of changing income and costs by 10 per cent. A change of 10 per cent did not significantly change the capacity of farms in the CIA to contribute to works associated with the LWMP.

Naunton and Co. (1995) also carried out a farm business survey for the MIA LWMP. This report differed from the Coleambally LWMP Financial Survey (1994) as it relied on secondary sources to provide farm financial information. Seven cooperating accounting firms within the district completed a questionnaire based on randomly selected farm business clients.

Profit results were reported for horticulture and broadacre farms in the MIA where profit was defined as;

$$\text{Profit} = Y - OE - Dep - IC - L$$

where,

|     |                                   |
|-----|-----------------------------------|
| Y   | Total farm income (\$)            |
| OE  | Operating expenses (\$)           |
| Dep | Depreciation (\$)                 |
| IC  | Interest and finance charges (\$) |
| L   | Lease and hire purchase (\$).     |

Profit represented the profit or loss calculated for taxation purposes. A profit of \$54 200 was calculated for the average large area farm in the MIA for the period 1992-1994. The majority of large area farms generated a profit in the period though farms that were predominantly livestock (ie. livestock generates more than 50 per cent of farm income) had a negative mean profit for the period.

The MIA report by Naunton and Co. (1994) did not include any specific analysis that determined the effect of changing policies on farm profit. A regression analysis was conducted to determine variables that significantly effected farm income. Farm type and year were found to have a statistically significant impact on farm income.

Bari and Jerrems (1997) recognise that a number of policies would change the farm financial conditions of landholders. The aim of Bari and Jerrems was to and assess the joint and individual impacts of policies on farm financial conditions using the MIA as a case study. A number of allocation and water price scenarios were examined.

A 36.9 per cent reduction in water allocation resulted in a decrease in farm profit of 24.5 percent. An increase in the volumetric charge for water of 47.3 per cent from \$2.83  $\text{MI}^{-1}$  to \$4.17  $\text{MI}^{-1}$  resulted in a decrease in farm profit of 6.1 per cent. The results indicate the importance of water supply to large area farming in the MIA. These results are preliminary.

The majority of studies examining the financial performance of farms rely on a single survey for information and a simple analysis. The financial model developed in the subsequent section aims to provide a methodology whereby analysis of the effect of policy options on farm financial performance can be undertaken and updates information can be incorporated with ease.

### **3.3 The Coleambally Farm Financial Model (CFFM)**

The CFFM is a spreadsheet model developed using the program, Excel 7.0. A second “add-in” program, @RISK (Palisade Corporation 1996) was used to enable analysis of the impact of variability in key variables on farm financial performance. Appendix 1 provides a description of the model. To operate this model, the user needs the electronic copy of the spreadsheet, together with copies of the programs, Excel 7.0, and @RISK.

The model was developed to provide a means for assessing the impact on farm incomes of changing water prices within the CIA. It enables single year “snap shot” forecasts of farm financial performance given a particular water price, based on the values and assumptions made within the various sheets of which the model is comprised.

The spreadsheet is comprised of a number of ‘sheets’ within a ‘workbook’. The first sheet contains general information about the model. The second sheet enables the user to select the farm type to be modelled, and to adjust water price information as required. Sheets three to six enable specification of each of four farm types in terms of size of holding, enterprise types and areas, water allocation, and various overhead costs. Subsequent sheets contain detailed cost and enterprise budget data.

The model is structured to draw information on farm variable costs, commodity yields and commodity prices from data sheets into enterprise gross margin sheets. Enterprise gross margin budgets were provided for the main cropping activities by NSW Agriculture. At present, pasture budgets are included in the model as a return per hectare. The gross margin is calculated as an average return from cattle and sheep enterprises and is based on the carrying capacity of the pasture. Specific and detailed livestock budgets have not yet been included in the model as more research is needed to link these activities to feed production activities within crop and pasture budgets.

Sensitivity analysis of selected variables may be performed with the model operating in deterministic mode. Alternatively, risk analysis may be used to examine the effect of variations in commodity prices, yields and crop water application on profitability at different water prices.

### **3.4 Specification of CIA Representative Farms**

A representative farm approach was employed to analyse the impact of higher water prices on farm financial viability.

#### **3.4.1 Farm Physical Data**

Four representative farms were analysed, based on combinations of two farm business sizes and two enterprise mixes. Here, a distinction has to be made between farms and farm businesses. As stated previously, farms are between 200 and 300 ha in size and were allocated to farmers in the 1960's by ballot. Home maintenance area restrictions, that were originally based on financial viability for a family, do not allow corporate ownership of land in the CIA. However, a number of farm businesses have more than one farm which are held in separate names. The individual farms are of a similar size so that the number of farms a business owns is a reliable guide to the area of the farm business.

The two farm sizes modelled are based on information gained from Coleambally Irrigation (Rzeszkowski *et al.* 1996). Forty six farmers were surveyed by telephone by Coleambally Irrigation staff with no 'non-responses'. The survey aimed to gauge the number of farm holdings per farm business and the enterprises undertaken on each farm. A summary of the results is given in Table 3. It is apparent from these results that rice, wheat, soybeans and winter pasture are the most frequent enterprises in the area.

**Table 3 Coleambally telephone survey summary results**

| Farm Holdings | Count | Rice<br>(ha) | Wheat<br>(ha) | Soybeans<br>(ha) | Winter Past.<br>(ha) |
|---------------|-------|--------------|---------------|------------------|----------------------|
| Single        | 20    | 19           | 14            | 4                | 8                    |
| Multiple      | 26    | 15           | 18            | 8                | 13                   |
| Total         | 46    | 44           | 34            | 12               | 21                   |

Of the 46 businesses covered in the survey, 20 were comprised of a single farm, 17 were comprised of two farms, five of three farms and four of four farms. For the purposes of developing representative farms in this study only single farm holdings and twin farm holdings are represented since these are the most common.

The average areas devoted to major enterprises are shown in Table 4. These figures do not represent a typical farm since they are averages across the survey sample.

**Table 4 Average crop areas from the Coleambally telephone survey**

| Farm Holdings | Rice<br>(ha) | Wheat<br>(ha) | Soybeans<br>(ha) | Winter Past.<br>(ha) |
|---------------|--------------|---------------|------------------|----------------------|
| Single        | 66           | 65            | 48               | 96                   |
| Multiple      | 71           | 58            | 59               | 58                   |

Other less common crops were barley and oats, with seven farms planting barley and nine planting oats. Crops reported three or less times were, canola, triticale, sunflower, sunflower, sorghum seed, lupins and mung beans. All three maize growers owned farm businesses comprised of multiple holdings. Seventeen farms reported running no stock at all, 22 ran sheep, nine cattle, and four farms ran both sheep and cattle.

### 3.4.2 Farm Financial Data

Farm overhead cost data used in specifying the model were derived from a survey conducted for the CIA LWMP by Naunton and Co. (1994). The validity of this information has been questioned in the LWMP as the sample size is regarded as too small (CIA LWMP Committee 1996). Nevertheless, data from the survey on average overhead costs per farm business costs are used in this study in the absence of alternative data.

**Table 5      Overhead data used in the CFFM model**

|                                             | <b>Single<br/>Holding (\$)</b> | <b>Multiple<br/>Holding (\$)</b> |
|---------------------------------------------|--------------------------------|----------------------------------|
| <b>Depreciation</b>                         | 5,041                          | 22,160                           |
| <b>Interest &amp;<br/>Development Costs</b> | 14,057                         | 26,872                           |
| <b>Drawings</b>                             | 30,858                         | 76,626                           |
| <b>Other Overhead Costs</b>                 | 22,153                         | 36,008                           |
| <b>Total Overhead<br/>Expenses</b>          | 72,109                         | 161,746                          |

The use of the Naunton and Co. (1994) figures require that this study use a viability indicator specified in the original survey. The indicators of viability as defined Naunton and Co. are trading result (TR), family cash surplus (FCS), return on capital (RC) and return on equity (RE). The TR is used as the indicator of profitability for this analysis.

$$TR = Y - OE - Dep - IC - Dr$$

where,

|     |                                                        |
|-----|--------------------------------------------------------|
| Y   | Total farm income (\$)                                 |
| OE  | Operating expenses (\$)                                |
| Dep | Depreciation (\$)                                      |
| IC  | Interest and finance charges (\$)                      |
| Dr  | Drawings for personal use, taxation and superannuation |

The TR identifies the performance of the farm business and is defined as ‘incomes from all sources and deducting all costs incurred in the operation and management of the business, including actual drawings made by owners’ (Naunton and Co. 1994).

Data on variable costs items (Appendix 1) and crop gross margins used in the model were provided by NSW Agriculture (Cochrane 1996, Curthoys 1996) and Prathapar and Madden (1995) for livestock gross margins.

### 3.4.3 Summary of Representative Farms

Four representative farms are specified for use in the CFFM. The farms are specified in terms of farm business area and type. Representative farms one and three (RF-1 and RF-3) are rice farms. Traditionally, rice farmers in the CIA grow their full entitlement of rice along with a mixture of cereal cropping and livestock. In recent times, more farms are moving towards row crops such as soybean and maize in conjunction with rice (RF-2 and RF-4). These farms are called 'row' farms in Table 6.

**Table 6 Representative farm business characteristics**

| <b>Characteristics</b>     | <b>Farm Businesses</b> |               |               |               |
|----------------------------|------------------------|---------------|---------------|---------------|
|                            | <b>RF - 1</b>          | <b>RF - 2</b> | <b>RF - 3</b> | <b>RF - 4</b> |
| <b>Type</b>                | Rice                   | Row           | Rice          | Row           |
| <b>Number of Farms</b>     | 1                      | 1             | 2             | 2             |
| <b>Area (ha)</b>           | 242                    | 242           | 484           | 484           |
| <b>Arable Area (ha)</b>    | 219                    | 219           | 437           | 437           |
| <b>Allocation (MI)</b>     | 1444                   | 1444          | 2888          | 2888          |
| <b>Irrigated Area (ha)</b> | 186                    | 189           | 370           | 356           |

Further details including the enterprise mix of the representative farms can be found in the model description in Appendix 1.

## 3.5 Data for Stochastic Analysis in the CFFM

The @Risk program allows specification of key model variables as probability distributions rather than point estimates. This allows analysis of how the variable of interest (in this case, farm trading result) varies with variation in key variables identified. This approach allows a probability distribution for the farm trading result to be generated. Stochastic commodity prices, yield and irrigation water use per hectare for each enterprise were specified by making assumptions about their probability distributions.

### 3.5.1 Commodity Prices

The probability distributions for commodity prices were assumed to take a triangular functional form which is defined by most likely, minimum and maximum values of the distribution (Palisade Corporation 1996). The figures are based on historical data obtained from ABARE (1996). Data for fababeans was estimated from NSW Agriculture figures as ABARE data was unavailable (Cochrane 1996). The minimum and maximum figures are the extremes over the period while the most likely is the mean of the range of prices received by farmers.

**Table 7 Commodity price probability distributions used in the model**

| <b>CROP</b>            | <b>Most Likely<br/>price (\$ t<sup>-1</sup>)</b> | <b>Minimum<br/>price (\$ t<sup>-1</sup>)</b> | <b>Maximum<br/>price (\$ t<sup>-1</sup>)</b> |
|------------------------|--------------------------------------------------|----------------------------------------------|----------------------------------------------|
| <b>Rice - medium</b>   | 200                                              | 180                                          | 220                                          |
| <b>Rice - long</b>     | 240                                              | 220                                          | 260                                          |
| <b>Wheat - ASW</b>     | 175                                              | 135                                          | 235                                          |
| <b>Wheat - biscuit</b> | 190                                              | 150                                          | 250                                          |
| <b>Maize</b>           | 180                                              | 160                                          | 200                                          |
| <b>Soybeans</b>        | 390                                              | 350                                          | 430                                          |
| <b>Fababeans</b>       | 250                                              | 230                                          | 280                                          |
| <b>Canola</b>          | 340                                              | 300                                          | 400                                          |

### 3.5.2 Crop Yields

Crop yields are another source of variability in the farm trading result. The minimum, most likely and maximum values come from the sensitivity analysis component of the budgets from NSW Agriculture (Cochrane 1996, Curthoys 1996) and McCaffery (1997, pers. com.).

**Table 8** Crop yields probability distributions used in the model

| <b>CROP</b>               | <b>Most Likely<br/>(t ha<sup>-1</sup>)</b> | <b>Minimum<br/>(t ha<sup>-1</sup>)</b> | <b>Maximum<br/>(t ha<sup>-1</sup>)</b> |
|---------------------------|--------------------------------------------|----------------------------------------|----------------------------------------|
| <b>Rice - medium</b>      | 9.50                                       | 7.00                                   | 10.50                                  |
| <b>Rice - long</b>        | 8.75                                       | 6.00                                   | 9.50                                   |
| <b>Wheat - ASW</b>        | 4.50                                       | 2.50                                   | 6.00                                   |
| <b>Wheat - biscuit</b>    | 4.50                                       | 2.50                                   | 5.00                                   |
| <b>Maize</b>              | 10.00                                      | 8.00                                   | 11.00                                  |
| <b>Soybeans</b>           | 2.80                                       | 1.60                                   | 3.50                                   |
| <b>Fababeans</b>          | 3.50                                       | 1.25                                   | 5.00                                   |
| <b>Canola</b>             | 2.80                                       | 2.0                                    | 3.50                                   |
| <b>Annual Pasture*</b>    | 10                                         | 7                                      | 13                                     |
| <b>Perennial Pasture*</b> | 15                                         | 12                                     | 18                                     |

\* Pasture yields given in DSE ha<sup>-1</sup>

The yield for pastures is given in Dry Sheep Equivalents (DSE) per ha. The most likely pasture yields are obtained from Prathapar and Madden (1995) and the minimum and maximum are estimates.

The distribution of yield in irrigation areas is relatively minor compared to dryland cropping as water is unlikely to be a limiting factor.

### 3.5.3 Irrigation Water Application

The water usage on crops varies both from one year to the next and between farms. The figures were obtained from NSW Agriculture (Cochrane 1996, Curthoys 1996) and CSIRO (Prathapar and Madden 1995).

**Table 9**      **Irrigation water applied probability distributions used in the model**

| <b>CROP</b>              | <b>Most Likely<br/>(MI ha<sup>-1</sup>)</b> | <b>Minimum<br/>(MI ha<sup>-1</sup>)</b> | <b>Maximum<br/>(MI ha<sup>-1</sup>)</b> |
|--------------------------|---------------------------------------------|-----------------------------------------|-----------------------------------------|
| <b>Rice - medium</b>     | 14.0                                        | 10.0                                    | 19.0                                    |
| <b>Rice - long</b>       | 15.0                                        | 10.0                                    | 20.0                                    |
| <b>Wheat - ASW</b>       | 3.6                                         | 2.0                                     | 4.0                                     |
| <b>Wheat - biscuit</b>   | 3.6                                         | 2.5                                     | 4.4                                     |
| <b>Maize</b>             | 9.5                                         | 8.0                                     | 11.0                                    |
| <b>Soybeans</b>          | 9.5                                         | 8.0                                     | 11.0                                    |
| <b>Fababeans</b>         | 3.6                                         | 2.5                                     | 4.4                                     |
| <b>Canola</b>            | 2.8                                         | 2.0                                     | 3.8                                     |
| <b>Annual Pasture</b>    | 6.0                                         | 5.0                                     | 7.0                                     |
| <b>Perennial Pasture</b> | 11.0                                        | 9.0                                     | 13.0                                    |

Irrigation water applied to a crop will vary with a number of factors including the irrigation layout of a farm and irrigation water management, which will vary between farms and farmers. Other physical influences such as soil type and depth to the watertable will also have an influence on water applied to a crop. Climatic variation will influence the  $E_i$  requirement of crops from year to year which will influence irrigation water applied.

### **3.6 Mean Gross Margins in the CFFM**

The gross margins used in the farm financial model incorporate yield, price and crop water use and therefore have an associated distribution. Mean gross margins for each crop are reported in Table 10. As the cost of irrigation water is one of the variables examined in the analysis, the gross margin figures below are calculated using the current irrigation water price within the CIA.

**Table 10** Mean gross margins calculated in the CFFM with an irrigation water price of \$12.52 and average water application

| <b>CROP</b>              | <b>Gross Margin (\$ ha<sup>-1</sup>)</b> |
|--------------------------|------------------------------------------|
| <b>Rice - medium</b>     | 1042                                     |
| <b>Rice - long</b>       | 793                                      |
| <b>Wheat - ASW</b>       | 464                                      |
| <b>Wheat - biscuit</b>   | 330                                      |
| <b>Maize</b>             | 1276                                     |
| <b>Soybeans</b>          | 368                                      |
| <b>Fababeans</b>         | 352                                      |
| <b>Canola</b>            | 459                                      |
| <b>Annual Pasture</b>    | 23                                       |
| <b>Perennial Pasture</b> | -14                                      |

### 3.7 Major Assumptions of the CFFM

A number of assumptions have been made in specifying an annual spreadsheet model to analyse the effect of policies on farm viability.

First, it was assumed that farm financial survey data from Naunton and Co. (1992) is representative of farms within the CIA. As mentioned previously the validity of the data has been questioned by the CIA LWMP (1996). Sensitivity analysis on key overhead data could be used to allow for any uncertainty in results. Second, as policies change it is assumed that the structure of fixed and variable costs remain the same. However, this assumption does not include water price for the policies that impact directly on irrigation water price. Third, the cropping mix of the representative farms is assumed to be unchanged as pricing policies are varied. Fourth, it was assumed that the crop water usage figure does not reflect increases in WUE.

## **4. THE COLEAMBALLY LINEAR PROGRAMMING FARM MODEL (CLPM)**

### **4.1 Linear Programming**

A linear programming model was developed using the program, GAMS, General Algebraic Modelling System (Brooke, Kendrick and Meeraus 1988). Appendix 2 contains a detailed description of the model. GAMS is a mathematical programming language and the linear programming solver that is used is MINOS, Modular In-core Non-linear Optimisation System, which was developed by the Department of Operations Research at Stanford University.

This mathematical programming approach makes it possible to include other physical and regulatory constraints such as labour demands and EPA requirements in the analysis. Linear programming makes use of a set of technological and resource options that face a firm as a starting point. The algorithm calculates the cost minimising pattern of inputs to achieve a given pattern of production. When input prices, such as water price, or the availability of a particular input are changed then the optimal pattern of production changes. This change in production generally shifts away from the input with the increased price.

Linear programming allows examination of optimal crop selection at current levels of irrigation allocation and irrigation water price in comparison with other water allocation or price regimes. The objective of the model is maximisation of profit and the degree of substitution of inputs assumes that profit maximisation remains the objective following any changes. Given that these models depend on the assumption of optimal adjustment to a change in input prices, the likely scale of response may be overstated (OECD 1997).

The representative farm approach has been much used in the past to address questions concerning the impact of policy options such as the three outlined in this dissertation. The relative homogeneity of the CIA and the availability of information should assist with this approach.

## 4.2 Review of Previous Models

A number of studies have been carried out in the recent past which use farm level models to analyse the impact of policy instruments on farm financial performance and specifically irrigated farm performance. In some cases measures of water use efficiencies have been estimated.

Bryant *et al.* (1993) examined the impact of reduced water allocation and recharge entitlements on farm gross margins and recharge for a sub-region of the MIA. A linear programming approach was used that included a surface water model. The objective was to maximise sub-regional gross margin.

Farm level models of the CIA have been developed by NSW Agriculture to assess on-farm options for the LWMP (Curthoys *et al.* 1994). These models are multi-period and maximise farm gross margins. Results from the model simulation are reported as benefit cost ratios over a thirty year period and aggregated to form regional estimates of various on-farm options.

