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When is the price right?[1]

Mary-Ann Franco-Dixon[2], Colin G. Brown[3] and Paul C. Riethmuller[4]

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[1] The views expressed in this paper are those of the primary author and do not necessarily reflect the views of the organisations she represent.

[2] School of Natural and Rural Systems Management, University of Queensland, St Lucia, Brisbane Qld 4072 Australia and the Department of Primary Industries, 80 Ann Street, Brisbane Qld 4000; Tel No. +61 7 3365-1829; Fax No. +61 7 3365 9016; Email Address: Mary-Ann.Franco-Dixon@uq.edu.au
[3] School of Natural and Rural Systems Management, University of Queensland, St Lucia, Brisbane Qld 4072 Australia, Email Address: Colin.Brown@uq.edu.au
[4] School of Economics, University of Queensland, St Lucia, Brisbane Qld 4072 Australia, Email Address: P.Riethmuller@uq.edu.au

1. Introduction

One key component of water supply regulation and allocation and one of the complex underlying issues in many water policy decisions is the setting of water prices for all its uses. In setting the price of water, the frequently asked question is whether the set price is right. But when is the price of water exactly right? As has been shown in various literature the price of water is said to be right if it has achieved what it was initially set for. Water pricing could be set to meet three main purposes such as:

- financial - to cover capital investment and operation and maintenance (O&M) costs of water services;

- efficiency - to emphasise among users the intrinsic value of resources and delivery systems and to discourage water wastage, strengthen institutional capacities and improve quality of services; and

- equity - to reduce gaps in income distribution and thereby achieve social justice.

In the literature, two different opposing schools of thought emerge with respect to water pricing. According to one school of thought, as represented in the findings of the Industry Commission (1992), the provision of irrigation water is heavily subsidised because prices for irrigation water fall short of covering the costs to governments of building, managing and maintaining dams and distribution systems which supply water. This view is endorsed by authors such as Alexandra and Fisher (1995). Watson (1995), however, argued that the role for the price mechanism in rationing water should be based on the scarcity of water and not 'cost recovery'.

Although the pricing policy in Queensland was established primarily to recover costs of water service or delivery, in future calculation and setting of water prices, the issue of the water user's capacity to pay as was raised by irrigators during consultations is acknowledged. This paper evaluates the irrigator's capacity to pay by looking at different water price levels and how four representative farms with their different land sizes and water allocations adjust to these water price levels. Some of the many factors that can influence the irrigators' capacity to pay such as variability of weather, water availability; product prices and debt levels are not included in this paper.

2. Integrated modelling approach

The main objective of this paper is to provide an indication of the on-farm financial impacts of alternative water price levels and thus the irrigator's capacity to pay. It is recognised that any analysis needs to reflect differences in the physical and financial characteristics of farms in the Emerald Irrigation Area. The magnitude of adjustments to some policy changes is such that it might easily threaten farm financial viability. Viability effects can be best assessed in a whole farm budgeting framework or linear programming models.

A linear programming model was developed using the integrated economic-biophysical-hydrologic framework (Figure 1). This farm level integrated biophysical-economic-hydrologic model was used to quantify the direct farm-level economic impact of water pricing scenarios. This model allows for the estimate and analysis of water demand under alternative policy scenarios of different water allocation levels and water pricing regimes. This model is a short-run model that includes different crop production techniques, different irrigation techniques and allow for the inclusion of variables that reflect different levels of management.

Mathematical programming is a robust methodological approach that can determine the economic impacts of water policy changes in agriculture by determining optimal activity and optimal resource input levels. Linear programming has been the method of choice in numerous researches on water in Australia and overseas because of the flexibility in accommodating research problems with huge size and high dimensions.

2.1 Bio-physical component

As shown in Figure 1 weather factors such as daylength, temperature, fallow and in-crop rainfall and evaporation were the primary inputs to both OZCOT and APSIM. Using Rainman, weather data was generated for the years 1900 to 1995 using the Emerald Post Office data. Agronomic factors such as planting dates and soil types were also incorporated to demonstrate differences in yield response under different crop water use. The model outputs of a combination of crop yield and crop water use provides the crop water functions of the different activities which is the different levels of crop yield under various irrigation water levels. These crop water functions are then included in the linear programming Economic Model.

2.2 Hydrologic component

The stochastic water supply was captured through the hydrological simulation model. As shown in Figure 1, inputs such as upstream and catchment inflow, total rainfall, evaporation, diversion, seepage and losses were incorporated in the Integrated Quality and Quantity Management (IQQM) model to generate the monthly streamflow data for 96 years (1900 to 1995). This streamflow data then inputs into the linear programming model.

2.3 Economic component

The linear programming economic model brings together the output data from OZCOT, APSIM and IQQM model incorporated with institutional, agronomic, physical and economic factors to achieve optimisation of farm net revenue. The outputs generated by the linear programming model as shown in Figure 1 are optimal net revenue; optimal water used, optimal area used, optimal crop mix, optimal labour used and optimal tractor hours

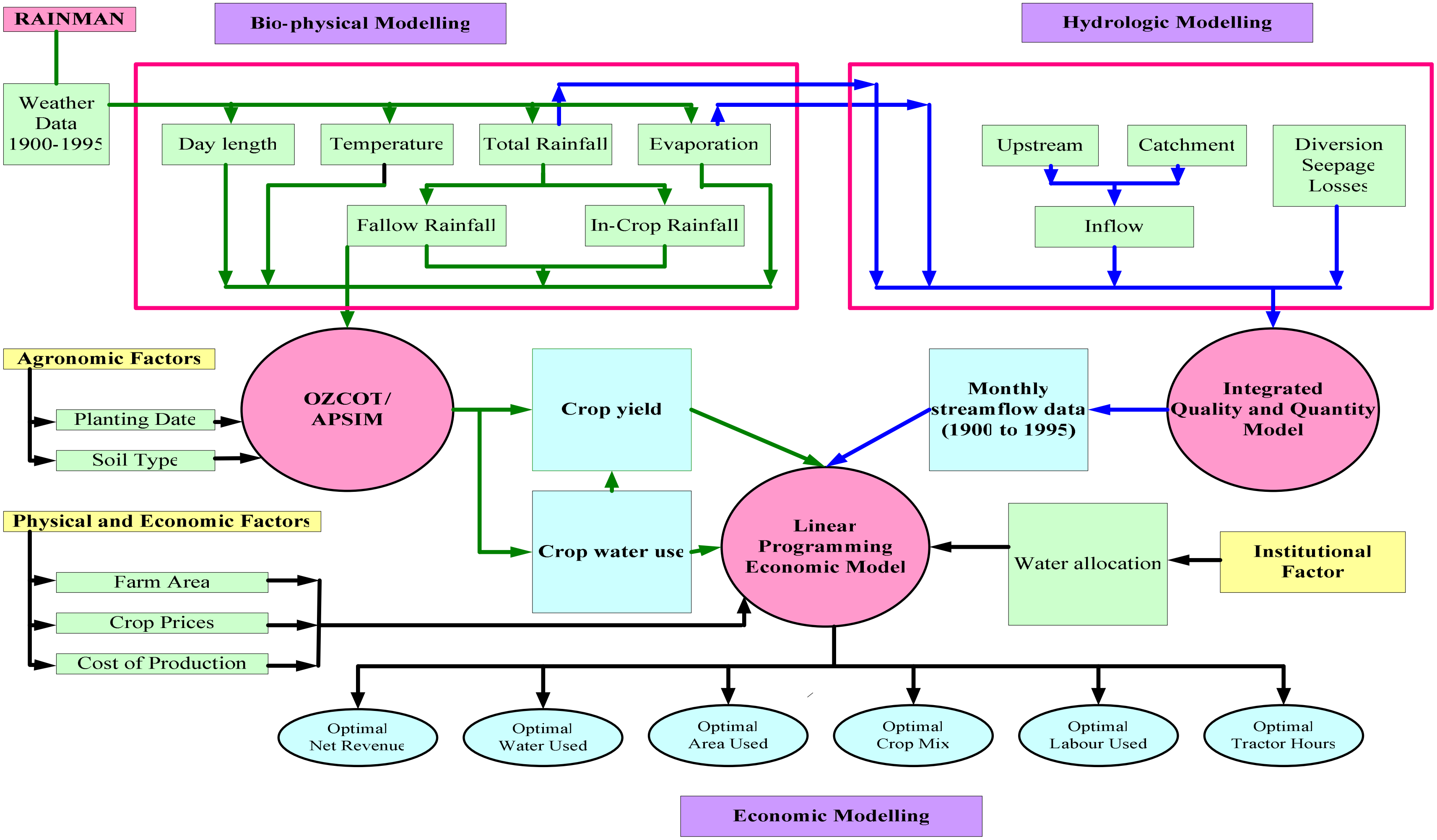

Figure 1. Integrated modelling

3. Farm-level linear programming model structure

The model developed in this study is an optimising farm model with cotton, sorghum, wheat and chickpeas. The linear programming approach was adopted to develop the farm level model using General Algebraic Modeling Systems (GAMS). It uses data on available land, water requirements per unit land area for different crops and net revenue per unit of land area, generated by the growing of those crops. This net revenue is calculated by deducting variable costs and payments for water (or water costs) from gross revenue.

The model takes the exogenous variables of water price for each of the farm types and generates endogenously the cropping pattern and choice which maximises net farm revenue. The water prices are then changed and the GAMS model re-solved several times to construct a demand function for each Farm Type and for the total water available. The water price was parameterised from the current charge to increasing total charges by increments of \$10 which is proportionally added to the Part A[5] and Part B[6] of the water price. For example, the water price of river supplemented water as shown in Table 1, has risen by an increment of \$10 in price scenario 1 but this \$10 was proportionally distributed to the Part A - \$6.20 (which is 62 per cent of water price) and Part B -\$3.80 (which is 38 per cent of water price). In addition to assessing effects of different water price levels, the model was also used to examine the effects of changes in water quantity allocations on optimal crop combinations.

Table 1. Water price for river supplemented water in Emerald Irrigation Area

Water charges	PSB	PS1 - \$10	PS2 - \$20	PS3 - \$30	PS4 - \$40
			Total price(increment)		
Part A	6.16 (62%)	12.36 (6.20)	24.76 (12.40)	43.36 (18.60)	68.16 (24.80)
Part B	3.75 (38%)	7.55 (3.80)	15.25 (7.60)	26.65 (11.40)	41.85 (15.20)

Note: Part A water charge or access charge or fixed charge
Part B water charge or volumetric charge or variable charge
PSB is price scenario base case
PS1 is price scenario 1, PS2 is price scenario 2, PS3 is Price Scenario 3, PS4 is Price Scenario 4

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[5] Part A water charge is referred to as access charge or fixed water charge or entitlement charge. Part A charge is payable for each megalitre (ML) of water entitlement or allocation.

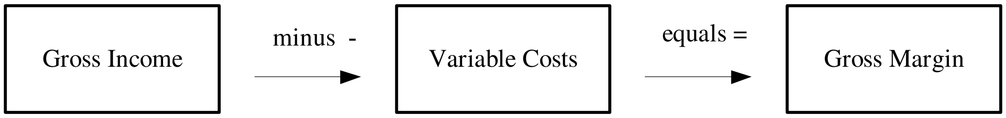
[6] Part B water charges is referred to as volumetric charge or variable water charge or usage charge Part B charge is payable for each megalitre (ML) of water used under the water entitlement.

The water charges that are used in the study relate to the current water policy which does not price water at its marginal or resource cost. Current water charges reflect costs of storage, repair and maintenance, water delivery and drainage.

