Australian Government
Productivity Commission

Responsiveness of Demand for Irrigation Water:

A Focus on the Southern Murray-Darling Basin

Productivity
Commission
Staff Working Paper

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Preface

The Productivity Commission is undertaking a suite of research related to water reform, including the effects of expanding water trade and the management of environmental externalities associated with the supply and use of irrigation water. This research is based on the irrigation industry in the southern Murray-Darling Basin — where the majority of irrigation in Australia occurs.

A foundation for this research is a detailed understanding of irrigated agriculture in the southern Murray-Darling Basin, including: the existing patterns of water use; the emerging trade in water property rights and the likely behavioural responses of individual irrigators to changing water prices. This paper explores the determinants of the elasticity of demand for irrigation water. It focuses on three main irrigated industries — rice, dairy and horticulture — to gain a greater understanding of the value that farmers place on water as an input. The paper provides detail relating to farm decision behaviour and biophysical production realities faced by irrigators in the southern Murray-Darling Basin.

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Abbreviations and explanations

Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
CI	Coleambally Irrigation
COAG	Council of Australian Governments
GL	gigalitre (a billion (10^9) litres)
GMW	Goulburn-Murray Water
GV	Goulburn valley
MDB	Murray-Darling Basin
MDBC	Murray-Darling Basin Commission
MI	Murray Irrigation
MIA	Murrumbidgee Irrigation Area
ML	megalitre (a million (10^6) litres)
VM	Victorian Murray

Key points

- There is no single market for irrigation water in the southern Murray-Darling Basin. Water utility charges vary between districts. Prices of traded water (for both seasonal allocations and entitlements) vary temporally and spatially between irrigation districts (reflecting constraints to trade between irrigation districts).
- Demand for irrigation water is relatively unresponsive to changes in the price of water at relatively lower prices in the short run, but becomes more responsive at higher prices, and in the long run.
- Irrigator responsiveness depends on the total water needs of an irrigator's crop. These needs are first satisfied from rainfall, then from seasonal allocations, and finally by purchases of traded water.
- Irrigator responsiveness to changes in water prices may vary substantially from year to year because of seasonal conditions locally and in the headwaters of the relevant catchment. Rainfall variability (and resultant variability of seasonal allocations) causes volatility in demand for, and prices of, traded irrigation water.
- Irrigators' responses to changing water prices will vary because of past investment decisions and available substitution choices.
  - In the short run, rice growers tend to reduce the area planted to rice in years when they expect relatively low seasonal allocations. Dairy farmers have more substitution choices, such as purchasing fodder rather than irrigating their own pastures. Horticulturists with perennial crops may be relatively unresponsive to changing seasonal prices for irrigation water, because of the cost of replanting if part of their crop dies.
  - In the long run, irrigators may respond to rising water prices by adopting water saving technologies or by altering their mix of irrigated activities. At current prices, on-farm water savings alone are unlikely to justify investment in water saving technology. Water 'saved' by use of water saving technology is likely to be used to irrigate more land, or sold to other irrigators (in the absence of a mechanism to allocate it to other uses).
  - Substitution can occur between alternative irrigation activities, and between irrigated and non-irrigated activities. If a large number of irrigators choose to move from one activity to another, the change may affect commodity prices received in both the activity they leave (prices may go higher) and the one they enter (prices may go lower), and may affect land and water prices.

1 Introduction

This paper examines the demand for irrigation water in major irrigation districts in the southern Murray-Darling Basin (MDB). The objective is to gain insights into how irrigators in major agricultural industries alter their use of water in the short and long run as utility charges and/or the market price of traded water change (hereafter referred to as water prices unless otherwise specified). The proportional change in the amount of water used, due to changes in water prices, is the price responsiveness or *elasticity* of water demand.

Irrigators may respond to changing water prices by deciding to continue using existing levels of water, or to adjust their water usage. For example, Gardner (1983) observed that an irrigator growing a crop, such as rice or cotton, might respond to an increase in the price of irrigation water by:

- leaving land fallow and demanding less water
- applying less water to the crop and risking some yield loss
- switching to less water demanding crops
- investing in more efficient irrigation techniques.

An understanding of how irrigators respond to changes in water prices can provide some insights into their likely responses to other economic changes, including reforms to the irrigation sector. It is also useful when constructing economic models (both quantitative and qualitative) that analyse the impacts of policy reform and that predict economic behaviour. If general equilibrium models, for example, are sufficiently disaggregated, they can be used to estimate the outcomes of economic and policy changes for specific regions of Australia. These models (such as TERM-Water) require characterisations of the behaviour of important economic agents in each region (Wittwer 2003). Partial equilibrium models often use elasticity estimates. Estimates are also needed to calibrate mathematical models of producer behaviour that do not use empirically estimated elasticities directly. A better understanding and estimation of demand responsiveness will improve the analytical and predictive power of these models.

1.1 Background and scope

Irrigated agriculture represents about 28 per cent of the gross value of agricultural production in Australia. Approximately 2.5 million hectares of land were irrigated in 2000-01, a 22 per cent increase since 1996-97 (ABS 2004b). This area represents about 5 per cent of the land sown to crops, pastures and grasses, and about 0.5 per cent of land used for agriculture (ABS 2004a).

Agriculture uses around 67 per cent of all water used in Australia (table 1.1). There is significant variation in the proportion of water consumed by agriculture across jurisdictions, ranging from around 40 per cent in Western Australia, to over 78 per cent for New South Wales and ACT combined. Most of the water used by Australian agriculture is consumed in New South Wales (44 per cent), Victoria (22 per cent) and Queensland (21 per cent).

The major agricultural water consumers in 2000-01 included the 'livestock, pasture, grains and other agriculture' industry (about 33 per cent), the cotton and dairy farming industries (about 17 per cent each), and the rice industry (about 12 per cent). The sugar and horticultural (fruit, grapes and vegetables) industries are also significant users.

Table 1.1 **Net water consumption for selected industries [a], 2000-01**

	NSW–ACT	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*Aust.*
	GL	GL	GL	GL	GL	GL	GL	GL
Livestock, pasture, grains and other agriculture	2 590	1 435	779	474	176	85	30	5 568
Dairy farming	401	1 685	288	320	65	76	–	2 834
Vegetables	96	131	103	65	111	49	1	556
Fruit	214	209	107	161	65	10	36	803
Grapes	174	238	6	284	23	1	3	729
Sugar	1	–	1 186	–	124	–	–	1 311
Cotton	1 921	–	985	–	3	–	–	2 908
Rice	1 924	27	–	–	–	–	–	1 951
Total for agriculture [b]	7 322	3 725	3 454	1 302	565	222	70	16 660
Total for Australia	9 425	7 140	4 711	1 647	1 409	417	160	24 909

[a] Net water consumption = mains water use + self-extracted water use – mains water supply. Excluding in-stream use. [b] Columns may not add to total because of rounding.

Source: ABS (2004b).

Irrigation water is used by irrigators to supplement rainfall in their agricultural production systems. In most cases, the local rainfall in regions where irrigation is located is insufficient for current farming practices to be sustained without irrigation. For example, in a typical season, a rice crop in southern New South

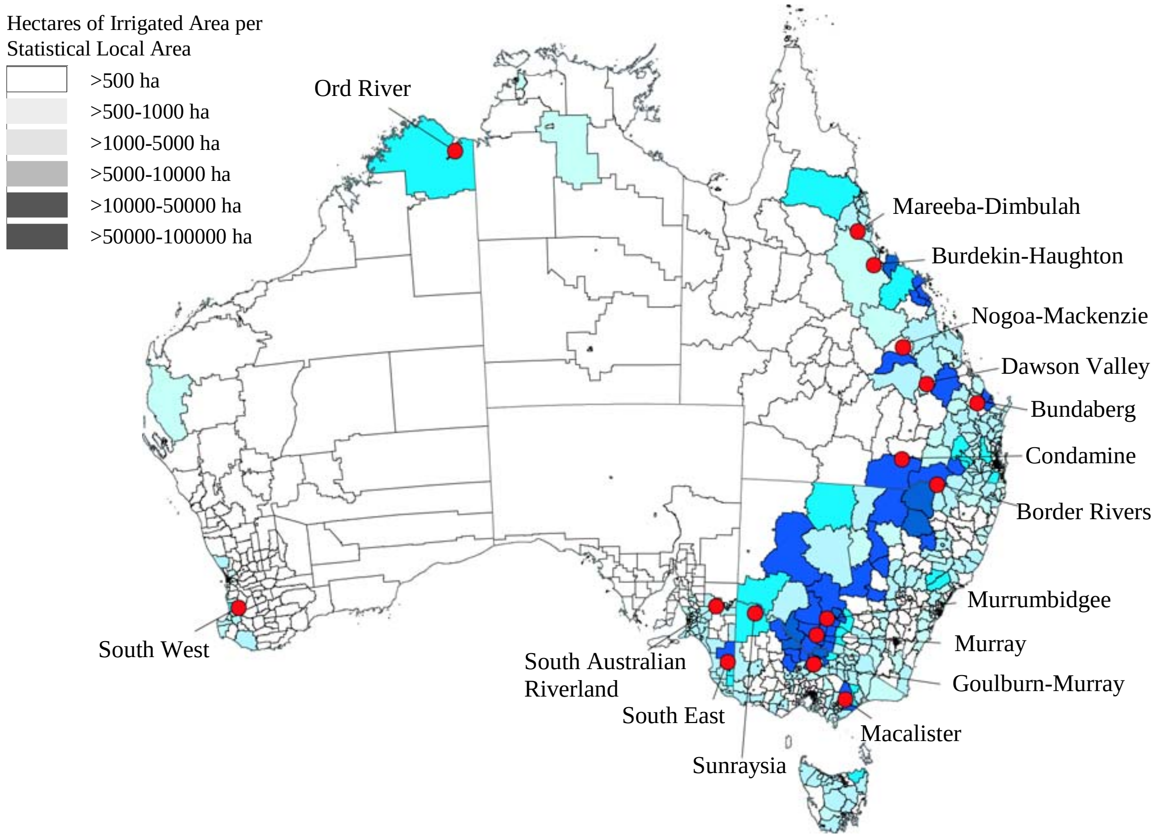
Wales needs 13 megalitres of irrigation water per hectare in addition to average rainfall during the growing season — the equivalent of adding 1300 millimetres to the annual regional rainfall of about 400–450 millimetres (NSW Agriculture 2003).

Irrigation water can be sourced by irrigators in a variety of ways, including:

- on-farm storage and diversion of surface water flows across farms
- on-farm pumping and diversion of ground water
- diversion of water from on-farm water courses
- via major storage, diversion and delivery infrastructure managed by public and private utilities — sometimes referred to as supplemented irrigation schemes.

The focus in this paper is on the last. Irrigation schemes are concentrated in the eastern states of New South Wales, Victoria and Queensland and draw water from Great Dividing Range catchments (figure 1.1).

Figure 1.1 **Major irrigation areas in Australia, 1997**



Data source: Australian Bureau of Statistics 1997 data used in NLWRA (2001).

Over 70 per cent of irrigation water use occurs within the MDB, with most supplemented irrigation located within the southern MDB (figure 1.2). Most irrigated farms in the southern MDB are grouped within discrete irrigation districts located in the valleys of the Murrumbidgee, Murray, and Goulburn rivers. Diversions of water from rivers supplying these districts represent around 70 per cent of all diversions in the MDB (MDBC 2003, p. 7).

Figure 1.2 **Major irrigation districts in the Murray-Darling Basin**

Data source: Murray-Darling Basin Commission.

Major irrigation districts include the Goulburn-Murray Water (GMW) district in northern Victoria (which can be subdivided into the Goulburn (GV) and Victorian

Murray (VM) districts), the Murrumbidgee Irrigation Area (MIA) and the Murray Irrigation (MI) and Coleambally Irrigation (CI) districts in southern New South Wales. These districts account for over 85 per cent of water entitlements in the southern MDB (table 1.2). Several smaller irrigation districts located along the Murray river, between Swan Hill in Victoria and Murray Bridge in South Australia, encompass the 'Sunraysia' and 'Riverland' districts.

Table 1.2 **Irrigation scheme entitlements in the southern Murray-Darling Basin, 2001-02**

Irrigation company	*Entitlement*
	ML
New South Wales	
Coleambally Irrigation	632 000
Murray Irrigation Limited	1 450 000
Murrumbidgee Irrigation	1 200 000
Western Murray Irrigation	61 000
West Corurgan Irrigation	78 000
Victoria	
First Mildura Irrigation Trust	85 055
Goulburn-Murray Water	1 600 000
Sunraysia Rural Water Authority	301 273
South Australia	
Central Irrigation Trust	120 000
Renmark Irrigation Trust	49 000

Source: Hassall & Associates in association with Musgrave (2002).

For an irrigator within the southern MDB, there are three broad 'types' of irrigation water supplied by utilities:

- *Water entitlements:* an irrigator's access rights to a specific quantity of water each irrigation season. In New South Wales, entitlements are either classified as having 'high' or 'general' supply reliability. South Australia and Victoria provide only one class of entitlement (which has high supply reliability). In all three states, the reliability of supply can differ between irrigation districts. If an entitlement is traded, it is sometimes called permanent water.
- *Seasonal allocations*: proportion of an irrigator's water entitlement allocated by water utilities during an irrigation season — allocations may be less than 100 per cent, equal to 100 per cent, or more than 100 per cent (see *Sales water*) of nominal entitlement. If a seasonal allocation is traded, it is sometimes called temporary water.
- *Sales water* (Victoria) and *Supplementary water* (New South Wales): in some years, individual water utilities may have 'excess' water available after all other needs (including environmental flows and maintaining reserves) have been met.

This water is made available to irrigators on the same basis as seasonal allocations. The right to access sales or supplementary water is proportional to each irrigator’s water entitlement. For example, each irrigator may be able to access sales (or supplementary) water of up to 30 per cent of their entitlement.

1.2 Determinants of water demand

Water is one of many inputs into agricultural production. As a productive input, it is valued for its contribution to farm outputs, rather than as a commodity for final consumption.

The relationships between irrigation farm inputs are complex and seldom linear. Some inputs are essentially fixed in the short run (such as land), while others are variable (such as fertilisers). Because some inputs are fixed, at some point diminishing returns occur such that the continued addition of variable inputs eventually yields smaller and smaller additional units of output.

There may be interactions between inputs. Complementary relationships between inputs are common in agriculture — applications of one input (such as fertiliser) are best matched with increased applications of other inputs (such as water). Substitution possibilities may exist between water and other inputs — the use of water-saving irrigation schedules requires more labour. Some input use may be independent of the application of other inputs, such as applying trace elements to soils that are deficient in them. Given these interrelationships, the demand for water, or any other input, cannot be described without reference to the additional inputs being used.

Overall, the demand for water is derived from:

- its price
- its contribution to production. This depends on the prices of all inputs (which determine the optimal quantities to use)
- the prices of outputs (which determine the optimal quantities to produce).

If a demand curve for water is presented for a given level of other inputs, changes in the price of water will lead to movement along the demand curve. Changes in output prices, or in the prices and use of other interdependent inputs, will lead to shifts of the demand curve for water.

Time frame of irrigators' responses

It is usual to classify farmers' responses to changing circumstances into different periods for analysis (box 1.1). The purpose of these periods is to simplify the discussion of possible responses, and to allow responses using similar resources to be considered together. They do not imply that irrigators' responses to changing circumstances will follow a hierarchical order.

Brennan (pers. comm., 9 June 2004) observed that the timing of irrigators' responses will be determined by many factors, and will be influenced by farm specific characteristics — for example, the age and condition of assets and the financial position of farmers. The pace of industry adjustment will reflect the many and varied responses at the farm level.

Box 1.1 **Defining the short and long run**

In the short run, at least one input can be varied while other resources are fixed. Importantly, in the short run, production decisions are assumed to be fixed and the mix of activities on the farm cannot be changed. Short run responses occur during a production season — for example, a marginal change in water applications.

In the long run, all inputs can be varied, including the amount and location of land owned and capital employed, all prices received and paid, and choice of activities. Long run responses can occur over many production seasons — for example, investing in new irrigation technology.

Source: Doll and Orazem (1984, p.27).