ABARE have conducted a number of assessments of the impact of irrigation policies. Soccimarro *et al.* (1996) used a mathematical programming approach to assess the impact of increased water charges on dairy farms in the Southern MDB. Their model, DAIRYPLAN, was specified for twenty years to cover medium term adjustment options and maximised cumulative net cash surplus over the period. The twenty year period is divided into an eight year development stage and a twelve year stabilisation stage to allow investment returns to be realised. The approach developed by Soccimarro *et al.* (1996) allows time for investment decisions to return income and taxation effects. Also discount rates are dispensed with since terminal cash surplus is maximised.

Hall *et al.* (1993) constructed farm scale models for the west Berriquin area to examine the effect of rising watertables and increasing water prices on farm performance. The objective of the analysis was to maximise net present value of consumption income. Three models were developed to represent dairy, rice and mixed farms in the area and were solved over a period of twenty years. The decisions of one year influence the next through groundwater levels and effects on yield. Adjustments include reduced irrigation or changes in enterprise mix.

A regional CIA model has been developed by Marshall *et al.* (1994) and was used to estimate losses resulting from soil salinity. It was solved in five-yearly steps

over a 30 year period and maximised total farm gross margins. Likely land use patterns in the future and present values of 'farm gate' revenue were reported.

Marshall and Jones (1992) also developed a linear programming whole farm financial model to analyse the economics of landforming in the MIA. The focus of the work was on on-farm costs and benefits of landforming over a period of 30 years. The effect of eligibility for concessional credit for landforming was also included in the analysis.

To assess the impact of reduced water allocation, demand elasticities have been determined for the CIA by Jones and Fagan (1996). They have reported the seasonal demand function given below for the whole area.

$$Dd = 632,442 - 7258P$$

where,

P            water price (\$)

Dd          demand in ML.

Jones and Fagan (1996) also determined an arc elasticity of demand for the CIA and demand for water was found to be highly inelastic between the price range \$0 to \$45. Inelastic short term demand is also reported by Collins (1996) and most studies that have derived measures of elasticity for irrigation water demand.

Simmons *et al.* (1991) provide an estimate of water usage of representative farms at various prices for the Coleambally area shown in Table 11.

**Table 11      Estimated water use at various price levels for the CIA**

| <b>Water Price<br/>(\$ MI<sup>-1</sup>)</b> | <b>Water Use<br/>(MI per farm)</b> |
|---------------------------------------------|------------------------------------|
| 5                                           | 1449                               |
| 10                                          | 1449                               |
| 15                                          | 1449                               |
| 20                                          | 1449                               |
| 25                                          | 1449                               |
| 30                                          | 1284                               |
| 35                                          | 730                                |
| 40                                          | 601                                |
| 45                                          | 591                                |
| 50                                          | 579                                |

The estimates of demand elasticity for the CIA are only suitable for the short term and do not suit the medium term approach that is required for consideration of the impact of price on WUE.

Dinar *et al.* (1989) looked at the three policy options that were proposed to reduce subsurface drainage under irrigation in California, U.S.A. The area under investigation has subsurface drainage installed and the drainage water disposal costs are high. The study examined the effects of various irrigation water pricing policies on optimal irrigation application, profits, and drainage volumes.

In summary, many models have been developed to examine the performance of irrigated farms and regions under various government policies. The majority of these models have been specific to problems under investigation. The availability of financial information required for these models is limited and as such a simple linear programming model has been developed to account for the conditions in the CIA and availability of data.

### 4.3 Coleambally Linear Programming Model

#### 4.3.1 Model Objective

The objective of the Coleambally Linear Programming Model (CLPM) is to maximise total trading surplus (TSURPLUS) per farm which is found by subtracting total overhead costs for the farm from total gross margin (TGM).

$$TSURPLUS = TGM - TOH$$

where,

$$TGM = \sum_c (GMLW - XC_c * WPRICE_c - LABCOST)$$

where,

|         |                                                                                 |
|---------|---------------------------------------------------------------------------------|
| GMLW    | Gross margin of a land use less cost of irrigation water (\$ ha <sup>-1</sup> ) |
| WPRICE  | Price of water (\$ ML <sup>-1</sup> )                                           |
| C       | Alternative land uses considered in a farm                                      |
| LABCOST | Labour cost (\$)                                                                |

Land uses (C) considered in the model were: rice (RICEM), long grain rice (RICEL), soybeans (SOYB), maize (MAIZE), fababeans (FABA), canola (CANOLA), wheat (WHEAT), dryland wheat (DWHEAT), barley (BARLEY), annual pasture (APASTURE), perennial pasture (PPASTURE), dryland annual pasture (DAPAST) and fallow (FALLOW).

### 4.3.2 Area Constraints Within the Model

- Area of a land use,  $X(C)$ , cannot exceed maximum allowable area (PMXA). The maximum limit was set to reflect real world considerations such as enterprise diversification, crop rotations, market demand and restrictions set by managers.

$$X(C) \leq PMXA$$

- Area of a land use must be greater than minimum required area (PMNA).

$$X(C) \geq PMNA$$

- RICEM and RICE L cannot sum to more than the environmental limit specified (RICELIM).

$$\sum_R X(C) \leq RICELIM$$

where,

R      Rice crops is a subset of (C)

- Crop rotations are specified in the model framework with constraints placed on minimum areas of winter crops (WINCROPS) and summer crops (SUMCROPS).

$$\sum_w XC_w \leq WINCROPS$$

$$\sum_s XC_s \leq SUMCROPS$$

### 4.3.3 Labour Constraints Within the Model

- The monthly labour required cannot exceed available family labour (FLAB) and available temporary labour (TLAB).

$$\sum_C \sum_M (LABOUR)_M \leq FLAB + TLAB$$

where,

|      |                                      |
|------|--------------------------------------|
| FLAB | Family labour availability (hrs).    |
| TLAB | Temporary labour availability (hrs). |

### 4.3.4 Irrigation Water Allocation Constraints

- The water requirement for crops grown cannot exceed the irrigation water allocation associated with the farm plus any off allocation water.

$$\sum_C X * AI_C \leq WALL + OFFALL$$

where,

|        |                                                          |
|--------|----------------------------------------------------------|
| X      | the area of crop (ha).                                   |
| AI     | the irrigation applied to a crop (MI ha <sup>-1</sup> ). |
| WALL   | irrigation water allocation per farm (MI).               |
| OFFALL | off allocation water per farm (MI).                      |

## 4.4 Coleambally Linear Programming Model Parameters

### 4.4.1 Gross Margins and Profit

Gross margins (GM) for landuses were obtained from a number of sources (Cochrane 1996, Crean 1992) including personal interviews (McCaffery 1997, pers. comm.). These values were corrected for the cost of irrigation water because irrigation levels and water prices are set exogenously to allow for

scenario analysis. Assumed yields and estimated gross margins for the land uses and land use practices considered are listed in Table 12. More detail regarding prices and variable costs can be found in the model listing in Appendix 2.

**Table 12**      **Assumed crop yields and gross margins less the cost of irrigation water**

| <b>Land Use</b>   | <b>Yield (t ha<sup>-1</sup>)</b> | <b>GMLW (\$ ha<sup>-1</sup>)</b> |
|-------------------|----------------------------------|----------------------------------|
| <b>RICEM</b>      | 9.50                             | 1232                             |
| <b>RICEL</b>      | 8.00                             | 1214                             |
| <b>MAIZE</b>      | 9.50                             | 482                              |
| <b>SOYB</b>       | 2.60                             | 1394                             |
| <b>WHEAT</b>      | 4.75                             | 165                              |
| <b>BARLEY</b>     | 5.00                             | 88                               |
| <b>FABA</b>       | 3.50                             | 395                              |
| <b>CANOLA</b>     | 2.80                             | 494                              |
| <b>APASTURE*</b>  | 10                               | 105                              |
| <b>PPASTURE*</b>  | 15                               | 115                              |
| <b>DAPASTURE*</b> | 1                                | 13                               |
| <b>DWHEAT</b>     | 2.20                             | 90                               |
| <b>FALLOW</b>     | 0                                | 0                                |

\* Pasture yields in DSEs

The values for prices represent averages from available data for the past eight years. The values for prices and variable costs were assumed to remain constant in real terms.

#### 4.4.2 Area Constraints

The base representative farm specified for the CLPM is 240 ha in size and it is assumed that the farm is all of one soil type. The model allows for the imposition of bounds on the areas of land uses (Table 13). This allows simulation modelling and the specification of constraints that ensure crop diversity and rotational constraints.

**Table 13      Imposed area constraints**

| <b>CROP</b>      | <b>Maximum (ha)</b> | <b>Minimum (ha)</b> |
|------------------|---------------------|---------------------|
| <b>RICEM</b>     | 69                  | 69                  |
| <b>RICEL</b>     | 69                  | 0                   |
| <b>WHEAT</b>     | 80                  | 0                   |
| <b>MAIZE</b>     | 80                  | 0                   |
| <b>SOYB</b>      | 80                  | 0                   |
| <b>FABA</b>      | 80                  | 0                   |
| <b>CANOLA</b>    | 80                  | 0                   |
| <b>WPASTURE</b>  | 80                  | 0                   |
| <b>SPASTURE</b>  | 80                  | 0                   |
| <b>DAPASTURE</b> | 80                  | 0                   |
| <b>DWHEAT</b>    | 80                  | 0                   |
| <b>FALLOW</b>    | 240                 | 0                   |

#### 4.4.3 Irrigation Water Application

The irrigation water applied to each crop is used to calculate the cost of water applied per ha and also the level of the second tier in conjunction with the estimation of  $E_c$ . A summary of land uses and irrigation amounts are presented in Table 14. These figures represent estimated average irrigation applications for the CIA.

**Table 14**      **Average district irrigation water levels (ML ha<sup>-1</sup>)**

| <b>Land use</b>  | <b>Irrigation Water Applied</b> |
|------------------|---------------------------------|
| <b>RICEM</b>     | 14                              |
| <b>RICEL</b>     | 13                              |
| <b>WHEAT</b>     | 4                               |
| <b>MAIZE</b>     | 10                              |
| <b>SOYB</b>      | 10                              |
| <b>FABA</b>      | 3                               |
| <b>CANOLA</b>    | 4                               |
| <b>WPASTURE</b>  | 3                               |
| <b>SPASTURE</b>  | 10                              |
| <b>DAPASTURE</b> | -                               |
| <b>DWHEAT</b>    | -                               |
| <b>FALLOW</b>    | -                               |

#### **4.4.4 Crop Evapotranspiration ( $E_t$ )**

$E_t$  is an important component of the linear programming model as it is used as a basis for determining the level of the pricing tiers. Estimation of  $E_t$  involves a number of steps and is based on agronomic practices within the CIA. The growing season for each land use was identified. The land use for the remainder of the year was assumed to be free of vegetation when estimating  $E_t$ .

The annual reference evapotranspiration (RET) varies from year to year, depending on weather conditions. In order to account for such variability, daily RET values for ten years (1984-1993) and annual RET values for the last 30 years (1962-1993), were analysed to calculate model RET (Meyer, 1994). The average annual RET for the CIA is 1913 mm. The annual average RET was multiplied by the percentage of annual RET to obtain the monthly RET and then the percentage of annual RET in each month (Table 15).

**Table 15** Average monthly RET during 1984-1993 (mm)

| Month     | RET (mm) | % of annual RET |
|-----------|----------|-----------------|
| January   | 294      | 15.3            |
| February  | 245      | 12.8            |
| March     | 203      | 10.6            |
| April     | 120      | 6.2             |
| May       | 69       | 3.6             |
| June      | 44       | 2.3             |
| July      | 49       | 2.6             |
| August    | 75       | 3.9             |
| September | 114      | 5.9             |
| October   | 186      | 9.7             |
| November  | 243      | 12.7            |
| December  | 279      | 14.5            |

The RET during the growing season for each crop was then determined using the monthly RET data. This was then weighted by a crop factor to estimate actual  $E_t$  for the crops and cultural practices specified in the model (Table 16).

**Table 16** Estimated actual crop evapotranspiration ( $E_t$ )

| Land use         | RET (MI ha <sup>-1</sup> ) | Crop Factor | $E_t$ (MI ha <sup>-1</sup> ) |
|------------------|----------------------------|-------------|------------------------------|
| <b>RICEM</b>     | 12.4                       | 0.97        | 12.0                         |
| <b>RICEL</b>     | 12.4                       | 0.97        | 12.0                         |
| <b>MAIZE</b>     | 11.0                       | 0.66        | 7.3                          |
| <b>SOYB</b>      | 11.8                       | 0.73        | 8.6                          |
| <b>WHEAT</b>     | 7.5                        | 0.87        | 6.5                          |
| <b>BARLEY</b>    | 6.7                        | 0.87        | 5.8                          |
| <b>FABA</b>      | 7.5                        | 0.87        | 6.5                          |
| <b>CANOLA</b>    | 6.7                        | 0.87        | 5.8                          |
| <b>WPASTURE</b>  | 8.0                        | 0.65        | 5.2                          |
| <b>SPASTURE</b>  | 19.1                       | 0.73        | 13.9                         |
| <b>DAPASTURE</b> | 6.5                        | 0.65        | 4.2                          |
| <b>DWHEAT</b>    | 7.5                        | 0.87        | 6.5                          |
| <b>FALLOW</b>    | 19.1                       | 1.00        | 19.1                         |

This information was used to calculate the excess level of irrigation water applied to a crop. This excess water is the basis of the tiers under the tiered pricing structure and is used to calculate the price of irrigation water per ha under different pricing scenarios.

#### 4.4.5 Crop Labour Requirements

Crop labour requirements are specified for all landuses in the model. The labour requirements were obtained from various sources from NSW Agriculture (Curthoys 1996, Cochrane 1996) and are shown in Table 17.

The estimate of labour supply for farms in the CIA came from Jones (1990) and were used for linear programming work carried out by NSW Agriculture. The labour supply for a farm with one worker on the farm was 3,170 man hours per year. For the purposes of the model, this was divided evenly by 12 to represent the supply of family labour for each month.

**Table 17      Total labour requirement for landuses in the CIA**

| <b>CROP</b>   | <b>Labour Requirement (hr ha<sup>-1</sup> y<sup>-1</sup>)</b> |
|---------------|---------------------------------------------------------------|
| <b>RICEM</b>  | 9.41                                                          |
| <b>RICEL</b>  | 9.41                                                          |
| <b>WHEAT</b>  | 5.45                                                          |
| <b>MAIZE</b>  | 11.60                                                         |
| <b>SOYB</b>   | 12.75                                                         |
| <b>FABA</b>   | 3.00                                                          |
| <b>CANOLA</b> | 4.66                                                          |
| <b>APAST</b>  | 2.25                                                          |
| <b>PPAST</b>  | 1.29                                                          |
| <b>DAPAST</b> | 0.13                                                          |
| <b>DWHEAT</b> | 1.32                                                          |
| <b>FALLOW</b> | 0.00                                                          |

Jones (1990) specifies irrigation labour requirements which are added to the cultivation and harvesting costs to estimate total labour requirement per ha.

## **5. RESULTS**

### **5.1 Introduction**

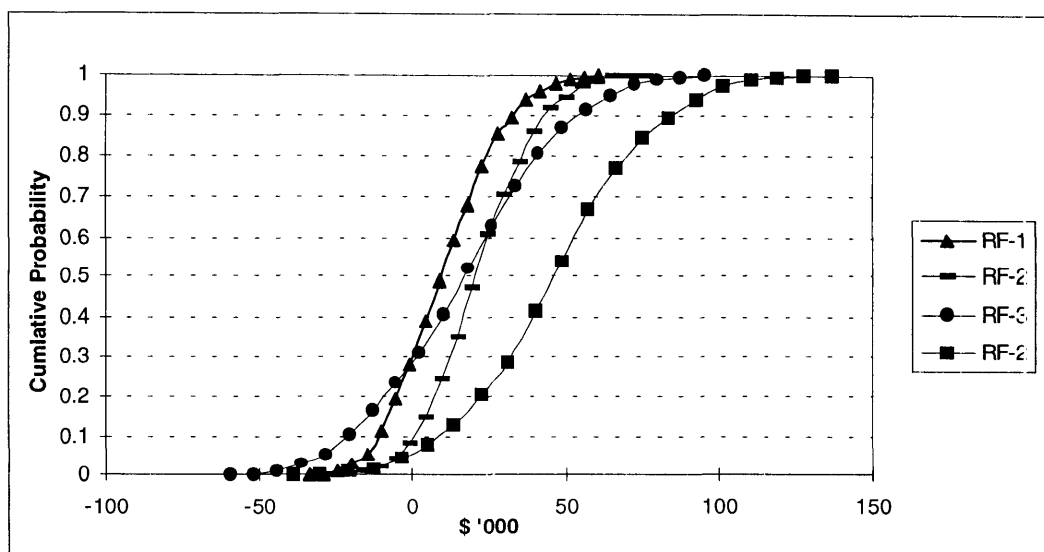
Chapters 3 and 4 have specified two models of representative farms in the CIA. The first (CFFM) is a spreadsheet simulation model which includes a stochastic analysis of farm trading surplus for four representative farms. This model is used to examine the effects of policies on short run farm financial performance. The second model (CLPM) is a linear programming model which is specified for two farm sizes, a single holding and a twin holding. The representative farms were based on RF-1 and RF-4 from Chapter 3. These two farms are chosen as they represent opposite extremes of farming practice in the CIA. The CLPM is an optimisation model which varies land uses to maximise farm trading result. The CLPM is used to examine likely effects on farm enterprise mix as policies are changed.

The first section of this chapter reports the base runs of the two models. The base run represents the current policy situation. In the following sections each of the policies, reduced allocations, increased water pricing and tiered water pricing, will be evaluated using one or both of the models.

### **5.2 Model Results Under Current Policy Conditions**

#### **5.2.1 The CFFM**

The CFFM model was run for four representative farms as specified in Chapter 3. The four farms represent different farm business sizes and types. The cumulative probability density functions of the four farms under the 'baseline' assumptions are displayed in Figure 7.



**Figure 7** Trading surplus cumulative probability density function for four representative farms under current pricing

The mean results for the CFFM under current policy conditions are displayed in Table 18. Row cropping farms have a higher mean trading surplus than traditional rice/cereal cropping farms. This conclusion has to be qualified as the overhead costs associated with row cropping are higher than traditional cropping and this difference is not detailed in the analysis due to lack of financial information.

**Table 18** Base annual mean farm trading surplus and standard deviation for the four representative farms

| Farm            | Mean (\$) | Standard Deviation |
|-----------------|-----------|--------------------|
| RF - 1 Rice-One | 9,960     | 16,905             |
| RF - 2 Row-One  | 21,319    | 16,586             |
| RF - 3 Rice-Two | 16,628    | 28,461             |
| FR - 4 Row-Two  | 46,083    | 28,623             |

### 5.2.2 The CLPM

The CLPM has been specified for two farms in the CIA. The model maximises the farm trading result so that the results for the two models can be compared. The model is an optimisation model and, as such, profit is likely to be higher than in the actual system. This results from the lack of detail on the rotations specified in the model. As the CLPM is annual, the hypothesised farmer maximises trading surplus without regard to longer term productivity effects from the 'optimal' cropping mix.

The model outputs for the two specified farms are displayed in Table 19.

**Table 19      Base results for the CLPM for two representative farms**

|                               | <b>RF - 1</b> | <b>RF - 4</b> |
|-------------------------------|---------------|---------------|
| <b>Trading Surplus (\$)</b>   | 45,640        | 83,497        |
| <b>Water Requirement (MI)</b> | 1,400         | 2,770         |
| <b>Water Costs (\$)</b>       | 17,528        | 34,683        |
| <b>Landuse Areas (ha)</b>     |               |               |
| <b>RICEM</b>                  | 69            | 136           |
| <b>MAIZE</b>                  | 13            | 22            |
| <b>CANOLA</b>                 | 60            | 160           |
| <b>FABA</b>                   | -             | 2             |
| <b>APASTURE</b>               | 21            | -             |
| <b>DAPASTURE</b>              | 19            | 44            |
| <b>DWHEAT</b>                 | -             | -             |
| <b>FALLOW</b>                 | 60            | 120           |

## 5.3 A Reduction in Irrigation Farm Allocation

### 5.3.1 Introduction

Murray Irrigation Limited (MIL) and Coleambally Irrigation have calculated the likely decrease in water allocations if the interim cap is made operational and becomes permanent. For a median weather year in the Murray Irrigation regions the regional water supply would be cut by 19 per cent (The Land 1997) and for the CIA it would be reduced to 87 per cent of allocation (Bramston 1997, pers. comm.).