3.1 Objective function

The objective function of the farm linear programming models is to maximise net revenue or profit at the farm level in the Emerald Irrigation Area by selecting the optimal mix of water-consuming crop production activities such as cotton, sorghum, wheat and chickpeas.

It is assumed in the analysis that irrigators are risk neutral and mainly profit maximisers. Maximising profits is the objective of the linear programming model and this requires some parameters such as general costs (such as planting costs, harvestings costs, herbicide costs, insecticide costs and others), depreciation and other costs that are specific to each decision variable. Calculating these parameters could be very subjective and is difficult because of the mass of data needed. It is therefore assumed in this study that gross margin is a good estimator of profit or revenue (Berbel and Gomez-Limon 2000 and Gomez-Limon et al. 1996)) and that the maximisation of profit is equivalent to the maximisation of gross margins (revenue less variable costs). The general representation of total gross margins is:



Thus, the GAMS model calculated the gross margin or net revenue. Total costs, total yield, area planted, total variable costs and total water related costs were also calculated by the model. The net revenue was calculated by deducting total crop costs (cotton, sorghum, wheat or chickpeas production costs) from total revenue. The objective function equation used in the linear programming model is shown in Equation 1. This is equivalent to the maximisation of total net private (farmer) economic benefits such as the net revenue.

$$\max \pi^{l} = \sum_{c=1}^{4}\sum_{w=1}^{3}\sum_{s=1}^{4}\sum_{e=1}^{3}\sum_{t=1}^{4} \mathrm{X}^{l}_{cwset} \times [(Y^{l}_{cwset} \times P_{cl}) \times 1 + (Y^{l}_{cwset} \times P_{cs}) \times 2.2]$$
$$- \sum_{c=1}^{4}\sum_{w=1}^{3}\sum_{s=1}^{4}\sum_{e=1}^{3}\sum_{t=1}^{4} \mathrm{X}^{l}_{cwset} \times (VC_{cwset} + WC^{l}_{cwset})$$

Equation 1

where:

c	is crop type (irrigated or raingrown solid, singleskip or doubleskip)
w	is irrigation water source (river or channel supplemented or unsupplemented)
s	is the soil type (based on the soil water holding capacity)
e	is irrigation efficiency as indicator for irrigation technology (89 per cent, 95 per cent, 99 per cent)
l	is the different levels of irrigation water application (0 to 10 ML per hectare)
π^{l}	is profit from the management scenario
X^{l}_{cslti}	are hectares of crop c, soil s, water level l, planting time t and irrigation type i under management scenario m
Y^{l}_{cwset}	are yields for irrigation level l associated with c, w, s, e and t activities
P_{cl}	is the price of cotton lint
P_{cs}	is the price of cotton seed
WC^{l}_{cwset}	is irrigation related costs for irrigation level l associated with c, w, s, e and t activities
VC_{cwset}	are variable costs associated with c, w, s, e and t activities

The variable costs and irrigation water related costs vary from one decision variable to another. The seven parts of the irrigation related costs are calculated based on Equation 2.

$$WC^{l}_{cwset} = IOC_{cwset} + IRSEC^{l}_{cwset} + ICSEC^{l}_{cswet} + IUSEC^{l}_{cwset}$$
$$+ IRSWC^{l}_{cwset} + ICSWC^{l}_{cwset} + IUSWC^{l}_{cwset}$$

Equation 2

where:

IOC_{cwset}	irrigation operating costs
$IRSEC^{l}_{cwset}$	electricity cost for pumping river supplemented water
$ICSEC^{l}_{cswet}$	electricity cost for pumping channel supplemented water
$IUSEC^{l}_{cwset}$	electricity cost for pumping unsupplemented water
$IRSWC^{l}_{cwset}$	river supplemented water cost
$ICSWC^{l}_{cwset}$	channel supplemented water cost
$IUSWC^{l}_{cwset}$	unsupplemented water cost

where:

$$IRSEC^{l}_{cwset} = PIRSWU^{l}_{cwset} \times ECIRS$$

$$ICSEC^{l}_{cswet} = PICSWU^{l}_{cwset} \times ECICS$$

$$IUSEC^{l}_{cwset} = PIUSWU^{l}_{cwset} \times ECIUS$$

3.2 Constraints

Water along with land is one of the usual constraints included in a linear programming model. Other farm constraints such as labour, fertiliser, equipment and others were held constant. This is because the focus of this study is to determine the farm level effects of changing water prices and quantity of allocation. In order to ensure that no other constraint is influencing the optimisation results, only water and land were included. The first set of constraints built in this model is the available irrigation water with three water types based on the water supply sources of river supplemented supply, channel supplemented supply and unsupplemented supply.

Water constraints are generally written in the form shown in Equation 3.

Equation 3

$$\sum W_{ij} \times X_{j} \leq W_{i}$$

where:

Wi is the total available amount of water type i.

In this model, Equation 4 was used as the water constraint equation.

$$\sum_{c=1}^{4}\sum_{w=1}^{3}\sum_{s=1}^{4}\sum_{e=1}^{3}\sum_{t=1}^{4} (PIRSW_{cwset}^{l} + PICSW_{cwset}^{l} + PIUSW_{cwset}^{l}) \leq W^{l}$$

Equation 4

where:

$PIRSW_{cwset}^{l}$	River supplemented water use
$PICSW_{cwset}^{l}$	Channel supplemented water use
$PIUSW_{cwset}^{l}$	Unsupplemented water use
W^{l}	Total available water or total water allocation at irrigation level l

The second constraint built into the model is available irrigable land of four different soil types such as alluvial, downs, scrub and duplex which have equivalent water holding capacity of 200 SWHC[7], 300 SWHC, 250 SWHC and 150 SWHC respectively.

The general form of the land constraint is show in Equation 5.

$$\sum X_{jk} \leq A_{k}$$

Equation 5

where:

k is the soil type listed previously

X_{jk} is the area of activity

j in soil type k

A_{k} is the total area available for soil type k .

The constraints ensure that the sum of the areas of the crops under each category k will not exceed the area available for that category.

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[7] SWHC – Soil available water holding capacity. Each soil type is characterised by its water holding capacity. This is the maximum volume of water that a specific type of soil can hold and would be the amount of water available for the crop to use.

The land constraint is expressed in Equation 6 as:

Equation 6

$$\sum_{c=1}^{4}\sum_{w=1}^{3}\sum_{s=1}^{4}\sum_{e=1}^{3}\sum_{t=1}^{4} X_{cwset}^{l} \leq A^{l}$$

where:

A^{l} is total area available at irrigation level l

4. The data for the model

Data was sourced from a combination of data results gathered through a survey of cotton growers in the Emerald Irrigation Area in September 2004, the use of statistical data from the Australian Bureau of Statistics (ABS) and the Australian Bureau of Agricultural and Resource Economics (ABARE), information gathered by various government departments and organisations such as SunWater; farmers; and farmer organisations. Data were validated through informal consultation with local farmers and representatives of organisations involved in agriculture and water management in Emerald region.

4.1 Current nominal and announced allocation

The irrigation water that farmers have available to them is dependent on both the nominal water allocation of each irrigator as well as the announced allocation. In Queensland, in-stream water allocation is predominantly ‘single-volumetric’. Under a single-volumetric water allocation, the authorities specify a nominal amount of water to each licensee. However, the actual quantities of water allocated each water year are limited by the water supply. Thus, at the commencement of each water year (which is 1st July), the water authority, having assessed the supply of water and after considering the supply to high reliability demand from industry, manufacturing and urban and town supplies, announces the amount of water that the authority could actually supply for irrigation as a percentage of each farm's nominal allocation.

The farm linear programming model used the total of supplemented and unsupplemented water as the threshold of water available (Table 2). The current supplemented water allocation for each farm type was then varied according to the water allocation scenarios.

Table 2. Total water available in all Farm Types by water source

Water supply source	Farm Type A	Farm Type B	Farm Type C	Farm Type D
	ML	ML	Ml	ML
River supplemented water	-	4 820	2 560	-
Channel supplemented water	1 300	-	2 560	-
Unsupplemented water	-	2 380	2 880	-
Overland flow	-	-	-	4 000
Total water	1 300	7 200	8 000	4 000

Source: September 2004 survey of cotton farmers

Table 3 shows the water allocation used in the farm linear programming model assuming that the water allocation of supplemented water is 100 per cent. Unsupplemented water was left constant when available in the farm type because the volume of water from this source is not affected by the availability of water from supplemented source coming from the dams, weir and channels.

Table 3. Supplemented water allocation by scenarios

Scenarios	Water allocation	Farm Type A	Farm Type B	Farm Type C
	%	ML	ML	ML
Base Case	100	1 300	4 820	5 120

Note: Farm Type D is not included in the table because total water supply in this Farm Type is from overland flow

The analysis includes the water use for the various crops based on the crop-yield relationship for each of the crops. The GAMS model calculated how much total water was required by the crops in each farm based on the optimal use of water.

4.2 Water price

The 2003-04 water prices for the different sources of water supply, shown in Table 4, were used in the model as the base case. These prices were set by the Department of Natural Resources, Mines and Water[8] for the Emerald Irrigation Area under the 'Rural Water Pricing Direction Notice (No. 01) 2000'. In October 2000, the Queensland government set five to seven-year price paths to ensure the majority of the irrigation schemes reached at least minimum financial viability by 2004-05. The 2003-2004 price schedules were used because the production, prices and costs data gathered from the September 2004 survey were based on financial year 2003-2004. The water charges set for the Emerald Regulated Section and the Emerald Channel

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[8] The current Department of Natural Resources Mines and Water, (NRMW) was also known as Department of Natural Resources and Mines (NR&M) and Department of Natural Resources (DNR)

under the Rural Water Pricing Direction Notice 2000 were up to 2004-05 and have been the same water charge from the 2nd year of the price path in 2001-02. The Department of Natural Resources, Mines and Water together with SunWater are currently looking at revising this price path.

Table 4. 2003-04 price schedule for the Emerald Irrigation Area

Water supply source	Part A	Part B	Total
	$/ML	$/ML	$/ML
River Supplemented (Emerald Regulated Section)	6.16	3.75	9.91
Channel Supplemented Water (Emerald Channel)	16.60	8.90	25.50
Unsupplemented Water			52.20

Source: Department of Natural Resources and Mines 2001

4.3 Crop and yield

The crops analysed are cotton, sorghum, wheat and chickpeas. Crop yields per hectare for cotton, sorghum, wheat and chickpeas were obtained from the results generated by the crop production models OZCOT and APSIM. These estimated yields reflect the different possible water availability levels based on various levels of water allocations; different planting dates; soil types; irrigation technologies; and water level application. This information was linked to the linear programming model to determine the irrigation levels for various soil types which maximise farm profitability or net revenue.

The analysis also assumes present and recent historical data reflect current and future irrigation in the region and therefore cropping patterns. In addition, where the area of land for irrigation is reduced due to the authorities allocating a less than nominal allocation of water to farmers, it is assumed that the farmers use the land for raingrown or dryland agricultural production.

Where farmers increase the area of land under irrigation due to an expected greater than nominal allocation, the model assumes the land had been previously used for dryland agricultural production.

4.4 Crop price and costs data

Table A.1 in Appendix A shows the 2003-2004 crop prices used in the linear programming model. The information on cotton lint and seed price is based on the September 2004 survey of cotton farmers while the crop prices for sorghum, wheat and chickpeas were from data provided by the Department of Primary Industries and Fisheries (2005).

Prices quoted for 2003-2004 farm costs are also based on growers' survey as well as industry benchmark figures (Table A.2).