1.3 Measuring the responsiveness of water demand

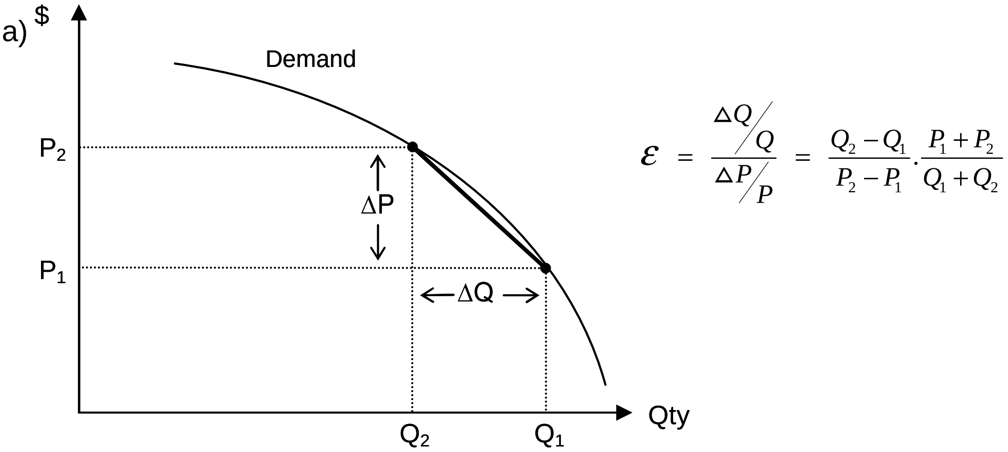
The change in the amount of water demanded, due to changes in price, is measured by price elasticity. It is likely that elasticities for water demand will vary over space, time and between irrigators — consequently there is no single elasticity of demand for irrigation water.

The own-price elasticity of demand is the percentage change in quantity demanded that results from a one per cent change in price (box 1.2). Irrigators have an incentive to reduce the quantity of water demanded if the price of water rises, therefore, own-price elasticities are negative. An elasticity is measured at a specified level of price or quantity, and will generally be different at other prices and quantities (Tomek and Robinson 1981):

- Between –1 and minus infinity, demand is said to be relatively *elastic*. That is, quantity demanded responds by more than the proportionate change in price. In such a case, the irrigator’s expenditure on water will fall as the price rises.
- Between zero and –1, demand is said to be relatively *inelastic*. That is, the quantity demanded, responds by less than the proportionate change in price. In such a case, the farmer’s expenditure on water will increase in response to an increase in price even though their consumption of water has fallen.

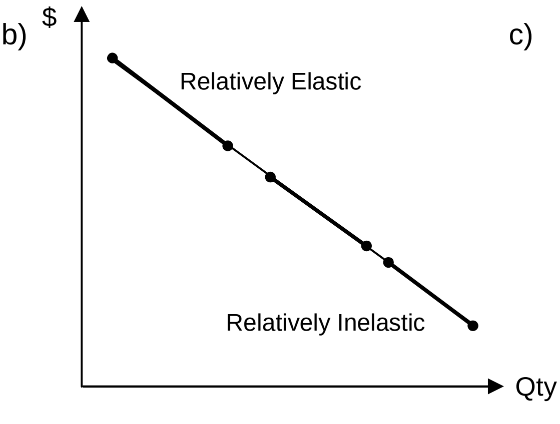
Box 1.2 **Determining the elasticity of demand**

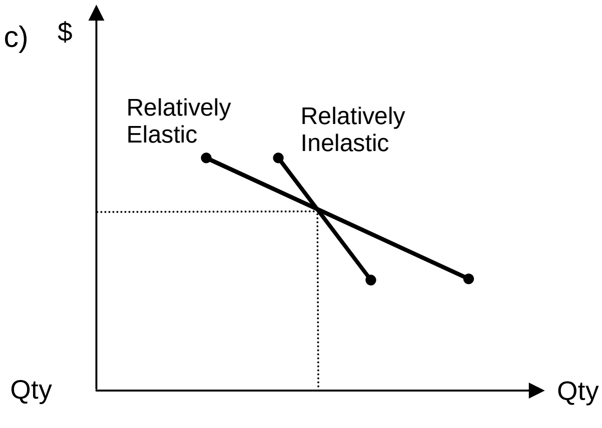
Elasticity (ε) is calculated by considering a percentage change in price, and the percentage change in quantity demanded that results from the price change (equation below). It can be seen that the elasticity of an arc segment of the demand curve depends on its slope and relative position in the price-quantity space diagram (a).



$$\varepsilon = \frac{\Delta Q / Q}{\Delta P / P} = \frac{Q_2 - Q_1}{P_2 - P_1} \cdot \frac{P_1 + P_2}{Q_1 + Q_2}$$

The elasticity of demand can vary along different segments of the demand curve. Even if the slope is constant, the position of the curve affects the magnitude of the proportional change (diagram b) — the further along the quantity axis, the smaller the relative change in quantity and hence the less elastic is demand. The elasticity will also vary as the slope changes — at a given point, a flatter curve is more elastic than a steeper one (diagram c).





In most empirical studies, elasticity is estimated as the arc elasticity. It is more difficult to arrive at an estimate of elasticity for a specific point using observational techniques.

For ease of discussion, economists often refer to ‘elastic’ or ‘inelastic’ demand curves. This is a simplification because elasticities are typically valid only for narrow ranges of prices. Elasticities vary with the slope and position of a demand curve. For a given linear demand curve, demand is more elastic the higher the price; and as the demand curve moves further from the axis, for every given price, the quantities demanded are larger and demand becomes less elastic.

The slope of the demand curve is determined by the availability of options that allow substitution away from water and the impact of rising water prices on the viability of the farm. For example, low substitutability and a low share of total costs can lead to inelastic water demand.

Movements of a demand curve will occur due to technological changes in production methods (investment in capital, such as more efficient irrigation systems), changes in crops mix and the quantity of water used by types of crop (application rates).

Consequently, elasticities of demand for irrigation water are likely to vary:

- between different price levels for a given demand curve
- between the different types of water users, including irrigators and industries
- over time as individual irrigators’ demand for water changes between the short and long run, becoming more elastic.

1.4 Outline of the paper

In chapter 2, the factors underlying demand for irrigation water are described and key features of utility charges and trade prices are summarised. In chapter 3, attempts to estimate the price responsiveness of irrigators are reviewed and qualitative insights from economic theory on irrigators’ price responsiveness are introduced. These insights are extended in chapters 4, 5 and 6 to consider the responsiveness in the short and long run. Appendix A summarises previous Australian studies.

2 Understanding irrigator demand and water prices

This chapter discusses factors underlying demand for irrigation water by individual irrigators. In section 2.1, physical influences on irrigators' use of irrigation water are reviewed. The relationships between water demand, plant needs, rainfall, and type of farming enterprise are discussed. An overview of trade in irrigation water is provided in section 2.2. The importance of seasonal conditions in determining demand for irrigation water and water trade is discussed in section 2.3. In section 2.4, charges and prices of irrigation water are summarised.

2.1 Physical factors influencing use of irrigation water

Use of irrigation water during an irrigation season is influenced by the difference between the optimal water input for an irrigator's crops and rainfall during the growing season.

Rainfall in the southern Murray-Darling Basin (MDB) varies significantly both within and between years. In this paper, four stylised seasonal types are used for illustrative purposes:

- *Typical seasons*: Irrigation seasons an irrigator would consider 'typical' or 'normal' for their district; rainfall would be similar to average rainfall.
- *Wetter seasons*: Irrigation seasons where rainfall is significantly greater than in typical seasons. In wetter seasons, too much rain may reduce farm production.
- *Drier seasons*: Irrigation seasons where rainfall is less than in a typical season, but not exceptionally so.
- *Very dry seasons*: Irrigation seasons where rainfall is in the bottom decile of expectations.

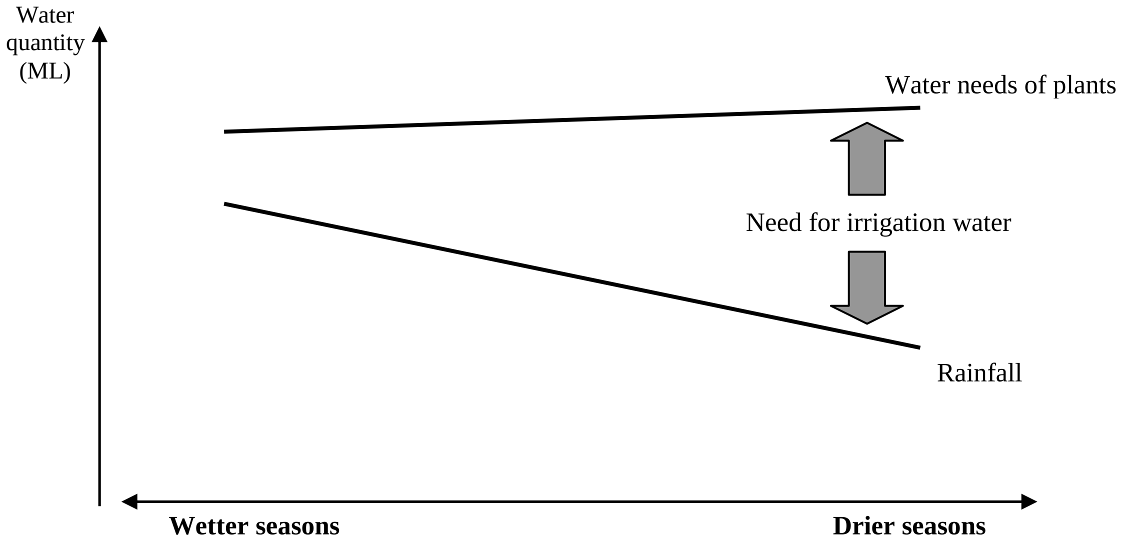
While there is considerable variability in rainfall within an irrigation season (for example, a 'dry' spring being followed by a 'typical' summer and a 'wetter' autumn), a further simplifying assumption in this paper is that the stylised irrigation seasons have uniform seasonal conditions (for example, a wetter irrigation season has a wetter spring, summer, and autumn). For ease of exposition, it is also assumed that seasonal conditions in an irrigation district corresponds with those in the relevant catchment.

Rainfall variability and plant water needs

The amount of irrigation water required by an irrigator in a particular season is the difference between the water requirements of the irrigator’s irrigated activities, and local rainfall during the growing season. Other things being equal, an irrigator will use less irrigation water in relatively wetter years, and more irrigation water in relatively drier years (figure 2.1).

For most irrigated agricultural activities in the southern MDB, rainfall over a growing season is less than the quantity of water needed by the plants. As a result, most existing irrigated activities could not exist in these regions without irrigation.

Figure 2.1 **Stylised need for irrigation water between irrigation seasons** [a]

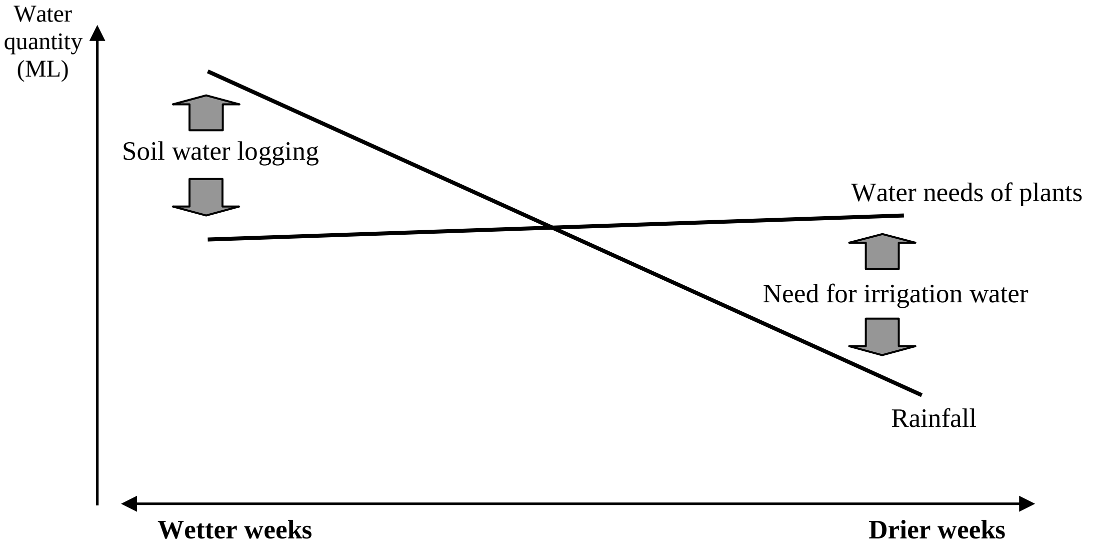


[a] The line representing plant needs for water slopes upwards because drier and very dry years typically have temperatures higher than average. Higher temperatures will increase plant needs for water by increasing transpiration and evaporation. Higher temperatures initially increase plant growth, but once temperatures exceed a threshold, plant growth may then diminish (for example, see Richards, Bange and Milroy (2003) for a discussion of the impact on high temperatures on cotton plants).

A feature of rainfall in the southern MDB is its variability. For example, there was sufficient rainfall during the decade 1988 to 1997 to allow GMW to provide seasonal allocations of 200 per cent of entitlement (100 per cent sales water) to irrigators in each year. In contrast, there have been relatively dry seasons since 1998 — allocations were reduced to 120 per cent in 1998 (utilising water stored from the previous year) and thereafter to 100 per cent. In 2002-03 allocations were 57 per cent of entitlement.

In general, the need for irrigation water in the southern MDB is greatest in the summer, followed by spring and autumn. However, because rainfall can be highly variable during an irrigation season, the seasonal pattern of need for irrigation water is also variable. In any irrigation season, there can be periods without rain and irrigation can be the main, even sole, source of water for the crop. Equally, there may be periods and places where rainfall is sufficient to meet all the short term water requirements, and irrigation may not be required. In periods of very high rainfall, too much water can be limiting to production, since (among other things) too much water (either from rain or irrigation) may lead to soil water logging (figure 2.2).

Figure 2.2 **Stylised need for irrigation water within an irrigation season**



Reliability of supply of irrigation water and risk

The limit on the amount of water potentially available for use in irrigation schemes in a catchment is the amount of runoff into tributaries to the main stream, less system losses and allocations to other users (such as urban and environmental uses). Major irrigation schemes enable the consumption of rain water on land downstream of where it fell. One reason for making such a transfer is that the downstream land may be more suited to profitable agricultural activities than the land where the runoff occurred.

Another reason for undertaking irrigated activities is to reduce risks associated with variable rainfall. Compared to neighbouring dryland farmers, irrigators have access to more water, and access to water for periods within a year when there is no rainfall. After the introduction of an irrigation scheme, farmers tend to change their activities to take advantage of this larger and more reliable water supply.

An important purpose of storing water in a reservoir is to deliver water to irrigators when they require it. If all the irrigation water is released from storage in a year, storage does not affect the total amount of water that can be used for irrigation within that year (ignoring evaporation, seepage and transmission losses). If an irrigation scheme is administered so that no water is held over between irrigation seasons (such as for some NSW irrigation water), then there is likely to be considerable variability in the allocations made available to irrigators each year.

Most rainfall in the catchments of the southern MDB irrigation schemes occurs in winter and spring. This means that irrigators can obtain information about likely seasonal allocations relatively early in the production season, and may be able to adjust their production decisions to match expected allocations. As noted earlier, most existing irrigated agricultural activities in the southern MDB could not exist without irrigation. Changing activities changes the nature of the risks associated with variable rainfall. Dryland farmers face the risks of having insufficient rain to plant crops; and, once a crop is planted, of having insufficient rain for the crop to grow to maturity. As a rule, a season where rainfall is insufficient to allow crop planting has fewer adverse financial consequences than seasons where crops are planted and then fail — because the variable costs of planting and tending the crop are not incurred. In contrast, an irrigator matching plantings to announced seasonal allocations faces less risk of crop failure, but still has variability in plantings.