Table 20 gives the likely impact of the introduction of the proposed CAP on allocations within the CIA.

**Table 20      Anticipated CAP allocation announcements for the CIA**

| <b>Percentile</b> | <b>Annual ET<br/>(mm)</b> | <b>Valley Cap<br/>(Gl)</b> | <b>CIA CAP (% of<br/>allocation announced)</b> |
|-------------------|---------------------------|----------------------------|------------------------------------------------|
| <b>Minimum</b>    | 978                       | 1620                       | 68                                             |
| <b>25</b>         | 1224                      | 1900                       | 80                                             |
| <b>Median</b>     | 1390                      | 2075                       | 87                                             |
| <b>75</b>         | 1488                      | 2200                       | 92                                             |
| <b>Maximum</b>    | 1739                      | 2500                       | 105                                            |

There are three scenarios analysed under the policy to reduce irrigation allocations. The first is the base scenario of 100 per cent of allocation, the second is receiving 87 per cent of allocation and the third is receiving 80 per cent of allocation as calculated by Coleambally Irrigation (Table 20).

The spreadsheet CFFM model was not used to analyse the effect of reduced irrigation allocations because a reduction in allocation will have a major impact on optimal farm enterprise mix. The CFFM requires exogenous specification of crop areas and hence linear programming is best suited to estimate adjustments to lower input availability.

### 5.3.2 Analysis of the Effect of Reduced Irrigation Water Allocations on Farm Financial Performance and Enterprise Mix

Based on the CLPM, a reduction in allocation has a marked effect on cropping mix and farm trading surplus. Tables 21 and 22 give the results under three scenarios: the base scenario, a reduction in announced water allocation to 87 per cent and a reduction to 80 per cent of farm allocation for RF-1 and RF-4 respectively.

**Table 21      Allocation scenario results for the CLPM for RF-1**

|                               | <b>Base - 100 per<br/>cent allocation</b> | <b>87 per cent<br/>allocation</b> | <b>80 per cent<br/>allocation</b> |
|-------------------------------|-------------------------------------------|-----------------------------------|-----------------------------------|
| <b>Trading Surplus (\$)</b>   | 45,640                                    | 33,621                            | 24,048                            |
| <b>Water Requirement (Ml)</b> | 1,400                                     | 1,218                             | 1,120                             |
| <b>Water Costs (\$)</b>       | 17,528                                    | 15,249                            | 14,022                            |
| <b>Landuse Areas (ha)</b>     |                                           |                                   |                                   |
| <b>RICEM</b>                  | 69                                        | 69                                | 69                                |
| <b>MAIZE</b>                  | 13                                        | 13                                | 13                                |
| <b>CANOLA</b>                 | 60                                        | -                                 | -                                 |
| <b>FABA</b>                   | -                                         | 41                                | 8                                 |
| <b>APASTURE</b>               | 21                                        | -                                 | -                                 |
| <b>DAPASTURE</b>              | 19                                        | 40                                | 44                                |
| <b>DWHEAT</b>                 | -                                         | 19                                | 52                                |
| <b>FALLOW</b>                 | 60                                        | 60                                | 60                                |

**Table 22      Allocation scenario results for the CLPM for RF-4**

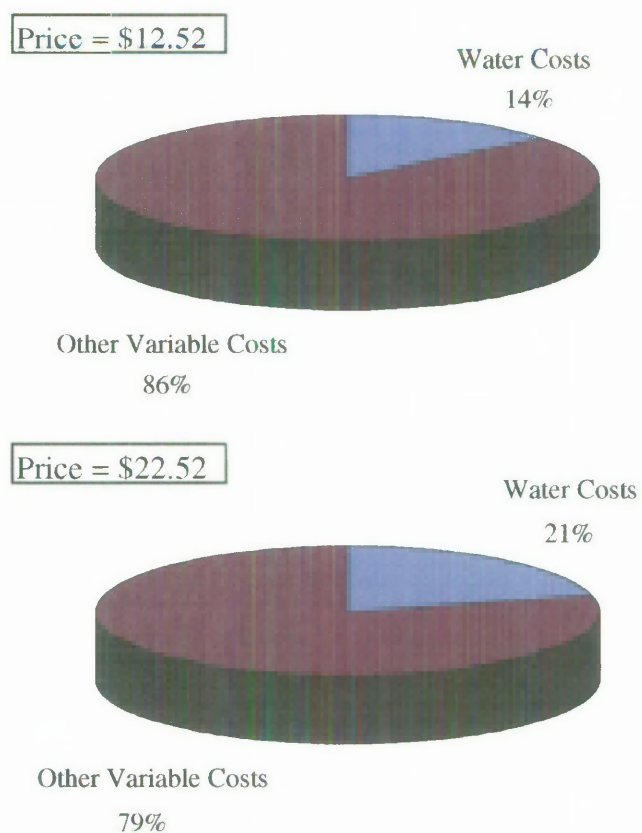
|                               | <b>Base - 100 per<br/>cent allocation</b> | <b>87 per cent<br/>allocation</b> | <b>80 per cent<br/>allocation</b> |
|-------------------------------|-------------------------------------------|-----------------------------------|-----------------------------------|
| <b>Trading Surplus (\$)</b>   | 83,497                                    | 63,011                            | 44,927                            |
| <b>Water Requirement (Ml)</b> | 2,770                                     | 2,536                             | 2,340                             |
| <b>Water Costs (\$)</b>       | 34,683                                    | 31,751                            | 29,297                            |
| <b>Landuse Areas (ha)</b>     |                                           |                                   |                                   |
| <b>RICEM</b>                  | 136                                       | 136                               | 135                               |
| <b>MAIZE</b>                  | 22                                        | 24                                | 26                                |
| <b>CANOLA</b>                 | 160                                       | 97                                | 43                                |
| <b>FABA</b>                   | 2                                         | -                                 | -                                 |
| <b>APASTURE</b>               | -                                         | -                                 | -                                 |
| <b>DAPASTURE</b>              | 44                                        | 42                                | 45                                |
| <b>DWHEAT</b>                 | -                                         | 64                                | 116                               |
| <b>FALLOW</b>                 | 120                                       | 120                               | 120                               |

## **5.4 Increased Water Prices**

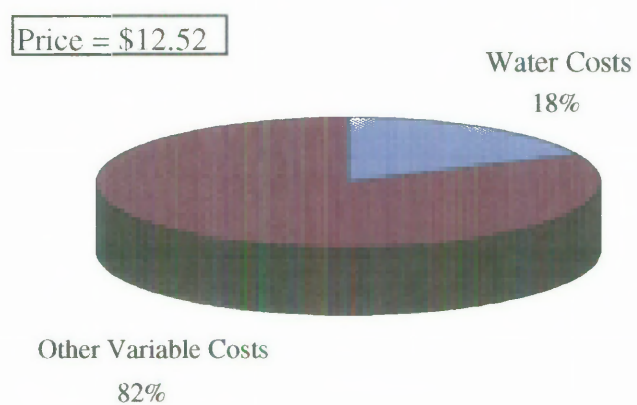
### **5.4.1 Introduction**

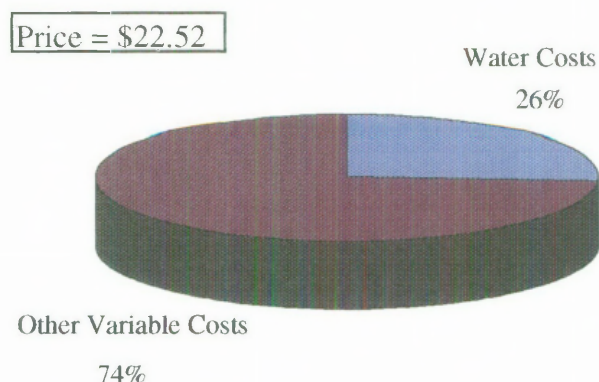
The Coleambally spreadsheet model (CFFM) was used to assess the impact of increased water charges on farm financial viability within the CIA. Three water price regimes were analysed. The first used the current price of \$12.52 per Ml as a base level water price (Cochrane 1996). In the second and third regimes the price was increased to \$17.22 and then to \$22.52. As discussed in Chapter 3, COAG have expressed the view that water pricing should reflect 'true' costs.

The alternative price scenarios are indicative prices only in the absence of any information from the NSW Government regarding the likely extent of water price increases in the foreseeable future. Water costs are a major component of variable costs associated with irrigation farms in the CIA. Figures 8 and 9 give the percentage of variable costs made up of water charges for two representative farms (RF-1 and RF-4) under the minimum and maximum price scenarios analysed.



**Figure 8** Water costs as a per cent of total variable costs for a single traditional rice farm (RF-1)





**Figure 9** Water costs as a per cent of total variable costs for a twin holding row cropping farm (RF-4)

Water costs represent a higher per cent of variable costs for the row cropping farm. The effect on farm performance of this difference is analysed in the next section.

#### 5.4.2 Analysis of the Effect of Increased Irrigation Water Prices on Farm Financial Performance

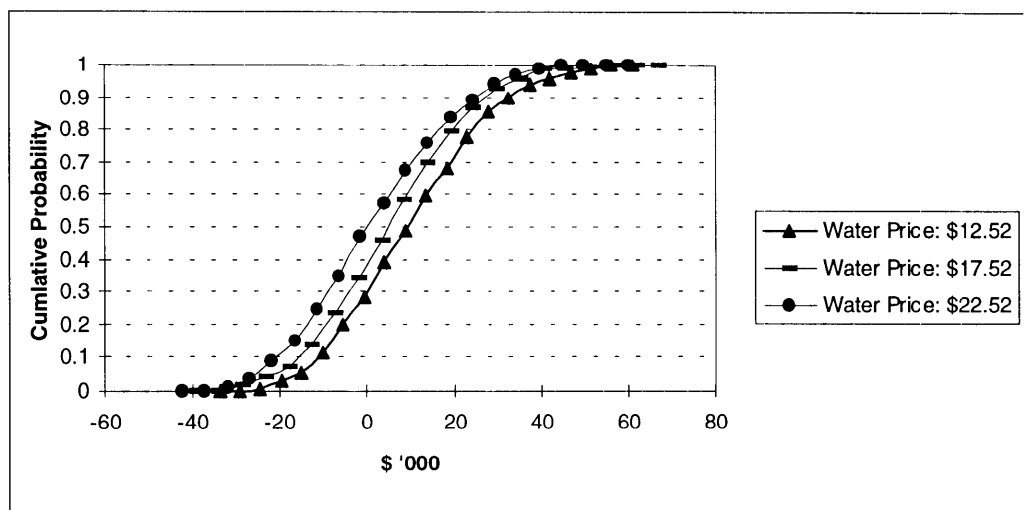
Results are shown graphically as cumulative probability density graphs for the four sample farms and for the three scenarios. The chart for RF-1 (Figure 10), with the water price increased by \$10, shows the farm businesses will make \$19 575 or less 50 per cent of the time.

The results are given in terms of farm trading surplus which represents outcomes of the financial transactions of the farm in any trading period. Mean trading surplus under the three scenarios is detailed in Table 23 and Figures 10,11,12 and 13. The farm businesses are described in terms of the enterprise mix and the number of farms.

**Table 23** Mean farm trading surplus under three water price scenarios (\$)

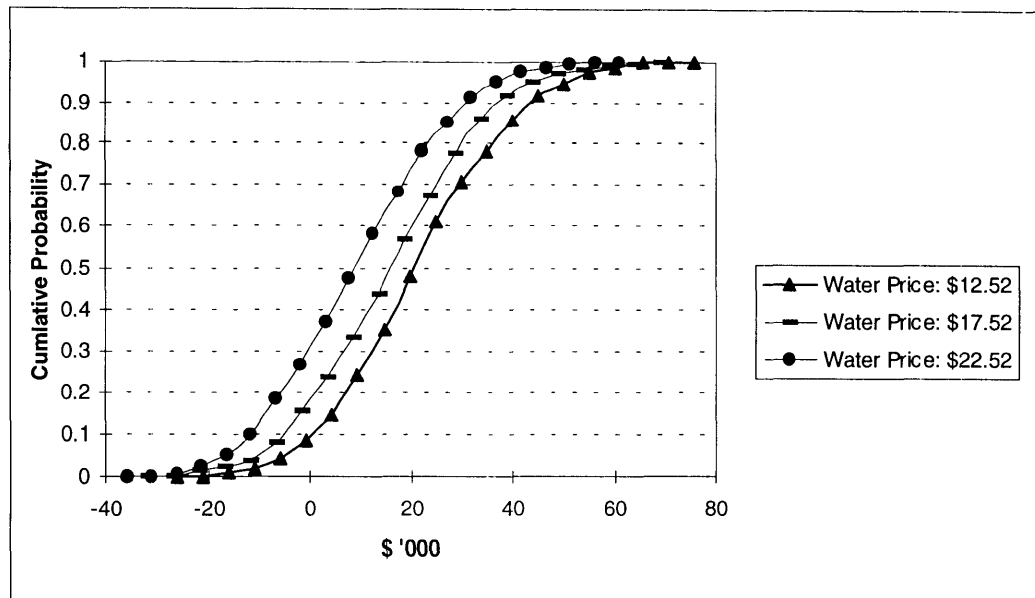
| Water Price<br>(\$ MI <sup>-1</sup> ) | RF - 1<br>Rice-One | RF - 2<br>Row-One | RF - 3<br>Rice-Two | FR - 4<br>Row-Two |
|---------------------------------------|--------------------|-------------------|--------------------|-------------------|
| Price - 12.52                         | 9,960              | 21,319            | 16,628             | 46,083            |
| Price - 17.52                         | 5,381              | 16,009            | 7,069              | 29,352            |
| Price - 22.52                         | 1,325              | 9,277             | -3,154             | 15,180            |

The base results are consistent with estimated farm performance in the Coleambally LWMP (CIA LWMP Committee 1996).

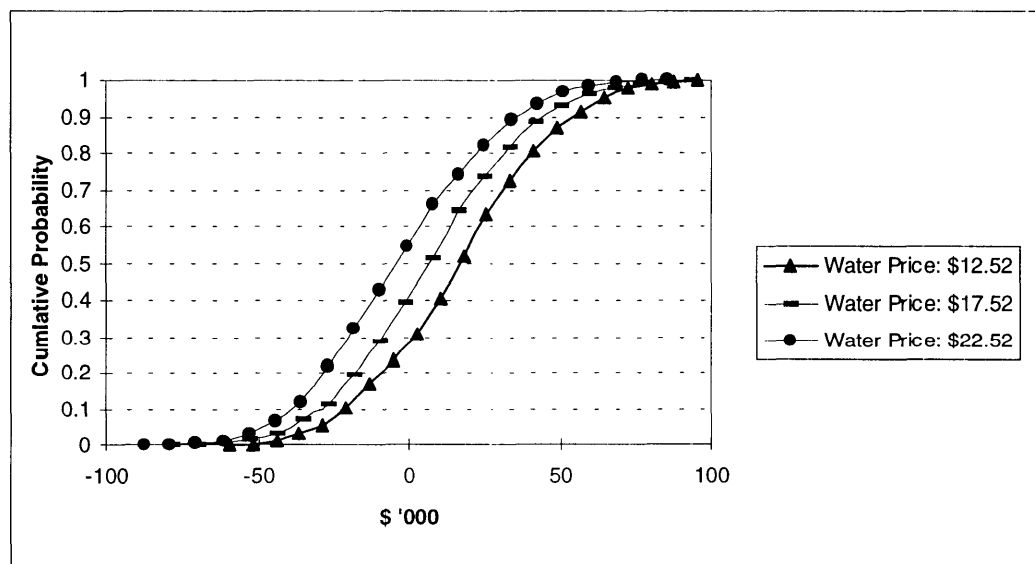


**Figure 10** Cumulative probability distribution of farm trading surplus for RF-1 under three water pricing scenarios

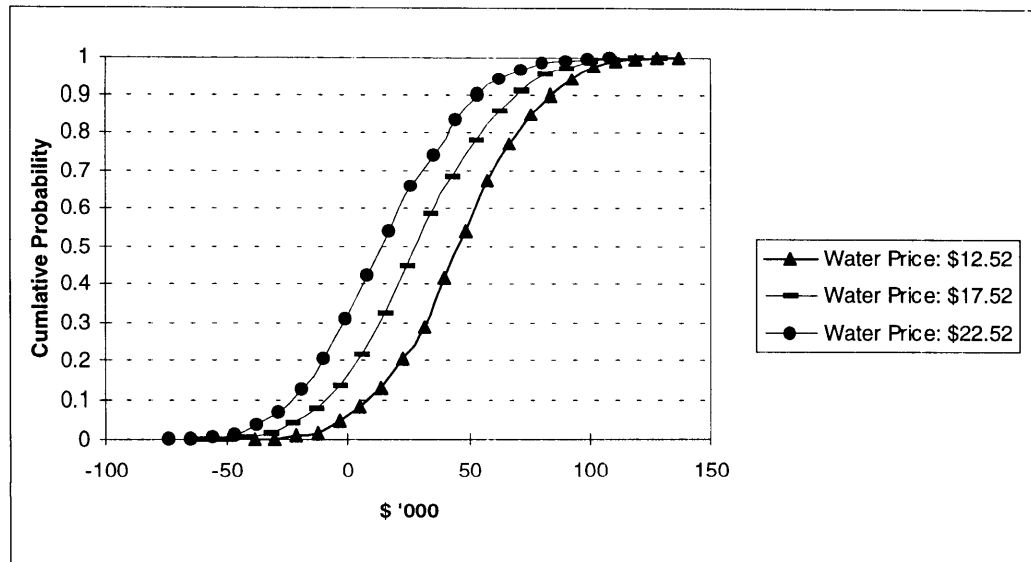
Representative farms 1 and 2 have a lower mean trading surplus than representative farms 3 and 4. This is because overhead costs are shared over a greater area when two farms are run jointly, hence profit is greater. Due to their larger cropping area and water use, RF-3 and RF-4 stand to lose more in absolute terms than the smaller farm businesses. RF-4 loses relatively more than RF-3 since crops such as maize and soybean require more water than the traditional crops grown in conjunction with rice. The differential is smaller between RF-1 and RF-2 since these farms carry out relatively little row cropping. It is possible that a higher water cost and restrictions in allocation will mean that farmers limit row cropping activities.



**Figure 11** Cumulative probability distribution of farm trading surplus for RF-2 under three water pricing scenarios



**Figure 12** Cumulative probability distribution of farm trading surplus for RF-3 under three water pricing scenarios



**Figure 13** Cumulative probability distribution of farm trading surplus for RF-4 under three water pricing scenarios

In summary, the results show that substantial impacts from the three water price scenarios on all four farm types are likely. While more reliable information on farm types and overhead cost data are required before firm conclusions can be drawn, the results indicate that the level of trading surplus would be significantly affected by changes in water prices of the magnitude analysed and that the likelihood of a negative trading surplus is increased.

#### **5.4.3 Analysis of the Effect of Increased Irrigation Water Prices on Farm Enterprise Mix**

The results of the CLPM support the results of the financial model since increased water costs have a direct effect on farm trading surplus. The farm enterprise mixes in both representative farms do not change when water prices are increased indicating an inelastic demand for irrigation water in the short run. Tables 21 and 22 show the effect of water prices on farm trading surplus. The traditional rice farm (RF-1) trading surplus decreases by approximately \$14 000 when the water price increases from \$12.52 to \$22.52  $\text{Ml}^{-1}$ .