Other costs shown in Table A.3 and Table A.4 include the costs for usual practices for herbicide, insect, pest and disease control requirements for well-managed crop in an average season. Well-managed crops are crops grown using necessary herbicides, insecticides and pesticides; irrigated with the minimum water requirement and planted in suitable soil type. Average season is a season with adequate rainfall minus the extremes of drought, flood or hail. All costs are based on the prices of the inputs paid by irrigators in Emerald Irrigation Area. The owner's labour costs are excluded.

5. Farm level production model results for Emerald Irrigation Area

The farm level model was developed to simulate mixed cropping using parameters reflecting current practices in the Emerald Irrigation Area. In the farm level model, it was assumed that the irrigation system used is surface irrigation, specifically furrow irrigation. This is the case for most of the Emerald Irrigation Area farms. It is assumed in this farm level model that farmers are profit maximisers. To maximise their net revenue, the optimal levels of irrigation are determined for each soil type, water source and irrigation level. Based on the estimates done by Kelly and Anderson (2004), the proportion of soil types in Emerald Irrigation Area used for the farm level model are Alluvial 65 per cent, Downs 13 per cent, Scrub 12 per cent and Duplex 10 per cent. Net revenue was then calculated by deducting total costs from total revenue.

Four mixed crop farm level linear programming models were generated depending on the farm types analysed. This was based on a more realistic assumption that a mixture of crops is grown similar to some combinations of crops grown in the Emerald Irrigation Area.

The cropping activities presented in the farm level model are cotton, sorghum, wheat and chickpeas production. Price data for cotton sales and variable costs data for cotton were sourced from the September 2004 survey of cotton growers in the Emerald Irrigation Area. Cotton yield data were sourced from the crop production simulation using OZCOT while sorghum, wheat and chickpeas yield data were sourced from the crop production simulation using APSIM.

As shown in Table B.1 in Appendix B, the highest mean cotton yield from the OZCOT simulation for the 95 year simulation occurred for planting dates between 1 November and 1 December. This is considered late planting in Emerald because it is riskier in terms of insects and pests problems. These yields were higher than those crops planted on the 1 October which was supposed to be in the window of conventional planting of last week of September to 1st week of October. For this reason, in building the farm level model, the yield from the 1 November planting date simulation was used in the linear programming model. This discrepancy in the more ideal planting date could be attributed to OZCOT not calibrated for losses due to insects and pests. But in order to be consistent in choosing the planting dates for all the crops, the highest mean yield planting date for the 95 year simulation was chosen.

The highest mean sorghum yield from APSIM simulation for the 95 year simulation was highest for planting dates 1 November and 1 December (Table B.2). This simulation result for sorghum is consistent with works done by the Department of Primary Industries and Hammer et al. (2002). The yield from the 1 December was used in the linear programming farm level model.

Table B.3 shows that wheat yield is highest when planted during the months of April and May. These yield results from the APSIM simulation is consistent with results obtained by Hammer et al. (2002) and with what is found to be true in the field based on the Department of Primary Industries and Fisheries results.

Chickpeas yield was highest during the months of April and May as shown in Table B.4. This is exactly the same as the results for wheat. Wheat and chickpeas are both winter crops and the optimum results occur when the temperature are low.

Error! Reference source not found. shows the gross margins of all the crops as an indicator of farm profit based on 2003 and 2004 price data.

Table 5. Gross margins of the crops grown

Crops	Gross Margins
	$/ha
Irrigated cotton	2 991
Raingrown cotton solid	833
Raingrown cotton single skip	763
Raingrown cotton double skip	692
Irrigated sorghum	945
Raingrown sorghum	381
Irrigated wheat	996
Raingrown wheat	522
Irrigated chickpeas	772
Raingrown chickpeas	427

Source: September 2004 survey of cotton growers, Department of Primary Industries, personal communication with growers.

Table 6 shows that for all farm types, the optimal solution from the model results in a farm growing monoculture cotton in summer with minimum chickpeas grown in winter. Sorghum and wheat did not come into the optimal solution because of the limited available labour in winter with the cotton land preparation competing with wheat planting. Because of the higher cotton gross margin, the model selects to grow cotton over wheat and winter labour is used for cotton land preparation instead of planting wheat. Planting chickpeas becomes an option in the models since in trying to optimise the net revenue, the model uses whatever amount of water is left available for other crops after planting and irrigating the optimal land area to cotton. This conforms with current practices observed since irrigated sorghum, wheat and chickpeas occur as opportunistic production in Emerald. This reflects the situation in the Emerald Irrigation Area where cotton farmers grow cotton as the primary summer crop and do not fallow as a normal management practice. Chickpeas, if irrigated with only 1 ML of water per hectare, yield around 2 tonnes per hectare. Assuming a crop price of $490 per tonne, the total revenue for chickpeas per hectare is $980. To produce the same total revenue, cotton yield has to be around 1.8 bales per hectare assuming a particular cotton price and at least have a minimum irrigation of 1 ML of water per hectare. Assuming that the labour constraint is constant, cotton is expected to be chosen over chickpeas. However, the total costs to produce cotton are higher than to produce chickpeas. Thus, the optimal solution uses the last volume of water for chickpeas.

Another intuitive result is for the farmer to keep the 10 per cent of the land it plants to chickpeas in fallow. Kelly and Anderson (2004) attribute the low fallowing rate in the

Emerald Irrigation Area to the landlocked situation in the area. Given a certain amount of water allocation, farmers would not be able to easily expand land planted to cotton or any other crop because of the fixed or finite land available to them. Thus, they keep planting the maximum irrigated land available year after year and would only involuntarily fallow if water is not available to plant cotton or any winter crop or when it becomes uneconomical to grow cotton under low water availability scenarios. Due to the high water cost and the higher returns from cotton production, it is expected that cotton is the crop of choice if adequate water is available to irrigate.

Table 6. Base case crop production

Farm type/Crops	Total revenue	Farm costs	Water costs		Net Revenue
			Part A	Part B*	
	($)	($)	($)	($)	($)
Farm type A (222 ha)	962 373	571 114	21 580	11 570	369 679
Farm type B (960 ha)	4 838 337	2 911 903	29 691	142 141	1 896 743
Farm type C (1100 ha)	5 426 209	3 288 656	58 266	182 749	2 079 987
Farm type D (580 Ha)**	2 735 734	1 538 886	0	0	1 196 848

Note: *Part B water costs and irrigation operation costs are included in the calculation of farm costs.
**Water supply from overland flow is assumed to have zero water cost and pumping cost.

Table 7 shows the modelling results for the mixed crop model in terms of the total area, optimal land area, and the per cent of optimal land area planted to cotton or other crops. The model was constructed as a single season model but with labour constraint divided into summer and winter labour. The seasonal labour requirements of cotton, sorghum, wheat and chickpeas were set in the model and is the variable driving the seasonality of growing these crops. As mentioned earlier, Emerald does not have a distinct summer and winter cropping for irrigated crops. All of the linear programming models for all the farm types grow irrigated cotton for summer cropping with irrigated chickpeas as the winter crop grown. Winter cropping in the Emerald Irrigation Area occurs when there is not enough water to plant and irrigate the total land area to cotton. In this situation whatever water is not used in growing cotton is then saved and used for winter cropping. The model calculates this optimal combination of summer and winter cropping. The percentage of irrigated cotton grown over irrigated chickpeas ranged from 77 per cent to 90 per cent depending on the farm type. The smaller farm type A had 51 hectares (23 per cent) of its land planted to chickpeas for winter, farm type B had 96 hectares, farm type C had 132 hectares and farm type D had 104 hectares. Thus, chickpeas production was minimal with the area of land planted to chickpeas only about 50 to 132 hectares with an average of 96 hectares. Thus the model optimises by planting small areas to chickpeas based on the extra water from the production of cotton. This could easily occur especially in farm types B and C where water allocation was high but with a limited land to plant more cotton.

Table 7. Optimal farm use for mixed-crop production each farm type

Farm type	Total Area	Optimal land use	Irrigated cotton	Irrigated chickpeas	Farm revenue
	ha	ha	%	ha	($)
Farm type A	222	222	77	23	369 679
Farm type B	960	960	90	10	1 896 743
Farm type C	1 100	1 100	88	12	2 079 987
Farm type D	580	580	82	18	1 196 848

Source: Linear programming model results

Another distinct characteristic of Emerald cotton growing is that raingrown cotton is not a common alternative to land use if there is not enough available water. Cotton farmers interviewed during the consultation all said that raingrown cotton growing is not profitable for the Emerald area. This is mainly because in extreme climate conditions, it is expected that rain would not come when needed. In contrast, Darling Downs cotton farmers do grow raingrown cotton. When the announced water allocation is low at the beginning of the water year, some Darling Downs cotton farmers take the risk and still plant the same cotton area and hope that rain will come to ease the water stressed plants.

Table 8 shows that the base case model runs for all farm types - which all have a predominantly cotton production - have the same pattern of water allocation usage. In all of the farm types, 100 per cent of the water allocation was used for crop production. Ninety-six per cent of the channel water allocation was used for cotton production in farm type A and 96 per cent of the overland flow in farm type D was also used for cotton production. When both river supplemented water and unsupplemented water are available as in the case of farm type B, all of the river supplemented water was used for cotton production and 96 per cent of the unsupplemented water was used for the water requirement of the cotton and the rest for chickpeas.

Table 8. Total water used as percentage of total allocation

	IRS		ICS		IUS		Overland Flow	
	Total allocation	Water Used	Total allocation	Water Used	Total allocation	Water Used	Total	Water Used
	ML	%	ML	%	ML	%	ML	%
Farm type A	0	0	1 300	100	0	0	0	0
Cotton (Summer)			1 249	96				
Chickpeas (Winter)			51	4				
Farm type B	4 724	66	0	0	2 476	34	0	0
Cotton (Summer)	4 724	100	0	0	1 996	81		
Chickpeas (Winter)	0	0	0	0	480	19		
Farm type C	2 560	32	2 560	32	2 880	36	0	0
Cotton (Summer)	2 560	100	2 560	100	2 721	94		
Chickpeas (Winter)	0	0	0	0	159	6	0	0
Farm type D							4 000	100
Cotton (Summer)							3 854	96
Chickpeas (Winter)							146	4

Source: Linear programming model results

The usage pattern for cotton resulting from the linear programming model is consistent with farm practices in Emerald where farmers with unsupplemented water allocation use this water source first before ordering water through the supplemented system. Unsupplemented allocation is based on the river flow conditions and when unsupplemented water becomes available as the in-stream water reaches some threshold level, water must be harvested or it will be an opportunity lost. When there is some water stored in on-farm dams from unsupplemented water harvesting, it is a common practice to use this first or losses from evaporation and seepage will occur. The availability of three water sources in farm type C shows that 100 per cent river supplemented and channel supplemented and 94 per cent unsupplemented water were all optimal sources of water for cotton.

6. Farm adjustment responses to changing water prices

One of the determinants of the impact of water charges on the profitability of irrigation farms relates to the types of adjustment responses that irrigators would adapt to water price increase. The adoption of an adjustment strategy is closely related to the concept of elasticity of demand. The price elasticity of demand[9] for water is defined as the percentage change in quantity of water demanded that occurs in

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[9] Demand is said to be elastic when the elasticity is greater than one (quantity changes proportionally more than price) and inelastic when the elasticity is less than one (quantity changes proportionally less than price) (Jayasuriya et al. 2001).

response to a percentage change in price. The demand for water is a derived demand based on the value of water as an input into agricultural production and as such the value of water is dependent on the profitability of the crops to which it is applied (Jayasuriya et al. 2001).

6.1 Demand curves for irrigation water using two-part pricing

Two-part pricing is one of the volumetric approaches in water pricing. It involves setting a water access charge as part A which farmers pay as a fixed charge regardless of the volume of water used. The part B charge is the variable charge that depends on the actual volume consumed by the farmer.