The annual reliability of the supply of irrigation water can be changed by forgoing the consumption in one year, and storing it for future years. For example, GMW's objective is to deliver the full allocation in 97 years in a 100. To achieve this objective, available irrigation water is released until the full allocation is delivered. Once that is delivered, no more irrigation water is made available until GMW is confident that it can deliver the following year's full allocation. Over-allocation or 'sales' water is then made available. This approach delivers a high reliability of supply. GMW has only failed to deliver the full allocation once (in 2002-03). Some irrigators are likely to respond to the increased supply reliability and reduced risk by planting perennial crops that have relatively inflexible requirements for water. In doing so, they increase their exposure to risk in the years when the utility is unable to deliver the full seasonal allocation.

The influence of farming enterprises

The amount of water required by irrigators will also be influenced by the nature of their farming activities. Annual croppers may purchase irrigation water to plant a crop in years when the water is likely to be available at relatively low prices. However, in years when the water price is relatively high (or when seasonal allocations are relatively low) they may reduce (or even forgo) the area planted to irrigated annual crops, using their land for some other purpose. In contrast, irrigators growing perennial horticultural crops, with long lags between planting and harvesting, are likely to use sufficient water to keep plants alive — provided the cost of buying irrigation water is less than the cost of replanting and nurturing them to the same maturity.

2.2 Water trade

The demand for irrigation water is complicated by the fact that irrigators can also supply irrigation water to other irrigators. They can sell part, or all, of their seasonal allocation or their underlying water entitlement. For example, an irrigator growing annual crops may choose not to plant a crop for a year if the expected returns from trading allocations, and alternative land uses, exceeds the expected return from the irrigated crop.

Uncertainty about future rainfall and the supply of irrigation water means that some irrigators may choose to hold a greater water entitlement than required in a typical year as a means of reducing risk. For example, a risk averse irrigator growing perennial horticultural crops may choose to hold a larger water entitlement than needed to meet plant water needs in a typical year as ‘insurance’ for seasons when the water utility is unable to provide the full water entitlement. In years when the full water entitlement is available, the irrigator could choose to trade any ‘excess’ irrigation water to other irrigators. In New South Wales, horticulturists are likely to hold high security water entitlements as an alternative means of managing risk. The majority of annual croppers (including rice growers) in New South Wales hold general security water entitlements.

Importantly, annual croppers and horticulturists are likely to demand, or supply, irrigation water at different times.

- The annual cropper is likely to demand irrigation water when prices are relatively low — typically wetter years. They may supply irrigation water when prices are relatively high — typically drier years.
- The perennial horticulturist is likely to supply irrigation water in wetter years and demand it in drier years (also see Freebairn 2004).

Individual irrigators’ decisions to supply water may also be affected by their relative endowments of water — individual irrigators have differing water entitlements, seasonal allocations and access to other water sources (such as overland flows, passing flows for water courses and storm drains, and groundwater). Soils, management skills and farming intensity, among other things, may also affect their ability or willingness to supply water.

2.3 Seasonal conditions and trade

Important factors to be considered when analysing supply and demand of traded seasonal allocations include:

- quantities and prices of the water traded
- characteristics of the district(s) in which trade occurred
- seasonal conditions under which trade occurred
- market conditions for produce.

Supply and demand relationships differ between irrigation areas. For example, in some irrigation districts (such as the GMW district), most of the available water entitlement is utilised every year. This means that an irrigator can acquire more water, supplied by a utility, only through trade with other irrigators.

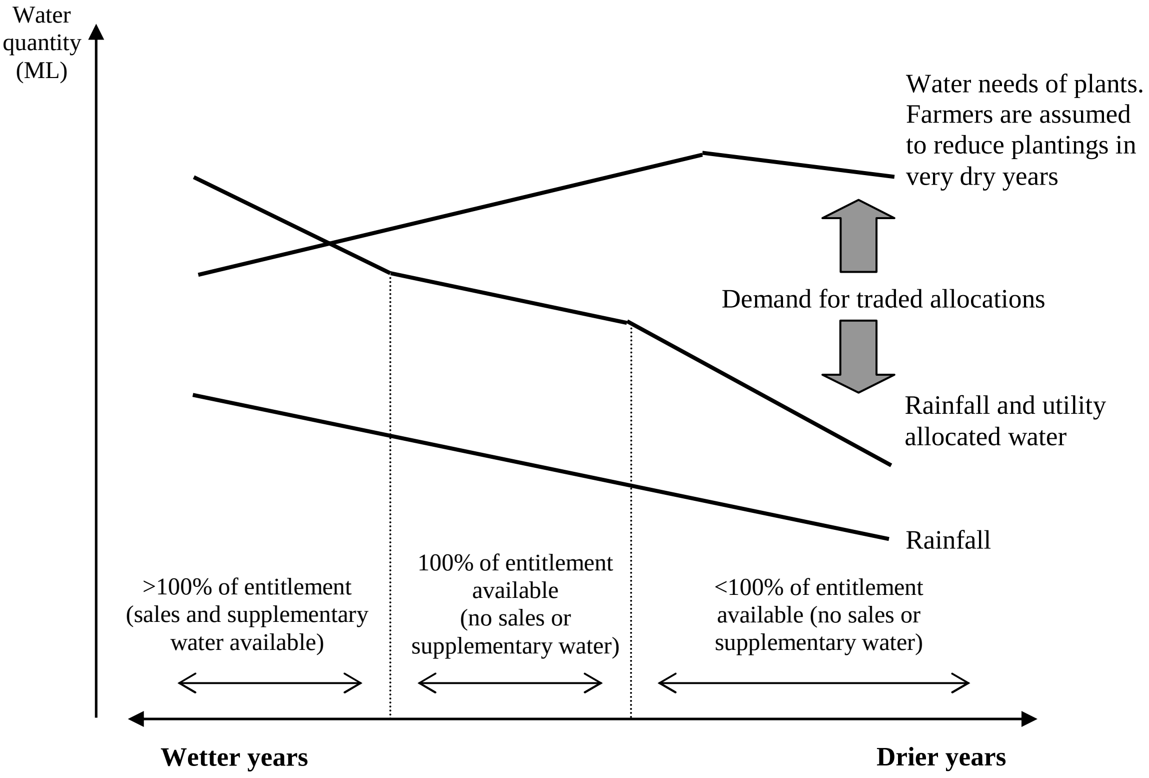
Seasonal supply and demand of traded irrigation water are linked, and will vary according to seasonal conditions. Irrigators’ demand for irrigation water depends on local seasonal conditions, while the ability of a water utility to supply irrigation water depends on seasonal conditions in the headwaters of the relevant catchment(s). The size of the southern MDB means seasonal conditions may vary between irrigation districts.

The demand for traded allocations under different seasonal conditions, for general security water in New South Wales, is stylised in figure 2.3. For simplicity, it is assumed that similar seasonal conditions apply in both the headwaters of the catchment and locally within each of the four scenarios, and that storage constraints allow sales or supplementary water to be allocated only in wetter years. The impact of wetter, typical, dry and very dry irrigation seasons on the supply and demand for traded irrigation water are discussed in the following scenarios.

Wetter seasons

Above average rainfall in an irrigation season can meet a substantial portion of some irrigators’ water needs (but rarely all) — and there is also a higher probability of sales or supplementary water being available in those years. As a result, many irrigators will use less than average quantities of irrigation water. They are likely to source their irrigation water first from their seasonal allocation, then from ‘sales’ or ‘supplementary’ water, and finally from traded allocations. Some irrigators may find that their needs are less than their seasonal allocation, and may attempt to trade ‘excess’ water. In such years, there is likely to be a relatively low demand for traded allocations, but a relatively high supply. Accordingly, prices for traded allocations in wetter seasons are likely to be relatively low.

Figure 2.3 **Stylised impact of seasonal conditions on aggregate demand for traded irrigation water** [a]



[a] This example assumes that there is no 'carryover' of water between irrigation seasons. In Victoria, carryover of water between seasons may mean that 'sales' water can be available in typical and drier years.

Typical seasons

In typical irrigation seasons, when conditions are such that seasonal allocations are fully met and sales or supplementary water is available, more irrigators may wish to supplement their seasonal allocation with the purchase of traded allocations. However, the same seasonal conditions are likely to decrease supply as irrigators who could make traded allocations available in wetter seasons may need to use more for their own needs. As a result, prices for traded allocations are likely to be relatively higher in typical seasons than in wetter seasons.

Drier seasons

In drier irrigation seasons, there is also a higher probability that sales or supplementary water will be unavailable. If there is little, or no, sales or supplementary water available, the demand for traded allocations will increase. Again, supply may be lower than in either wetter or typical seasons. As a result, the price of traded allocations will be higher, with the price rise moderated by an increase in the supply of traded allocations as some irrigators find that they can obtain a higher return by trading their water (and using their land for alternative activities).

Very dry seasons

In very dry irrigation seasons (like 2002-03 in the southern MDB) there is little rainfall, and water utilities may be unable to deliver the full water entitlement. In these years, there will be strong competition for traded allocations. Most irrigators with perennial pastures or crops will seek to purchase traded allocations to augment their reduced seasonal allocation. The supply of traded allocations is likely to come from irrigators engaged in annual cropping who find that the relatively high prices offered for traded allocations will offer a higher return than attempting to crop with reduced water supplies.

2.4 Irrigation water charges and prices

Utilities charge irrigators for seasonal allocations and deliveries to the farm. Prior to water trade emerging, utility charges were the price of water to an irrigator. Trade in seasonal allocations and water entitlements has lead to premiums for water above utility charges and has revealed opportunity costs for water that differ from the utility charge (box 2.1).

Box 2.1 The opportunity cost of seasonal allocations

An irrigator who holds a water entitlement is entitled to receive a seasonal allocation of water, and has an obligation to pay water utility charges. One ‘price’ of the water received is the water utility charge.

Another ‘price’ is the opportunity cost of water. Doll and Orazem (1984, p. 82) observed that:

> Every resource used in the production process has but one true cost: its opportunity cost. The opportunity cost of a resource is the return the resource can earn when put to its best alternative use. Suppose *(an irrigator has a megalitre of water).* Suppose further that *(trading the water)* will add $150 to his total revenue …, but spreading it on his field will add $100 to his total revenue. If he *(waters his field)* his opportunity cost is $150; he has foregone $150 to earn $100. The most return from a unit of input is realised when the actual earned return is equal to or greater than the opportunity cost.

If an irrigator chooses to trade water, their financial position is improved if the price of traded allocations is higher than the return from using it on the farm.

Utility charges are designed primarily to recover the operational, maintenance and some capital costs associated with supply activities including harvesting, storage, diversions and delivery. In most districts, utilities charge irrigators a two-part tariff consisting of:

- a fixed component — a charge based on the volume of an irrigator's water entitlement
- a variable component — a charge on either the volume of water allocated or volume delivered during the irrigation season (see table 2.1).

Utility charges in the GMW, MI and MIA districts

For many utilities, supply charges are based primarily on the volume of the water entitlement rather than the consumption of water by irrigators. Some utilities have a variety of charges within the fixed and variable components. When a trade in seasonal allocations occurs, the seller is responsible for the fixed charges related to the traded entitlement. The variable or volume related charges are paid by the buyer of the water (DNRE 2001).

Utility charges for irrigation water are likely to be higher in pumped districts. Some smaller irrigation districts are supplied with pumped water — whereas all of the subdistricts in the MI and MIA districts and most of the subdistricts in the GMW district are supplied via a gravity delivery system.

For gravity delivery in the GMW district, irrigators pay a fixed fee comprising two components — an entitlement storage fee and an infrastructure access fee. Irrigators also pay variable usage fees.

In the MI district, irrigators are charged a fixed entitlement storage and infrastructure access fee as well as other fixed fees which include drainage charges and Land and Water Management Plan charges. A variable usage fee is also charged as well as a volume based drainage charge.

In the MIA, charges consist of a fixed charge comprising water (entitlement) storage and access to infrastructure, and a usage charge for water supply. These charges are separated for high security (used mainly for perennial plantings) water and general or low security (used mainly for annual crops) water (Murrumbidgee Irrigation, pers. comm., 21 January 2004). The charging structures of the three utilities are summarised in table 2.1.

Table 2.1 **Typical utility charges, 2003-04**[a]

District	*Type of entitlement*	*Entitlement storage and infrastructure access fees*	*Other fixed fees*	*Usage fees*
		$/ML of entitlement	$/ML of entitlement	$/ML delivered
GMW	‘Water right’	19.25–29.37[b]	—	5.62–11.05
MI	‘General security’	7.10	0.51-2.72[c] 0.28-1.12[d]	8.50–9.72[e]
MIA	‘General security’	6.15	n/a	12.40
	‘High security’	9.89	n/a	29.00

[a] The total cost per megalitre of water delivered may not be calculated by adding the rows horizontally in years when the seasonal allocations are different to the entitlement. [b] Fixed charges levied in the GMW district for gravity delivery vary across subdistricts. [c] Fixed drainage charge. [d] Land and Water Management Plan fixed charges. [e] Includes variable drainage charges.

Sources: Goulburn-Murray Water, pers. comm., 1 April 2004; MI, pers. comm., 16 April 2004; MIA, pers. comm., 7 and 27 April 2004.

The price of traded seasonal allocations

Understanding the market for seasonal allocations is useful when considering irrigators’ responses to changes in prices and charges. Trade volumes can be large and prices can differ significantly from utility charges. Prices paid for traded seasonal allocations vary from irrigation district to irrigation district, and irrigation season to irrigation season.

The market for seasonal allocations is well developed and active in some areas, but almost non-existent in others. For example, during 2002-03 about 5500 irrigators in the GV purchased about 153 gigalitres, and about 6300 irrigators sold about 133 gigalitres — with around 20 gigalitres of allocations imported from other irrigation districts. The volume of water traded was about 20 per cent of total usage for the year (GMW 2003). However, there are some (relatively small) trading regions within the irrigation district where no trading was recorded.

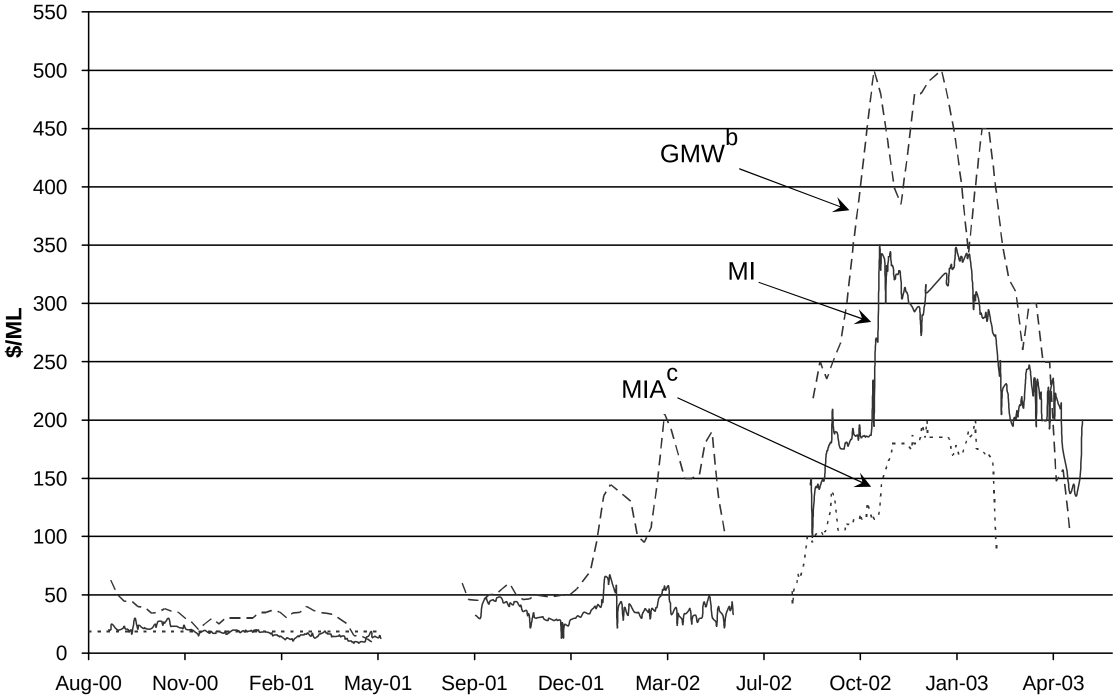
As a rule, when seasonal allocations are traded, the volume of water purchased is the same as the volume sold (‘a megalitre is a megalitre’) irrespective of where the water is acquired from, or the nature of the underlying entitlement. However, there are exceptions which reflect transmission losses. For example, an exchange rate of 0.85 applies to water purchased by MI irrigators from GMW irrigators — if a GMW vendor sells 100 megalitres, the MI purchaser pays for 100 megalitres, but is only delivered 85 megalitres. There is also an exchange rate of 0.95 for all seasonal allocations traded to South Australia.