**Table 24 Price scenario results for the CLPM for RF-1**

|                             | <b>Base - Water price<br/>12.52 (\$ MI<sup>-1</sup>)</b> | <b>Water price -<br/>17.52 (\$ MI<sup>-1</sup>)</b> | <b>Water price -<br/>22.52 (\$ MI<sup>-1</sup>)</b> |
|-----------------------------|----------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| <b>Trading Surplus (\$)</b> | 45,640                                                   | 38,640                                              | 31,639                                              |
| <b>Water Required (MI)</b>  | 1,400                                                    | 1,400                                               | 1,400                                               |
| <b>Water Costs (\$)</b>     | 17,528                                                   | 24,528                                              | 31,528                                              |
| <b>Landuse Areas (ha)</b>   |                                                          |                                                     |                                                     |
| <b>RICEM</b>                | 69                                                       | 69                                                  | 69                                                  |
| <b>MAIZE</b>                | 13                                                       | 13                                                  | 13                                                  |
| <b>CANOLA</b>               | 60                                                       | 60                                                  | 60                                                  |
| <b>APASTURE</b>             | 21                                                       | 21                                                  | 21                                                  |
| <b>DAPASTURE</b>            | 19                                                       | 19                                                  | 19                                                  |
| <b>FALLOW</b>               | 60                                                       | 60                                                  | 60                                                  |

Farm trading surplus is decreased by \$27 702 for RF-1 as the irrigation water price is increased from \$12.52 to \$22.52 MI<sup>-1</sup>. Again there is no change in the enterprise mix.

**Table 25 Pricing scenario results for the CLPM for RF-4**

|                             | <b>Base - Water price<br/>12.52 (\$ MI<sup>-1</sup>)</b> | <b>Water price -<br/>17.52 (\$ MI<sup>-1</sup>)</b> | <b>Water price -<br/>22.52 (\$ MI<sup>-1</sup>)</b> |
|-----------------------------|----------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| <b>Trading Surplus (\$)</b> | 83,497                                                   | 69,646                                              | 55,795                                              |
| <b>Water Required (MI)</b>  | 2,770                                                    | 2,770                                               | 2,770                                               |
| <b>Water Costs (\$)</b>     | 34,683                                                   | 48,533                                              | 62,384                                              |
| <b>Landuse Areas (ha)</b>   |                                                          |                                                     |                                                     |
| <b>RICEM</b>                | 136                                                      | 136                                                 | 136                                                 |
| <b>MAIZE</b>                | 22                                                       | 22                                                  | 22                                                  |
| <b>CANOLA</b>               | 160                                                      | 160                                                 | 160                                                 |
| <b>FABA</b>                 | 2                                                        | 2                                                   | 2                                                   |
| <b>APASTURE</b>             | -                                                        | -                                                   | -                                                   |
| <b>DAPASTURE</b>            | 44                                                       | 44                                                  | 44                                                  |
| <b>DWHEAT</b>               | -                                                        | -                                                   | -                                                   |
| <b>FALLOW</b>               | 120                                                      | 120                                                 | 120                                                 |

## 5.5 Tiered Block Pricing Structure

### 5.5.1 Introduction

The tiered scheme used for the farm income analysis is based upon the  $E_t$  requirements for crops. The figures used for  $E_t$  requirements are estimated from a model developed by Prathapar and Madden (1995) and are regarded as provisional only.

As shown in Figure 4 the amount of water applied to crops varies between farms. This occurs because soils, depth to the watertable and management practices all differ across farms. Three sets of irrigation applications were run to examine the differential effect of tiered pricing on farms with varying irrigation efficiencies. 'Efficient' farm water use was compared to an 'average' WUE farm and to an 'inefficient' farm. These labels are described in Table 26.

**Table 26** Estimated crop evapotranspiration requirement and irrigation water applied under different efficiency levels

| <b>Crop</b>              | <b><math>E_t</math><br/>(<math>\text{Ml ha}^{-1}</math>)</b> | <b>Average<br/>Water Use<br/>(<math>\text{Ml ha}^{-1}</math>)</b> | <b>Efficient<br/>Water Use<br/>(<math>\text{Ml ha}^{-1}</math>)</b> | <b>Inefficient<br/>Water Use<br/>(<math>\text{Ml ha}^{-1}</math>)</b> |
|--------------------------|--------------------------------------------------------------|-------------------------------------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>Rice - long*</b>      | 11.6                                                         | 15.0                                                              | 13.0                                                                | 16.0                                                                  |
| <b>Rice - medium*</b>    | 11.6                                                         | 14.3                                                              | 12.7                                                                | 16.0                                                                  |
| <b>Wheat - ASW</b>       | 4.7                                                          | 3.2                                                               | 2.9                                                                 | 4.9                                                                   |
| <b>Wheat - biscuit</b>   | 4.7                                                          | 3.5                                                               | 3.0                                                                 | 5.0                                                                   |
| <b>Maize</b>             | 5.8                                                          | 9.3                                                               | 7.2                                                                 | 9.7                                                                   |
| <b>Soybeans</b>          | 6.9                                                          | 9.2                                                               | 7.0                                                                 | 9.5                                                                   |
| <b>Fababeans</b>         | 4.0                                                          | 3.5                                                               | 3.3                                                                 | 4.5                                                                   |
| <b>Canola</b>            | 4.6                                                          | 2.9                                                               | 2.6                                                                 | 3.5                                                                   |
| <b>Annual Pasture</b>    | 4.2                                                          | 6.3                                                               | 5.8                                                                 | 7.1                                                                   |
| <b>Perennial Pasture</b> | 11.0                                                         | 10.0                                                              | 9.3                                                                 | 12.3                                                                  |

\* Source for  $E_t$  estimate Humphreys and Meyer (1996).

A three tiered scheme was analysed using the CFFM model. The first tier price was set at \$12.52  $\text{Ml}^{-1}$  (Cochrane 1996) the second is \$15.00 and the third \$20.00  $\text{Ml}^{-1}$ .

### 5.5.2 Analysis of the Effect of Tiered Pricing on Farm Financial Performance

The effects of tiered pricing on farm financial performance are reported in Tables 27 and 28 which show the difference in water costs under the two pricing structures. The tiered pricing has little impact upon the price of irrigation water if irrigation is efficient and close to the  $E_i$  requirement of the crop. However, if irrigation is inefficient then the costs of irrigating a hectare of crop can increase significantly which is important as it indicates that tiered pricing will provide an incentive to increase WUE for inefficient farmers.

**Table 27 Water price paid under a flat pricing structure and a three tier pricing structure with efficient practices**

| <b>Crop</b>       | <b>Current Pricing<br/>(\$ ha<sup>-1</sup>)</b> | <b>Tiered Pricing<br/>(\$ ha<sup>-1</sup>)</b> |
|-------------------|-------------------------------------------------|------------------------------------------------|
| Rice - medium     | 188                                             | 230                                            |
| Rice - long       | 179                                             | 214                                            |
| Wheat - ASW       | 40                                              | 40                                             |
| Wheat - biscuit   | 44                                              | 44                                             |
| Maize             | 117                                             | 161                                            |
| Soybeans          | 115                                             | 143                                            |
| Fababeans         | 44                                              | 44                                             |
| Canola            | 36                                              | 36                                             |
| Annual Pasture    | 79                                              | 79                                             |
| Perennial Pasture | 125                                             | 193                                            |

**Table 28 Water price paid under a flat pricing structure and a three tier pricing with inefficient practices**

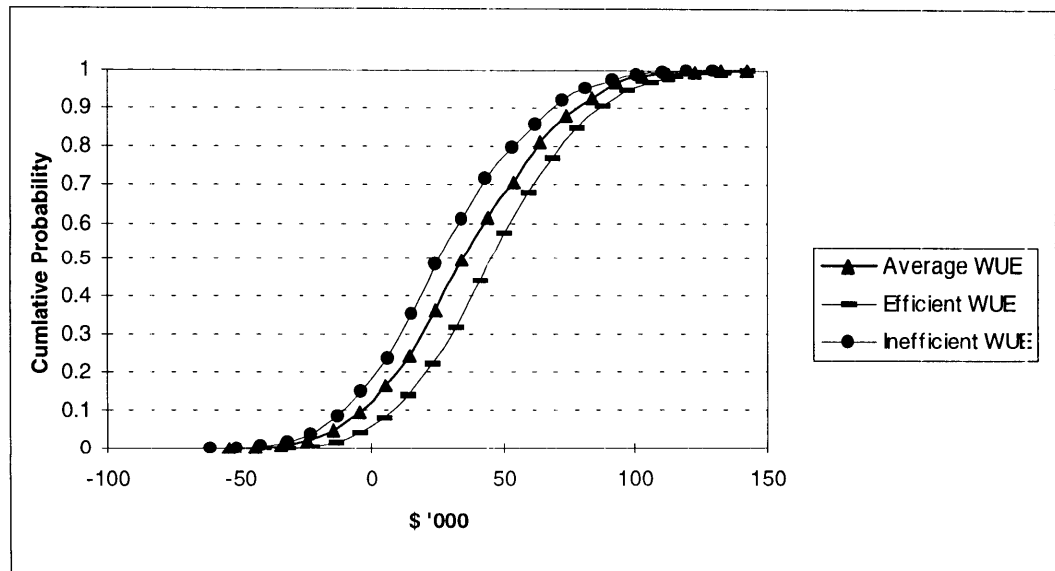
| <b>Crop</b>       | <b>Current Pricing<br/>(\$ ha<sup>-1</sup>)</b> | <b>Tiered Pricing<br/>(\$ ha<sup>-1</sup>)</b> |
|-------------------|-------------------------------------------------|------------------------------------------------|
| Rice - medium     | 209                                             | 267                                            |
| Rice - long       | 204                                             | 259                                            |
| Wheat - ASW       | 61                                              | 64                                             |
| Wheat - biscuit   | 62                                              | 66                                             |
| Maize             | 121                                             | 169                                            |
| Soybeans          | 119                                             | 151                                            |
| Fababeans         | 47                                              | 47                                             |
| Canola            | 44                                              | 44                                             |
| Annual Pasture    | 88                                              | 88                                             |
| Perennial Pasture | 154                                             | 251                                            |

The CFFM was run for four representative farm types under a range of prices and the three irrigation efficiencies as outlined in Table 29. The farm trading results of the representative farms were compared.

As reflected in the price data, if a farm is currently efficient in its water use the impact of the tiered pricing structure is minimal. However, if a farmer uses excessive water the impact of tiered pricing is significant. Under a tiered pricing scheme the water costs are split into categories so that this extra charge becomes transparent. Hence, farmer attention is focused on WUE.

**Table 29      Impact of tiered pricing on farm trading surplus**

|                        | <b>Efficient<br/>water<br/>application<br/>(\$)</b> | <b>Average<br/>water<br/>application<br/>(\$)</b> | <b>Inefficient<br/>water<br/>application<br/>(\$)</b> |
|------------------------|-----------------------------------------------------|---------------------------------------------------|-------------------------------------------------------|
| <b>RF-1</b>            |                                                     |                                                   |                                                       |
| <b>Current pricing</b> |                                                     | 9,960                                             |                                                       |
| <b>Tiered pricing</b>  | 9,669                                               | 7,152                                             | 4,496                                                 |
| <b>RF-2</b>            |                                                     |                                                   |                                                       |
| <b>Current pricing</b> |                                                     | 21,319                                            |                                                       |
| <b>Tiered pricing</b>  | 21,278                                              | 16,920                                            | 14,097                                                |
| <b>RF-3</b>            |                                                     |                                                   |                                                       |
| <b>Current pricing</b> |                                                     | 16,629                                            |                                                       |
| <b>Tiered pricing</b>  | 17,994                                              | 12,044                                            | 4,543                                                 |
| <b>RF-4</b>            |                                                     |                                                   |                                                       |
| <b>Current pricing</b> |                                                     | 46,083                                            |                                                       |
| <b>Tiered pricing</b>  | 46,422                                              | 36,296                                            | 27,771                                                |



**Figure 14 Cumulative probability density function of farm trading surplus for RF-4 under tiered water pricing with three levels of irrigation application efficiency**

Figure 14 shows the effect of the three irrigation efficiencies on farm trading surplus. It can be seen that the introduction of tiered pricing will have a greater negative impact on farm financial performance for those farms with 'inefficient' irrigation practices.

### 5.5.3 Analysis of the Effect of Tiered Pricing on Farm Enterprise Mix

The CLPM model was run for RF-4, the representative row cropping farm. The three scenarios are efficient, average efficiency, and inefficient levels of irrigation application.

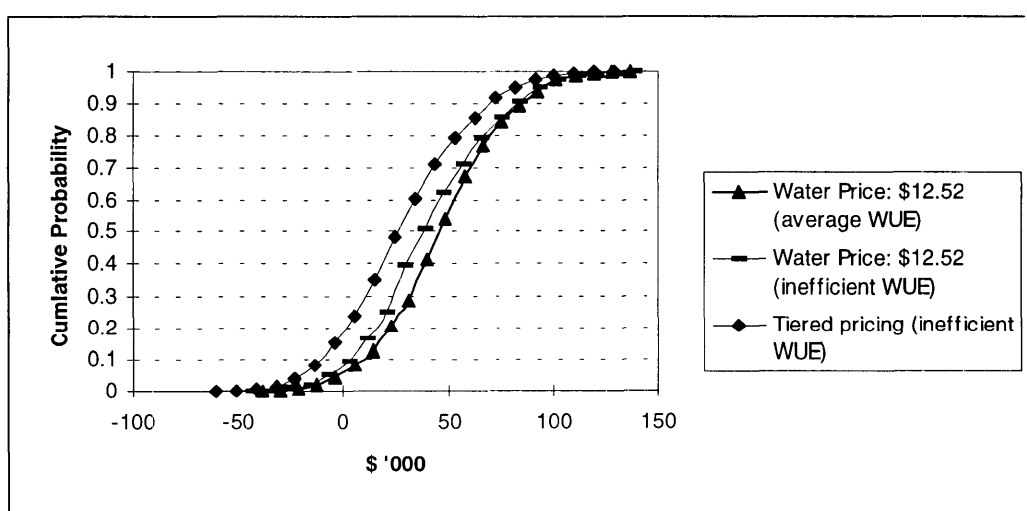
The effect of a tiered price on an efficient and average farm in terms of irrigation application is minimal, based on the  $E_i$  levels detailed in Table 30. However, with inefficient irrigation practices, the reduction in farm trading surplus is not a simple linear reduction as was the case under a flat price increase.

**Table 30** Tiered pricing scenario results for the CLPM for RF-4

|                           | Average<br>Irrigation<br>Application | Efficient<br>Irrigation<br>Application | Inefficient<br>Irrigation<br>Application |
|---------------------------|--------------------------------------|----------------------------------------|------------------------------------------|
| Trading Surplus (\$)      | 79,399                               | 87,138                                 | 53,581                                   |
| Water Requirement (Ml)    | 2,770                                | 2,347                                  | 2,900                                    |
| Water Costs (\$)          | 38,781                               | 31,041                                 | 44,024                                   |
| <b>Landuse Areas (ha)</b> |                                      |                                        |                                          |
| RICEM                     | 136                                  | 136                                    | 136                                      |
| MAIZE                     | 22                                   | 22                                     | 24                                       |
| CANOLA                    | 160                                  | 160                                    | 105                                      |
| FABA                      | 2                                    | 2                                      | -                                        |
| APASTURE                  | -                                    | -                                      | -                                        |
| DAPASTURE                 | 44                                   | 44                                     | 42                                       |
| DWHEAT                    | -                                    | -                                      | 57                                       |
| FALLOW                    | 120                                  | 120                                    | 120                                      |

## 5.6 Using the CFFM to Compare Pricing Policies

The CFFM is used to compare the effect of changing pricing policies on farm trading surplus for RF-4. Figure 15 shows that the introduction of tiered pricing has little effect on an 'efficient' farmer while an 'inefficient' farmer faces a greatly reduced trading surplus.



**Figure 15** Cumulative probability density function of farm trading surplus for RF-4 comparing tiered with flat water pricing

## **6. CONCLUSIONS**

### **6.1 Introduction**

This dissertation provides a framework that will assist in evaluating various policy instruments that target net recharge in the irrigation areas of the Southern MBD. The resulting effects on financial situations of individual farms of three options, reduced water allocation, a flat water price increase and tiered water pricing have been analysed.

A representative farm approach was adopted to analyse the effects of the three policy options on farm financial performance and land use. Two models were developed and run to examine the two aspects of farm response to policies. The first a financial spreadsheet model examined the short run financial impacts of the three policies on four representative farms. The second, a linear programming model examined the impacts on farm enterprise selection of the three policies. The three policies are addressed in turn.

### **6.2 Reduced Irrigation Water Allocations**

A reduction in the irrigation water for farms in the CIA will have a major impact on farm performance and land use. The linear programming model was used to analyse this policy as the spreadsheet model has no endogenous adjustment mechanism to reduce the area sown to crops that require irrigation water.

Under a reduction in irrigation water allocation of 20 per cent of allocation for a rice farm the trading surplus decreased by 47 per cent. This is a major reduction in financial performance. The land use also moved from irrigation crops to dryland crops such as dryland wheat and dryland annual pasture. This would indicate that a reduction in water allocation will provide a strong incentive to improve WUE. However, if the capacity to improve WUE is restricted the impact of this policy on farm financial performance will be substantial.

### 6.3 Flat water price increases

A number of water pricing scenarios were examined using both the spreadsheet model and the linear programming model. Water costs represent approximately 20 per cent of the variable costs of a CIA irrigation farm therefore any increase has the capacity to have a major effect on the financial performance of all irrigation farms in the area whether they achieve efficient application of irrigation water or not.

The spreadsheet model and the linear programming model showed that the water price increases result in a decreased financial performance for all four representative farms. The interesting point was that adding \$10 to the current water price saw no change in the land use patterns of the four representative farms though farm financial performance decreased by 30 per cent. This decrease is less than the likely decrease when irrigation water allocations are reduced by 80 per cent. The price rises examined are unlikely to have a major impact on farm practice in the short run.

It has been noted that if a farmer's limiting input is water they will already practice demand management and higher prices will imply reduce net incomes. Given the high usage of allocation in the CIA this proposition will hold true.

### 6.4 Introduction of a Tiered Pricing Structure

Tiered pricing has a differential effect between those farms which are efficient and those that are inefficient in terms of WUE. The results show little difference to current price effects on those farms that are considered 'efficient'. That is, irrigation application levels close to the  $E_i$  requirements of the crop. However, for 'inefficient' farmers there is a large effect on financial performance and also farm land use.

Financial analysis of a tier pricing structure highlights the impact of tiered pricing on inefficient farms. Under a tiered pricing structure the tiers can be varied in both the irrigation level when the higher price is implemented and the actual price of the highest tier to suit local conditions.

Tiered pricing for irrigation water has the potential to directly address the environmental problems of irrigation areas in the Southern MDB. Tiered pricing provides a direct and ongoing incentive to continuously improve irrigation WUE.

## 6.5 The Hypothesis

The hypothesis of the dissertation from Chapter 1 was:

*Tiered water pricing will have a less deleterious impact on irrigation farm incomes in the CIA than will a flat price increase or reduced allocations. Further, that tiered pricing will have a positive effect on reducing net recharge in the Irrigation Areas of Southern NSW.*

The hypothesis can be conditionally supported by the analysis conducted within this dissertation. Farmers which currently are 'efficient' irrigators will suffer a decrease in financial performance under the introduction of the tiered pricing structure analysed. This decrease will be less than that suffered under the flat price increase scenarios examined. However, 'inefficient' irrigators will be affected financially by the introduction of a tiered pricing structure to a greater extent than under a flat price increase.

The linear programming analysis suggests that tiered pricing will have a greater motivation for farmers to change land use patterns than a flat price increase. This again only holds for those irrigators' considered 'inefficient'.

## 6.6 Areas for Further Development

The models developed provides a basis for examining changes to water prices in the short run and can serve as a tool to develop an understanding of the structure of farms within the CIA and the effect of increased water prices on their viability. However, some of the assumptions that have been made due to lack of data and time could be investigated to improve confidence in the results from the spreadsheet model. This section outlines some of the areas of the model that are perceived to be weak.