The mixed crop model was run for the four farm types to evaluate the response of agricultural production to increase in water prices ranging from $10 to $600 per ML using the two-part pricing approach.

The results generated for the four farm types by the linear programming model are shown in Table C.1 to Table C.4 in Appendix C. The proportion of crop in farm type A is the same for all water price levels. All the water allocation was consumed for 100 per cent of the irrigated land. Farm type A is a smaller cotton property with 222 hectares of land planted to cotton. For a farm such as this the optimal use of the water was to use all of its water to irrigate all of its land in order to obtain the same revenue. At the highest water price level of $600 per ML, farmers continued planting the same area of land for cotton and irrigating with the same amount of water. The interpretation of this result is that linear programming will solve for a $0 optimal solution where the most profitable alternative for the farmer is to produce nothing. The negative results in this model are based on the way this model was set where part A charge is deducted after linear programming finds the optimal solution for the particular scenario. This approach was taken since part A charge is a fixed cost incurred by the whole farm.

The mixture of crops planted in farm type A for the base case is shown in Table 9. In this farm type, irrigated cotton was the only crop planted except for 51 hectares of chickpeas. Irrigated cotton was planted in three soil types with soil type 1 yielding a gross profit of $ 316 241 (81 per cent of total gross profit). Looking at the plant available water capacity among the soil types, soil type 2 is expected to have higher cotton yields but as was shown in the OZCOT results in bio-physical simulation chapter, this was not necessarily true since yield is not only a function of the plant available water capacity but also of a range of agronomic parameters such as starting water, planting date as well as plant variety among others. In this model soil type 2 was used to plant chickpeas.

Table 9. Crops in farm type A

PSB	Has	Water	Yield	Total Revenue	Total Cost	Gross Profit
IC.ICS.IE1.T4.SWHC1.R7	119	833	244	777 666	461 423	316 241
IC.ICS.IE1.T4.SWHC1.R8	25	200				
IC.ICS.IE1.T4.SWHC3.R8	27	216	45	142 895	86 512	56 382
ICh.ICS.IE1.T3.SWHC2.R1	29	29	54	26 289	13 295	12 992
ICh.ICS.IE1.T3.SWHC4.R1	22	22	32	15 523	9 882	5 640
Total	222	1300	374	962 372	571 112	391 255

Source: Linear programming model results

Note: IC- irrigated cotton, ICh – irrigated chickpeas, ICS – irrigated channel supplemented, IE1 – flood irrigation, T3 and T4 – conventional planting, SWHC1 – alluvial, SWHC2 – Downs, SWHC3 –Scrub, R7 – water level of 7 ML per hectare

The demand curve for farm type A shown in Figure 2 is perfectly inelastic. This means that the quantity of water demanded remains the same even if the price of water progressively increases to $600 per ML of water. The size of the farm in this particular farm type is a significant factor in this management decision. Because the farm is small with only 222 ha, the farmer continued to plant the same land area to get similar yields to cover the increasing production costs.

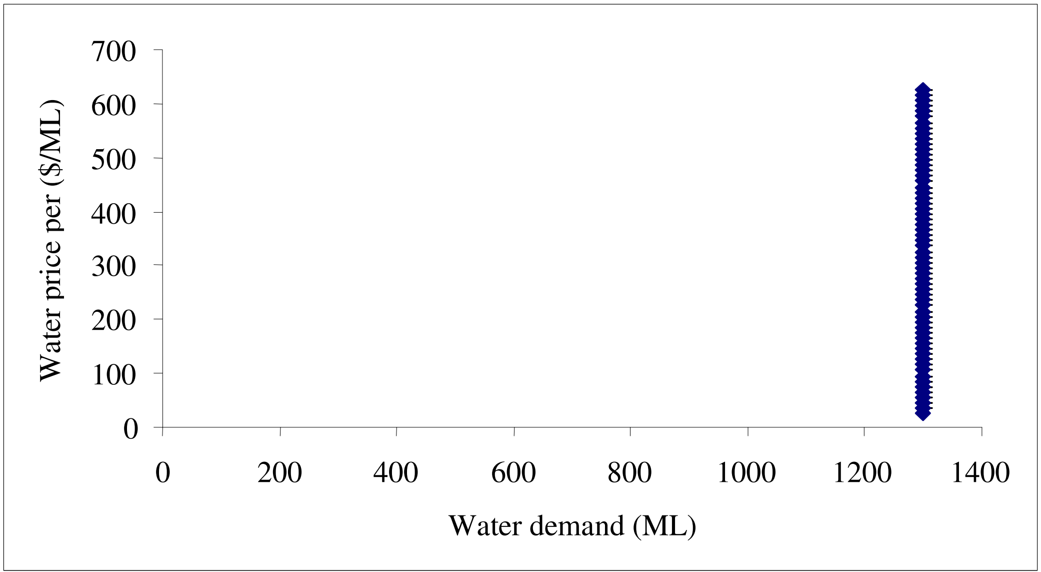

Figure 2. Irrigation demand curve for farm type A

In farm type B, the total optimal land area remained as 960 hectares of fully irrigated land and the optimal use of water was 7 200 ML for water price levels of $10 to $300 as shown in Table C.2 in Appendix C. From a price level of $310, the model results show various ways in which the farmer could adjust. In many of the water price analysed, there is change in total farm water use and total land irrigated for cotton. However, crop mix and irrigation levels change in the determining the optimum solution for the models.

At a price level of $310, the water used decreased by 13 per cent to 6 258 ML while total irrigated land remained at 960 hectares as shown in Table C.2 in Appendix C. With a water price of $310 per ML, the model adjusted to this water price increase by keeping the same area of land planted to crops but decreasing water consumption. There was a decrease of the volume of water consumed because of the change in the proportion of crop mix. The land planted to chickpeas increased from 96 hectares in the base case to 221 hectares. This is at the expense of planting cotton which decreased in area planted to 739 hectares from 864 hectares in the base case which have a very low level of optimum water requirement. This means that farmer is still able to maximise his revenue by using 87 per cent of the total water allocation of 7 200 ML for the $320 per ML increment when the total water used started decreasing to 6 133 ML per hectare but using the same total land area of 960 hectares.

At the water price level increment of $360 to $380 per ML, the land planted to cotton remained at 960 hectares but water consumption decreased to 5 509 ML per hectare. This decrease in water consumption was due to farmer applying 7 ML of water to 624 hectares of cotton planted with the rest (115 hectares) still irrigated with 8 ML per hectare. Up until price level of $420 per ML, area land irrigated remained at 960 hectares but water consumption decreased to 4 704 ML. From price increment of $430 per ML to $490 per ML, the total land area finally decreased of 864 hectares and water utilised was 4 608 ML per hectare. This decrease in land is now reflecting the decreasing profitability of continuing to irrigate chickpeas. Thus the decrease in land irrigated is actually due to 96 hectares of chickpeas not planted and irrigated in this scenario. This model result reflects the opportunistic growing of chickpeas in Emerald as mentioned earlier where their growing is dependent on the availability and cost of extra water. At water price levels of $500 to $590 per ML, water consumption dropped significantly to 864 ML per hectare. At this price level the optimal solution was to plant pure chickpeas in 864 hectares with a water irrigation level of 1 ML per hectare. This scenario has not occurred in Emerald as yet but may not be out of the question in the future if the current severe drought continues. At the highest price level analysed of $600 per ML, chickpeas production decreased by 72 per cent to 240 hectares. This is not a surprising result given that the most profitable crop in this area is cotton. Although chickpeas are also quite profitable they would not cover for the significant water cost at $600 per ML of water.

Figure 3 shows the decreasing area of irrigated cotton land in farm type B as the price of water increases. At water price level of $500 per ML of water, the model stopped growing cotton altogether and instead shifted to chickpeas production.

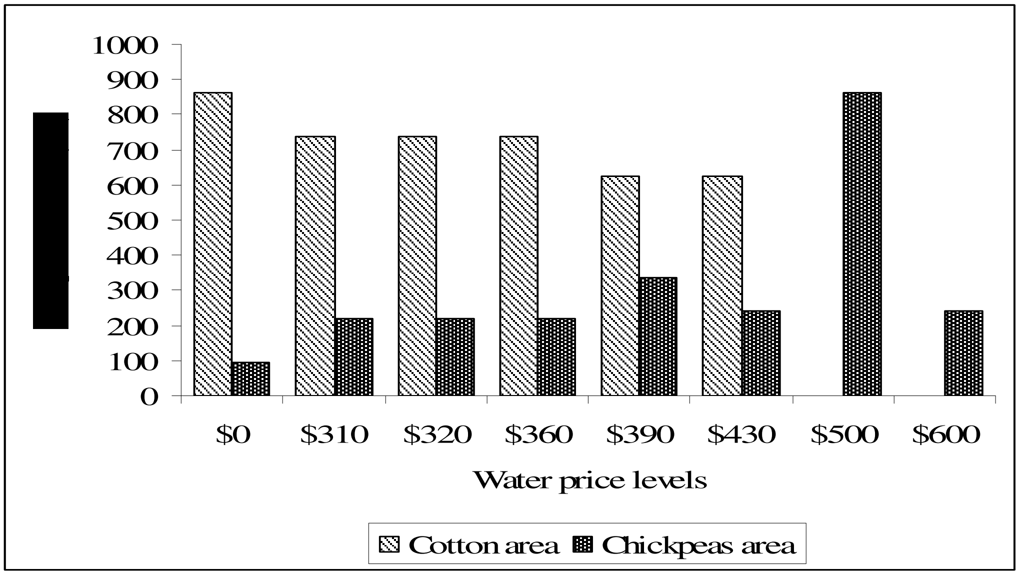

Figure 3. Cotton and chickpeas area based on water price levels in farm type B

The water price and the total water demanded for crop production (farm type B) in columns 1 and 3 in Table C.2 are presented in Figure 4 as the short-term demand curve for total water used. The linear curve was then applied to ascertain the best fitting curve. There is a very strong correlation between price and demand in farm type B as shown by the high correlation coefficient R^2. The estimated coefficients for farm type B are slope = -0.1283; intercept = 1359.56 and R^2 = 0.7510.

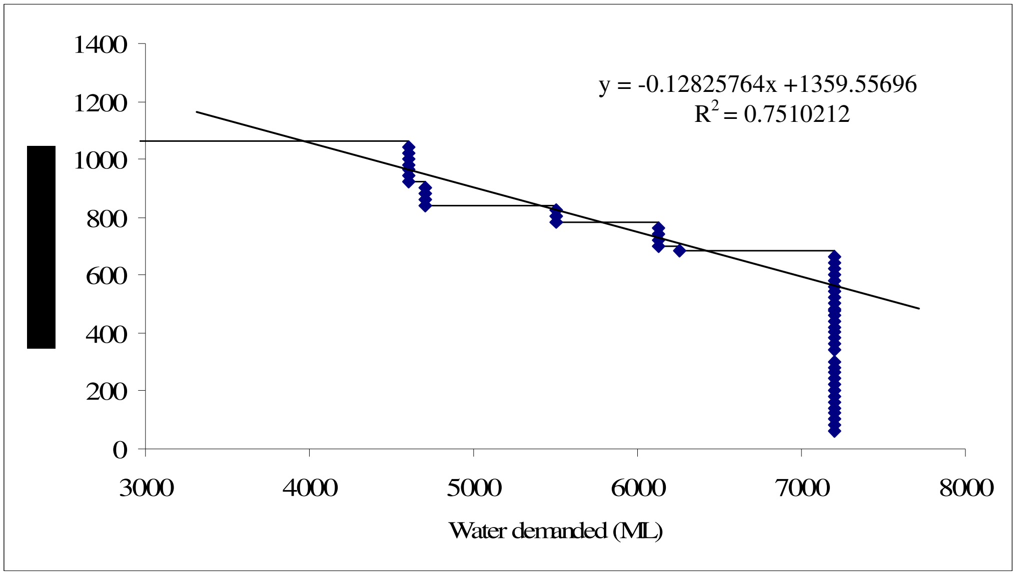

Figure 4. Irrigation demand curve for farm type B

The mixture of crops planted in farm type B for the base case is in Table 10. Similar to farm type A, farm type B has a mixture of only irrigated cotton and irrigated chickpeas. Irrigated cotton was planted in four soil types as discussed earlier but the optimal soil type was alluvial. One hundred per cent of the unsupplemented water allocation (2 380 ML) was used to irrigate 282 hectares and 100 per cent of the river supplemented water (4 820 ML) was used to irrigate 678 hectares. The optimal land irrigated is 100 per cent of the total land area in farm type B. In a good season and at current water pricing using 100 per cent of their land, farm type B farms generates a net revenue of $1 926 433.