In each year, the market for seasonal allocations is likely to reflect the allocation decisions of the relevant water utility, and seasonal conditions in both the headwaters of the catchment, and locally. For example, Brennan (2004, p. 14) highlights that the price of traded allocations is closely related to the percentage of seasonal allocation delivered by the utility. High prices for traded allocations correspond to seasons when allocations are low and lower prices with seasons when allocations are fully met.

Spatial variation

The markets for traded allocations in each major irrigation district appear to be heterogenous spatially, with the prices paid in any week differing markedly between districts (figure 2.4). For example, between 2000-01 and 2002-03, the prices paid in the Greater Goulburn subdistrict of the GMW district were higher than prices paid in the MI trading district and in the MIA.

Figure 2.4 **Average weekly prices per megalitre for traded allocations in major irrigation districts**[a]



[a] Average weekly pooled price per megalitre; MIA price for 2000-01 is a yearly average. [b] GMW data for the Greater Goulburn subdistrict. [c] MIA data for 2001-02 were not available.

Data sources: Goulburn-Murray Water, pers. comm., 1 December 2003; MI, pers. comm., 22 December 2003; MIA, pers. comm., 2 February 2004.

Prices differ because various constraints impede the trade of irrigation water from one irrigation district to another. For example, irrigation water cannot be traded directly between the Greater Goulburn subdistrict of the GMW district, and the MI and MIA districts (see box 2.2).

Box 2.2 **Restrictions on trade of seasonal allocations**

Trade of seasonal allocations between different irrigation districts can be limited by regulations, physical and ‘market based‘ constraints.

Regulations constraining trade can occur within and between irrigation districts. For example, the New South Wales Water Allocation Plan 2003–2004 for the Murray and Lower Darling valleys provided:

> Due to the low water availability in both the Murray and Murrumbidgee River valleys at the start of the 2003–2004 seasons, there will be no temporary (annual) trades between these valleys. This restriction may be relaxed with a significant improvement in available water resources. (DIPNR 2003, p. 14)

Similarly, GMW does not permit the trade of more than 30 per cent of an irrigator’s sales water. If GMW irrigators trade sales water, their total use and trade of sales water is restricted to 30 per cent. MI applies an exchange rate of 0.85 on each megalitre bought from GMW irrigators.

Direct trade is also prohibited between certain trading subdistricts within an irrigation district and from certain trading districts within an irrigation district to other irrigation districts. For example, irrigators in the Greater Goulburn subdistrict are not permitted to trade directly with irrigators from the MI district and vice versa.

The extent to which regulatory constraints on trades of seasonal allocations reflect hydrological limitations is unclear. For example, while the MIA is located on a different river to the MI and GMW districts, all districts source water from the Snowy Mountains Scheme, and deliver water to the Murray. The hydrological links of these districts are sufficient to enable trade. Important hydrological considerations are capacity constraints of the supply and delivery system. For example, each trade has to be approved by the utility to ensure that the delivery can be met without affecting either the environment or the allocation deliveries of other irrigators. In the case of the Barmah Choke, a natural flow constraint, water trades are prevented from districts above the choke to districts below.

In some irrigation districts, water use standards apply that penalise irrigators for exceeding certain irrigation volumes per hectare during an irrigation season. In addition, some irrigation districts along the Murray River, between Nyah and the South Australian border, have been designated high and low salinity impact zones and regulations preventing trade into high impact zones.

‘Market based’ constraints include differing supply reliabilities and tenures of tradeable water, and a lack of information on trade opportunities in some markets (particularly for entitlements).

The 2002-03 irrigation season was relatively dry in all irrigation districts in the southern MDB, and seasonal allocations were reduced. For example, allocations were 57 per cent in the Goulburn Valley district. Seasonal allocations were even lower for general security water in New South Wales — just 8 per cent in the MI district. Some New South Wales irrigators were also able to use irrigation water they had 'carried over' (not used) in the previous year.

Prices paid for traded allocations in the MI district during the 2002-03 irrigation season may reflect the greater importance of dairy and horticulture in that area compared to the MIA, but the lesser importance of those activities compared to the Greater Goulburn trading subdistrict. Irrigated agriculture in the Greater Goulburn trading subdistrict is dominated by dairy, with significant perennial horticulture industries, such as fruits and wine grapes, and comparatively less annual cropping and mixed farming enterprises. Further, there were few substitutes for irrigation water for horticulturists who faced large costs if they allowed their plants to die. For dairy farmers, the main substitute for irrigation water — purchased fodder — was also relatively expensive that year. As a result, there was a high demand for traded allocations in the irrigation area — as both major irrigated activities sought to meet the shortfall in their seasonal allocations.

In contrast, annual crops (such as rice) are significant agricultural activities in the MIA. Irrigators have the flexibility to match their plantings of crops to the expected supply of irrigation water. In 2002-03, many irrigators in the MIA chose to reduce their plantings significantly, knowing they were likely to receive small seasonal allocations, and that the values of their allocations were likely to be high if sold.

Brennan (2004) notes that price differentials for traded allocations also exist between trading zones where there are no legal barriers to trade. The differential is attributed to trading rules which require a seller to nominate which trading zones they wish to sell in. Brennan suggests that there would be efficiency gains by removing these rules.

Temporal variation

As well as spatial variation, there are also wide variations in prices of traded allocations within an irrigation district both during and between irrigation seasons (figure 2.4).

The variation of prices of traded seasonal allocations within and between irrigation seasons was most apparent in the 2002-03 season when allocations were reduced due to drought and consequent low storages. For example, in the Greater Goulburn subdistrict, the average weekly price of seasonal allocations was about $360 per megalitre over the 2002-03 season (table 2.2). This can be compared to prices under

$60 per megalitre between 1999-2000 and 2000-01 when allocations averaged above 90 per cent. In fact, the price increases over time have been so large that the first decile price paid in the 2001-02 and 2002-03 irrigation seasons exceeded the ninth decile price paid in the respective previous seasons.

Table 2.2 **Average prices for traded allocations Greater Goulburn trade subdistrict, 1999-2000 to 2002-03** [a]

	1999-2000	*2000-01*	*2001-02*	*2002-03*
	$/ML	$/ML	$/ML	$/ML
Average weekly price	55	34	102	360
Median weekly price	58	34	82	369
9th decile weekly price	90	41	161	480
1st decile weekly price	13	19	46	230

[a] Prices rounded to nearest dollar. 2003-04 average not calculated due to incomplete data.

Sources: Watermove (2004); Goulburn-Murray Water, pers. comm., 1 December 2003; Goulburn-Murray Water (2003); PC estimates.

Prices of water entitlements

The MDBC has initiated a Pilot Interstate Water Trading Project, but there have been few interstate trades (box 2.3).

Box 2.3 **MDBC's Pilot Interstate Water Trading Project**

This pilot scheme restricts trade to private diverters (not group irrigation schemes) in the Mallee Region — the Murray River between Nyah and the mouth of the Murray. The table below shows that only 2 trades occurred to transfer water out of South Australia (one each to Victoria and New South Wales). In contrast, 104 entitlement trades transferred over 15 000 megalitres into South Australia. About half of this volume was transferred from each of New South Wales and Victoria.

Number and volume of entitlement trades by origin and destination (ML)

September 1998 to February 2004

Origin		Destination			Total
		NSW	Vic	SA	
New South Wales	vol.	–	271.0	7 070.0	7 341.0
	no.	–	2	47	49
Victoria	vol.	1 619.5	–	8 084.6	9 704.1
	no.	24	–	57	81
South Australia	vol.	100.0	2 182.0	–	2 282.0
	no.	1	1	–	2
Total	vol.	1 719.5	2 453.0	15 154.6	19 327.0
	no.	25	3	104	132

Source: Murray-Darling Basin Commission, pers. comm., 26 February 2004.

Within states, the majority of net entitlement trades tend to occur within, rather than between, trade districts (DNRE 2001; Bjornlund 2001). In Victoria, the volume of transfers of entitlements has increased gradually since trading commenced in 1990-91, although it remains significantly less than the volume of trade in seasonal allocations. A substantial proportion of early trades of entitlements involved the sale of previously unused (or ‘sleeper’) licenses (DNRE 2001). Between 1990-91 and 2000-01, a volume equal to 6 per cent of the total entitlements of farmers in Victoria was transferred. Entitlement trades are currently averaging about 1 per cent (25 000 megalitres) of total entitlements per year. In 2000-01, the average entitlement trade was 65 megalitres (DNRE 2001). Further, there is anecdotal evidence that some trades in seasonal allocations are occurring on a longer term basis with some irrigators negotiating agreements for more than one irrigation season.

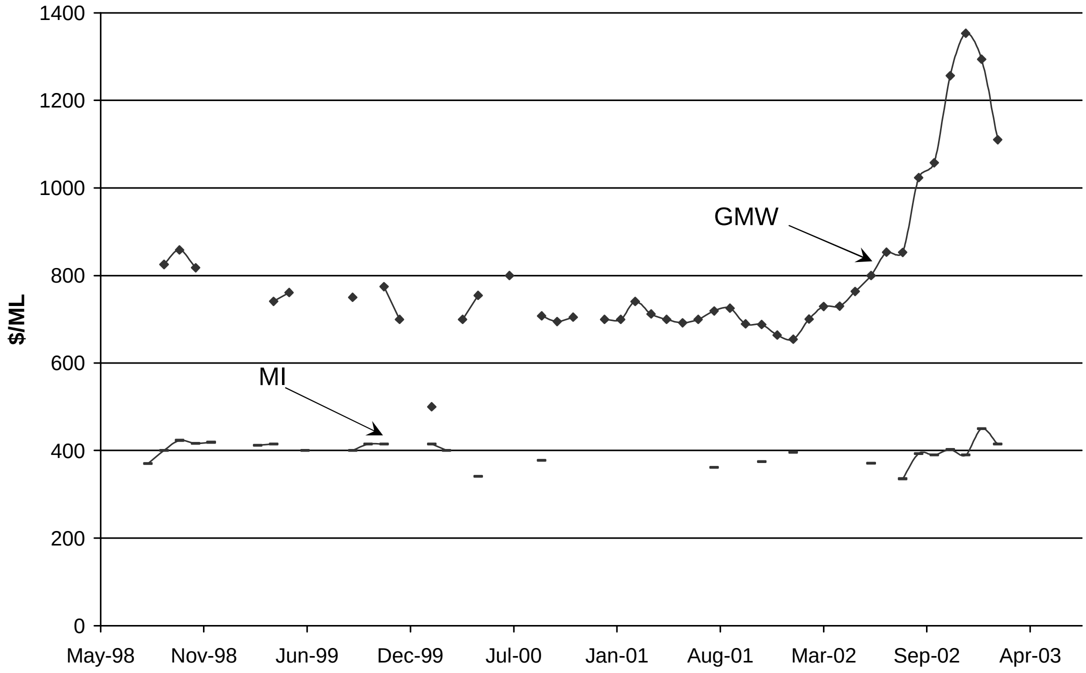
Prices of entitlements:

- are significantly higher than the price for seasonal allocations because entitlements buy a stream of future allocations, including the current allocation or the remaining portion thereof.
- differ across irrigation districts, partly as a result of the differing rights attached to the entitlements. The prices of water entitlements from the GMW district, for example, are substantially higher than in the MI district, because of differing supply reliabilities and attached conditions.
- vary spatially. The relatively thin market and confidential nature of many entitlement trades mean that there is little publicly available information about the prices being paid. Further, the differing supply reliabilities of irrigation water in different irrigation districts make comparison difficult.

DNRE (2001) note that prices of traded entitlements have increased over time in nominal and real terms. In 1993-94, 12 000 megalitres of Sunraysia entitlements were sold at auction for about $440 per megalitre, mainly to Sunraysia buyers. In 1999-2000, Sunraysia prices reached $1000 per megalitre.

Figure 2.5 shows a time series of entitlement prices in the Greater Goulburn subdistrict of the GMW district and the MI district. Prices for entitlements tend to be more stable than prices for seasonal allocations but there was an increase in nominal prices during the 2002-03 drought. One explanation for the increase during that year was that attached seasonal allocations were trading at relatively high prices (up to $500 per megalitre).

Figure 2.5 **Average monthly prices for trade in water entitlements, Goulburn-Murray Water and Murray Irrigation**



Data sources: Goulburn-Murray Water, pers. comm., 1 April 2004; Murray Irrigation Limited, pers. comm.., 22 December 2003.

The slow emergence of the entitlement market and the relatively low volumes and numbers of transfers which currently occur can be explained by the following factors (see Bjornlund 2001; DNRE 2001):

- administrative issues — including restrictions on inter-regional trade and time delays for processing entitlement transfers
- taxation issues — purchases of entitlements may be treated as a capital asset and the cost only deducted when the asset is sold
- the need to maintain an annual income — access to irrigation water ameliorates farmers' exposure to rainfall variability
- the perception that selling water erodes the capital value of the farm and reduces future options (discussed further in chapter 6)
- policy uncertainty.

2.5 Summary

- Irrigated crops have greater total water needs than can be satisfied by local rainfall. Without irrigation, they could not be grown in that area. The physical needs for irrigation water is the difference between the total water needs of irrigators’ crops and effective rainfall over a season.
- The total water needs of all crops increase in hotter years because of increased plant growth, transpiration and evaporation. As rainfall is generally lower in these years, the demand for irrigation water can increase substantially. The corollary is that the demand for irrigation water is relatively less in cooler and wetter years. Consequently, an irrigator’s demand for irrigation water changes from year to year.
- The existence of markets for irrigation water means that irrigators can sell as well as use irrigation water, sometimes simultaneously. The nature of an irrigator’s activities influences decisions to sell or use water. For example, an irrigator growing annual crops is likely to buy traded allocations when water prices are relatively low, and sell when they are relatively high.
- Markets for seasonal allocations change from irrigation area to irrigation area, and from year to year. In any year the market for seasonal allocations will depend on the allocation decisions of the relevant water utility, as well as seasonal conditions in both the headwaters of the catchment and locally.

3 A conceptual framework

In this chapter, economic theory is examined to explain why water demand is inelastic at low prices and becomes more elastic at higher prices. Empirical estimates of the responsiveness of demand for irrigation water are then reviewed. It appears that there are no published econometric studies that estimate the price responsiveness of demand of Australian irrigators. Consequently, the focus of this chapter is on mathematical programming studies that model the responsiveness of representative farms with assumptions about production relationships.

3.1 Factors affecting demand responsiveness

Marshall (1920) argued that four factors can lead to inelastic (derived) demand for production inputs:

- other inputs that are complements in production are inelastically supplied
- the output, that it facilitates production of, is itself inelastically demanded
- the input accounts for only a small part of production costs
- the input has no good substitutes.

Input complements

Because water is an essential input in irrigation enterprises, it is unlikely that prices of input complements will significantly influence irrigator responsiveness to the price of irrigation water.

Demand for outputs

The demand for outputs does not much explain why the demand for irrigation water tends to be inelastic. The value of water is related to its value in producing an output — its contribution to a valuable end-product. The value of water as an input is therefore dependent on the price of the commodity produced.

Export markets are important for most irrigated production. In these markets, irrigators are price takers and have little influence over market prices. Therefore, at the relevant range of outputs and inputs, demand for much irrigated production tends to be price elastic. Other things being equal, elastic demand for an irrigator's outputs is more likely to lead to elastic derived demand for their inputs.

Irrigation water and farm costs

If the demand for an irrigator's produce was relatively elastic, hence cost increases cannot be passed through to commodity prices, the degree to which irrigation costs contribute to total farm costs may affect farmers' responses to rising water prices.

If irrigation costs make up a large proportion of total activity variable costs, rises in the price of irrigation water can have a significant impact on profit margins. This could lead to more elastic demand for irrigation water because rising water prices could make some irrigated activities relatively unprofitable. Irrigators would respond by reducing (or ceasing) production of relatively unprofitable activities. In contrast, if irrigation costs are only a small component of total activity costs, rising irrigation water prices may not affect the relative profitability of activities and irrigators may largely continue their current activities.