1. The statistical validity of the overhead data used from Naunton and Co. (1994) has been questioned by the Coleambally LWMP Committee. To have full confidence in overhead costs and other financial data a survey should be conducted to provide up to date and statistically reliable figures.
2. For some key parameters mean data are used in the model. Variability in trading surplus is addressed by specifying probability distributions of commodity prices, crop yield and crop water usage per hectare. The model

does not address differences in overhead costs and interest costs between farm businesses in the CIA. This information should be included in any future analysis of farm financial viability.

3. The model is annual in nature and does not allow for any detailed analysis of adjustments in farm enterprises that may be made in response to higher water prices. Further model development should include an analysis of the investment ramifications of policy options.
4. The treatment of livestock gross margins in the model is simplistic. Pasture enterprises are allocated a gross margins figure which is composite of sheep and cattle enterprise gross margins. Alterations should be made to allow specification of livestock enterprises in the model.
5. Further work needs to be conducted to address specific concerns relating to the tiered pricing concept. A number of the operational concerns should be addressed in this process. This process should include questions of equity between efficient and inefficient farmers.

## COLEAMBALLY FARM FINANCIAL MODEL (CFFM)

### Variables:

**Farm No.**

**2**

**Pricing Structure**

**2**

### Farm Summary:

1. Traditional rice farm, single holding
2. Rowcropping and rice, single holding
3. Traditional rice farm, multiple holding
4. Rowcropping and rice, multiple holding

### Pricing Summary:

1. Flat price structure
2. Tiered price

### Application Efficiency

**3**

Average application  
Efficient application  
Inefficient application

### Flat Water Price

#### Variable Water Costs

|                           |                    |
|---------------------------|--------------------|
| - Variable usage charge   | <b>\$9.22 /ML</b>  |
| - Delivery service charge | <b>\$0.90 /ML</b>  |
| - Entitlement fee         | <b>\$1.05 /ML</b>  |
| - Resource management     | <b>\$1.35 /ML</b>  |
| Water Usage Price         | <b>\$12.52 /ML</b> |

### Tier Water Prices

|                  |                    |
|------------------|--------------------|
| First Tier Price | <b>\$12.52 /ML</b> |
| First Tier Price | <b>\$15.00 /ML</b> |
| First Tier Price | <b>\$25.00 /ML</b> |

### Outputs:

| <b>INCOME</b>               |             |                    |
|-----------------------------|-------------|--------------------|
| <b>Total Gross Margin</b>   |             | \$90,898.44        |
| <b>Less Overheads</b>       | \$22,153.00 |                    |
|                             |             | \$68,745.44        |
| <b>Less Depreciation</b>    | \$5,041.00  |                    |
|                             |             | \$63,704.44        |
| <b>Less Interest</b>        | \$14,057.00 |                    |
|                             |             | \$49,647.44        |
| <b>Less Drawings</b>        | \$30,858.00 |                    |
|                             |             |                    |
| <b>Farm Trading Surplus</b> |             | <b>\$18,789.44</b> |

Note: Cells shaded are input cells

## WATER USAGE UNDER THREE APPLICATION EFFICIENCIES

### Average Application

| CROP            | Water Usage |             | Water Price |         |       | ET Req   | Tiered P | Normal P | Price   | Price |
|-----------------|-------------|-------------|-------------|---------|-------|----------|----------|----------|---------|-------|
|                 | First Tier  | Second tier | Third tier  | MI/ha   | \$/ha |          |          |          |         |       |
|                 | MI/ha       | \$/ML       | \$/ML       | \$/ML   | MI/ha | (\$/ha)  | (\$/ha)  |          |         |       |
| Rice - Medium   | 15.00       | \$12.52     | \$15.00     | \$25.00 | 11.60 | \$230.23 | \$187.80 | \$230.23 | \$15.35 |       |
| Rice - Long     | 14.33       | \$12.52     | \$15.00     | \$25.00 | 11.60 | \$213.57 | \$179.45 | \$213.57 | \$14.90 |       |
| Wheat - ASW     | 3.20        | \$12.52     | \$15.00     | \$25.00 | 4.70  | \$40.06  | \$40.06  | \$40.06  | \$12.52 |       |
| Wheat - Biscuit | 3.50        | \$12.52     | \$15.00     | \$25.00 | 4.70  | \$43.82  | \$43.82  | \$43.82  | \$12.52 |       |
| Maize           | 9.33        | \$12.52     | \$15.00     | \$25.00 | 5.80  | \$160.95 | \$116.85 | \$160.95 | \$17.24 |       |
| Soybeans        | 9.17        | \$12.52     | \$15.00     | \$25.00 | 6.90  | \$143.05 | \$114.77 | \$143.05 | \$15.61 |       |
| Fababeans       | 3.50        | \$12.52     | \$15.00     | \$25.00 | 4.00  | \$43.82  | \$43.82  | \$43.82  | \$12.52 |       |
| Canola          | 2.87        | \$12.52     | \$15.00     | \$25.00 | 4.20  | \$35.89  | \$35.89  | \$35.89  | \$12.52 |       |
| Annual Past     | 6.33        | \$12.52     | \$15.00     | \$25.00 | 11.00 | \$79.29  | \$79.29  | \$79.29  | \$12.52 |       |
| Perennial Past  | 10.00       | \$12.52     | \$15.00     | \$25.00 | 4.60  | \$192.59 | \$125.20 | \$192.59 | \$19.26 |       |

### Efficient Application

| CROP            | Water Usage |            | Water Price |            |       | ET Req        | Tiered   | Normal P | Price   | Price |
|-----------------|-------------|------------|-------------|------------|-------|---------------|----------|----------|---------|-------|
|                 | MI/ha       | First Tier | Second tier | Third tier |       |               |          |          |         |       |
|                 | MI/ha       | \$/ML      | \$/ML       | \$/ML      | MI/ha | Price (\$/ha) | (\$/ha)  | in GM    | per MI  |       |
| Rice - Medium   | 13.03       | \$12.52    | \$15.00     | \$25.00    | 11.60 | \$181.07      | \$163.18 | \$181.07 | \$13.89 |       |
| Rice - Long     | 12.67       | \$12.52    | \$15.00     | \$25.00    | 11.60 | \$171.90      | \$158.59 | \$171.90 | \$13.57 |       |
| Wheat - ASW     | 2.93        | \$12.52    | \$15.00     | \$25.00    | 4.70  | \$36.73       | \$36.73  | \$36.73  | \$12.52 |       |
| Wheat - Biscuit | 3.00        | \$12.52    | \$15.00     | \$25.00    | 4.70  | \$37.56       | \$37.56  | \$37.56  | \$12.52 |       |
| Maize           | 7.20        | \$12.52    | \$15.00     | \$25.00    | 5.80  | \$107.62      | \$90.14  | \$107.62 | \$14.95 |       |
| Soybeans        | 7.00        | \$12.52    | \$15.00     | \$25.00    | 6.90  | \$88.89       | \$87.64  | \$88.89  | \$12.70 |       |
| Fababeans       | 3.33        | \$12.52    | \$15.00     | \$25.00    | 4.00  | \$41.73       | \$41.73  | \$41.73  | \$12.52 |       |
| Canola          | 2.57        | \$12.52    | \$15.00     | \$25.00    | 4.20  | \$32.13       | \$32.13  | \$32.13  | \$12.52 |       |
| Annual Past     | 5.83        | \$12.52    | \$15.00     | \$25.00    | 11.00 | \$73.03       | \$73.03  | \$73.03  | \$12.52 |       |
| Perennial Past  | 9.33        | \$12.52    | \$15.00     | \$25.00    | 4.60  | \$175.93      | \$116.85 | \$175.93 | \$18.85 |       |

### Inefficient Application

| CROP            | Water Usage<br>MI/ha | Water Price         |                      |                     |       | ET Req<br>MI/ha | Tiered<br>Price (\$/ha) | Normal P<br>(\$/ha) | Price<br>in GM | Price<br>per MI |
|-----------------|----------------------|---------------------|----------------------|---------------------|-------|-----------------|-------------------------|---------------------|----------------|-----------------|
|                 |                      | First Tier<br>\$/ML | Second tier<br>\$/ML | Third tier<br>\$/ML |       |                 |                         |                     |                |                 |
| Rice - Medium   | 16.67                | \$12.52             | \$15.00              | \$25.00             | 12.00 | \$266.91        | \$208.67                | \$266.91            | \$16.01        |                 |
| Rice - Long     | 16.33                | \$12.52             | \$15.00              | \$25.00             | 12.00 | \$258.57        | \$204.49                | \$258.57            | \$15.83        |                 |
| Wheat - ASW     | 4.90                 | \$12.52             | \$15.00              | \$25.00             | 4.70  | \$63.84         | \$61.35                 | \$63.84             | \$13.03        |                 |
| Wheat - Biscuit | 4.97                 | \$12.52             | \$15.00              | \$25.00             | 4.70  | \$65.51         | \$62.18                 | \$65.51             | \$13.19        |                 |
| Maize           | 9.67                 | \$12.52             | \$15.00              | \$25.00             | 5.80  | \$169.28        | \$121.03                | \$169.28            | \$17.51        |                 |
| Soybeans        | 9.50                 | \$12.52             | \$15.00              | \$25.00             | 6.90  | \$151.39        | \$118.94                | \$151.39            | \$15.94        |                 |
| Fababeans       | 3.77                 | \$12.52             | \$15.00              | \$25.00             | 4.00  | \$47.16         | \$47.16                 | \$47.16             | \$12.52        |                 |
| Canola          | 3.50                 | \$12.52             | \$15.00              | \$25.00             | 4.20  | \$43.82         | \$43.82                 | \$43.82             | \$12.52        |                 |
| Annual Past     | 7.07                 | \$12.52             | \$15.00              | \$25.00             | 11.00 | \$88.47         | \$88.47                 | \$88.47             | \$12.52        |                 |
| Perennial Past  | 12.33                | \$12.52             | \$15.00              | \$25.00             | 4.60  | \$250.93        | \$154.41                | \$250.93            | \$20.35        |                 |

## REPRESENTATIVE FARM BUSINESS UNITS

### REPRESENTATIVE FARM 1

**Description:** Traditional rice farm, single holding

**Farm Area:** 243 Ha

**Arable Area:** 219 Ha

**Irrigation Allocation:** 1444 ML

#### Enterprise Mix:

| Landuse         | Area          | GM/ha   | Total GM        | Water Usage    |
|-----------------|---------------|---------|-----------------|----------------|
| Rice - Long     | 20.00         | \$741   | \$14,825        | 16.7 ML/Ha     |
| Rice - Medium   | 49.00         | \$991   | \$48,536        | 16.3 ML/Ha     |
| Wheat - ASW     | 65.00         | \$148   | \$9,619         | 4.9 ML/Ha      |
| Wheat - Biscuit | 0.00          | \$105   | \$0             | 5.0 ML/Ha      |
| Maize           | 0.00          | \$1,281 | \$0             | 9.7 ML/Ha      |
| Soybeans        | 0.00          | \$388   | \$0             | 9.5 ML/Ha      |
| Fababeans       | 0.00          | \$367   | \$0             | 3.8 ML/Ha      |
| Winter Pasture  | 52.00         | \$147   | \$7,645         | 3.5 ML/Ha      |
| Summer Pasture  | 0.00          | \$384   | \$0             | 7.1 ML/Ha      |
| Canola          | 0.00          | \$500   | \$0             | 12.3 ML/Ha     |
| <b>Total</b>    | <b>186.00</b> |         | <b>\$80,625</b> | <b>1634 ML</b> |

### Nauton & Co Figures

**Overhead Costs** \$22,153

**Depreciation** \$5,041

**Interest & Development Costs** \$14,057

**Drawings including tax & super** \$30,858

## REPRESENTATIVE FARM BUSINESS UNITS

### REPRESENTATIVE FARM 2

**Description:** Rowcropping and rice, single holding

**Farm Area:** 243 Ha

**Arable Area:** 219 Ha

**Irrigation Allocation:** 1444 ML

#### Enterprise Mix:

| Landuse         | Area          | GM/ha   | Total GM        | Water Usage    |
|-----------------|---------------|---------|-----------------|----------------|
| Rice - Long     | 20.00         | \$741   | \$14,825        | 16.7 ML/Ha     |
| Rice - Medium   | 51.00         | \$991   | \$50,517        | 16.3 ML/Ha     |
| Wheat - ASW     | 20.00         | \$148   | \$2,960         | 4.9 ML/Ha      |
| Wheat - Biscuit | 0.00          | \$105   | \$0             | 5.0 ML/Ha      |
| Maize           | 0.00          | \$1,281 | \$0             | 9.7 ML/Ha      |
| Soybeans        | 40.00         | \$388   | \$15,539        | 9.5 ML/Ha      |
| Fababeans       | 0.00          | \$367   | \$0             | 3.8 ML/Ha      |
| Winter Pasture  | 48.00         | \$147   | \$7,057         | 3.5 ML/Ha      |
| Summer Pasture  | 0.00          | \$384   | \$0             | 7.1 ML/Ha      |
| Canola          | 0.00          | \$500   | \$0             | 12.3 ML/Ha     |
| <b>Total</b>    | <b>179.00</b> |         | <b>\$90,898</b> | <b>1812 ML</b> |

### Nauton & Co Figures

**Overhead Costs** \$22,153

**Depreciation** \$5,041

**Interest & Development Costs** \$14,057

**Drawings including tax & super** \$30,858

## REPRESENTATIVE FARM BUSINESS UNITS

### REPRESENTATIVE FARM 3

**Description:** Traditional rice farm, multiple holding

**Farm Area:** 486 Ha

**Arable Area:** 437 Ha

**Irrigation Allocation:** 2888 ML

#### Enterprise Mix:

| Landuse         | Area   | GM/ha   | Total GM  | Water Usage |
|-----------------|--------|---------|-----------|-------------|
| Rice - Long     | 69.00  | \$741   | \$51,146  | 16.7 ML/-ha |
| Rice - Medium   | 69.00  | \$991   | \$68,347  | 16.3 ML/-ha |
| Wheat - ASW     | 50.00  | \$148   | \$7,399   | 4.9 ML/Ha   |
| Wheat - Biscuit | 0.00   | \$105   | \$0       | 5.0 ML/Ha   |
| Maize           | 0.00   | \$1,281 | \$0       | 9.7 ML/Ha   |
| Soybeans        | 0.00   | \$388   | \$0       | 9.5 ML/Ha   |
| Fababeans       | 30.00  | \$367   | \$11,008  | 3.8 ML/Ha   |
| Winter Pasture  | 50.00  | \$147   | \$7,351   | 3.5 ML/Ha   |
| Summer Pasture  | 0.00   | \$384   | \$0       | 7.1 ML/Ha   |
| Canola          | 60.00  | \$500   | \$30,023  | 12.3 ML/Ha  |
| Total           | 328.00 |         | \$175,275 | 3550 ML     |

#### Nauton & Co Figures

**Overhead Costs** \$36,008

**Depreciation** \$22,160

**Interest & Development Costs** \$26,872

**Drawings including tax & super** \$76,626

## REPRESENTATIVE FARM BUSINESS UNITS

### REPRESENTATIVE FARM 4

Description: Rowcropping and rice, multiple holding

Farm Area: 486 Ha

Arable Area: 437 Ha

Irrigation Allocation: 2888 ML

#### Enterprise Mix:

| Landuse         | Area   | GM/ha   | Total GM  | Water Usage |
|-----------------|--------|---------|-----------|-------------|
| Rice - Long     | 67.00  | \$741   | \$49,663  | 16.7 ML/Ha  |
| Rice - Medium   | 69.00  | \$991   | \$68,347  | 16.3 ML/Ha  |
| Wheat - ASW     | 20.00  | \$148   | \$2,960   | 4.9 ML/Ha   |
| Wheat - Biscuit | 0.00   | \$105   | \$0       | 5.0 ML/Ha   |
| Maize           | 50.00  | \$1,281 | \$64,069  | 9.7 ML/Ha   |
| Soybeans        | 40.00  | \$388   | \$15,539  | 9.5 ML/Ha   |
| Fababeans       | 0.00   | \$367   | \$0       | 3.8 ML/Ha   |
| Winter Pasture  | 0.00   | \$147   | \$0       | 3.5 ML/Ha   |
| Summer Pasture  | 0.00   | \$384   | \$0       | 7.1 ML/Ha   |
| Canola          | 0.00   | \$500   | \$0       | 12.3 ML/Ha  |
| Total           | 246.00 |         | \$200,579 | 3205 ML     |

#### Nauton & Co Figures

Overhead Costs \$36,088

Depreciation \$22,160

Interest & Development Costs \$26,872

Drawings including tax & super \$76,626

## CROP PRICES

| CROP              | Most Likely<br>price (\$/t) | Minimum<br>price (\$/t) | Maximum<br>price (\$/t) | Price Used in<br>GM Sheet |
|-------------------|-----------------------------|-------------------------|-------------------------|---------------------------|
| Rice med - Amaroo | \$191.25                    | \$151.00                | \$263.00                | \$201.75                  |
| Rice long - Pelde | \$191.25                    | \$151.00                | \$263.00                | \$201.75                  |
| Wheat - ASW       | \$136.53                    | \$86.95                 | \$170.27                | \$131.25                  |
| Wheat - Biscuit   | \$136.53                    | \$86.95                 | \$170.27                | \$131.25                  |
| Maize             | \$240.83                    | \$176.00                | \$324.00                | \$246.94                  |
| Soybeans          | \$401.33                    | \$349.00                | \$441.00                | \$397.11                  |
| Faba              | \$250.00                    | \$230.00                | \$280.00                | \$253.33                  |
| Canola            | \$353.75                    | \$325.00                | \$378.00                | \$352.25                  |
| Winter Pasture    | 266.50 c/kg                 | 232.30 c/kg             | 307.15 c/kg             | 268.65 c/kg               |
| Summer Pasture    | 266.50 c/kg                 | 232.30 c/kg             | 307.15 c/kg             | 268.65 c/kg               |

**Notes:** Prices are on-farm.

Minimum and Maximum values come from NSW Ag sensitivity analysis.