Table 10. Crops in farm type B

PSB	Has	Water	Yield	Total Revenue	Total Cost	Gross Profit
IC.IRS.IE1.T4.SWHC1.R8	515	4 121	907	2 890 486	1 711 689	1 178 797
IC.IRS.IE1.T4.SWHC3.R9	67	603	116	369 544	223 580	145 964
IC.IUS.IE1.T4.SWHC1.R8	109	871	192	610 923	361 777	249 146
IC.IUS.IE1.T4.SWHC2.R9	125	1 125	203	645 611	412 731	232 880
IC.IUS.IE1.T4.SWHC3.R8	48	384	80	254 036	157 963	96 073
ICh.IRS.IE1.T3.SWHC3.R8	96	96	138	67 738	44 164	23 573
Total	960	7 200	1 635	4 838 537	2 911 903	1 926 433

Note: IC- irrigated cotton, ICh – irrigated chickpeas, IRS irrigated river supplemented, IE1 – flood irrigation, T3 and T4 – conventional planting, SWHC1 – alluvial, SWHC2 – Downs, SWHC3 – Scrub, R8 – water level of 8 ML per hectare

Table C.3 in Appendix C shows the water demand responses to changing water prices in farm type C. Similar to the results in farm types A and B, the crop mixture in farm type C was also cotton and chickpeas only. Sorghum and wheat did not come into the solution as alternative crops even at a high water price scenario. The optimal irrigated area in farm type C remained the same at 1 100 hectares from water price level increments of $10 to $290 per ML and the optimal use of water was 100 per cent of the total water allocation of 8000 ML up until the $290 per ML after which the total water used started to decrease to 7 172 ML per hectare.

At the water price level increment of $410 per ML, the total irrigated land planted decreased to 990 hectares with 715 hectares of cotton still planted but chickpeas area decreased by 29 per cent to 275 hectares. At price increment of $490 per ML, the whole total land area of 990 hectares was planted to irrigated chickpeas. This then decreased to just 275 hectares at price level of $590 per ML. As with farm type B, the solution indicates that in farm type C, mono-culture irrigated chickpea was the optimal crop choice when water becomes so expensive that it is no longer profitable to grow irrigated cotton. Water cost including both part A and part B payments plus irrigation operational cost at this level is 27 per cent more than the gross revenue.

Figure 5 shows the decreasing area of irrigated cotton land in farm type C as the price of water increases. Similar to the trend in farm type B, at the water price level of $490 per ML in farm type C, the farmer stopped growing any cotton and shifted to chickpeas production. There is a similarity between the two results in that large farms are inelastic at the first 29 price increment levels. The model keep using the same amount of water of 8 000 ML. To optimise its revenue when faced with increasing water costs, farm type C in the model adjusted to the situation and varies the combinations of water sources with the different soil types so optimal solution is one that will result in profitable business. This then results in a shift in the combination of crops with mono-culture irrigated chickpeas planted from the water price level of $490 per hectare.

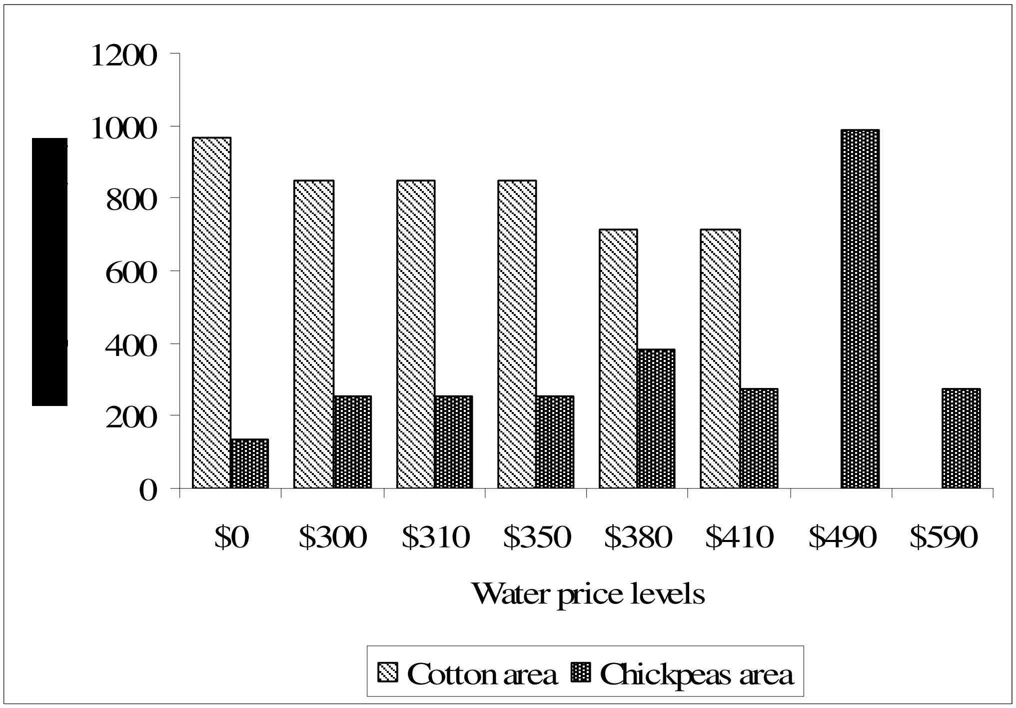

Figure 5. Cotton and chickpeas area based on water price levels in farm type C

The mixture of crops planted in farm type C for the base case appears in Table 11. In this farm type, irrigated cotton and chickpeas were the only crops planted similar to the results obtained in Farm types A and B. Irrigated cotton was planted in four soil types as discussed earlier but the optimal soil type was alluvial. Ninety-four per cent of the unsupplemented water allocation (2 721 ML) was used to irrigate 340 hectares of cotton and the rest (135 ML) was used to irrigate chickpeas. One hundred per cent of the river supplemented was used to irrigate 305 hectares of cotton and 100 per cent of the channel supplemented was used to irrigate 320 hectares of cotton. The optimal area of land irrigated was 100 per cent of the total land area of 1 100 hectares in Farm Type C. In a good season, at current water prices and using 100 per cent of their land, Farm type C farms generates net revenue of $2 138 251.

Table 11. Crops in farm type C

PSB	Has	Water	Yield	Total Revenue	Total Cost	Gross Profit
IC.IRS.IE1.T4.SWHC1.R8	187	1 495	329	1 048 900	625 776	423 123
IC.IRS.IE1.T4.SWHC2.R9	118	1 065	192	610 932	393 863	217 068
IC.ICS.IE1.T4.SWHC1.R8	320	2 560	563	1 795 594	1 071 256	724 338
IC.IUS.IE1.T4.SWHC1.R8	208	1 665	366	1 167 537	696 556	470 981
IC.IUS.IE1.T4.SWHC3.R8	132	1 056	219	698 598	437 673	260 924
ICh.IUS.IE1.T3.SWHC2.R2	25	49	57	27 732	12 585	15 147
ICh.IUS.IE1.T3.SWHC1.R1	110	110	158	77 616	50 946	26 670
Total	1 100	8 000	1 884	5 426 909	3 288 654	2 138 251

Source: Linear programming model results

Note: IC- irrigated cotton, ICh – irrigated chickpeas, IRS- irrigated river supplemented, ICS – irrigated channel supplemented, IUS-Unsupplemented, IE1 – flood irrigation, T3 and T4 – conventional planting, SWHC1 – alluvial, SWHC2 – Downs, SWHC3 –Scrub, R8 – water level of 8 ML per hectare

Figure 6 shows the short-term demand curve for cotton in Farm type C. As with farm type B, there is a strong correlation between price and demand as shown by the high correlation coefficient R^2. The estimated coefficients for farm type B are slope = -0.16953; intercept = 1996.652 and R^2 = 0.7558.

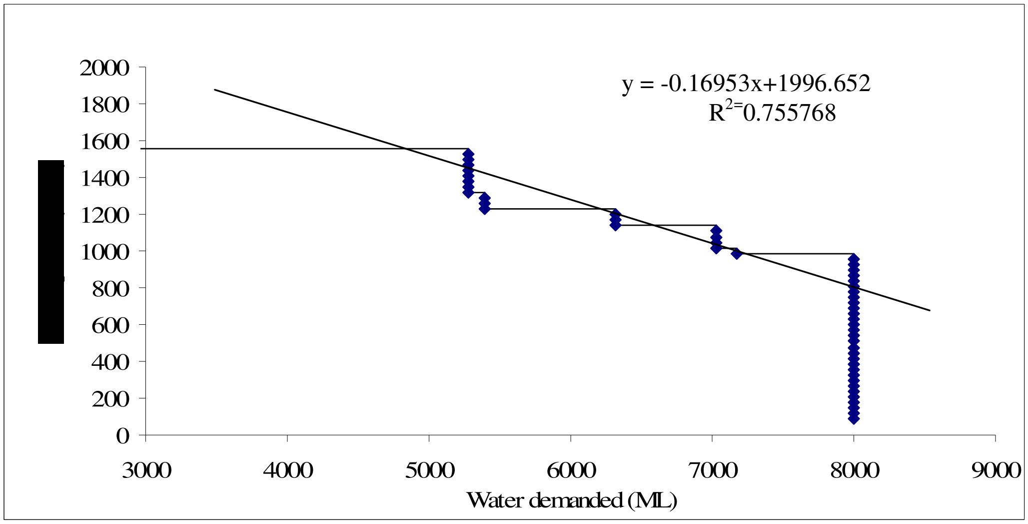

Figure 6. Irrigation demand curve for farm type C

Table C.4 in Appendix C shows the water demand responses to changing water prices in farm type D. Similar to the results in farm types A, B and C, farm type D farm model of cotton, sorghum, wheat and chickpeas resulted in cotton and chickpeas farm combination. The optimal irrigated area in farm type D remained constant at 580 hectares from water price level increments of $10 per ML to $200 per ML. The optimal use of water was 4 000 ML or 100 per cent of the total water allocation of

4000 ML up until the $200 per ML increment when the total water used started to decrease to 3 709 ML per hectare but using the same total land area of 580 hectares.

At the water price level increment of $210 per ML, the land planted to cotton remained at 580 hectares but only 90 per cent is cotton production. From the price increment of $230 per ML to $260 per ML, the total land area of 580 hectares was still utilised but the proportion of cotton area decreased to 77 per cent and raingrown increased to 23 per cent. The irrigated area further decreased to 65 per cent when the water price increment became $270 per ML. Because of the contraction of the irrigated area, there was also a corresponding decline in water demand. The changes in the combination of irrigated and raingrown cotton is a typical response of farmers in the Emerald region. Given declining water availability due to the change in prices, farmers tend to adapt to this situation by non-irrigating some of their cotton and opting to irrigate lesser area.