The costs of existing farm irrigation infrastructure are sunk costs, are not affected by changes in the prices of water, and are not included in the following estimates of water costs as a proportion of total activity costs. The estimated share of irrigation costs as a percentage of total costs is highest in rice (16 per cent) and dairy (14 per cent), and lowest in grapes (3 per cent), vegetables (2 per cent) and fruit (1 per cent) (CSIRO 2002). In part, this reflects the relative capital intensity of perennial horticultural activities, and labour intensity of vegetables. Other things being equal, these relative costs shares may imply that the demand for irrigation water would be relatively more elastic in the rice and dairy industries, and relatively less elastic in horticultural industries.

Substitution possibilities

Other things being equal, demand for an input will be inelastic if the input has few substitutes. All plants require water — but irrigators have choices as to outputs produced and the mixture of inputs used in production (including the sources of irrigation water and the technologies used to apply it). The more substitution choices available to an irrigator, the more elastic their demand for irrigation water may be.

The main substitution choices available to irrigators will be discussed in the next three chapters. These responses will be divided into those typically undertaken in the short run (chapter 4) and those undertaken in the long run. Chapter 5 focuses on long run substitution choices involving the sourcing of irrigation water, and investment in differing irrigation technologies. Chapter 6 discusses broader long run adjustment options.

Individual versus market responsiveness

Although the focus of this study is on the responses of individual irrigators to changing water prices, the economic consequences of aggregate behaviour should not be overlooked. This is particularly the case for irrigation water because irrigators can be both buyers and sellers of water. The demand and supply of water into the market are derived from irrigators' individual water demands.

In general, the broader market response will follow the movements of the individual demands from which it is aggregated. The Productivity Commission (2004) note an interesting case — that of changing utility prices, possibly through the levying of environmental taxes on water use. In cases where the utility price remains below market prices for traded water, price rises through the imposition of water taxes may not lead to any changes in the aggregate quantity of water being demanded — taxes simply reduce the price of traded water by the level of the tax.

3.2 Estimation studies and market data

Data of observed prices and quantities of water exchanged are required to estimate the responsiveness of demand. Data of this kind have been difficult to obtain because of the relative infancy of Australian water markets. Analyses of the responsiveness of demand for irrigation water using Australian market data have not been published to date.

A large and open market for trading water is the electronic exchange 'Watermove' operated by Goulburn Murray Water. In this market, observed prices paid for seasonal allocations during 2002-03 were much higher than previously experienced (see table 2.4). The high prices paid in that year compared to previous years shows that some irrigators' demand for water can be highly inelastic under some conditions.

Brennan (2004) plotted bids of buyers on the Watermove exchange and concluded that the price elasticity of demand for traded seasonal allocations during the 2002-03 irrigation season changed substantially during the irrigation season. Demand for traded seasonal allocations was relatively more elastic at the start of the irrigation season in August when there was some expectation of an increase in allocations for the season. Demand for traded seasonal allocations became more price inelastic between October and March as these expectations were disappointed. Finally, demand for traded seasonal allocations became more price elastic at the end of the irrigation season, following rain in April, and the fact that many potential buyers had either purchased their desired volume of water, or adjusted their production plans to suit available water.

Some of the factors that could lead to relatively high prices and changing elasticities of demand for traded seasonal allocations are discussed in box 3.1.

Box 3.1 **Understanding some recent market responses: the Greater Goulburn trading subdistrict**

The 2002-03 irrigation season was the first year that GMW did not deliver full seasonal allocations, with only 57 per cent of water entitlement allocated in the Greater Goulburn trading subdistrict (or approximately half the average seasonal allocation of the previous 10 years). Prices of up to $500 per megalitre were paid for traded allocations during the year.

The relatively high market prices increased the opportunity cost of water for all irrigators. Trade occurs when some irrigators choose to forgo the use of their seasonal allocation, and sell it to other irrigators. Sellers do this because they consider the expected returns from trading water are greater than the likely returns for irrigated activities.

Some horticulturists with perennial crops may have faced the risk of ‘catastrophic loss’ — that their crops would die from insufficient water. This group is likely to have a relatively inelastic demand for water, and to have purchased seasonal allocations rather than lose their perennial crops. In the absence of water trading, the economic costs of the reduction in supply of irrigation water in the 2002-03 irrigation season would have been much greater because irrigators with perennial crops would not have been able to supplement their seasonal allocations, and may have lost part of their crops.

The potential influence of strategic bidding to purchase (or sell) seasonal allocations may also be important. Early in the season, some irrigators may have identified a potential shortfall in the availability of irrigation water. They may have believed that there was some probability that either local rainfall, or rainfall in the catchment area and a resulting increase in seasonal allocations, could reduce the potential shortfall. They may have also believed that prices of traded water could decrease if there was an increase in allocations. These beliefs could influence them to spread purchases over the irrigation season, rather than acquire the potential shortfall in one purchase. Weekly trading on Watermove would allow an irrigator to enter a relatively low bid early in the season, and revise their bidding strategy each week until they had acquired the seasonal allocations they needed. This, in turn, could affect their farm management decisions. For example, failure to acquire a certain volume of water below a threshold price could mean that they curtailed some planned activities, reducing their expected water needs.

CGE models

Computable General Equilibrium (CGE) models are built on a number of technical and behavioural assumptions (including input substitution choices) about the economic agents which they describe. In most of these models, the elasticity of water demand is implicit in the choices the modellers make regarding some of the parameter values. TERM-Water is a CGE model used to examine the effects of water trade — within it water demand is highly inelastic in both the short run and long run (see appendix A), even at relatively high market prices.

Mathematical programming

Econometric estimation of demand for water using market price data is difficult when the markets for water are thin or non-existent (de Fraiture and Perry 2002). Consequently, analysts have relied on the indirect approach of using models of agricultural production to derive the demand for irrigation water.

Mathematical programming models can be used to derive elasticities by estimating the value of the marginal product of water in an agricultural production system. Given other farm inputs, the models can be used to determine the additional value of agricultural production for each additional unit of water used. Generally, these models are:

- designed for representative enterprises at either the region or farm level
- based on a stylised ‘average’ farm using average or industry standard technologies and operating in ‘average’ seasonal conditions
- solved for the optimising choices made by a decision maker who controls endogenous variables of the model
- of step-wise functional form such that at threshold prices irrigators are assumed to alter their production systems enabling reductions in water use
- of a short run nature. Short run production options are the only variables used. An exception is Pagan et al. (1997) which used long run variables that permitted investment, such as new irrigation technology, and estimates of the long run price elasticity of demand.

In such analyses, the location considered will determine the dominant agricultural industries. If the analysis occurs at a regional level, a number of different production systems may be involved. Some regions may be dominated by a single crop or species of livestock. For example, irrigated cotton is the typical crop in the Namoi River region, a rotation of irrigated crops including rice is the typical crop in the MIA and dairy is the predominant industry in the GV district.

The irrigation water demand relationships estimated by eight different studies within the MDB are compared in appendix A. In all the models, demand is inelastic at relatively low prices ($0–$20 per megalitre). Some models indicated that demand was inelastic for prices in the range $0–$55 per megalitre (Read, Sturgess and Associates 1991). In most studies, demand was estimated to be inelastic within the range of utility supply charges applying at the time of the study.

In general, the estimated elasticity of demand increased at higher price levels. In studies that reported more than one elasticity (over different price ranges), it was found that water demand functions were more elastic at higher price ranges — with elasticity greater than 1 at the highest price range considered. It is difficult to apply these results to the behaviour of irrigators participating in recent water markets because the observed price of water (especially in markets for seasonal allocations) has exceeded, at times considerably, the highest of the price ranges considered in the models. All linear programming models predicted that demand by irrigators would become increasingly elastic at prices where strong trade has been observed (see, for example, Briggs-Clark et al. 1986). The highest price considered in the linear programming models examined in appendix A was $100 per megalitre. Trade has been observed at prices in excess of $100 per megalitre since 2001-02.

Allowing a longer time horizon within the mathematical models increased the estimate of the responsiveness of water demand. This is because more response options to rising water prices become available. For example, Pagan et al. (1997) (allowing for investment in new irrigation capital) calculated that the own price elasticity of demand for prices between $30 and $50 per megalitre was –0.19 in the short run and –0.25 in the long run. Whereas, for prices between $50 and $70 per megalitre, the elasticities of demand were –2.8 in the short run and –3.0 in the long run.

The price elasticity of demand was generally found to become more elastic beyond some threshold price (see appendix A, table A.1). The OECD (1999) observed that in such models the level of the price threshold depended on:

- the economic productivity of the water
- the set of alternative production strategies that farmers adopt in order to substitute for water consumption
- the proportion of land devoted to permanently-irrigated crops
- the irrigation technologies in place
- the size of the seasonal allocation.

Limitations of the models

Any model is a partial representation of reality. For example, farm level models are based on stylised ‘production functions’ for agricultural processes. Many of the models that have been used to estimate the price elasticity of demand for irrigation water have been constructed by aggregating farms into a stylised farm for a region. This may involve different types of agricultural production being incorporated into the one irrigation district. This limits the conclusions that can be drawn about the responsiveness of water demand to characteristics of certain cropping or livestock processes, and whole systems.

Another limitation is the limited range of prices over which responsiveness of demand was considered. Most estimates derive elasticities from price ranges well below the observed prices for recent irrigation seasons. Given that the responsiveness of water demand varies between different price and water combinations, the estimates hold little significance beyond the ranges for which they were estimated.

Existing models were based on a yearly time frame and with average rainfall. These models can mask fluctuations in water demand throughout stages of crop development or other agricultural processes. They also mask the effect that uncertainty of rainfall and seasonal allocations (including timing of allocation announcements) can have on farmer decision making**.**

3.3 Summary

- There are no published empirical estimates of the price responsiveness of demand for irrigation water in Australia derived from observing irrigators’ behaviour in historical water purchases. Nevertheless, there is a growing body of data about water trading that could enable estimations to be made in the future.
- Mathematical models of representative farm production systems have been used to estimate elasticities of demand for water in major irrigation areas. All the models estimate very inelastic demand for irrigation water at low prices ($0–$50 per megalitre) and less inelastic demand at higher prices.
- The low price ranges in which inelastic demand is predicted generally fall within existing utility supply charges. However, price ranges over which elastic demand is predicted are well below those recently observed in markets for seasonal allocations.

4 Short run responses

This chapter discusses the factors influencing irrigators' short run responses to changing charges by water utilities and market prices of seasonal allocations. The short run is defined as a period of such length that the mix of activities on the farm cannot be changed, and only some inputs can be changed. Section 4.1 discusses factors affecting short run responses to changing water charges and prices. Possible short run responses in the rice, dairy and perennial horticultural industries are described in section 4.2.

4.1 Influences on irrigator responses

An irrigator's short run response to increases in the cost of water (box 4.1) depends on, among other things:

- whether the increase relates to the fixed or variable component of utility charges
- whether trade is allowed
- what costs are still to be incurred.

Fixed and variable costs and charges

In the short run, changes in fixed costs (such as the volume independent component of a water utility charge) may not influence production decisions because the total cost remains the same irrespective of the quantity of water used. This is not to say that fixed costs are unimportant: they affect an irrigator's profitability and influence long run decisions.

In contrast, changes in variable costs (such as the volume dependent component of a water utility charge) may affect production decisions even in the short run. An irrigator facing an increase in a variable cost may be able to reduce the resultant impact of the cost increase on profits by reducing the amount of the input used and/or substituting other inputs.

The impact of trade in seasonal allocations

Allowing trade in seasonal allocations adds an additional opportunity for holders of entitlements to water. In the absence of trade, the opportunity cost of irrigation water is established by the most profitable available activity on the farm. An irrigator will continue to use irrigation water (to the limit of their entitlement) while the marginal revenue from applying an additional megalitre exceeds the marginal cost. If variable utility charges are relatively low, the marginal cost will also be relatively low for gravity irrigation systems. In most irrigation districts in 2003-04, typical variable charges ranged from $5.62 to $12.40 per megalitre delivered (see table 2.1).

When trade is allowed, the opportunity cost of irrigation water could be either the market price of seasonal allocations in the zone(s) in which trade is permitted, or expected net returns from the most profitable available farm activity. An irrigator's most profitable use for water is to sell it to another irrigator if, at the margin, the expected net revenue of sale exceeds the expected increase in net revenue from using the water to irrigate their crops.

Costs still to be incurred

Planting costs could have been important in determining which crop to plant, but once a crop is planted, the costs of planting are 'sunk' and do not effect irrigators' future decision making. Consequently, to maximise the net revenue from the crop, an irrigator's economic decisions are restricted (in the normal range of events) to controlling future inputs to that crop.

Irrigators will continue production of a crop while expected marginal revenue exceeds the expected marginal costs still to be incurred. As the growing season progresses and additional expenditures are incurred, more and more costs become sunk. Irrigators become less sensitive to increases in water prices as harvest approaches and more costs become sunk. The final decision to be made is whether to harvest, and this will be done while expected revenue exceeds expected harvest and post-harvest costs (box 4.1, also see Douglas, Dwyer and Peterson 2004).

In contrast to annual crops, many perennial horticultural crops are characterised by a large capital investment, a relatively long pre-productive period where the crop is maintained (sometimes four to five years), and then a (usually lengthy) period of production (box 4.2). Having invested in a perennial horticultural crop, an irrigator may be relatively unresponsive to changing water prices for the life of the crop. This is because establishment costs are sunk, variable costs are usually small compared to variable revenues, and there would be large costs to replant the crop.

Box 4.1 **Average and marginal prices paid for water**

The gross margin budget for long grain rice in the Murrumbidgee Irrigation Area shows expected gross revenue of around $2850 per hectare, variable costs of around $1100 per hectare and a gross margin of around $1750 per hectare. The budget shows an expected gross margin of around $135 per megalitre of water used. This means that if the *average* price of water increased by $135 per megalitre or more before planting, an irrigator should not plant — they would expect to lose money.

However, if an irrigator needed to purchase a *marginal* volume of water immediately before harvest (say just 0.5 megalitre of water per hectare), the price that the irrigator could pay may be relatively high if it 'saved the crop' and ensured harvest. For example, paying a $500 per megalitre (or $250 per hectare) for the final watering would be worthwhile if it ensured an otherwise doubtful harvest and about $2500 of net revenue (after allowing for harvest and post-harvest costs of $350 per hectare).

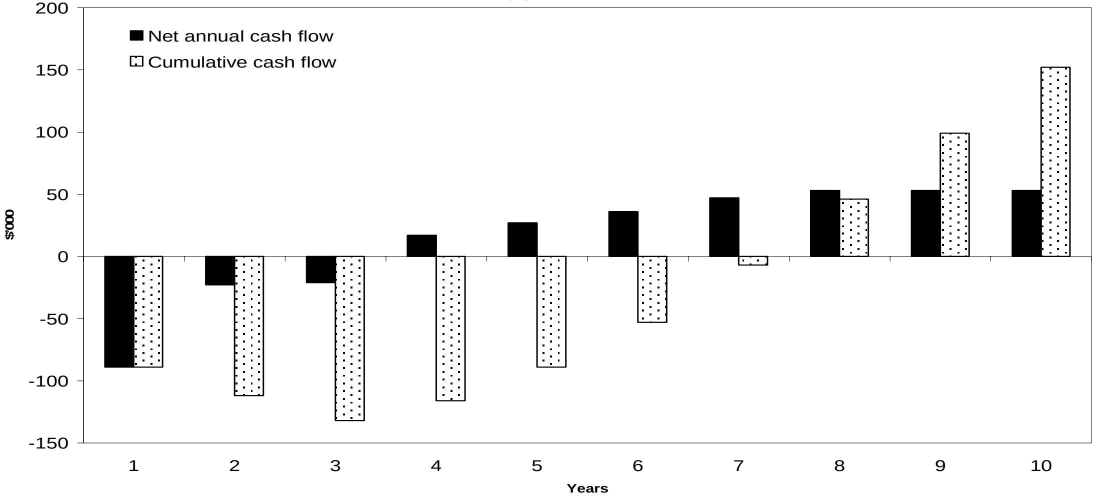
Sources: NSW Agriculture (2003); Douglas, Dwyer and Peterson (2004).