## CROP YIELDS

| CROP              | Most Likely<br>(t/ha) | Minimum<br>(t/ha) | Maximum<br>(t/ha) | Yield Used in<br>GM Sheet |
|-------------------|-----------------------|-------------------|-------------------|---------------------------|
| Rice med - Amaroo | 9.50                  | 7.50              | 11.50             | 9.50                      |
| Rice long - Pelde | 8.00                  | 6.00              | 10.00             | 8.00                      |
| Wheat - ASW       | 4.50                  | 1.50              | 7.50              | 4.50                      |
| Wheat - Biscuit   | 4.00                  | 2.50              | 5.50              | 4.00                      |
| Maize             | 9.50                  | 7.50              | 11.50             | 9.50                      |
| Soybeans          | 2.80                  | 1.60              | 4.00              | 2.80                      |
| Faba              | 3.50                  | 1.25              | 5.75              | 3.50                      |
| Canola            | 2.80                  | 1.30              | 4.30              | 2.80                      |
| Annual Pasture    | 10 DSE/ha             | 7 DSE/ha          | 13 DSE/ha         | 10 DSE/ha                 |
| Perennial Pasture | 15 DSE/ha             | 12 DSE/ha         | 18 DSE/ha         | 15 DSE/ha                 |

## CROP WATER USE

| CROP              | Water Usage |
|-------------------|-------------|
| Rice - Long       | 14.3 ML/Ha  |
| Rice - Medium     | 15.0 ML/Ha  |
| Wheat - ASW       | 3.2 ML/Ha   |
| Wheat - Biscuit   | 3.5 ML/Ha   |
| Maize             | 9.5 ML/Ha   |
| Soybeans          | 9.5 ML/Ha   |
| Fababeans         | 3.5 ML/Ha   |
| Canola            | 2.9 ML/Ha   |
| Annual Pasture    | 6.3 ML/Ha   |
| Perennial Pasture | 12.0 ML/Ha  |

Source: NSW Agriculture

Enterprise:  
Description:  
Location:

## RICE - Medium Grain

Flood Irrigated - Aerial Sown  
Murrumbidgee Valley

81

### GROSS MARGIN BUDGET: 1 HA

#### INCOME:

9.50 Tonnes/Ha      \$201.75 /Tonne

Standard  
Budget  
\$/Ha

\$1,916.63

#### A. Total Income

**\$1,916.63**

#### VARIABLE COSTS:

##### *Machinery Operations*

| <u>Month</u> | <u>Operation</u>                              | <u>Tractor time</u><br>(Hrs/Ha) | <u>Tractor Cost</u><br>(\$/Hr) |          |
|--------------|-----------------------------------------------|---------------------------------|--------------------------------|----------|
| August       | Disc                                          | 0.65                            | \$12.13                        | \$7.89   |
| September    | Scarify                                       | 0.50                            | \$12.13                        | \$6.07   |
|              | Broadcast Super                               | 0.30                            | \$12.13                        | \$3.64   |
| Sep/Oct      | Combine Urea                                  | 0.30                            | \$12.13                        | \$3.64   |
|              | Reform Banks                                  | 0.20                            | \$12.13                        | \$2.43   |
|              | Rolling                                       | 0.30                            | \$12.13                        | \$2.43   |
|              | Push Ends                                     | 0.10                            | \$12.13                        | \$1.21   |
|              | Contract Aerial Sow                           |                                 |                                | \$25.00  |
| Oct/Nov      | Contract Aerial Spray molinate + chlorpyrifos |                                 |                                | \$12.50  |
|              | Contract Aerial Spray Londax® + chlorpyrifos  |                                 |                                | \$12.50  |
| January      | Contract Aerial Topdress Urea                 |                                 |                                | \$21.00  |
| Apr/May      | Contract Harvest                              | @                               | \$22.50 /Tonne                 | \$213.75 |
|              | Field Bin                                     | 0.35                            | \$12.13                        | \$4.25   |
| <b>Seed</b>  | 130 Kg/Ha                                     | @                               | \$0.18 /Kg                     | \$23.40  |
| malathion    | 0.60 L/Ha                                     | @                               | \$7.50 /Litre                  | \$4.50   |

##### *Fertiliser*

|                |           |   |                 |          |
|----------------|-----------|---|-----------------|----------|
| - Urea         | 300 Kg/Ha | @ | \$430.00 /Tonne | \$129.00 |
| - Single Super | 125 Kg/Ha | @ | \$200.00 /Tonne | \$25.00  |

##### *Herbicide*

|            |            |   |                |         |
|------------|------------|---|----------------|---------|
| - Londax®  | 0.07 Kg/Ha | @ | \$586.00 /Kg   | \$41.02 |
| - molinate | 3.75 L/Ha  | @ | \$12.40 /Litre | \$46.50 |

##### *Insecticide*

|                |           |   |                      |        |
|----------------|-----------|---|----------------------|--------|
| - chlorpyrifos | 0.06 L/Ha | @ | \$18.50 /Litre (X 2) | \$2.22 |
|----------------|-----------|---|----------------------|--------|

|                   |            |   |             |          |
|-------------------|------------|---|-------------|----------|
| <b>Irrigation</b> | 16.7 ML/Ha | @ | \$16.01 /ML | \$266.91 |
|-------------------|------------|---|-------------|----------|

|                |           |   |               |         |
|----------------|-----------|---|---------------|---------|
| <b>Cartage</b> | 9.50 T/Ha | @ | \$6.50 /Tonne | \$61.75 |
|----------------|-----------|---|---------------|---------|

|                       |  |  |               |        |
|-----------------------|--|--|---------------|--------|
| <b>Crop Insurance</b> |  |  | \$1.00 /Tonne | \$9.50 |
|-----------------------|--|--|---------------|--------|

#### B. Total Variable Costs

**\$926.09**

GROSS MARGIN /HA (A-B)

**\$990.54**

GROSS MARGIN/ ML

**\$59.43**

BREAK - EVEN YIELD (T/HA)

**4.59**

Source: NSW Agriculture, Yanco.

Cochrane, Summer Crop Budgets, Southern Zone Irrigated, 1996, p. 10

Enterprise:  
Description:  
Location:

## RICE - Long Grain

Flood Irrigated - Aerial Sown  
Murrumbidgee Valley

### GROSS MARGIN BUDGET:

1 HA

Standard  
Budget  
\$/Ha

#### INCOME:

8.00 Tonnes/Ha      \$201.75 /Tonne

\$1,614.00

#### A. Total Income

**\$1,614.00**

#### VARIABLE COSTS:

##### *Machinery Operations*

| <u>Month</u>          | <u>Operation</u>                              | <u>Tractor time</u><br>(Hrs/Ha) | <u>Tractor Cost</u><br>(\$/Hr) |          |
|-----------------------|-----------------------------------------------|---------------------------------|--------------------------------|----------|
| August                | Disc                                          | 0.65                            | \$12.13                        | \$7.89   |
| September             | Scarify                                       | 0.50                            | \$12.13                        | \$6.07   |
|                       | Broadcast Super                               | 0.30                            | \$12.13                        | \$3.64   |
| Sep/Oct               | Combine Urea                                  | 0.30                            | \$12.13                        | \$3.64   |
|                       | Reform Banks                                  | 0.20                            | \$12.13                        | \$2.43   |
|                       | Rolling                                       | 0.30                            | \$12.13                        | \$2.43   |
|                       | Push Ends                                     | 0.10                            | \$12.13                        | \$1.21   |
| October               | Contract Aerial Sow                           |                                 |                                | \$25.00  |
| Oct/Nov               | Contract Aerial Spray molinate + chlorpyrifos |                                 |                                | \$12.50  |
|                       | Contract Aerial Spray Londax® + chlorpyrifos  |                                 |                                | \$12.50  |
| January               | Contract Aerial Topdress Urea                 |                                 |                                | \$21.00  |
| Apr/May               | Contract Harvest                              | @                               | \$22.50 /Tonne                 | \$180.00 |
|                       | Field Bin                                     | 0.35                            | \$12.13                        | \$4.25   |
| <b>Seed</b>           | 130 Kg/Ha                                     | @                               | \$0.18 /Kg                     | \$23.40  |
| malathion             | 0.60 L/Ha                                     | @                               | \$7.50 /Litre                  | \$4.50   |
| <b>Fertiliser</b>     |                                               |                                 |                                |          |
| - Urea                | 300 Kg/Ha                                     | @                               | \$430.00 /Tonne                | \$129.00 |
| - Single Super        | 125 Kg/Ha                                     | @                               | \$200.00 /Tonne                | \$25.00  |
| <b>Herbicide</b>      |                                               |                                 |                                |          |
| - Londax®             | 0.07 Kg/Ha                                    | @                               | \$586.00 /Kg                   | \$41.02  |
| - molinate            | 3.75 L/Ha                                     | @                               | \$12.40 /Litre                 | \$46.50  |
| <b>Insecticide</b>    |                                               |                                 |                                |          |
| - chlorpyrifos        | 0.06 L/Ha                                     | @                               | \$18.50 /Litre (X 2)           | \$2.22   |
| <b>Irrigation</b>     | 16.3 ML/Ha                                    | @                               | \$15.83 /ML                    | \$258.57 |
| <b>Cartage</b>        | 8.00 T/Ha                                     | @                               | \$6.50 /Tonne                  | \$52.00  |
| <b>Crop Insurance</b> |                                               |                                 | \$1.00 /Tonne                  | \$8.00   |

#### B. Total Variable Costs

**\$872.75**

GROSS MARGIN /HA (A-B)

**\$741.25**

GROSS MARGIN/ ML

**\$45.38**

BREAK - EVEN YIELD (T/HA)

**6.77**

Source: NSW Agriculture, Yanco.

Cochrane, Summer Crop Budgets, Southern Zone Irrigated, 1996, p. 14

Enterprise:

**WHEAT - ASW (grain only)**

Description:

Flood Irrigated - Border Check / Conv. Sown

Location:

Murrumbidgee Valley

**GROSS MARGIN BUDGET: 1 HA**Standard  
Budget  
\$/Ha**INCOME:**

4.50 Tonnes/Ha      \$131.25 /Tonne ON FARM      \$590.63

**A. Total Income****\$590.63****VARIABLE COSTS:*****Machinery Operations***

| <u>Month</u> | <u>Operation</u> | <u>Tractor time</u><br>(Hrs/Ha) | <u>Tractor Cost</u><br>(\$/Hr) |         |
|--------------|------------------|---------------------------------|--------------------------------|---------|
| November     | Rip Banks        | 0.50                            | \$12.13                        | \$6.07  |
|              | Disc Plough      | 0.65                            | \$12.13                        | \$7.89  |
| Dec/Jan      | Scarify          | 0.40                            | \$12.13                        | \$4.85  |
| February     | Landplane        | 1.00                            | \$12.13                        | \$12.13 |
|              | Bank up          | 0.20                            | \$12.13                        | \$2.43  |
| Mar/Apr/May  | Sow              | 0.50                            | \$12.13                        | \$6.07  |
|              | DAP              | (with above)                    |                                |         |
|              | Tail Drains      | 0.50                            | \$12.13                        | \$6.07  |
| June         | Boomspray Puma   | 0.20                            | \$12.13                        | \$2.43  |
| July         | Topdress Urea    | 0.20                            | \$12.13                        | \$2.43  |
| Nov/Dec      | Contract Harvest |                                 | \$12.00 /tonne                 | \$54.00 |
|              | Chaser Bin       | 0.10                            | \$12.13                        | \$1.21  |

**Seed**      125 Kg/Ha      @      \$0.50 /kg      \$62.50

***Fertiliser***

- Urea      185 Kg/Ha      @      \$430.00 /tonne      \$79.55  
 - DAP      150 Kg/Ha      @      \$480.00 /tonne      \$72.00

***Herbicide***

- Puma S      0.50 L/Ha      @      \$56.00 /litre      \$28.00

**Irrigation**      4.9 ML/Ha      @      \$13.03 /ML      \$63.84

**Cartage**      (when use delivered price)      \$0.00

**Board & Research Levies**      3% Farm gate      \$17.72

**Crop Insurance**      2.28% of value      \$13.47

**B. Total Variable Costs****\$442.64****GROSS MARGIN /HA (A-B)****\$147.99****GROSS MARGIN / ML****\$30.20****BREAK - EVEN YIELD (T/HA)****\$3.37****NOTES:**

Source: NSW Agriculture, Yanco.

Curthoys, Winter Crop Budgets, Southern Zone Irrigated, 1996, p. 18

Enterprise:

**WHEAT (Winter) - Biscuit**

Description:

Flood Irrigated - Border Check / Conv. Sown

Location:

Murrumbidgee Valley

**GROSS MARGIN BUDGET:****1 HA**
**Standard  
Budget  
\$/Ha**
**INCOME:**

4.00 Tonnes/Ha      \$131.25 /Tonne ON FARM      \$525.00

**A. Total Income****\$525.00****VARIABLE COSTS:*****Machinery Operations***

| <u>Month</u> | <u>Operation</u> | <u>Tractor time</u><br>(Hrs/Ha) | <u>Tractor Cost</u><br>(\$/Hr) |         |
|--------------|------------------|---------------------------------|--------------------------------|---------|
| November     | Rip Banks        | 0.50                            | \$12.13                        | \$6.07  |
|              | Disc Plough      | 0.65                            | \$12.13                        | \$7.89  |
| Dec/Jan      | Scarify          | 0.40                            | \$12.13                        | \$4.85  |
| February     | Landplane        | 1.00                            | \$12.13                        | \$12.13 |
|              | Bank up          | 0.20                            | \$12.13                        | \$2.43  |
| Apr/May      | Sow              | 0.50                            | \$12.13                        | \$6.07  |
|              | DAP              | (with above)                    |                                |         |
|              | Tail Drains      | 0.50                            | \$12.13                        | \$6.07  |
| June         | Boomspray Puma   | 0.20                            | \$12.13                        | \$2.43  |
| July         | Topdress Urea    | 0.20                            | \$12.13                        | \$2.43  |
| Dec          | Contract Harvest |                                 | \$12.00 /tonne                 | \$48.00 |
|              | Chaser Bin       | 0.10                            | \$12.13                        | \$1.21  |

**Seed**      125 Kg/Ha      @      \$0.50 /kg      \$62.50
***Fertiliser***
- Urea      150 Kg/Ha      @      \$430.00 /tonne      \$64.50  
- DAP      150 Kg/Ha      @      \$480.00 /tonne      \$72.00
***Herbicide***

- Puma S      0.50 L/Ha      @      \$56.00 /litre      \$28.00

**Irrigation**      5.0 ML/Ha      @      \$13.19 /ML      \$65.51

**Cartage**      (when use delivered price)      \$0.00

**Board & Research Levies**      3% Farm gate      \$15.75

**Crop Insurance**      2.28% of value      \$11.97
**B. Total Variable Costs****\$419.79****GROSS MARGIN /HA (A-B)****\$105.21****GROSS MARGIN / ML****\$21.18****BREAK - EVEN YIELD (T/HA)****3.20**

Enterprise:

**MAIZE - Grit**

Description:

Rows/Beds

Location:

Murrumbidgee Valley

**GROSS MARGIN BUDGET:****1 HA**Standard  
Budget  
\$/Ha**INCOME:**

9.50 Tonnes/Ha

\$246.94 /Tonne on farm

\$2,345.96

**A. Total Income****\$2,345.96****VARIABLE COSTS:*****Machinery Operations***

| <u>Month</u>          | <u>Operation</u>                 | <u>Tractor time</u><br>(Hrs/Ha) | <u>Tractor Cost</u><br>(\$/Hr) |          |
|-----------------------|----------------------------------|---------------------------------|--------------------------------|----------|
| February              | Deep Rip                         | 0.70                            | \$12.13                        | \$8.49   |
|                       | Disc                             | 0.65                            | \$12.13                        | \$7.89   |
| Mar/Apr               | Scarify                          | 0.50                            | \$12.13                        | \$6.07   |
|                       | Lilliston                        | 0.50                            | \$12.13                        | \$6.07   |
| August                | Contract Aerial Spray Glyphosate |                                 |                                | \$12.50  |
| Aug/Sep               | Incorp Pre-plant N               | 0.50                            | \$12.13                        | \$6.07   |
| Sep/Oct               | B.Spray Metolachlor              | 0.20                            | \$12.13                        | \$2.43   |
|                       | Lilliston/Incorp/Shape           | 0.50                            | \$12.13                        | \$6.07   |
| Oct/Nov               | Tail Drains                      | 0.50                            | \$12.13                        | \$6.07   |
|                       | Sow                              | 0.50                            | \$12.13                        | \$6.07   |
|                       | MAP                              | (with above)                    |                                |          |
|                       | Spray Terbufos                   | (with above)                    |                                |          |
| Nov/Jan               | Water Run Urea                   |                                 |                                |          |
| December              | Inter Row Cultivate              | 0.50                            | \$12.13                        | \$6.07   |
| Apr/May               | Contract Harvest                 |                                 |                                | \$99.00  |
|                       | Field Bin                        | 0.35                            | \$12.13                        | \$4.25   |
| <b>Seed</b>           | 20 Kg/Ha                         | @                               | \$6.00 /Kg                     | \$120.00 |
| <b>Fertiliser</b>     |                                  |                                 |                                |          |
| - Urea                | 530 Kg/Ha                        | @                               | \$430.00 /Tonne                | \$227.90 |
| - MAP                 | 185 Kg/Ha                        | @                               | \$475.00 /Tonne                | \$87.88  |
| <b>Herbicide</b>      |                                  |                                 |                                |          |
| - glyphosate 450      | 0.80 L/Ha                        | @                               | \$10.50 /Litre                 | \$8.40   |
| - Primextra®          | 5.30 L/Ha                        | @                               | \$8.60 /Litre                  | \$45.58  |
| <b>Insecticide</b>    |                                  |                                 |                                |          |
| - Counter®            | 2.00 Kg/Ha                       | @                               | \$8.00 /Kg                     | \$16.00  |
| <b>Irrigation</b>     | 9.7 ML/Ha                        | @                               | \$17.51 /ML                    | \$169.28 |
| <b>Drying</b>         | 9.50 T/Ha                        | @                               | \$12.00 /Tonne                 | \$114.00 |
| <b>Crop Levy</b>      |                                  |                                 | 0.20% Farm gate                | \$4.69   |
| <b>Crop Insurance</b> |                                  |                                 | 4.00% Est.Crop Value           | \$93.84  |
| <b>Cartage</b>        |                                  |                                 |                                | \$0.00   |

**B. Total Variable Costs****\$1,064.58****GROSS MARGIN /HA (A-B)****\$1,281.39****GROSS MARGIN/ ML****\$132.56****BREAK - EVEN YIELD (T/HA)****4.31**

Source: NSW Agriculture, Yanco.

Cochrane, Summer Crop Budgets, Southern Zone Irrigated, 1996, p. 17

Enterprise:  
Description:  
Location:

## SOYBEANS

Rows/Beds  
Murrumbidgee Valley

86

### GROSS MARGIN BUDGET:

1 HA

Standard  
Budget  
\$/Ha

#### INCOME:

2.80 Tonnes/Ha      \$397.11 /Tonne on farm

\$1,111.91

#### A. Total Income

**\$1,111.91**

#### VARIABLE COSTS:

##### *Machinery Operations*

| <u>Month</u>          | <u>Operation</u>                 | <u>Tractor time</u><br>(Hrs/Ha) | <u>Tractor Cost</u><br>(\$/Hr) |                          |
|-----------------------|----------------------------------|---------------------------------|--------------------------------|--------------------------|
| February              | Deep Rip                         | 0.70                            | \$12.13                        | \$8.49                   |
|                       | Disc                             | 0.65                            | \$12.13                        | \$7.89                   |
| Mar/Apr               | Scarify                          | 0.50                            | \$12.13                        | \$6.07                   |
|                       | Lilliston                        | 0.50                            | \$12.13                        | \$6.07                   |
| Sep/Oct/Nov           | IncorpGLSup/shape                | 0.50                            | \$12.13                        | \$6.07                   |
|                       | B.Spray trifluralin              | 0.20                            | \$12.13                        | \$2.43                   |
|                       | Lillist./Incorp/Shape            | 0.50                            | \$12.13                        | \$6.07                   |
| Nov/Early Dec         | Tail Drains                      | 0.50                            | \$12.13                        | \$6.07                   |
|                       | Sow                              | 0.50                            | \$12.13                        | \$6.07                   |
| December              | Inter Row Cultivate              | 0.50                            | \$12.13                        | \$6.07                   |
| Dec/Jan               | B.Spray Sertin®                  | 0.20                            | \$12.13                        | (1/3 of area)<br>\$0.81  |
|                       | B.Spray Hallmark®                | 0.20                            | \$12.13                        | \$2.43                   |
| Feb/Mar               | Contract Aerial Spray Decis®     |                                 |                                | \$12.50                  |
|                       | Contract Aerial Spray Spinnaker® |                                 |                                | \$12.50                  |
| Apr/May               | Contract Harvest                 |                                 |                                | \$80.00                  |
|                       | Field Bin                        | 0.10                            | \$12.13                        | \$1.21                   |
| <b>Seed</b>           | 100 Kg/Ha                        | @                               | \$0.86 /Kg                     | \$86.00                  |
| Inoculum              | 100 Kg/Ha                        | @                               | \$0.03 /Kg of seed             | \$3.00                   |
| <b>Fertiliser</b>     |                                  |                                 |                                |                          |
| - Grain L. Super      | 350 Kg/Ha                        | @                               | \$415.00 /Tonne                | \$145.25                 |
| <b>Herbicide</b>      |                                  |                                 |                                |                          |
| - trifluralin         | 2.80 L/Ha                        | @                               | \$6.00 /Litre                  | \$16.80                  |
| - Sertin®             | 1.00 L/Ha                        | @                               | \$30.00 /Litre                 | (1/3 of Area)<br>\$10.00 |
| - Spinnaker®          | 0.40 L/Ha                        | @                               | \$107.00 /Litre                | (1yr in 2)<br>\$21.40    |
| <b>Insecticide</b>    |                                  |                                 |                                |                          |
| - Hallmark®           | 0.30 L/Ha                        | @                               | \$46.50 /Litre                 | \$13.95                  |
| - Decis®              | 0.50 L/Ha                        | @                               | \$34.50 /Litre                 | \$17.25                  |
| <b>Irrigation</b>     | 9.5 ML/Ha                        | @                               | \$15.94 /ML                    | \$151.39                 |
| <b>Drying</b>         | 2.80 T/Ha                        | @                               | \$12.00 /Tonne                 | (1 yr in 3 )<br>\$11.20  |
| <b>Grains Board</b>   |                                  |                                 | \$1.50 /Tonne                  | \$4.20                   |
| <b>Research Levy</b>  |                                  |                                 | 1.00% Farmgate                 | \$11.12                  |
| <b>Crop Insurance</b> |                                  |                                 | 5.50% Est. Crop value          | \$61.15                  |
| <b>Cartage</b>        |                                  |                                 |                                | \$0.00                   |

#### B. Total Variable Costs

**\$723.42**

GROSS MARGIN /HA (A-B)

**\$388.49**

GROSS MARGIN/ ML

**\$40.89**

BREAK - EVEN YIELD (T/HA)

**1.82**

Source: NSW Agriculture, Yanco.