The mixture of crops planted in farm type D for the base case is in Table 12. In this farm type, irrigated cotton and chickpeas were the only crops planted similar to the results obtained in Farm types A, B and C. Irrigated cotton was planted in four soil types as discussed earlier but the optimal soil type was soil type 1. One hundred per cent of the overland flow water (4 000 ML) was used to irrigate 580 hectares. The optimal land irrigated was 100 per cent of the total land area of 580 hectares in Farm type D. In a good season, at current water prices and using 100 per cent of their land, Farm type D generated a net revenue of $1 196 848.

Table 12. Crops in farm type D

PSB	Has	Water	Yield	Total Revenue	Total Cost	Gross Profit
IC.OW.IE1.T4.SWHC1.R7	377	3 016	664	2 115 434	1 181 113	934 321
IC. OW.IE1.T4.SWHC2.R9	31	278	50	159 374	95 292	64 081
IC. OW.IE1.T4.SWHC3.R8	70	560	116	370 469	217 067	153 402
ICh.OW.IE1.T3.SWHC2.R2	44	88	101	49 533	20 108	29 425
ICh.OW.IE1.T3.SWHC1.R1	58	58	84	40 925	25 306	15 619
Total	580	4 000	1 014	2 735 734	1 538 886	1 196 848

Source: Linear Programming model results

Note: IC - irrigated cotton, ICh – irrigated chickpeas, OW – overland flow, IE1 – flood irrigation, T4 – conventional planting, SWHC1 – alluvial, SWHC2 – Downs, SWHC3 –Scrub, R7 – water level of 7 ML per hectare

Figure 7 shows the short-term demand curve for water in farm type D. Compared to farm types B and C, there is a strong correlation between price and demand for Farm type D but to a lesser degree as shown by the correlation coefficient R^2. The estimated coefficients for farm type B are slope = -0.07548; intercept = 427.4785 and R^2 = 0.8244.

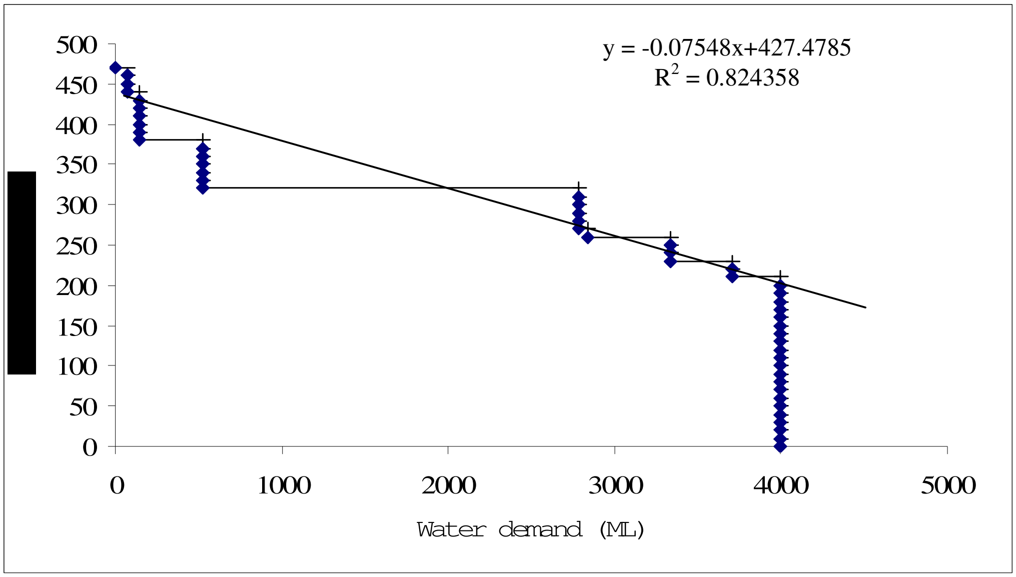

Figure 7. Irrigation demand curve for farm type D

After examination of the demand curves for mixed crops in Figures 2, 4, 6 and 7, some conclusions could be derived. The crop model resulted in more vertical demand curve at the left hand side. This is because at the higher end of the price range analysed, irrigated cotton becomes unprofitable, usually of limited area and stays in the optimal basis over the rest of the range of prices examined.

The regression coefficient for the four farm types using mixed crops are shown in Table 13. This results show that, in the short-run, small cotton farmers with existing high capital outlay and high farm costs do not reduce their water use as soon as the price increases. Rather they keep planting the same land area and use the same amount of water to maintain their revenue even with increasing water cost. The price elasticity of demand for water for farm type A demonstrates a perfectly inelastic demand. One conclusion that could be derived from this result is that in smaller farms there is not much option to vary the management alternatives and farmers tend to stick with their existing management practices of their cotton farms. The elasticities of farm types B and C are almost the same and indicate inelasticities at the price range used which is $300 per ML.

Table 13. **Regression coefficients of optimum water demand curves and water demand elasticity of 4 farm types with cotton production**

Farm types	Coefficient for slope	Coefficient for intercept	R^2	Elasticity (at Pa = \$300)
Farm type A	-0.00000	325.500	0.00000	0.00000
Farm type B	-0.12826	1 359.557	0.75210	-0.08402
Farm type C	-0.16952	1 996.652	0.75577	-0.07678
Farm type D	-0.07548	427.4785	0.82436	-0.31537

6.2 Concluding remarks for water pricing

The water price or tariff structure used in order to be ‘right’ must reflect the wider objectives of water charging which normally is either cost recovery or demand management or both. This is because some pricing methods are more suitable in achieving certain goals than others. In Jordan, pricing reflects concerns over cost recovery in the state managed Jordan Valley Authority rather than using pricing to control demand (Shatanawi and Salem 2002).

According to Rhodes and Sampath (1988), volumetric water pricing is ‘superior’ as a means to induce efficient water application by individual farmers but it may not be the most suitable method to generate the revenue to cover full cost or the operations and maintenance costs. This is because the implementation costs of volumetric pricing are high and may outweigh revenues (Perry 1995). Maximising revenue through full cost recovery through volumetric pricing and inducing water saving behaviour (and hence promoting lesser water sales) are inherently contradictory objectives. A good example is the bulk water pricing in Sao Paolo, Brazil examined by Azevedo and Asad (2000). They estimated that once water charges increase, users will reduce the amount of water they use and revenue will fall. This then creates a problem in sustaining the system since there will be less input for operations and maintenance costs.

Most of the irrigation systems in the world still rely on simpler, fixed water pricing such as area-based pricing. Even in an advanced and water scarce economy such as Spain, Berbel and Gomez-Limon (2000) reported that a fixed cost per hectare for irrigation water is still the most widespread charging mechanism. There are, however, reports of trials and two-part tariff structures on three Spanish schemes as reported by Maetsu (2000).

There are numerous descriptive and normative literature on water pricing but there are few analytical studies that numerically assess the impact on farmer behaviour

(Bosworth et al. 2002). Most of these studies deal with Western America and OECD countries and developing countries. This paper contributes to the shortfall of analytical studies on farmer's adjustment responses to changes in water charges. The impact of volumetric water pricing and farmer response to increased charges depends on many factors but existing low prices of water may be the main reason why farmers are not very responsive to price changes (Bosworth et al. 2002). This finding by Bosworth et al. (2002) supports the results in this paper where because of the low initial price of water, farmers were less responsive to price increases. The lower the initial price, the smaller the farmer's response to price increase. Other studies that support the results in this paper are those of Briscoe (1996) in the western United States and that of the OECD (1999) where a comparative study among Organisation of Economic Cooperation and Development countries reveals that, despite the wide range of modelled price elasticities in irrigation water demand, at low water prices they are consistently low.

In the two-part pricing in this paper, water consumption does not fall until prices reach such a level that farm income is negatively affected. The income effect of price increases seems so small that the water demand barely responded. This is probably because water prices is a very small percentage of the overall crop budget and is a small fraction of crop net revenues. The results in this paper favours the use of two-part pricing (given the assumptions used) because it forces a more immediate response to price changes. This is shown in Table 14 where the income effect of the different water price levels in both fixed or access charge (part A) and variable or volumetric charge (part B) resulted in water demand starting to respond at a lower price charge. There are, however, factors other than price that may have greater impact on the quantity of water demanded such as climate variation, the country's agricultural policy, product prices and reliability of water.

Table 14. Decrease in farm income before water demand falls

Farm types	Two-part pricing
	%
Farm Type A	-70
Farm Type B	-66
Farm Type C	-66
Farm Type D	-70

Source: Linear programming model results

Comparing the effect of water pricing on farm income in this paper with those of other studies, a common finding is that farm income has to be severely impacted before water demand decreased. Berbel and Gomez-Limon (2000) estimated that farm income will have to decrease by around 40 per cent before water demand decreases significantly. Perry (1995) estimates that inducing a 15 per cent reduction in water demand in Egypt through volumetric pricing would decrease farm incomes by 25 per cent. In Ray and Williams (1999), an analytical model developed for India shows that in order to induce the water conserving response under existing allocation, a six-fold price increase would be needed. In Iran, water prices need to be raised by a factor of ten to be effective in curtailing demand (Perry 2001). Price increases of the magnitude modelled in this paper as well as in the other studies mentioned previously are quite unlikely to be implemented in the current prevailing political conditions and thus volumetric water pricing as a tool to reduce demand is questionable.

The price elasticity of demand for irrigation water is defined as the percentage change in quantity demanded in response to a percentage change in price. As in previous studies (OECD1999; Bosworth et al. 2002), this paper shows results with a wide range of price elasticity estimates as shown in Table 13 for two-part pricing (0.0000 to 0.31537). Price elasticity estimates from a study in OECD countries ranged from -0.05 to -17.7.

According to the US Bureau of Reclamation (1997) and based on some empirical evidence on elasticity or responsiveness of demand of agricultural water to price, elasticity depends on:

- initial price of water (the lower the price, the less responsive farmers are to price increases);
- the availability and relative cost of alternative water sources;
- crop value (elasticity is higher for low value crops);
- production costs (if water is only a small part of the input costs there is little incentive to change irrigation method);
- ability to change crops (climate, soils and markets); and
- ability to change to more efficient irrigation technology.

The results in this paper show that irrigation water demand curves in the Emerald Irrigation Area exhibited a perfectly inelastic (non-responsive) stretch at low prices and become elastic (price responsive) beyond a certain threshold. These elasticities differ between farm types and depend so much on the different farm characteristics.

Table 15. Maximum water price levels when water demand is inelastic

Farm types	Two-part pricing
	$/ML
Farm Type A	> 600
Farm Type B	300
Farm Type C	290
Farm Type D	200

Source: Linear programming model results

This OECD study (1999) states that only above a certain threshold price does demand become elastic which is the same pattern of result in this paper. The US Bureau of Reclamation (1997) reported the same results. Explanations for this result were discussed in Dinar and Letey (1996). They observed that because surface water is a quantity rationed input, small water price increases would not alter producer decisions and would not induce water saving. Varela-Ortega et al. (1998) supports this finding in this paper with what they observed in Spain.

Thus, the level of price ‘threshold’ depends on factors such as:

- the economic productivity of water;
- price of water compared to overall production costs;
- the set of alternative production strategies to substitute for water consumption;
- proportion of land devoted to permanently irrigated crops;
- irrigation technologies in place; and
- the size of water allocation.