Box 4.2 **A selected perennial horticultural crop**

The annual and cumulative cash flows resulting from investment in a selected horticultural crop are shown below. The crop is planted on six hectares, and has an expected productive period of more than 40 years. The installation of a drip fertigation system (an irrigation system — typically drip irrigation — which can also deliver fertilisers) is the major part of the initial capital costs (about $10 000 per hectare). Skilfully used, a fertigation system can ensure that most fertilisers used are taken up by the crop minimising fertiliser accessions to ground or surface water. Fertigation systems are more expensive to install than conventional irrigation systems. Fertilisers used in fertigation systems may cost more than conventional fertilisers because they must be readily soluble in water.

When the crop reaches maturity, the expected net annual cash flow is around $8000 per hectare. The expected net cash flow would have to decline considerably, and/or an even more profitable crop become available, before this activity would be discontinued.

Annual and cumulative cash flow for a hypothetical horticultural investment



Source: PC estimates.

4.2 Short run responses in selected industries

In this section, possible industry-specific, short run management responses to changing water prices are discussed.

Rice

Some of the key characteristics of rice growing are summarised in box 4.3. Rice growers' responses to an increase in the unit cost of water will depend upon whether the increase occurs before or after planting. Before planting, their response will be whether to plant, and if so, how much and when. After planting, their response will reflect the costs expected to be incurred until the crop is harvested, and the expected returns from the crop.

Box 4.3 **Rice growing in the southern Murray–Darling Basin**

Rice farms tend to be mixed farms where *one* of the activities is rice growing. Rice growing predominantly occurs in the Murrumbidgee and Murray valleys.

Most rice growers have general access water entitlements which generally have a relatively low supply reliability. Rice growers in the Murrumbidgee Valley are likely to hold a larger water entitlement per unit of land than those in the Murray Valley, while Murray Valley irrigators are more likely to trade water partly because of their lower entitlements.

Environmental standards constrain annual rice plantings on individual farms to 30 per cent of the soils that can be suitably planted to rice. Under the standards, rice can only be grown on clay soils that minimise accessions to the watertable. A common rotation on a rice farm would commence with rice being planted as a summer crop. This could immediately be followed by a winter crop (often cereals such as wheat) to take advantage of the residual soil moisture from the rice crop. The residual soil moisture from the rice crop ensures the water needs of the wheat crop for several months after planting, and is an important component of the overall rotation, providing both economic, agronomic and environmental benefits. Singh et al. (2004) state that the environmental benefits include 'more efficient use, minimising run-offs and accessions to the groundwater and increasing water use from upflow from shallow water tables'. They estimate that planting a winter crop immediately after rice reduces recharge by about one megalitre per hectare.

The initial wheat crop could be followed by another wheat crop, which in turn could be followed by an oat crop under-sown with lucerne or pasture. Depending on the individual rotation, it could be at least four years before rice was replanted in the same paddock.

Sources: Ricegrowers Association of Australia, pers. Comm.., 3 February 2004; Singh et al. (2004).

In years of below average allocation (and relatively higher traded prices, other things being equal), rice growers may choose to reduce the area of rice planted, and use a relatively higher proportion of available water on their growing wheat crops, to maintain existing pastures, or to sell some water. Rice growers closely monitor the likely seasonal allocations before planting. They may choose to change varieties and plant rice later in the season in order to gain a greater insight into the likely seasonal allocation for the year. If their allocation is not sufficient to water the planted area of rice, they face exposure to the market in seasonal allocations and the risk of having to pay a high price for the required water. In years with extremely low allocations, where sufficient water may not be available at a price to allow rice to be grown profitably, they may choose not to plant rice at all.

Once a rice crop has been planted, the rice grower will attempt to obtain sufficient water to ensure that the crop is harvested and the demand for irrigation water tends to become relatively inelastic. Therefore, risk-averse rice growers plant if they believe that they are likely to receive most of the required water from their allocation. Consequently, it is likely that they may only require a relatively small additional allocation from the water utility, and/or purchase of traded allocations, to meet their water needs. Some rice growers (with less risk aversion) may plant with lower allocations and rely on increases in announced allocations and the market for seasonal allocations to ensure their crop.

Typical to wetter years

The gross margin budget for long grain rice in the MIA is about $135 per megalitre (the water needs of a rice crop are described in box 4.4) (NSW Agriculture 2003). This implies that the *average* cost per megalitre of irrigation water would have to approach $160 per megalitre (an increase of $135 over the budgeted price of $25 per megalitre) before the variable costs of growing the rice crop exceeded its return and the planting of rice became unprofitable. However, a combination of dryland agricultural activities and the sale of seasonal allocations is likely to become a more profitable alternative well before average water prices reach $160 per megalitre.

Very dry years

In southern Australia, very dry years tend to be relatively hotter years. Hotter seasons increase the water needs of rice because of the related increase in the rate of plant growth, a lack of soil moisture prior to sowing, and because there will be more evaporation from the rice paddies.

Box 4.4 **Estimated water needs of a rice crop**

NSW Agriculture's gross margin budgets for rice are based on 13 megalitres of irrigation water (industry figures indicate an average of 12 megalitres) being required to produce a hectare of rice in an average season. Annual average rainfall in the rice growing areas of the Murrumbidgee and Murray valleys is about 400 millimetres. About half the rainfall, or the equivalent to the application of 2 megalitres of irrigation water per hectare, typically occurs immediately prior to planting, or during, the rice growing season. Therefore, the total water needs of a rice crop is, on average, about 15 megalitres during the growing season.

A typical rice farm in the Murrumbidgee Irrigation Area is 240 hectares. In an average year, about one-third of the farm is sown to rice, with the balance being used either for the production of cereals, other summer crops or pasture — all of which may be irrigated in drier seasons.

A typical rice farm has a water entitlement of 1300 megalitres. For example, 80 hectares of rice would typically need about 1040 megalitres of irrigation water. The balance of the water entitlement (about 260 megalitres) would be available to meet the irrigation needs of the other activities on the farm, to 'carry-over' to the next season, or for sale. It should be noted that in this scenario, all available water is either delivered by the water utility, or stored until the following year.

Sources: PC estimates; Ricegrowers Association of Australia, pers. comm., 3 February and 28 July 2004; NSW Agriculture (2003).

Water utilities are likely to reduce the seasonal allocation of irrigation water in very dry years. For example, in the 2002-03 irrigation season, rice growers in the MIA received a final allocation of 38 per cent of their water entitlement. For a typical rice farm, only about 500 megalitres would be delivered in these years.

Other crops (wheat and pasture) on the rice farm will also have an increased need for irrigation water. To the extent that these crops have been planted and are growing, the irrigator may give watering these crops a high priority. The irrigator may be aware that the prices for grain and fodder are likely to be relatively high in a very dry year, increasing the relative profitability of these crops.

Continuing the example in box 4.4, assume the water needs of wheat and pasture crops increased by 10 per cent from about 260 megalitres in an average year to about 290 megalitres in a very dry year. This would mean that only about 210 megalitres of irrigation water (about one quarter of the normal quantity) would be available to grow rice in a year with similar allocations to 2002-03. The dry conditions will also lead to a reduced supply, and therefore relatively high price, of traded allocations. Consequently, the rice grower may only plant an area of rice proportionate to their reduced seasonal allocation. For example, only about 38 000 hectares were planted with rice in 2002-03 compared to 150 000 hectares in

2001-02, and around 65 000 hectares was planted to rice during 2003-04 (ABARE 2003, 2004).

An important feature of this analysis is that the demand for irrigation water is for the whole rice farm, and not just the water demand of the rice crop itself. The large variation in the observed plantings of rice during very dry years is explained in part by the use of a higher proportion of the reduced supply of irrigation water for other activities on the rice farm to which the owners were already committed.

Dairy farmers

Dairy farming accounts for the majority of irrigation water used for pasture in the southern MDB. In the GMW district, dairy farming represents over 50 per cent of all irrigation water use. The other major dairying area is near Finley in the MI district. In these districts, the main form of feed of dairy cows is grazing — either on perennial rye grass and clover pastures, or to a lesser extent annual pastures. Seasonal calving is common in dairy herds. Typically, the majority of the herd are mated to calve in spring. Most milk is produced during spring, summer, and autumn when pasture growth is highest. Cows are then ‘dried off’ in the winter, prior to calving.

Wet years

Wet years can often limit production. In wet years, perennial pasture growth can be slowed if temperatures are low and/or soils are waterlogged for part of the season. Pasture growth can be sufficient without irrigation water, but usually for only part of the season. If a wet spring is encountered, dairy farmers tend to hold rather than sell water with the expectation that they will irrigate more frequently at the peak of summer, and as an insurance against not getting good rains in autumn to provide pasture before winter — an ‘autumn break’.

Wetter conditions can make the production of good quality hay and silage difficult. They can also result in greater availability of poorer quality concentrated feeds at relatively low prices, such as rain-damaged wheat and barley.

Typical years

Over the spring and summer months, dairy farmers grow and store pasture (usually in the form of hay or silage) for the following winter when pasture growth is low. Some farmers grow forage crops which can be harvested over the winter for the dry and calving herd.

Dairy farmers plan feed and water requirements many months in advance. Most dairy farms are heavily stocked compared to other grazing enterprises (stocking rates of three cows per hectare are not uncommon) and pastures are carefully managed to ensure sufficient feed is available for the herd on a daily basis. Relatively small declines in feed quality and quantity can have a significant impact on milk production. Over the irrigation season, pastures can deteriorate rapidly if sufficient water is not applied at appropriate intervals. Dairy farmers apply more fertilisers (relative to other livestock farmers) to boost the quantity of pasture that can be grown from a megalitre of irrigation water.

Providing more feed at the start of lactation makes it possible to extend and increase the rest of the lactation. Pasture is the primary form of feed input but it can at times be cost effective to substitute it at the margin. It is common practice for dairy farmers to supplement pastures by also feeding concentrates and other high energy foodstuffs over the milk producing period. A typical concentrate would be crushed grain which is fed as the cow is milked. Assuming similar labour costs and sufficient physical infrastructure, the choice depends on the prices of milk, irrigation water, and the feed input. Dairy farmers may find irrigating pastures less economic than supplementary feeding when water prices are relatively high and grain and fodder prices are relatively low.

Given standard stocking rates, it is relatively unusual for dairy farmers to sell cows on the basis of feed availability — cows are culled for poorer production rather than marginal feed constraints. Dairy cows are costly to purchase (in excess of $1000 for a two year old) — taking two years to breed and enter the herd for their first lactation. Cows also take a number of years to reach peak production and can have productive lives in excess of 8 to 10 years. Selling stock can also result in lost genetic potential from the herd. When pasture feed shortages occur, dairy farmers will purchase feed, and/or agist part of their herd, rather than reduce their standard stock rate significantly. The extent of this is evident by the recent drought in the GMW district where dairy farmers agisted cows with other dairy farmers in Gippsland and Western District rather than cull parts of their herd.

Very dry years

In very dry years, dairy farmers are likely to irrigate their pasture about every fourteen days at the peak of summer. In these years, storages are likely to be lower and ‘sales’ water may not be available. Dairy farmers are unlikely to grow the usual volumes of pasture for hay and silage and consequently will purchase fodder from other farmers. Reduced (or no) ‘sales’ water and lower allocations mean that dairy farmers have to chose between decline of production, purchasing additional water, or purchasing additional fodder and concentrates. There is a limit to how much concentrate can be fed to a cow, as cows need roughage for their rumens.

Most dairy farmers will use more labour to ensure water use is economised. The farmer will spend more time monitoring the timings and avoid wastage, such as water overrunning irrigation bays and becoming return flows. Dairy farmers may also chose to irrigate smaller areas of the farm, for example, avoiding irrigating lighter and more porous soils, or irrigating half bays so seepage is minimised.

These changes are also likely to coincide with increasing use of supplementary feed. Grains are usually the first choice, but if large volumes are required pasture based feeds such as hay and silage are likely to be also used. The choice and timing of these feeds will depend on the relative prices of the feeds and traded allocations. Usually in drier seasons, the price of supplementary feed is dearer because grain and hay producers have also had a poorer season.

Ceasing milk production for the season is usually not economic until later in the lactation when cows can be dried off early with minimal losses. Production lost early in the season cannot be easily recovered. Dairy farmers may choose to dry off relatively less productive cows rather than effect the production capacity of their more productive cows.

Perennial horticulture

Perennial horticulture in the southern MDB includes industries such as wine grapes, olives, citrus, stone and pome fruits. Each industry has its own special characteristics, but the factors influencing their demand for irrigation water will be relatively similar. This section describes the likely need for irrigation water by a hypothetical perennial horticulture farm in average to wetter years, and in very dry years. It is assumed that this farm is located in the upper Goulburn Valley, Victoria. (box 4.5).

Typical to wetter years

In typical to wetter years, the irrigator described in box 4.5 would attempt to trade the small volume of ‘excess’ water provided the expected proceeds exceeded transaction costs.

Box 4.5 Estimated water needs of a selected perennial horticultural crop

In typical years, a perennial horticultural crop will require about 6 megalitres of irrigation water per hectare (assuming use of drip irrigation). In addition, it will receive about 700 millimetres of rainfall, or the equivalent of 7 megalitres of irrigated water per hectare.

The hypothetical horticultural farm is about 20 hectares, which means that in an average year about 120 megalitres of irrigation water and 140 megalitres of rain, a total of 260 megalitres, will be required to meet the water needs of the crop. The gross margin of the crop is about $6000 per hectare.

The irrigator has a water entitlement of 130 megalitres, which allows for some increase in water needs in drier and hotter years.

The produce is exported, and therefore prices received are unlikely to increase due to local scarcity.

Source: PC estimates.

Very dry years

In very dry years, the water needs of the crop increase. Assuming the irrigator uses drip irrigation, the increase in irrigation water lost to evaporation should be relatively small. If the irrigator is using a drip irrigation system efficiently, there may be little potential for water savings by altering the irrigation schedule to provide more frequent waterings with lower volumes.

If the seasonal allocation from the water utility is reduced in a very dry year — as happened in 2002-03 — the irrigator is likely to be willing to pay very high prices for traded allocations. This is because the costs of allowing the crop to die and the subsequent replanting, including the loss of income during the pre-productive period, would far exceed the cost of purchasing traded allocations. Continuing the example in box 4.5, assume in 2002-03, the total water needs of the irrigator's crop increased from 260 to 270 megalitres because of the hot and dry conditions. Meanwhile, the irrigator would have received 57 per cent of his water entitlement, or about 75 megalitres as an allocation. Annual rainfall in 2002-03 was about 400 millimetres (about 4 megalitres per hectare or 80 megalitres on the farm). Total water available from rain and seasonal allocations would have been about 155 megalitres. The irrigator would have needed to purchase about 115 megalitres of traded allocations to meet the water needs of the crop. Even if he paid the highest observed price of $500 per megalitre during the 2002-03 irrigation season (a total cost of about $57 500), the crop would still have produced a positive gross margin of about $60 000 in that year (but the main benefit is the avoidance of catastrophic loss of the perennial crop).

4.3 Summary

- Water utilities' charges typically have fixed components (based on water entitlement) and variable components (based on water usage). In the short run, irrigators can be expected to respond to changes in variable costs and charges whose impact depends on the volume of water used. They are less likely to respond to increases in fixed costs and charges whose impact is independent of the volume of water used.
- Once a crop is planted, it is likely that irrigators become less responsive to changing water prices as the production season progresses and harvest approaches.
- A crop's need for irrigation water tends to increase in hotter and dryer years because of a related increase in the rate of plant growth, and increased transpiration. The reduced rainfall in these years means that there will be an increased need for irrigation water to replace the rainfall deficit. As well, there is greater evaporation of irrigation water in channels and when applied to fields.
- Rice growers tend to reduce the area planted to rice in years when they expect relatively low seasonal allocations. Once a rice grower has incurred the costs of planting a crop, short run demand for irrigation water tends to become more inelastic.
- Dairy farmers tend to have more substitution choices than rice growers or horticulturists. Possible substitution choices include substituting purchased fodder for irrigation water, or grazing 'dry' cows on non-irrigated pastures. The relative prices of water compared to the relative prices of substitution choices will determine which choice is more profitable.
- Horticulturists with perennial crops may have an inelastic short run demand for irrigation water because variable costs are usually small, compared to variable revenues, and the costs of replanting if part of their crop dies. This group is likely to purchase traded allocations if their water utility's allocation falls significantly.