Cochrane, Summer Crop Budgets, Southern Zone Irrigated, 1996, p. 22

Enterprise:

**FABABEANS**

87

Description:

Flood Irrigated - Beds

Location:

Murrumbidgee Valley

**GROSS MARGIN BUDGET: 1 HA**
**Standard  
Budget  
\$/Ha**
**INCOME:**

3.50 Tonnes/Ha      \$253.33 /Tonne ON FARM      \$886.67

**A. Total Income****\$886.67****VARIABLE COSTS:*****Machinery Operations***

| <u>Month</u>                     | <u>Operation</u>                           | <u>Tractor time</u><br>(Hrs/Ha) | <u>Tractor Cost</u><br>(\$/Hr) |         |
|----------------------------------|--------------------------------------------|---------------------------------|--------------------------------|---------|
| February                         | Burn Stubble                               |                                 |                                |         |
| April                            | Clean furrows                              | 0.50                            | \$12.13                        | \$6.07  |
|                                  | B.Spray Glyphosate                         | 0.20                            | \$12.13                        | \$2.43  |
| Apr/May                          | Sow                                        | 0.50                            | \$12.13                        | \$6.07  |
|                                  | Seed Inoculant (with above)                |                                 |                                |         |
|                                  | Grain Leg. Super (with above)              |                                 |                                |         |
| June                             | B.Spray Verdict                            | 0.20                            | \$12.13                        | \$2.43  |
| June/July                        | B.Spray Dithane                            | 0.20                            | \$12.13                        | \$2.43  |
| Aug/Sept                         | Contract Aerial Spray Dithane              |                                 |                                | \$9.50  |
| September                        | Contract Aerial Spray Dithane              |                                 |                                | \$9.50  |
| October                          | Contract Aerial Spray Dithane + Endosulfan |                                 |                                | \$9.50  |
| November                         | Contract Harvest                           |                                 | \$24.00 /tonne                 | \$84.00 |
| December                         | Chaser Bin                                 | 0.10                            | \$12.13                        | \$1.21  |
| <b>Seed</b>                      | 140 Kg/Ha                                  | @                               | \$0.50 /kg                     | \$70.00 |
| - Seed Inoc.                     | 140 kg/Ha                                  | @                               | \$0.20 /kg                     | \$28.00 |
| <b>Fertiliser</b>                |                                            |                                 |                                |         |
| - Grain L. Super                 | 225 Kg/Ha                                  | @                               | \$331.00 /tonne                | \$74.48 |
| <b>Herbicide</b>                 |                                            |                                 |                                |         |
| - Glyphosate 450                 | 1.00 L/Ha                                  | @                               | \$10.50 /litre                 | \$10.50 |
| - Verdict                        | 0.75 L/Ha                                  | @                               | \$55.00 /litre                 | \$41.25 |
| <b>Fungicide</b>                 |                                            |                                 |                                |         |
| - Dithane M45                    | 2.20 kg/Ha                                 | @                               | \$7.00 /kg (4 applns)          | \$61.60 |
| <b>Insecticide</b>               |                                            |                                 |                                |         |
| - Endosulfan                     | 2.10 L/Ha                                  | @                               | \$7.50 /litre                  | \$15.75 |
| <b>Irrigation</b>                | 3.8 ML/Ha                                  | @                               | \$12.52 /ML                    | \$47.16 |
| <b>Cartage</b>                   | (when use delivered price)                 |                                 |                                | \$0.00  |
| <b>Board and Research Levies</b> |                                            |                                 | 1.00% of value Farm gate       | \$8.87  |
| <b>Crop Insurance</b>            |                                            |                                 | 3.27% of value                 | \$28.99 |

**B. Total Variable Costs****\$519.72****GROSS MARGIN /HA (A-B)****\$366.95****GROSS MARGIN / ML****\$97.42****BREAK - EVEN YIELD (T/HA)****2.05****NOTES:**

Source: NSW Agriculture, Yanco.

Curthoys, Winter Crop Budgets, Southern Zone Irrigated, 1996, p. 27

Enterprise:

**CANOLA**

Description:

Flood Irrigated - Beds

Location:

Murrumbidgee Valley

**GROSS MARGIN BUDGET:****1 HA**
**Standard  
Budget  
\$/Ha**

INCOME:

2.80 Tonnes/Ha      \$352.25 /Tonne ON FARM

\$986.30

**A. Total Income****\$986.30**

VARIABLE COSTS:

***Machinery Operations***

| <u>Month</u>                     | <u>Operation</u>                 | <u>Tractor time</u><br>(Hrs/Ha) | <u>Tractor Cost</u><br>(\$/Hr) |          |
|----------------------------------|----------------------------------|---------------------------------|--------------------------------|----------|
| Dec                              | Rip Banks                        | 0.50                            | \$12.13                        | \$6.07   |
| Dec/Jan                          | Disc Plough                      | 0.65                            | \$12.13                        | \$7.89   |
| February                         | Scarify                          | 0.40                            | \$12.13                        | \$4.85   |
| March                            | Topdress Gypsum                  | 0.50                            | \$12.13                        | \$6.07   |
|                                  | Shape beds, fertilise            | 0.50                            | \$12.13                        | \$6.07   |
| April                            | B.Spray Treflan+Inc              | 0.30                            | \$12.13                        | \$3.64   |
|                                  | Additional bed shape             | 0.50                            | \$12.13                        | \$6.07   |
| Apr/May                          | Sow                              | 0.50                            | \$12.13                        | \$6.07   |
|                                  | DAP                              | (with above)                    |                                |          |
|                                  | Tail Drains                      | 0.50                            | \$12.13                        | \$6.07   |
| May                              | B.Spray Endosulfan               | 0.20                            | \$12.13                        | \$2.43   |
| July                             | Contract Aerial Topdress Urea    |                                 |                                | \$17.00  |
| Sep/Oct                          | Contract Aerial Spray Endosulfan | (1 yr in 3)                     |                                | \$3.17   |
| Nov/Dec                          | Contract Harvest                 |                                 | \$24.00 /tonne                 | \$67.20  |
|                                  | Chaser Bin                       | 0.10                            | \$12.13                        | \$1.21   |
| <b>Seed</b>                      | 4 Kg/Ha                          | @                               | /kg                            | \$0.00   |
| <b>Fertiliser</b>                |                                  |                                 |                                |          |
| - Gypsum                         | 300 kg/Ha                        | @                               | \$43.00 /tonne                 | \$12.90  |
| - Trifos                         | 200 Kg/Ha                        | @                               | \$480.00 /tonne                | \$96.00  |
| - Urea                           | 250 Kg/Ha                        | @                               | \$430.00 /tonne                | \$107.50 |
| <b>Herbicide</b>                 |                                  |                                 |                                |          |
| - Lontrel                        | 0.30 L/Ha                        | @                               | \$50.20 /litre                 | \$15.06  |
| - Treflan                        | 2.10 L/Ha                        | @                               | \$6.00 /litre                  | \$12.60  |
| <b>Insecticide</b>               |                                  |                                 |                                |          |
| - Endosulfan                     | 0.50 L/Ha                        | @                               | \$7.50 /litre                  | \$3.75   |
| - Karate                         | 180 mL/Ha                        | @                               | \$70.00 /litre (1 yr in 3)     | \$4.20   |
| <b>Irrigation</b>                | 3.5 ML/Ha                        | @                               | \$12.52 /ML                    | \$43.82  |
| <b>Cartage</b>                   | (when use delivered price)       |                                 |                                | \$0.00   |
| <b>Board and Research Levies</b> | \$1.50 /tonne &                  |                                 | 1% Farm gate                   | \$14.06  |
| <b>Crop Insurance</b>            | @                                |                                 | \$0.03 of value                | \$32.25  |

**B. Total Variable Costs****\$485.92****GROSS MARGIN /HA (A-B)****\$500.38****GROSS MARGIN / ML****\$142.97****BREAK - EVEN YIELD (T/HA)****1.38**

**Enterprise:** WINTER ANNUAL PASTURE (sub clover based)

**Description:** Flood Irrigated - Border Check

**Location:** Murrumbidgee Valley

**INCOME:** Yield (DSE/ha)  
10.00

|              | <b>DSE</b> | <b>GM per animal</b> |
|--------------|------------|----------------------|
| <b>Beef</b>  | 16.00      | \$347.00             |
| <b>Sheep</b> | 2.30       | \$27.00              |

|                        |                 |
|------------------------|-----------------|
| <b>A. Total Income</b> | <b>\$167.13</b> |
|------------------------|-----------------|

Crean (1992) pg 16 & 42

### **1. ESTABLISHMENT -**

Deleted

### **2. MAINTENANCE**

#### **VARIABLE COSTS:**

|                                |                    |                                  |                                 | <b>Standard<br/>Budget<br/>\$/Ha</b> |
|--------------------------------|--------------------|----------------------------------|---------------------------------|--------------------------------------|
| <b>Machinery Operations</b>    |                    |                                  |                                 |                                      |
| <u>Month</u>                   | <u>Operation</u>   | <u>Tractor time<br/>(Hrs/Ha)</u> | <u>Tractor Cost<br/>(\$/Hr)</u> |                                      |
| Feb/Mar                        | Topdress Super     | 0.20                             | \$12.13                         | \$2.43                               |
| May/Jun                        | B.Spray Dimethoate | 0.20                             | \$12.13                         | \$2.43                               |
|                                | B.Spray Bromoxynil | 0.20                             | \$12.13                         | \$2.43                               |
| <b>Fertiliser</b>              |                    |                                  |                                 |                                      |
| - Single Super                 | 125 Kg/Ha          | @                                | \$200.00 /tonne                 | \$25.00                              |
| <b>Herbicide</b>               |                    |                                  |                                 |                                      |
| - Bromoxynil                   | 2.00 L/Ha          | @                                | \$12.75 /litre                  | \$25.50                              |
| <b>Insecticide</b>             |                    |                                  |                                 |                                      |
| - Dimethoate                   | 0.09 L/Ha          | @                                | \$8.50 /litre                   | \$0.77                               |
| <b>Irrigation</b>              | 7.1 ML/Ha          | @                                | \$12.52 /ML                     | \$88.47                              |
| <b>B. Total Variable Costs</b> |                    |                                  |                                 | <b>\$147.02</b>                      |
| <b>GROSS MARGIN /HA (A-B)</b>  |                    |                                  |                                 | <b>\$20.11</b>                       |
| <b>GROSS MARGIN / ML</b>       |                    |                                  |                                 | <b>\$2.85</b>                        |

Source: NSW Agriculture, Yanco.

Curthoys, Winter Crop Budgets, Southern Zone Irrigated, 1996, p. 31

**Enterprise:** SUMMER PERENNIAL PASTURE (white clover/ryegrass)

**Description:** Flood Irrigated - Border Check

**Location:** Murrumbidgee Valley

**INCOME:** Yield (DSE/ha)  
15.00

|              | <b>DSE</b> | <b>GM per animal</b> |
|--------------|------------|----------------------|
| <b>Beef</b>  | 16.00      | \$347.00             |
| <b>Sheep</b> | 2.30       | \$27.00              |

**A. Total Income**

**\$250.70**

Crean (1992) pg 16 & 42

### ***1. ESTABLISHMENT - Prepared Seed-bed***

Deleted

### ***2. MAINTENANCE***

**VARIABLE COSTS:**

|                                    |                         |                                         |                                        | <b>Standard<br/>Budget<br/>\$/Ha</b> |
|------------------------------------|-------------------------|-----------------------------------------|----------------------------------------|--------------------------------------|
| <b><i>Machinery Operations</i></b> |                         |                                         |                                        |                                      |
| <b><u>Month</u></b>                | <b><u>Operation</u></b> | <b><u>Tractor time<br/>(Hrs/Ha)</u></b> | <b><u>Tractor Cost<br/>(\$/Hr)</u></b> |                                      |
| Apr/May                            | B.Spray Dimethoate      | 0.20                                    | \$12.13                                | \$2.43                               |
| May                                | Apply Bromoxynil        | 0.20                                    | \$12.13                                | \$2.43                               |
| August                             | Top-dress Super         | 0.20                                    | \$12.13                                | \$2.43                               |
| <b><i>Fertiliser</i></b>           |                         |                                         |                                        |                                      |
| - Single Super                     | 500 Kg/Ha               | @                                       | \$200.00 /tonne                        | \$100.00                             |
| <b><i>Insecticide</i></b>          |                         |                                         |                                        |                                      |
| - Dimethoate                       | 0.09 L/Ha               | @                                       | \$8.50 /litre                          | \$0.77                               |
| <b><i>Herbicide</i></b>            |                         |                                         |                                        |                                      |
| - Bromoxynil                       | 2.00 L/Ha               | @                                       | \$12.75 /litre                         | \$25.50                              |
| <b><i>Irrigation</i></b>           | 12.3 ML/Ha              | @                                       | \$20.35 /ML                            | \$250.93                             |
| <b>B. Total Variable Costs</b>     |                         |                                         |                                        | <b>\$384.47</b>                      |
| <b>GROSS MARGIN /HA (A-B)</b>      |                         |                                         |                                        | <b>(\$133.77)</b>                    |
| <b>GROSS MARGIN / ML</b>           |                         |                                         |                                        | <b>(\$10.85)</b>                     |

Source: NSW Agriculture, Yanco.

Curthoys, Winter Crop Budgets, Southern Zone Irrigated, 1996, p. 32

## APPENDIX TWO - LISTING OF THE CLPM

### COLEAMBALLY LINEAR PROGRAMMING MODEL (CLPM)

Developed by

J.C. Madden (May 1997)

Written in GAMS

Objective:

Determine on-farm landuses which result in maximum trading surplus.

### SETS

C crop / RICEM, RICEL, SOYB, MAIZE, FAB A, CANOLA, WHEAT,  
DWHEAT, BARLEY, APAST, PPAST, DAPAST, FALLOW /

WC(C) winter crops / FAB A, CANOLA, WHEAT, DWHEAT, BARLEY /

SC(C) summer crops / RICEM, RICEL, SOYB, MAIZE /

PC(C) pasture / APAST, PPAST, DAPAST /

### SCALAR

|           |                                            |           |
|-----------|--------------------------------------------|-----------|
| STRUCTURE | 1 if current structure 2 if tiered pricing | /1/       |
| BASEPRICE | price of water dollars per MI              | /24.52/   |
|           | Price on first tier                        | 12.52/    |
|           | Price of second tier                       | /20.00/ ; |

\* Farm Characteristics that vary between representative farms

### SCALAR

|          |                                         |           |
|----------|-----------------------------------------|-----------|
| AREA     | Area of farm ha                         | /240/     |
| WALL     | Water allocation per farm in MI         | /1400/    |
| RICELIM  | Allowable rice area                     | /69/      |
| PASTURE  | Area set aside for pasture if livestock | /40/      |
| WCROPS   | Minimum are for winter crops            | /60/      |
| SCROPS   | Minimum area of summer crops            | /0/       |
| OFFALL   | Off allocation supply                   | /00/      |
| FWAGE    | Family wage rate (doll per hr)          | /10/      |
| TWAGE    | Temp labour wage rate (doll per hr)     | /12.50/   |
| FAMLAB   | Annual family labour (hrs)              | /3170/    |
| DEPREC   | Depreciation                            | /5041/    |
| IDCOST   | Interest and development costs          | /14057/   |
| XTRAOH   | Fixed costs per farm                    | /22153/   |
| DRAWINGS | Drawings for family                     | /30858/ ; |

\* MXAR : Maximum total farm area a landuse is allowed

\* MNAR : Minimum total farm area a landuse is allowed

TABLE LANDAREA(C,\*)

|        | MXAR  | MNAR    |
|--------|-------|---------|
| RICEM  | 69.0  | 69.00   |
| RICEL  | 69.0  | 0.00    |
| SOYB   | 80.0  | 0.00    |
| MAIZE  | 80.0  | 0.00    |
| FABA   | 80.0  | 0.00    |
| CANOLA | 80.0  | 0.00    |
| WHEAT  | 80.0  | 0.00    |
| DWHEAT | 80.0  | 0.00    |
| BARLEY | 80.0  | 0.00    |
| APAST  | 80.0  | 0.00    |
| PPAST  | 80.0  | 0.00    |
| DAPAST | 80.0  | 0.00    |
| FALLOW | 240.0 | 60.00 ; |

TABLE GM(C,\*)

|        | YIELD | PRICE | VCOSTS |
|--------|-------|-------|--------|
| RICEM  | 9.5   | 202   | 686.82 |
| RICEL  | 8.0   | 232   | 641.82 |
| SOYB   | 2.8   | 397   | 629.62 |
| MAIZE  | 9.5   | 247   | 952.71 |
| FABA   | 3.5   | 253   | 490.63 |
| CANOLA | 2.8   | 352   | 491.54 |
| WHEAT  | 4.5   | 131   | 423.98 |
| DWHEAT | 2.0   | 131   | 197.73 |
| BARLEY | 5.0   | 110   | 462.34 |
| APAST  | 10.0  | 17    | 64.92  |
| PPAST  | 15.0  | 17    | 139.92 |
| DAPAST | 1.00  | 17    | 3.52   |
| FALLOW | 0.00  | 0.00  | 0.00 ; |

TABLE ET(C,\*)

|        | GPRD | CFACT | MRET |
|--------|------|-------|------|
| RICEM  | 150  | 0.97  | 12.4 |
| RICEL  | 150  | 0.97  | 12.4 |
| SOYB   | 140  | 0.73  | 11.8 |
| MAIZE  | 130  | 0.66  | 11.0 |
| FABA   | 200  | 0.87  | 7.5  |
| CANOLA | 190  | 0.87  | 6.7  |
| WHEAT  | 200  | 0.87  | 7.5  |
| DWHEAT | 200  | 0.87  | 7.5  |
| BARLEY | 190  | 0.87  | 6.7  |

|        |     |      |        |
|--------|-----|------|--------|
| APAST  | 230 | 0.65 | 8.0    |
| PPAST  | 365 | 0.73 | 19.1   |
| DAPAST | 180 | 0.65 | 6.5    |
| FALLOW | 365 | 1.00 | 19.1 ; |

PARAMETER AI(C) Applied irrigation in Ml per ha

|         |       |
|---------|-------|
| / RICEM | 14    |
| RICEL   | 13    |
| SOYB    | 10    |
| MAIZE   | 10    |
| FABA    | 3     |
| CANOLA  | 4     |
| WHEAT   | 4     |
| BARLEY  | 2     |
| APAST   | 3     |
| PPAST   | 10 /; |

\* Temporary labour is set at arbitrary levels as little information

\* on labour availability in CIA available.