In this paper, results from two-part pricing show that demand are more inelastic and the burden of higher prices of water falls on farmers’ income. The results obtained provide no clear advantage of one water pricing mechanism over the other but if the threshold level is considered as the criteria on which pricing mechanism is better in limiting demand, two-part pricing could be said to be more superior. However, in practical conditions, threshold level is not the only variable to consider and in assessing which water mechanism is a better approach, it all depends on wether the objective is cost recovery or demand management.

As shown by the results, the precise ability of farmers to pay is variable, depending on crops and production levels and the model outcomes depend on the assumption s made such as the water price levels which are clearly many times the current water charges. Also, in financial and economic terms irrigators should be willing to pay if they obtain an adequate return.

Some other factors that influence the farmers' response to increasing water charges are existing water use practices and irrigation technology. Varela-Ortega et al. (1998) compared the price elasticity of water demand in Andalucia, Castille and Valencia in Spain. In comparing the old and the modern water districts in the three regions, they concluded that water demand is less elastic in the modern water districts where technical endowment is high resulting in a less responsive water user. In contrast, in the old water districts, where water application techniques were relatively inefficient, the response to increasing water charges was much higher. Assuming a less efficient irrigation technology such as furrow or flood irrigation is a proxy for an irrigation area being characterised as 'old' it is expected that in a farm using 'drip' irrigation (a more modern farm) in the Emerald Irrigation Area, the response to increasing water charges will be lower than the results in this paper.

Dinar and Letey (1996) in analysing the effectiveness of water pricing in reducing water demand in California concluded that price policies were found to be less effective in regions where water is relatively abundant and price is relatively low. This seems to be similar to the results in this paper in the Emerald Irrigation Area where because of the relatively low initial price, water demand response was barely affected not until a dramatic reduction in net revenue. Based on the result of this paper and the other studies discussed above, the effects of volumetric pricing on water use seem to be limited and because of the inelastic demand for water, reliance on price mechanisms to conserve water has a limited impact in the short-run. An important conclusion that Dinar and Letey (1996) drew in their study, however, is that water quantity reduction policies were found to be more effective than water price policies. This is supported by works done by Perry (2001) and Ray where they found that enforceable and transparent allocation rules and abstraction licenses may be a more effective way to curtail demand. The following section will investigate the significance of these conclusions from earlier studies to the Emerald Irrigation Area.

The nature of the demand function estimated may not shed much light on what farmers will do in the short run if water prices undergo a sharp shift. However, it is expected that over a longer time span, farmers will tend to adjust to what the analysis indicates they should.

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Appendix A

Crop Prices and Costs Data

Table A.1 Crop prices in the study area, 2004

Product	Price
	$
Cotton lint	516.00[a]
Cotton seed	94.35[a]
Sorghum	218.00[b]
Wheat	280.00[b]
Chickpeas	490.00[b]

Note: [a]Price per bale
[b]Price per tonne

Source: September 2004 survey of cotton growers and Department of Primary Industries and Fisheries 2004

Table A.2 Machinery costs including fuel, oil, repairs and maintenance allowance

Crop type	Cotton	Sorghum	Wheat	Chickpeas
	$/ha	$/ha	$/ha	$/ha
Irrigated	87.41	36.23	27.00	21.28
Raingrown – solid	110.82	43.50	20.00	14.73
Raingrown – single skip	108.98			
Raingrown – double skip	108.98			

Source: September 2004 survey of cotton growers, Department of Primary Industries, personal communication with growers

Table A.3 Other farm costs for irrigated production

	Cotton	Sorghum	Wheat	Chickpea
	$/ha	$/ha	$/ha	$/ha
Planting cost	375.80	52.00	44.00	90.68
Fertiliser cost	267.64	185.42	107.00	32.70
Herbicide cost	201.43	20.44	4.00	8.48
Insecticide cost	808.49	24.60	0.00	42.94
Fungicide cost	-	-	-	9.00
Harvesting cost	330.00	79.00	72.00	50.00
Contract module*	24.41	-	-	-
Ginning cost*	525.00	-	-	-
Cartage cost*	49.00	223.28	50.00	44.78
Levies cost*	37.19	15.44	9.65	11.73
Insurance cost	140.00	0.00	0.00	0.00
Others	90.00	76.00	9.50	19.50

Source: September 2004 survey of cotton growers, Department of Primary Industries, personal communication with growers.

Note: * These costs are usually $ per bale for cotton and $ per tonne for sorghum, wheat and chickpeas. To calculate $ per hectare, a cotton yield of 8.75 bales per hectare; a sorghum yield of 8.00 tonnes per hectare; a wheat yield of 5.00 tonnes per hectare; and a chickpea yield of 2.5 tonnes per hectare were assumed.

Table A.4 Other farm costs for raingrown* production

	Cotton	Sorghum	Wheat	Chickpea
	$/ha	$/ha	$/ha	$/ha
Planting cost	74.22	39.25	48.00	91.28
Fertiliser cost	29.58	88.46	53.00	16.35
Herbicide cost	78.39	20.44	4.00	8.48
Insecticide cost	254.12	24.60	0.00	42.94
Fungicide cost	-	-	-	6.00
Harvesting cost	151.80	52.00	45.00	50.50
Contract module**	10.29	-	-	-
Ginning cost**	210.00	-	-	-
Cartage cost**	24.15	97.69	25.00	26.87
Levies cost**	13.13	6.76	4.83	7.04
Insurance cost	34.00	0.00	0.00	0.00
Others	45.00	33.25	9.50	19.50

Source: September 2004 survey of cotton growers, Department of Primary Industries, personal communication with growers.

Note: * Costs for cotton is based on an average of costs for raingrown solid, single skip and double skip production

** These costs are usually $s per bale for cotton and $s per tonne for sorghum, wheat and chickpeas. To calculate $ per hectare a cotton yield of 3.50 bales per hectare, sorghum yield of $3.50 tonnes per hectare, wheat yield of 2.50 tonnes per hectare and chickpea yield of 1.5 tonnes per hectare were assumed.

Appendix B

Crop Yield

Table B.1 Cotton yield by planting dates and irrigation levels

Irrigation level	Planting dates					
	1 September	1 October	1 November	1 December	1 January	1 February
ML/ha	Bales/ha	Bales/ha	Bales/ha	Bales/ha	Bales/ha	Bales ha
0	1.50	1.72	2.14	2.23	1.64	0.80
1	1.81	2.21	2.70	2.74	2.11	1.21
2	2.47	3.04	3.54	3.53	2.71	1.59
3	3.87	3.71	4.28	4.51	3.60	1.84
4	4.69	4.86	5.34	5.58	4.41	1.89
5	5.40	5.82	6.13	6.34	5.00	1.87
6	5.92	6.49	6.67	6.78	5.21	1.86
7	6.29	6.91	6.98	6.95	5.25	1.86
8	6.48	7.12	7.11	7.01	5.25	1.86
9	6.57	7.18	7.14	7.02	5.25	1.86
10	6.60	7.19	7.14	7.02	5.25	1.86

Source: OZCOT model simulation results

Table B.2 Sorghum yield by planting dates and irrigation levels

Irrigation level	Planting dates					
	1 September	1 October	1 November	1 December	1 January	1 February
	Kg/ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha
0	1 727	2 140	2 687	3 277	3 534	3 019
1	3 261	3 538	3 959	4 372	4 390	4 146
2	4 043	4 343	4 763	4 997	4 831	4 614
3	4 444	4 844	5 321	5 427	5 131	4 801
4	4 667	5 218	5 685	5 676	5 297	4 849
5	4 724	5 361	5 810	5 756	5 348	4 852
6	4 732	5 397	5 839	5 773	5 356	4 852
7	4 732	5 403	5 844	5 776	5 356	4 852
8	4 732	5 404	5 844	5 776	5 356	4 852
9	4 732	5 404	5 844	5 776	5 356	4 852
10	4 732	5 404	5 844	5 776	5 356	4 852

Source: APSIM model simulation results

Table B.3 Wheat yield by planting dates and irrigation levels

Irrigation level	Planting dates					
	1 February	1 March	1 April	1 May	1 June	1 July
	Kg/ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha
0	1 452	1 439	1 451	1 227	1 042	918
1	1 977	2 159	2 221	2 005	1 717	1 557
2	2 559	2 889	3 062	2 818	2 402	2 224
3	3 307	3 764	4 011	3 767	3 238	2 952
4	4 240	4 868	5 224	5 071	4 418	3 943
5	4 996	5 622	6 247	6 318	5 745	5 059
6	5 412	5 961	6 796	7 120	6 813	6 084
7	5 570	6 075	6 995	7 458	7 357	6 737
8	5 617	6 101	7 045	7 553	7 533	7 011
9	5 624	6 102	7 053	7 566	7 564	7 084
10	5 624	6 102	7 054	7 568	7 567	7 093

Source: APSIM model simulation results

Table B.4 Chickpeas yield by planting dates and irrigation levels

Irrigation level	Planting dates					
	1 February	1 March	1 April	1 May	1 June	1 July
	Kg/ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha
0	944	1 154	1 406	1 111	732	592
1	1 187	1 566	2 001	1 752	1 283	1 071
2	1 329	1 725	2 192	2 073	1 628	1 400
3	1 433	1 803	2 283	2 301	1 886	1 647
4	1 488	1 838	2 331	2 482	2 157	1 930
5	1 503	1 846	2 343	2 560	2 337	2 145
6	1 505	1 847	2 345	2 583	2 418	2 270
7	1 505	1 847	2 345	2 587	2 445	2 329
8	1 505	1 847	2 345	2 588	2 452	2 352
9	1 505	1 847	2 345	2 588	2 452	2 358
10	1 505	1 847	2 345	2 588	2 452	2 360

Source: APSIM model simulation results

Appendix C

Crop Yield

Table C.1 Optimal selected values for different water prices in farm type A

Water price increment	Irrigated area	Total water use	Water per land	Water costs	% increase in water costs	Net revenue	% decrease in net revenue
$/ML	Ha	ML	ML/ha	$ '000	%	$ '000	%
Base case	222	1 300	6	49		370	
10	222	1 300	6	62		357	-4
20	222	1 300	6	75	26	344	-7
30	222	1 300	6	88	53	331	-11
40	222	1 300	6	101	79	318	-14
50	222	1 300	6	114	105	305	-18
60	222	1 300	6	127	131	292	-21
70	222	1 300	6	140	158	279	-25
80	222	1 300	6	153	184	266	-28
90	222	1 300	6	166	210	253	-32
100	222	1 300	6	179	237	240	-35
110	222	1 300	6	192	263	227	-39
120	222	1 300	6	205	289	214	-42
130	222	1 300	6	218	315	201	-46
140	222	1 300	6	231	342	188	-49
150	222	1 300	6	244	368	175	-53
160	222	1 300	6	257	394	162	-56
170	222	1 300	6	270	421	149	-60
180	222	1 300	6	283	447	136	-63
190	222	1 300	6	296	473	123	-67
200	222	1 300	6	309	499	110	-70
210	222	1 300	6	322	526	97	-74
220	222	1 300	6	335	552	84	-77
230	222	1 300	6	348	578	71	-81
240	222	1 300	6	361	605	58	-84
250	222	1 300	6	374	631	45	-88
260	222	1 300	6	387	657	32	-91
270	222	1 300	6	400	684	19	-95
280	222	1 300	6	413	710	6	-98
290	222	1 300	6	426	736	-7	-102
300	222	1 300	6	439	762	-20	-105
310	222	1 300	6	452	815	-33	-109
320	222	1 300	6	465	841	-46	-113
330	222	1 300	6	478	868	-59	-116
340	222	1 300	6	491	894	-72	-120
350	222	1 300	6	504	920	-85	-123
360	222	1 300	6	517	946	-98	-127
370	222	1 300	6	530	973	-111	-130
380	222	1 300	6	543	999	-124	-134
390	222	1 300	6	556	1 025	-137	-137
400	222	1 300	6	569	1 052	-150	-141
410	222	1 300	6	582	1 078	-163	-144
420	222	1 300	6	595	1 104	-176	-148
430	222	1 300	6	608	1 130	-189	-151
440	222	1 300	6	621	1 157	-202	-155
450	222	1 300	6	634	1 183	-215	-158
460	222	1 300	6	647	1 209	-228	-162
470	222	1 300	6	660	1 236	-241	-165
480	222	1 300	6	673	1 261	-254	-169
490	222	1 300	6	686	1 288	-267	-172
500	222	1 300	6	699	1 314	-280	-176
510	222	1 300	6	712	1 341	-293	-179
520	222	1 300	6	725	1 367	-306	-183
530	222	1 300	6	738	1 393	-319	-186
540	222	1 300	6	751	1 420	-332	-190
550	222	1 300	6	764	1 446	-345	-193
560	222	1 300	6	777	1 472	-358	-197
570	222	1 300	6	790	1 498	-371	-200
580	222	1 300	6	803	1 525	-384	-204
590	222	1 300	6	816	1 551	-397	-207
600	222	1 300	6	829	1 577	-410	-211