5 Long run responses — sources and use of water

In the long run, all outputs and inputs are variable. Two broad technological responses are discussed in section 5.1 — seeking irrigation water from sources other than water utilities; and investing in water-saving irrigation technologies. This is followed by a discussion of two recent Australian case studies examining the impact of adopting new irrigation technologies. Long run responses in selected industries are discussed in section 5.2.

5.1 Broad technological responses

Substitution choices available to irrigators in the long run include seeking alternative sources of irrigation water and/or adopting more efficient irrigation technologies.

Alternative sources of irrigation water

Some irrigators may be able to substitute the purchase of water from utilities, and/or markets, with water from other sources, including:

- storing surface water runoff from rainfall and irrigation in farm dams
- opportunistic pumping of passing return flows and passing flows in surface drains and watercourses
- pumping of groundwater.

The availability and cost of water from these sources will determine the extent to which they are substitutes for water supplied by utilities. Farms will have differing endowments of these resources and access to them is regulated through licensing and property entitlement arrangements. Alternative (non-utility) sources of irrigation water tend to be opportunistic and supplementary at the margin rather than perfect substitutes for utility supply. Nevertheless, some irrigators may have large endowments of, and licences to use, alternative water supplies. The extent to which they can act as substitutes will depend on the extraction costs. For example, some irrigation districts overlay deep aquifers and some irrigators (usually only a small number) may have licences to extract water from the aquifer. In addition, in irrigation schemes where flood technologies are employed, irrigators often have access to return flows from their own and neighbouring farms, and localised groundwater aquifers are often recharged by regular flood irrigation. In some regions the underlying salinity of groundwater can limit its usefulness. For some irrigators, access to alternative water sources may mean that their demand for water from utilities becomes more elastic as charges rise.

In general, alternative sources of irrigation water are imperfect substitutes for water supplied by utilities because alternative supplies tend to be constrained both in terms of volumes and certainty of supply. Regulations governing the harvesting of surface and groundwater mean that the total volume of water available for use by irrigators is unlikely to increase substantially over existing harvesting entitlements. Recent changes in New South Wales and Victoria (box 5.1) effectively prevent irrigators from obtaining further access to additional irrigation water by restricting the construction of more farm irrigation dams.

Box 5.1 **Farm dam regulation in New South Wales and Victoria**

The New South Wales Farm Dams Policy limits to 10 per cent of farm area the amount of runoff which can be harvested for all purposes, including irrigation. For most of New South Wales (the exception is the Western Division), this has been expressed in terms of a ‘harvestable right per hectare’ which ranges from 0.02 megalitres per hectare in low rainfall areas to 0.16 megalitres per hectare in high rainfall areas. The volume of water than can be harvested is then calculated by multiplying the area of a farm by the appropriate harvestable right per hectare. The New South Wales Farm Dams Policy Statement provides an example of a 200 hectare farm at Inverell, in an area with 0.07 megalitres per hectare harvestable right being allowed dams with a volume of 14 megalitres. Inverell has an average rainfall of about 750 millimetres — the equivalent of 7.5 megalitres per hectare — per year.

In Victoria, farm dams used for irrigation must be licensed. In catchments in the MDB, new farm dams for irrigation will only be approved if the irrigator purchases (or converts) an equivalent water entitlement in the same valley.

The effect of the Victorian legislation is that building a farm dam for irrigation will be a costly method of obtaining irrigation water since the irrigator will have to pay both the capital cost of the farm dam and the water entitlement. There are several possible reasons why an irrigator may choose to construct a new irrigation dam. One reason could be that the land that they wish to irrigate is not in an irrigation district, nor close to an irrigation stream. Another reason could be that the dam would allow an irrigator to continue irrigating outside the irrigation season. Similarly, an irrigator with a licence to extract water in winter would need a storage dam to allow use in other seasons. A further reason may be that the irrigation dam might assist in improving reliability of supply.

Sources: DWLC (1998); *Water (Irrigation Farm Dams) Act 2002* (Victoria); GMW, pers. comm., 7 July 2004.

Irrigators’ access to groundwater is subject to state government regulation aimed at ensuring ‘sustainable use’ of the resource. Groundwater sources can be broadly divided into deep and shallow resources. As a rule, deep groundwater resources recharge slowly (often over thousands of years) and can be considered to be a finite resource that can be exhausted. In Victoria, regulation aims to prevent further depletion by matching annual extractions to annual recharge. In contrast, many shallow groundwater resources recharge quickly, especially where they are associated with irrigation activities, and can be considered a renewable resource (subject to water quality issues).

The location of a farm can determine the extent to which groundwater extraction may be a viable alternative source of irrigation water. For example, the expense of bringing a bore online is related to its depth, with deeper bores being more expensive to establish. Increased depth will often provide a greater reliability of supply.

Changing irrigation technologies

At the margin, an irrigator can substitute capital for water by investing in irrigation technologies that reduce water applications per unit of output (box 5.2 and 5.3). This shifts an irrigator’s long run demand curve for water since the relative value of water (price willing to pay) at each possible quantity demanded is changed.

Box 5.2 **Effects of improved irrigation efficiency**

Investment in more efficient methods of applying water or technology to reuse water can reduce water availability to some irrigators by reducing the ‘leakages’ in the water distribution system. In doing so, the return flows from users — the water that returns to the river system through run-off and seepage from the farm, and available to other users downstream — are reduced.

Reductions in run-off can affect downstream water users since less water ends up flowing in drainage channels. These channels can act as an alternative water supply to some farmers. Consequently, an increase in irrigation efficiency by one farmer might limit the options for water procurement by other farmers.

Some studies (such as Young and McColl 2003) suggest that price increases might *increase* the total water consumption of farms by leading to efficiency improvements without significantly reducing the volume of water purchased.

Sources: Young and McColl (2003); de Fraiture and Perry (2002); OECD (1999).

Irrigation technologies can differ across and within irrigation schemes. They can include gravity flow (flood and furrow irrigation) and pressurised systems (spray, micro-spray, trickle and drip systems). Each can have differing impacts on the environment. The choice of irrigation technology can be affected by a variety of factors other than the cost of water including: crop choice; location; labour costs; climate; and soils.

Box 5.3 **Irrigation application systems and water use efficiency**

Flood irrigation, commonly with laser-graded land forming, is the main method for irrigating pastures and broadacre crops, such as rice. Furrow irrigation is common for horticulture, field crops and floriculture, and also for tree and vine crops. Large to medium scale spray irrigation, including central pivot sprays, are used for some tree crops, vines, vegetables and fodder crops. Micro-spray irrigation, trickle/drip and sub-surface drip methods are used for trees and vines.

Water use efficiency is the proportion of applied water which is used by the plant, rather than percolating below the rootzone, evaporating, or becoming runoff. It is a measure of technical efficiency, not economic efficiency. Irrigation systems with a wide range of technical efficiencies could be economically efficient. For example, an inexpensive and technically inefficient irrigation system could be more economically efficient than a system which achieved greater technical efficiency at significantly greater cost.

Flood and furrow irrigation tend to be less efficient in terms of water use than other methods. However, increased groundwater recharge from flood irrigation may result in greater river baseflow. Broadacre spray systems such as lateral and centre pivot sprays tend to be more technically efficient than flood and furrow irrigation. Micro-spray, trickle and drip systems enable more accurate scheduling of water application, reducing losses to groundwater and evaporation — however, these methods are not suited to irrigating pasture. Other factors which influence the water use efficiency of different application systems include soil type, topography, wind, climate variability and use of irrigation scheduling methods (such as soil water monitoring).

Sources: DNRE (2001); Raine and Foley (2002).

The use of different irrigation technologies varies considerably between jurisdictions. In New South Wales and Victoria, where gravity delivery systems dominate, flood irrigation is by far the most common irrigation technology with little adoption of more technically efficient methods between 1990 and 2000 (ABS 2003b) (table 5.1). In contrast, there was a substantial increase in the use of drip irrigation, with a commensurate reduction in the use of both spray and flood irrigation in South Australia over the same period. Nevertheless, the relatively larger areas of irrigation in New South Wales and Victoria compared to South Australia (chapter 2), mean that flood and furrow irrigation are by far the most widely used form of irrigation technology in the southern Murray-Darling Basin.

Table 5.1 **Distribution of irrigation technologies by State, 1990–2000**

	2000				1990			
	NSW	*Vic*	*SA*	*Aust*	*NSW*	*Vic*	*SA*	*Aust*
	%	%	%	%	%	%	%	%
Spray	11	12	44	22	13	8	51	20
Drip or micro	3	5	44	8	1	2	13	3
Flood or furrow	85	82	21	70	84	90	33	74
Other	1	—	1	1	2	—	3	3

Source: ABS (2003b).

Renzetti (2002) reviewed US data and found that the choice of irrigation technology can be affected by a variety of factors other than the cost of water. The study surveyed international literature on water demand, and concluded that most irrigation technology adoption models show that the adoption of modern irrigation technologies is more likely on lower quality land, when crop and input prices are high and when the costs of switching technologies is low. It also found:

> … the elasticity of probability of adopting modern irrigation technology with respect to its water cost saving is significant but small (0.028) and that farmers using groundwater are more likely to adopt modern technologies than those relying on surface water in part because suppliers of surface water have designed their conveyancing systems to work with traditional irrigation methods. (Renzetti 2002, pp. 9.60–63)

In a study of the irrigation regions of Spain, Varela-Ortega et al. (1998) noted water demand was more responsive to prices in old irrigation schemes, where irrigation technologies were relatively inefficient, than in schemes where modern irrigation technologies had been employed. In older, gravity fed flood irrigation districts, for example, there are substitution possibilities within the existing flood irrigation technologies. Irrigators can laser grade or employ more labour or electronic sensor technology to monitor timing and volume of water applications as ways to improve use efficiency. They noted that it is misleading to characterise modern irrigation technologies as ‘water saving’ and that the introduction of drip irrigation will not guarantee water conservation. They concluded that adoption of water saving irrigation technology makes water demand more inelastic because it exhausts a substitution possibility.

> … For a given water pricing, while water savings could be achieved in old (technology) water districts, it is likely that no reduction in water consumption will result in modern (technology) districts and only farm income losses may eventuate. (Varela-Ortega et al. 1998, p. 201)

Similarly, in an earlier study of irrigation practices in California, Caswell and Zilberman (1985) found that small farm size, high water or labour costs, levels of rainfall, lower temperatures and soils with low water holding capacity all increase the likelihood of adopting sprinkler systems. They observed that drip and sprinkler irrigation are land augmenting technologies and can enable water sensitive crops, such as vine fruits, to replace less water sensitive crops, such as perennial pasture, on poorer soils. They found the effect of water charges on the decision to adopt modern irrigation technologies was not strong — raising prices four fold increased the probability of adopting sprinkler systems by only 0.058 per cent.

Carey and Zilberman (2002) observe that investment in water saving technology tends to be driven by random events — '…the adoption of drip irrigation increased dramatically during drought periods in California'. The authors developed a stochastic dynamic model of the adoption of irrigation technology based on option value theory developed by Dixit and Pindyck. It is assumed that irrigators have the choice of buying water in a market instead on investing. They conclude:

> … when a farm has access to a water market, it will not invest in modern irrigation technology until the expected present value of investment exceeds the cost of investment by a potentially large hurdle rate. … The size of the hurdle rate is especially sensitive to the degree of uncertainty in future water prices. The greater the uncertainty, the larger must be the expected benefit before a farm is willing to invest. (Carey and Zilberman 2002, p. 181)

Brennan (2004) argues that increasing scarcity and higher opportunity costs of water in Australia has probably caused many irrigators to adopt relatively inexpensive water saving technologies where they were available.

Recent Australian case studies

Two recent Australian studies by Wood et al. (2003) and Singh and Hutton (2003) demonstrate that:

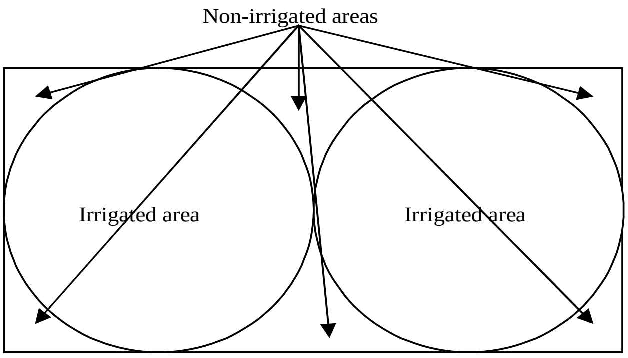
- changing technologies may involve large capital costs and long pay-off periods
- water savings alone are unlikely to be sufficient to pay for new technology, particularly where powered technology replaces gravity technology
- changing technologies can have an impact on other aspects of the farm.

Dairy farm conversion to centre pivot

Wood et al. (2003) found that converting a dairy farm with flood irrigation to a centre pivot system would be unprofitable at utility charges of $28 per megalitre unless more land could be acquired cheaply and the total area under irrigation increased (box 5.4). The potential water savings were an important determinant of the viability of the project. In lighter soils (where water savings of more than two megalitres per hectare a year could be expected) the returns from the technology change were likely to be greater than on heavier soils where less water savings could be expected. Where investment was justified, the key determining factor was increased pasture production because of more timely applications of water, rather than water savings. Changing to centre pivot irrigation without purchasing additional land to account for lost irrigable land would only become attractive if water prices rose significantly (from 50 to 100 per cent, depending on assumptions).

Box 5.4 **A dairy farm conversion to centre pivot irrigation**

Wood et al. (2003) examined the conversion of a border-check flood irrigation system on a 72 hectare dairy farm to a centre-pivot spray system. The centre-pivot irrigation system results in 10 per cent reduction in the land that can be irrigated. The area 'lost' to production are the corners of the centre pivot as shown below — modern centre-pivot irrigators can partially irrigate some of the corners shown, but many farms will not have the regular shape shown and may lose further irrigable land.



The total capital costs for the conversion were estimated to be between $240 000 to $280 000. The capital cost of the centre pivot was around $3800 per hectare — a system with the capability to irrigate about 26 hectares would cost about $100 000. Additional capital costs are also incurred including filling in channels, removing banks, connecting larger electricity mains, changes to fencing, and establishing pump stations.

The costs of pumping water were significant, and may offset the savings in water utility charges from using less water. Centre pivot systems can be automated and therefore result in labour savings, but they are subject to the risk of mechanical failure.

In suitable soil conditions, annual water savings of up to two megalitres per hectare were expected. The expected cost was about $1600 to $1850 per megalitre of water 'saved' — much more than the then market price of an equivalent water right. Irrigators were assumed to sell the water savings, or irrigate more land.

Source: Wood et al. (2003).

Citrus orchard conversion to drip irrigation

Singh and Hutton (2003) concluded that the conversion of a citrus orchard in the MIA from furrow to drip irrigation was economically viable if Navel oranges (which are mainly used for fresh fruit) were grown and the quality improvement resulted in higher prices received for fruit (box 5.5). However, the conversion was not justified for Valencia oranges (which are mainly used for orange juice) where the increased quality did not result in increased prices. The paper did not provide analysis to indicate how sensitive the results were to reduced water savings and it is not clear if the authors considered the impact of pumping costs.

Box 5.5 **Converting a citrus orchard to drip irrigation**

Singh and Hutton examined converting a citrus orchard from furrow to drip irrigation. They found that:

- about 70 per cent of citrus farmers ‘would need a water storage structure for assured water supply if they were to shift to the drip irrigation system’
- changing to drip irrigation was expected to halve water use from 9 megalitres per year to 4.5 megalitres per year
- the drip system would cost about $5400 per hectare or about $100 000 per farm. The storage dam would cost about another $15 000
- drip irrigation does not increase yield, but does increase fruit quality
- the use of drip irrigation is likely to reduce labour requirements.

Source: Singh and Hutton (2003).

5.2 Long run responses in selected industries

In this section, long run responses to rising water prices for specific irrigated activities are discussed.

Rice

In the long run, rice growers’ main responses to increased water prices are likely to involve technological change — such as plant varietal improvements to reduce water consumption. Precision irrigation technologies, including spray or drip, are not compatible with the semi-aquatic needs of the plant. Wider adoption of modern flood irrigation technology, such as raised growing beds, are also emerging as a technology response to water scarcity (Singh et al. 2004).