PARAMETER TEMPLAB(M) Available temporary labour per month

|       |        |
|-------|--------|
| / JAN | 100    |
| FEB   | 100    |
| MAR   | 100    |
| APR   | 100    |
| MAY   | 100    |
| JUN   | 100    |
| JUL   | 100    |
| AUG   | 100    |
| SEP   | 100    |
| OCT   | 100    |
| NOV   | 100    |
| DEC   | 100/ ; |

\* Table below gives and labour requirements in hrs per ha. Cultivation and harvest figures from \* NSW Agriculture handbooks (Cocharne 1996, Elton 1997a). Dryland estimates from Elton

\* (1997b). Harvesting contracted out is assumed to be contracted out. Irrigation labour

\* requirements from Jones (1990).

TABLE LABOUR(C,M) LABOR REQUIREMENTS FOR CROPPING (HRS PER HA)

|        | JAN  | FEB  | MAR  | APR  | MAY  | JUN  | JUL  | AUG  | SEP  | OCT  | NOV  | DEC  |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|
| RICEM  | 0.86 | 0.86 | 0.57 | 0.20 | 0.15 | 0.00 | 0.00 | 0.65 | 0.80 | 2.32 | 2.14 | 0.86 |
| RICEL  | 0.86 | 0.86 | 0.57 | 0.20 | 0.15 | 0.00 | 0.00 | 0.65 | 0.80 | 2.32 | 2.14 | 0.86 |
| SOYB   | 2.27 | 2.75 | 2.40 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.20 | 2.60 | 1.93 |
| MAIZE  | 1.87 | 2.75 | 1.40 | 0.35 | 0.00 | 0.00 | 0.00 | 0.50 | 0.20 | 0.50 | 2.60 | 1.43 |
| FABA   | 0.00 | 0.00 | 0.50 | 0.70 | 0.50 | 0.20 | 0.20 | 0.00 | 0.40 | 0.40 | 0.00 | 0.10 |
| CANOLA | 0.40 | 0.00 | 1.50 | 0.80 | 1.20 | 0.20 | 0.00 | 0.00 | 0.23 | 0.23 | 0.10 | 0.00 |
| WHEAT  | 0.40 | 1.20 | 0.50 | 0.50 | 0.50 | 0.20 | 0.20 | 0.00 | 0.23 | 0.47 | 1.25 | 0.00 |
| DWHEAT | 0.20 | 0.00 | 0.00 | 0.00 | 0.16 | 0.13 | 0.26 | 0.00 | 0.00 | 0.22 | 0.00 | 0.35 |
| BARLEY | 0.00 | 0.40 | 1.62 | 0.40 | 1.00 | 0.20 | 0.20 | 0.00 | 0.23 | 0.00 | 0.60 | 0.65 |
| APAST  | 0.00 | 0.70 | 0.46 | 0.23 | 0.20 | 0.20 | 0.00 | 0.00 | 0.23 | 0.23 | 0.00 | 0.00 |
| PPAST  | 0.00 | 0.00 | 0.23 | 0.43 | 0.20 | 0.00 | 0.00 | 0.20 | 0.23 | 0.00 | 0.00 | 0.00 |
| DAPAST | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| FALLOW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

## PARAMETER

|             |                                                          |
|-------------|----------------------------------------------------------|
| CGM(C)      | Calculated gross margin                                  |
| MONLAB(M)   | Labour available on farm per month                       |
| CET(C)      | Crop ET requirement                                      |
| TOH         | Total overhead costs on the farm                         |
| WATPRICE(C) | Price paid per ha given irrigation and pricing structure |
| LABCROP(C)  | Total labour required for a crop in a year               |
| TIER1(C)    | First tier for each crop in ML                           |
| TIER2(C)    | Second tier for each crop in ML ;                        |

\* Calculate ET for each crop per hectare

$$CET(C) = ET(C, 'CFACT') * ET(C, 'MRET') ;$$

\* Calculating tiers for each crop in ML

$$TIER1(C) = CET(C) * (AI(C) \geq CET(C)) + AI(C) * (AI(C) < CET(C)) ;$$

$$TIER2(C) = (AI(C) - CET(C)) * (AI(C) > CET(C)) ;$$

\* Calculate GM of crops from yield, prices and variable cost data

$$CGM(C) = GM(C, 'PRICE') * GM(C, 'YIELD') - GM(C, 'VCOSTS') ;$$

\* Monthly labour available from family

$$MONLAB(M) = FAMLAB / 12 ;$$

\* Calculate total annual labour required for crops

$LABCROP(C) = SUM((M), LABOUR(C,M))$  ;

\* Calculation of total overhead costs and drawings (from Naunton and Co 1994)

$TOH = DEPREC + IDCOST + XTRAOH + DRAWINGS$  ;

\* Calculating irrigation costs

$WATPRICE(C)\$(STRUCTURE \text{ eq 1}) = BASEPRICE * AI(C)$  ;

$WATPRICE(C)\$(STRUCTURE \text{ eq 2}) = ((TIERONE*TIER1(C))+ (TIERTWO*TIER2(C)))$ ;

Display CGM, MONLAB, TOH, CET, TIER1, TIER2, WATPRICE, LABCROP ;

#### VARIABLES

|         |                          |
|---------|--------------------------|
| X(C)    | area of crop in the farm |
| TGM     | total gross margin       |
| TS      | farm trading surplus     |
| FLAB(M) | Family labour            |
| TLAB(M) | Temporary Labour         |
| LABCOST | Cost of labour ;         |

POSITIVE VARIABLE X(C), FLAB, TLAB, LABCOST ;

#### EQUATIONS

|          |                                                     |
|----------|-----------------------------------------------------|
| EWALL    | Total farm water use cannot exceed water allocated  |
| MIN(C)   | Ensure minimum area per crop                        |
| MAX(C)   | Ensure maximum area per crop                        |
| EMAXRICE | Ensure total rice area below environmental limit    |
| EMINPAST | Ensure pasture area above specified ha if livestock |
| EMINWINT | Ensure winter crop area specified                   |
| EMINSUM  | Ensure summer crop area specified                   |
| AREAC(C) | Estimate area of each crop                          |
| AREAT    | Ensure entire farm area is accounted for            |
| REVENUE  | Estimate gross margin for landuses optimised        |
| TSURPLUS | Farm revenue minus OH labour costs and drawings     |
| ELABC    | Estimate labour costs                               |
| ELAB(M)  | Labour supply-demand relation for each month        |
| ELABF(M) | Ensure family labour does not exceed supply         |
| ELABT(M) | Ensure temporary labour does not exceed supply ;    |

ELAB(M)..  $\text{SUM}((C), \text{LABOUR}(C,M)*X(C)) = L = \text{FLAB}(M) + \text{TLAB}(M)$  ;

\* Find total costs of labour

ELABC..  $\text{LABCOST} = E = \text{SUM}((M), ((\text{FWAGE} * \text{FLAB}(M)) + (\text{TWAGE} * \text{TLAB}(M))))$  ;

\* Ensure that family labour does not exceed available family labour

ELABF(M)..  $\text{FLAB}(M) = L = \text{MONLAB}(M)$  ;

\* Ensure that temporary labour does not exceed available temporary labour

ELABT(M)..  $\text{TLAB}(M) = L = \text{TEMPLAB}(M)$  ;

\* Ensure that total area planted to rice does not exceed environmental limit

EMAXRICE..  $X('RICEM') + X('RICEL') = L = \text{RICELIM}$  ;

\* Ensure that area of pastures is greater than specified if livestock farm

EMINPAST..  $X('APAST') + X('PPAST') + X('DAPAST') = G = \text{PASTURE}$  ;

\* Ensure that area of pastures is greater than specified if livestock farm

EMINSUM..  $X('MAIZE') + X('SOYB') + X('RICEL') + X('RICEM') = G = \text{SCROPS}$  ;

\* Ensure that area of pastures is greater than specified if livestock farm

EMINWINT..  $X('WHEAT') + X('FABA') + X('DWHEAT') + X('BARLEY') + X('CANOLA') = G = \text{WCROPS}$  ;

\* Minimum area of crop to be maintained

MIN(C)..  $X(C) = G = \text{LANDAREA}(C, 'MNAR')$ ;

\* Maximum area of crop to be maintained

MAX(C)..  $X(C) = L = \text{LANDAREA}(C, 'MXAR')$ ;

\* Total area of the farm should be equal to the sum of area under each land use

AREAT..  $\text{SUM}(C, X(C)) = E = \text{AREA}$  ;

\* Water requirement should not exceed water allocated

EWALL..  $\text{SUM}((C), X(C)* \text{AI}(C)) = L = \text{WALL} + \text{OFFALL}$ ;

\* Total revenue equal area of a crop multiplied by GM minus labour costs

REVENUE.. TGM =E= ((SUM(C, X(C)\* ((CGM(C)-WATPRICE(C)))))-LABCOST) ;

\* Profit taking into account overhead costs, depreciation and interest costs

TSURPLUS.. TS =E= (TGM - TOH) ;

MODEL FARMF /

ELABC  
ELAB  
ELABF  
ELABT  
EWALL  
MIN  
MAX  
EMAXRICE  
EMINPAST  
EMINWINT  
EMINSUM  
AREAT  
REVENUE  
TSURPLUS /;

SOLVE FARMF USING LP MAXIMIZING TS ;

\* Additional arithmetic

PARAMETER WREQ Total irrigation water used in the farm;

WREQ = SUM ((C), X.L(C) \* AI(C));

PARAMETER WCOSTS Total irrigation water costs for the farm;

WCOSTS = SUM ((C), X.L(C) \* WATPRICE(C));

PARAMETER LAB Total labour use on farm;

LAB = SUM ((C,M), X.L(C) \* LABOUR(C,M));

Display

WREQ

WCOSTS

X.l

LAB

FLAB.l

TLAB.l

LABCOST.l

TGM.l

TS.l ;

## REFERENCES

- ABARE (1996) Irrigated Farms: Performance in the Murrumbidgee region. *Farm Surveys Report 1996*. Canberra.
- ABARE (1997) Irrigated Farming on Broadacre Farms in the Southern Murray-Darling Basin. *Farm Surveys Report 1997*. Canberra.
- Area News (1997) 'Irrigation Restrictions on Meeting's Agenda' *Area News*, 2<sup>nd</sup> June, p. 6.
- Bari, M. and Jerrems, R. (1997) Economic Modelling of Policy Interactions: A Case Study in the Murrumbidgee Region, NSW. Paper presented at the 41<sup>st</sup> Annual Conference of the AARES. Pan Pacific Hotel, Gold Coast, Queensland 22-24 January 1997.
- Brooke, A, Kendrick, D. and Meeraus, A. (1988) *GAMS A Users Guide*. The Scientific Press. Redwood City, USA.
- Bryant, M.J., Cummins, T.F. and Nosworthy, B. (1996) *Investigation of Institutional Arrangements Relating to the Management Implementation, and Adoption of the MIA and Districts Land and Water Management Plan*. Centre for Water Policy Research, UNE.
- Bryant, M.J., Greiner, R. and Prathapar, S.A. (1993) 'Evaluation of Policies to Reduce Recharge to Shallow Watertables in Irrigated Areas', in *International Conference on Environmentally Sound Water Resources Utilization*. Bangkok, Thailand, 8-11 Nov 1993.
- Cochrane, H. (1996) *Summer Crop Budgets: Southern Zone Irrigated 1996*. NSW Agriculture, Yanco.
- Coleambally Land and Water Management Plan Committee (March 1996) *Coleambally Land and Water Management Plan, Draft*. Coleambally Irrigation.
- Coleambally Management Board (1993) *Activities Report 1993/94*. Presented to Customers at AGM 3<sup>rd</sup> November 1993. Coleambally Irrigation.
- Coleambally Management Board (1995) *Activities Report 1994/95*. Presented to Customers at AGM December 1995. Coleambally Irrigation.
- Collins, D. (1996) 'COAG Water Reforms and Farm Incomes in the Southern Murray-Darling Basin', in proceedings of *Outlook 1996*, Canberra 6-8 Feb 1996, Vol 1. ABARE.

- Cone, D. and Wichelns, D. (1994) *Irrigation District Programs To Motivate Farm Water Conservation Under Tiered-Block Water Pricing*. Final Report - Executive Summary December 31 1994.
- Crean, J. (1992) *Farm Budget Handbook: Livestock Budgets 1992*. Western Riverina and Southern Irrigation Districts. NSW Agriculture, Yanco.
- Curthoys, C., Marshall, G., and Jones, R. (1994) *Coleambally Land and Water Management Plan, Economics of On-Farm Proposals*. Economic Services Unit, NSW Agriculture, Yanco.
- Curthoys, C. (1996) *Farm Budget Handbook - Irrigated Winter Crop: Southern Zone Irrigated 1996*. NSW Agriculture, Yanco.
- Dinar, A. (1993) 'Economic Factors and Opportunities as Determinants of Water Use Efficiency in Agriculture', *Irrigation Science*.13:0-00. Springer-Verlag.
- Dinar, A., Knapp, K.C., and Letey, J. (1989) 'Irrigation Water Pricing Policies to Reduce and Finance Subsurface Drainage Disposal', *Agricultural Water Management*, 16 (1989) 155-171.
- Environmental Defenders Office (1994) *Inland Rivers: Regulatory Strategies for Ecologically Sustainable Management*. EDO, Sydney.
- Fisher Dowell Associates (Sept. 1992) *Berriquin Irrigation District Financial Study*. Swan Hill.
- Food and Agriculture Organisation of the United Nations (1995) *Reforming Water Resources Policy; A guide to Methods, Processes and Practices*. FAO Irrigation and Drainage Paper 52. Rome, Italy.
- Giesler, G., Salassi, M., Schnitkey, M., Coats, R. and Zapata, H. (1996) 'A Rice Farm Financial-Policy Simulation Model', in *Proceedings of the Twenty-Sixth Rice Technical Working Group*. San Antonio, Texas February 25-28<sup>th</sup>.
- Government Pricing Tribunal of NSW (1995) *Pricing of Bulk Water Services in NSW: An Issues Paper*. GPT, Sydney.
- Greiner, R. (1994) 'Economic Implications of Managing Dryland Salinisation on a Catchment Level- a Mathematical Modelling Approach', in *Proceedings of Water Down Under 94*, Adelaide. 21-25th Nov., 1994.

- Hall, N., Poulter, D., Wilson, S. and Soccimarro, M. (1993) 'The Economic Impact of Alternative Irrigation Management Policies: A Case Study in the West Berriquin District', in *Proceedings of a Symposium on the Future of Irrigation Farming in the Murray-Darling Basin*, Griffith NSW, 10-12 August 1993.
- Hall, N., Poulter, D. and Curtotii, R. (1994) *ABARE Model of Irrigation Farming in the Southern Murray-Darling Basin*. ABARE, Canberra.
- Haskew, H. (1996) *Has Irrigation Become Degradation*. Signs Publishing, Victoria.
- Humphreys E. and Meyer, W.S. (1996) How much water does rice really need? *Farmers Newsletter, No. 148, Large Area*. Irrigation Research and Extension Committee, Griffith.
- Independent Pricing and Regulatory Tribunal of New South Wales (1996) *Bulk Water Prices: An Interim Report*. IPART, Sydney.
- Industry Commission (1992) *Water Resources and Waste Water Disposal. Report No. 26*. AGPS, Canberra.
- Jones, R. (1990) *Input-Output Coefficients for the Murrumbidgee Irrigation Area*. NSW Agriculture and Fisheries Rural and Resource Economics Report. Yanco.
- Jones, R. (1991) 'The Farm Level Benefits of an Annual Water Transfer Scheme in the Murrumbidgee Irrigation Area', *Paper presented to the 35th Annual Conference of the AARES*. University of New England, Feb 11-14, 1991.
- Jones, R. and Fagan, M. (1996) 'Estimated Demand and Supply for Irrigation Water in Southern NSW', *Paper Presented to the 40th Annual Conference of the AARES*. University of Melbourne, Feb 11-16, 1996.
- Marshall, G., McGrath, S. and Jones, R. (July, 1994) *Agricultural Effects of Soil Salinisation and Waterlogging in the Coleambally Irrigation Area: Evaluation of Current Trends Scenario*. NSW Agriculture, Yanco.
- McDermott, N. (1993) *Summary of the Consultant's Report which Reviews Structural Reform Options for the NSW Irrigation Areas and Districts*.
- Meyer, W.S. (1985) 'Irrigation Scheduling - Principles', *IAA Journal*, August 1985.

- Meyer, W.S. (1994) *Calculation of Standard Reference Evaporation for Inland South-Eastern Australia*. Technical Memorandum, CSIRO Division of Water Resources. (in press).
- MIA Council of Horticultural Associations (1996) *Submission to the Government Pricing Tribunal: Bulk Water Pricing in NSW*. Griffith.
- Naunton and Co. Pty Ltd, and Rendall McGaukian (May 1994) *Coleambally Land and Water Management Plan: Financial Survey*. Bendigo.
- Naunton and Co Pty Ltd (December 1995) *Final Report: MIA Farm Business Survey. Prepared for the Murrumbidgee Irrigation Area and Districts Land and Water management Plan*. Bendigo.
- Norwood, C. (1997) 'Irrigation Should be Banned', *Pastoral Times*, 20<sup>th</sup> May, p. 1. Deniliquin.
- Organisation for Economic Co-operation and Development (1997) *Evaluating Economic Instruments for Environmental Policy*. OECD, France.
- Palisade Corporation (March, 1996) *@Risk, Advanced Risk Analysis for Spreadsheets*. Windows Version.
- Parker L. (January 1995) *Summary of Coleambally Land and Water Management Plan for Community Meetings*. Coleambally Irrigation.
- Prathapar, S.A. (1994) *Net Recharge Management, Project Proposal*. CSIRO.
- Prathapar, S.A. and Madden, J.C. (1995) *Determining Optimal Intensity of Irrigation for Representative Farms in The Murray Valley*. Consultancy Report 95/17. CSIRO, Division of Water Resources. Griffith.
- Prathapar, S.A., Madden, J.C. and Bramston, M. (1996) Tiered pricing for irrigation water. *Farmers Newsletter, No. 148, Large Area*. Irrigation Research and Extension Committee.
- Reichelderfer, K. and Kramer, R.A. (1993) 'Agricultural Resource Policy' in *Agricultural and Resource Economics*, eds. Carlson, G., Zilberman, D. and Miranowski, J. Oxford University Press. New York.
- Rzeszkowski, A., Baulch, W. and Madden, J.C. (1996) *Coleambally Farm Telephone Survey*. Unpublished, CSIRO, Griffith.
- Simmons, P., Poulter, D. and Hall N. (1991) *Management of irrigation water in the Murray-Darling Basin*. ABARE, Canberra.

- Soccimarro, M., Branson, J., Wall, L., and Mallawaarachchi, T. (1996) 'Modelling the impact of water policy reforms on dairy farm performance in the Southern Murray-Darling Basin', *Paper Presented at the 40th Annual Conference of the AARES*. University of Melbourne, Feb 11-16, 1996.
- Tijs, S. (1994) *Soil Salinity Survey in the Murrumbidgee and Coleambally Irrigation Areas*. Department of Water Resources, NSW, Griffith.
- van der Lely, A. (October, 1988) *Benerembah Irrigation District: Options for Management of Waterlogging and Salinisation*, Working Papers. Technical Report 88/025. Department of Water Resources, NSW, Griffith.
- van der Lely, A. (1994) *Coleambally Land and Water Management Plan: Optimisation of Options*. Department of Water Resources, NSW, Leeton.
- Wichelns, D. and Cone, D. (1992) Tiered pricing motivates Californians to conserve water. *Journal of Soil and Water Conservation*, March-April, 1992. Pp. 139-144.