Source: Linear programming model results

Table C.2 Optimal selected values for different water prices in farm type B

Water price increment	Irrigated area	Total water use	Water per land	Water costs	% increase in water costs	Net revenue	% decrease in net revenue
$/ML	Ha	ML	ML/ha	$ '000	%	$ '000	%
Base case	960	7 200	8	229		1 897	
10	960	7 200	8	301	31	1 825	-4
20	960	7 200	8	373	63	1 753	-8
30	960	7 200	8	445	94	1 681	-11
40	960	7 200	8	517	126	1 609	-15
50	960	7 200	8	589	157	1 537	-19
60	960	7 200	8	661	188	1 465	-23
70	960	7 200	8	733	220	1 393	-27
80	960	7 200	8	805	251	1 321	-30
90	960	7 200	8	877	282	1 249	-34
100	960	7 200	8	949	314	1 177	-38
110	960	7 200	8	1 021	345	1 105	-42
120	960	7 200	8	1 093	377	1 033	-46
130	960	7 200	8	1 165	408	961	-49
140	960	7 200	8	1 237	439	889	-53
150	960	7 200	8	1 309	471	817	-57
160	960	7 200	8	1 381	502	745	-61
170	960	7 200	8	1 453	534	673	-65
180	960	7 200	8	1 525	565	529	- 72
190	960	7 200	8	1 597	596	457	-76
200	960	7 200	8	1 669	628	385	-80
210	960	7 200	8	1 741	659	313	-83
220	960	7 200	8	1 813	690	241	-87
230	960	7 200	8	1 885	722	169	-91
240	960	7 200	8	1 957	753	97	-95
250	960	7 200	8	2 029	785	25	-99
260	960	7 200	8	2 101	816	-47	-102
270	960	7 200	8	2 173	847	-119	-106
280	960	7 200	8	2 245	879	-191	-110
290	960	7 200	8	2 317	910	-263	-114
300	960	7 200	8	2 389	942	-331	-117
310	960	6 258	7	2270	890	-397	-121
320	960	6 133	6	2310	907	-463	-124
330	960	6 133	6	2376	936	-528	-128
340	960	6 133	6	2442	965	-594	-131
350	960	6 133	6	2508	993	-657	-135
360	960	5 509	6	2429	959	-719	-138
370	960	5 509	6	2491	986	-781	-141
380	960	5 509	6	2553	1013	-843	-144
390	960	4 704	5	2415	953	-900	-147
400	960	4 704	5	2472	978	-958	-150
410	960	4 704	5	2529	1003	-1015	-154
420	960	4 704	5	2587	1028	-1072	-157
430	864	4 608	5	2613	1040	-1129	-160
440	864	4 608	5	2670	1064	-1185	-162
450	864	4 608	5	2727	1089	-1242	-165
460	864	4 608	5	2784	1114	-1299	-168
470	864	4 608	5	2841	1139	-1356	-171
480	864	4 608	5	2897	1163	-1413	-174
490	864	4 608	5	2954	1188	-1457	-177
500	864	864	1	1838	701	-1453	-177
510	864	864	1	1873	717	-1527	-181
520	864	864	1	1908	732	-1562	-182
530	864	864	1	1943	747	-1597	-184
540	864	864	1	1978	762	-1632	-186
550	864	864	1	2013	778	-1667	-188
560	864	864	1	2047	793	-1702	-190
570	864	864	1	2082	808	-1737	-192
580	864	864	1	2117	823	-1772	-193
590	864	864	1	2152	838	-1805	-195
600	240	240	1	1924	739	0	-100

Source: Linear programming model results

Table C.3 Optimal selected values for different water prices in farm type C

Water price increment	Irrigated area	Total water use	Water per land	Water costs	% increase in water costs	Net revenue	% decrease in net revenue
$/ML	Ha	ML	ML/ha	$ '000	%	$ '000	%
Base case	8 000	1 100	7	318		2 080	
10	8 000	1 100	7	398	25	2 000	-4
20	8 000	1 100	7	478	50	1 920	-8
30	8 000	1 100	7	558	76	1 840	-12
40	8 000	1 100	7	638	101	1 760	-15
50	8 000	1 100	7	718	126	1 680	-19
60	8 000	1 100	7	798	151	1 600	-23
70	8 000	1 100	7	878	176	1 520	-27
80	8 000	1 100	7	958	201	1 440	-31
90	8 000	1 100	7	1 038	227	1 360	-35
100	8 000	1 100	7	1 118	252	1 280	-38
110	8 000	1 100	7	1 198	277	1 200	-42
120	8 000	1 100	7	1 278	302	1 120	-46
130	8 000	1 100	7	1 358	327	1 040	-50
140	8 000	1 100	7	1 438	352	960	-54
150	8 000	1 100	7	1 518	378	880	-58
160	8 000	1 100	7	1 598	403	800	-62
170	8 000	1 100	7	1 678	428	720	-65
180	8 000	1 100	7	1 758	453	560	-73
190	8 000	1 100	7	1 838	478	480	-77
200	8 000	1 100	7	1 918	504	400	-81
210	8 000	1 100	7	1 998	529	320	-85
220	8 000	1 100	7	2 078	554	240	-88
230	8 000	1 100	7	2 158	579	160	-92
240	8 000	1 100	7	2 238	604	80	-96
250	8 000	1 100	7	2 318	629	0	-100
260	8 000	1 100	7	2 398	655	-80	-104
270	8 000	1 100	7	2 478	680	-160	-108
280	8 000	1 100	7	2 558	705	-240	-112
290	8 000	1 100	7	2 638	730	-317	-115
300	7 172	1 100	7	2 549	702	-391	-119
310	1 100	7 029	6	2 594	716	-466	-122
320	1 100	7 029	6	2 669	740	-540	-126
330	1 100	7 029	6	2 743	763	-614	-130
340	1 100	7 029	6	2 817	786	-685	-133
350	1 100	6 314	6	2 724	757	-755	-136
360	1 100	6 314	6	2 794	779	-825	-140
370	1 100	6 314	6	2 864	801	-894	-143
380	1 100	5 390	5	2 702	750	-958	-146
390	1 100	5 390	5	2 777	774	-1 023	-149
400	1 100	5 390	5	2 831	791	-1 087	-152
410	990	5 280	5	2 861	800	-1 151	-155
420	990	5 280	5	2 925	820	-1 215	-158
430	990	5 280	5	2 988	840	-1 279	-161
440	990	5 280	5	3 052	861	-1 342	-165
450	990	5 280	5	3 116	881	-1 406	-168
460	990	5 280	5	3 180	901	-1 470	-171
470	990	5 280	5	3 244	921	-1 534	-174
480	990	5 280	5	3 308	941	-1 577	-176
490	990	990	1	2 014	534	-1 615	-178
500	990	990	1	2 053	546	-1 654	-179
510	990	990	1	2 091	558	-1 692	-181
520	990	990	1	2 129	570	-1 730	-183
530	990	990	1	2 168	582	-1 769	-185
540	990	990	1	2 206	594	-1 807	-187
550	990	990	1	2 244	606	-1 845	-189
560	990	990	1	2 283	618	-1 884	-191
570	990	990	1	2 321	630	-1 922	-192
580	990	990	1	2 360	643	-1 957	-194
590	275	275	1	2 094	559	-1 991	-196
600	275	275	1	2 128	570	0	-100

Source: Linear programming model results

Table C.4 Optimal selected values for different water prices in farm type D

Water price increment	Irrigated area	Total water use	Water per land	Water costs	% increase in water costs	Net revenue	% decrease in net revenue
$/ML	Ha	ML	ML/ha	$ '000	%	$ '000	%
Base case	580	4 000	7	29		1 197	
10	580	4 000	7	69	138	1 157	-3
20	580	4 000	7	109	276	1 117	-7
30	580	4 000	7	149	414	1 077	-10
40	580	4 000	7	189	552	1 037	-13
50	580	4 000	7	229	690	997	-17
60	580	4 000	7	269	828	957	-20
70	580	4 000	7	309	966	917	-23
80	580	4 000	7	349	1103	877	-27
90	580	4 000	7	389	1241	837	-30
100	580	4 000	7	429	1 379	797	-33
110	580	4 000	7	469	1 517	757	-37
120	580	4 000	7	509	1 655	717	-40
130	580	4 000	7	549	1 793	677	-43
140	580	4 000	7	589	1 931	637	-47
150	580	4 000	7	629	2 069	597	-50
160	580	4 000	7	669	2 207	557	-53
170	580	4 000	7	709	2 345	517	-57
180	580	4 000	7	749	2 483	437	-64
190	580	4 000	7	789	2 621	397	-67
200	580	4 000	7	829	2 759	359	-70
210	580	3 709	6	808	2 686	322	-73
220	580	3 709	6	845	2 814	285	-76
230	580	3 332	6	795	2 643	252	-79
240	580	3 332	6	829	2 758	218	-82
250	580	3 332	6	862	2 872	189	-84
260	580	2 842	5	768	2 548	161	-87
270	522	2 784	5	778	2 582	133	-89
280	522	2 784	5	806	2 678	105	-91
290	522	2 784	5	833	2 774	77	-94
300	522	2 784	5	861	2 870	50	-96
310	522	2 784	5	889	2 966	38	-97
320	522	522	1	193	566	33	-97
330	522	522	1	198	584	28	-98
340	522	522	1	177	512	22	-98
350	522	522	1	209	620	17	-99
360	522	522	1	214	638	12	-99
370	522	522	1	219	656	10	-99
380	145	145	1	62	115	8	-99
390	145	145	1	64	120	7	-99
400	145	145	1	65	125	5	-100
410	145	145	1	67	130	4	-100
420	145	145	1	68	135	3	-100
430	145	145	1	70	140	2	-100
440	75	75	1	37	27	1	-100
450	75	75	1	38	29	0	-100
460	75	75	1	38	32	0	-100
470	0	0	0	0	-100	0	-100
480	0	0	0	0	-100	0	-100
490	0	0	0	0	-100	0	-100
500	0	0	0	0	-100	0	-100
510	0	0	0	0	-100	0	-100
520	0	0	0	0	-100	0	-100
530	0	0	0	0	-100	0	-100
540	0	0	0	0	-100	0	-100
550	0	0	0	0	-100	0	-100
560	0	0	0	0	-100	0	-100
570	0	0	0	0	-100	0	-100
580	0	0	0	0	-100	0	-100
590	0	0	0	0	-100	0	-100
600	0	0	0	0	-100	0	-100

Source: Linear programming model results