Current research and development priorities for the rice industry include the development of varieties with shorter growing seasons and/or greater cold tolerance (Ricegrowers Association, pers. comm., 23 January 2004). For example, rice varieties with shorter growing seasons will tend to reduce water consumption by requiring a shorter period of irrigation. Rice varieties with greater cold tolerance will allow a lower height of water in the rice paddy, particularly at the critical time of flowering. The lower water height will not only reduce water usage, but also decrease hydraulic pressure and accessions to the water table.

Rice growers are also likely to adopt yield enhancing technologies, such as precision application of fertilisers. To the extent that these technologies increase the profitability of growing rice, they increase the willingness of rice growers to pay higher prices for irrigation water.

Some rice growers may attempt to reduce the impact of low supply reliability by either using facilities which allow irrigators to ‘carry-over’ part of one year’s seasonal allocation to the next year, and/or choosing to purchase additional entitlements. Irrigators in both the Murrumbidgee and Murray valleys can choose to consume only part of one year’s allocation of water, and carry-over the residue until the next irrigation season. The carry-over mechanism can enable rice growers to ‘smooth’ variations in seasonal allocation, and hence their production of rice and other crops, from year to year.

Some rice growers may choose to decrease the risk of variable seasonal allocations by purchasing additional entitlements. This would ensure that they would obtain more water in all years. In years of high allocation when available water is greater than average water needs, they could choose to carry over any excess, lease it, or plant an annual crop to use the water on-farm.

Rice growers may also change to dryland enterprises if these enterprises are more profitable. The continued production of rice implies it is a relatively profitable enterprise for many irrigators in the Murrumbidgee and Murray valleys.

Dairy

Dairy farmers have a number of possible long run responses to higher water costs that may not involve changing irrigation technology. They include further investment in infrastructure to allow greater substitution of purchased fodder for water, changing pasture technologies (for example, changing from perennial to annual pastures), and using agistment or non-irrigated grazing for non-milking cows.

Some dairy farmers may be able to increase the productivity of their existing perennial pastures, for a given application of water, by applying more fertilisers. Other dairy farmers may choose to further increase productivity by changing some of their land and other inputs to annual pastures. These productivity improvements would also come at the cost of additional inputs such as fertiliser, seed and labour.

Another option for some dairy farmers could be to alter the mix of irrigated and non-irrigated pastures. Some dairy farmers already have access to areas of non-irrigated pastures for feeding ‘dry’ cows. Further access to non-irrigated land could be obtained by converting existing irrigated pastures, purchasing, leasing or renting non-irrigated land, or by agistment. Some irrigators may choose to grow annual, rather than perennial, pastures on non-irrigated land.

The more opportunities that are available for dairy producers to move away from water intensive production methods, the more responsive their demand for irrigation water will be as the price of water rises.

Perennial horticulture

Irrigators of perennial horticultural crops tend to have more irrigation technologies available because individual vines or trees are planted in a series of rows. They can include spray irrigation and drip irrigation (including fertigation) which is widely used on high value crops. Increased water prices may influence the decision to invest in new horticultural plantations, but may have little impact on water demand from existing plantations with sunk capital costs.

For some horticultural crops (such as grapes) there can be problems with using spray irrigation technologies because watering the plant from above wets both the leaves and the fruit, resulting in potential for crop damage through fungus. Further, spray irrigation normally results in higher losses through transpiration and evaporation than if water is delivered directly to root systems using drip irrigation.

However, some spray irrigation systems can provide an additional benefit of providing frost protection, for a relatively small increase in capital outlays. This may influence the choice of irrigation systems for some frost sensitive crops. However, high water application rates are required. The Western Australian Department of Agriculture (2004) suggests application rates of between 2.5 and 3.5 mm per hour, or over 0.25 megalitres per hectare for 10 hours protection. The Department notes higher water rates may be applied but that the higher water run-off can lead to vineyard management issues such as waterlogging, poor drainage, poor trafficability and inefficient use of water and power (Western Australian Department of Agriculture 2004).

As discussed earlier, it is unlikely that the savings from water alone will be a sufficient incentive for adopting new irrigation technology. However, water saving technology may be adopted where there are associated productivity and quality gains, cost savings in other areas, or if the price of water were to increase. In the wine-grape industry, adoption of water saving technologies can produce premium grapes — of higher value due to their concentrated juices and higher quality for wine making.

In contrast to investment in irrigation technology, the decision to invest in new horticultural plantations may be more sensitive to expected higher water prices. There is likely to be an inverse relationship between the capital intensity of a prospective horticultural investment and responses to increased water prices. If a prospective investment has relatively low capital costs, the response to expected higher water prices may be elastic. However, as capital intensity increases and the relative cost share of water decreases, the response to expected higher water prices may become more inelastic.

5.3 Summing up

- Regulations governing the harvesting of surface and groundwater mean that the total volume of water available for use by irrigators is unlikely to increase substantially over existing harvesting entitlements.
- A substitute for additional water purchases is to invest in more efficient irrigation application systems. Recent Australian case studies indicate that water savings alone may not justify investment in water saving technologies. However, associated productivity and quality gains may make such investments profitable.
- Water savings from improved technologies depend on soil types. Changing technologies have an impact on other aspects of the farm, and may lead to increased production and/or labour savings. However, changing from gravity to pressurised systems may increase irrigation costs due to high pumping costs.
- Changing technologies may involve large capital costs and long pay-off periods.
- In the long run, rice growers' responses to increased water prices are likely to involve technological change such as plant varietal improvement to reduce water consumption.
- Dairy farmers' responses to increased water prices include substituting other inputs, such as fertiliser, purchased fodder, pasture varieties or non-irrigated land for irrigated pastures.
- Increased water prices will influence the decision to develop new perennial horticultural plantations, but may have little impact on water demand from existing plantations.

6 Other long run responses

In this chapter, more general long run responses to, and impacts of, changes in water prices are considered. In the long run, all inputs are variable including the amount and location of land owned and capital employed. Possible constraints on long run decision making are briefly described in section 6.1. This is followed by a discussion of the likely impact of changing water prices on the price of water entitlements and land.

6.1 Long run decision making

In the long run, irrigators have further options to respond to higher prices and charges for irrigation water. They can exit from agriculture, or change the mixture of all outputs and all inputs to achieve an enterprise that meets their financial and personal needs. Even if an irrigator leaves agriculture, the land will not remain idle. The new owner will make decisions about which mixture of outputs and inputs will meet their financial and personal needs.

Long run responses involve evaluating a series of investment options. From an economic perspective, the irrigator's objective is to maximise long run profits, subject to a number of important economic constraints and other objectives. Irrigators will respond to changes in relative prices received for outputs and paid for inputs. They will respond to changing climatic conditions, environmental expectations, technological innovation and international economic conditions.

Changes in the price of irrigated water are only one factor in any long run changes in irrigated agriculture. Changes in farming systems will occur because of: changes in consumer tastes; climatic changes that influence the quantity of irrigation water made available or the growth of plants; advances in irrigation or other technologies; unforeseeable factors such as disease outbreaks; and other reasons. For internationally traded commodities, international developments in each of these areas may be as important as developments in Australia.

6.2 Changing outputs

If water prices increase, some irrigators may find that their current mix of activities is still the most profitable mix for their farm in the long run. Other irrigators may find that even a small increase in the long-term price, or expected price, of irrigation water changes the relative profitability of the activities available to them, and will choose to change activities and outputs. This can in turn affect commodity prices (box 6.1).

Constraints on changing outputs

Those irrigators who perceive that changing outputs may be more profitable in the long run may be subject to a number of constraints affecting their decisions. For example, physical constraints, including the topography of the farm, soil types, water availability and climate, affect irrigators' responses in the long run. On any farm, some activities will be more appropriate than others. Farms with undulating topography, for example, may not be suited to gravity irrigation technologies.

The ease with which farmers can move to different activities, or reduce the proportion of water intensive crops in crop systems, will affect the long run demand for irrigation water. If significant amounts of infrastructure are required to switch to other crops, this lack of flexibility could lead to less elastic demand for water. Some farming systems require 'lumpy' capital infrastructure. For example, dairy farmers have large fixed infrastructure, such as milk harvesting and cattle feeding systems, which might be redundant (although some may be salvageable) if the irrigator switches to an alternative farming system. Similarly, some irrigated crops, such as tree fruits and vines with long pre-productive periods tend to have large start-up costs compared to annual crops. Farms with existing perennial horticultural plantations may also face high costs of clearing the land for alternative activities.

Existing farm infrastructure may also influence the choices of some irrigators. Many farms have infrastructure specific to the activities undertaken on the farm, such as dairies and rice paddies. If the profits from an activity decline, the irrigator may continue to undertake that activity because the costs of the infrastructure are sunk. The irrigator maximises long run profits by continuing the activity and utilising the asset even though current profit levels would not justify new investment. Expected future profits from the activity and use of the infrastructure would have to decline below expected future profits from alternatives before it was abandoned (Dixit and Pindyck 1994). An investment may also be abandoned when the expected salvage value exceeds the expected net benefits from continued use of the asset (Edwards 1959). Should the irrigator decide to change activities or adopt new technology, capital outlays of many thousands of dollars per hectare, and hundreds of thousands of dollars per farm, may be required.

Box 6.1 **Impacts on commodity prices**

In the long run, prices received by irrigators are variable, and will change because of farmers responses to changing circumstances. The long run price of an output in competitive industries should cover total long run average costs, and also provide a ‘normal’ profit to the irrigator. Consequently, any significant decrease in long run costs will eventually be passed on to the consumer.

In some industries, the long run responses to prices can be slow and difficult to see. This may particularly be the case in industries where a substantial portion of production is exported, such as the dairy industry.

The wine grape industry is an example of an industry that appears to follow a cyclical behaviour of price and quantity. Initial high after-tax returns led to substantial investment, both within Australia and overseas. After a number of years, this led to a significant increase in domestic and world production, with a subsequent decline in prices received.

When considering irrigators’ long run responses to increased water prices, it should be remembered that if a large number of irrigators choose to move from one activity to another, the change may affect commodity prices received in both the industry they leave (prices may rise) and the one they enter (prices may fall).

Source: Douglas, Dwyer and Peterson (2004).

The type of tenure for land may be another factor influencing the ability of some irrigators to change activities (where change to the infrastructure of the farm is required). Irrigators who lease land may be reluctant to invest in new infrastructure unless they can capture sufficient benefits of their investment.

The reliability of supply of irrigation water is an important constraint in determining what activities an irrigator can choose from. A relatively low supply reliability is more likely to influence irrigators to adopt opportunity cropping activities. It provides the flexibility to match their annual plantings with the annual expected supply of irrigation water. In some cases, they may decide not to plant in years when small seasonal allocations are expected. On the other hand, a relatively high supply reliability may encourage investment in perennial crops and reduce annual cropping. There is a need to gain a greater understanding of the interaction between supply reliability of irrigation water and maximising the economic benefits from all resources available to the irrigator, including (but not only) water.

A further constraint to the selection of alternative activities may be access to markets and associated infrastructure. For example, producing vegetables close to markets provides access to markets for fresh produce and reduces transport costs. Similarly, it may be difficult to undertake an enterprise in an area lacking necessary infrastructure to process the produce.

Potential tax liabilities may also provide a constraint where the cessation of one enterprise triggers a contingent tax liability. This is most likely to occur in self-replacing dairy herds where the tax value of a herd may be much less than the market value. Selling part, or all, of the herd may trigger a tax liability, reducing the amount of money available to fund alternative investments. Similarly, enterprise changes which involve selling part, or all, of the water entitlement may result in capital gains tax liabilities.

The availability of labour and management may provide a constraint to some mixtures of activities. For example, some activity mixes may allow the use of available labour and management evenly over a production season. Changing to an alternative activity mix may require larger or smaller inputs of labour and management at certain times of the year. Shortages of labour and management at certain times may constrain the irrigator's choice of that activity.

An irrigator's skills may be an important constraint. For example, a grape-grower may need to develop new skills to become an efficient dairy farmer, or vice versa. Even more broadly, a farm family's ability to respond can be affected by their values, goals, financial position, and desire to remain on the land. Inevitably, this means that there will be considerable variation between land users. While many farm families seek to maximise their financial welfare, other factors — such as a desire for lifestyle and minimising risk — can be important.

Age may also be important. ABARE (2003) estimates that around 99 per cent of farm businesses are run by owner-managers. The 1996-97 ABARE survey of New South Wales irrigators reports an average age of 53 years, 3 years younger than the average age of all New South Wales farmers. The average age of irrigators is older than the general workforce. Older irrigators without bequest motives, or those planning to retire, may have a relatively short investment horizon. A short investment horizon may make some older irrigators reluctant to invest in activities with long pay-off periods, and where it was perceived that the cost of the investment may not be fully realised if the enterprise was sold prior to reaching full production.

Changing the area of the farm

A response to increased water prices, and changes in outputs, may be to change the area of land farmed. This, in turn, affects land prices (box 6.2). For example, suppose an irrigator responds to higher water prices by changing to a high value-added activity. The irrigator may sell some land and farm the remaining area more intensively. In some cases, the sale of ‘excess’ land may fund the change to the new activity.

Box 6.2 **Impacts on land prices**

Part of the long run response to changing water prices will be changing factor prices, in particular for land and water entitlements. Land within an irrigation area normally attracts a higher price than similar land just outside the irrigation area. However, some caution is needed in interpreting the differential.

Even if the land outside an irrigation area has identical fertility and physical characteristics to the land within an irrigation area, they may not be perfectly interchangeable. This is because the land within an irrigation area has access to the irrigation distribution system. Industry consultations revealed that dryland properties at the periphery of irrigation schemes in the southern MDB have increased in value by around $2000 per hectare upon gaining access to the distribution system. These increases in value have occurred despite the properties not having any on-farm irrigation infrastructure nor a water entitlement (GMW, pers. comm., 8 July 2004). Possible explanations for farmers paying a premium for land with access to an irrigation distribution system include:

- Irrigated agriculture is less subject to climatic risk than other agriculture. Other factors being equal, the prices of factors of production of a less risky activity should be higher than the factors of production of a more risky activity.
- Irrigated agriculture may be perceived to be more profitable than dryland agriculture. However, given that irrigated activities are normally capital-intensive activities, it may be difficult to determine what portion of any additional profitability is a premium to irrigation rather than a return on capital.

Further, irrigated land normally has structural improvements that make it suitable for irrigated activities, such as dairies and various types of irrigation systems, ranging from drip to flood irrigation. These structural improvements should account for part of the observed price differential.

While the determinants of the price of rural land are complex, the potential profitability of the activities that can be carried out on that land is undoubtedly a factor. It follows that any change that reduces the long run profitability of irrigated activities could lead to a fall in the price of that land.

Other irrigators may respond to increased water prices by changing their production mix to include more non-irrigated agricultural activities, and fewer irrigated activities. Non-irrigated agricultural activities tend to be more land-intensive than irrigated activities, and it may become necessary to acquire more land to achieve a farm size that is likely to provide sufficient financial returns to meet their family goals.

Yet other irrigators may respond to increased water prices by pursuing greater economies of size from their existing activity. For example, it is possible that some irrigators who adopt water saving technologies may use the water ‘saved’ to irrigate more land. This could mean that they have to purchase the land.

Buying and selling water entitlements

If irrigators respond to changing water prices by changing outputs, it is possible that their initial water entitlement will be inappropriate for their new activities.

Impacts on the price of water entitlements

As irrigators respond to changing prices for seasonal allocations, the value of water entitlements may also be affected. This is because the price of water entitlements is, in part, a function of the expected price of traded allocations, holding costs, and the expected residual value of the entitlement at the end of the investment horizon.

The impact on the price of water entitlements may depend on *which* price of *what* type of water increases, with the potential for very different impacts. For example, assume a water utility substantially increases its delivery charges, and it is expected that this increase is permanent. At the margin, this should mean that some low value-added activities will be reduced or cease, while the benefits from new investment into irrigated activities may be reduced. Incentives for investment in water saving technology should increase. Initially, such responses could lead to more water entitlements being offered for sale, reducing price. In the longer run, the higher utility charge should reduce the price paid for traded allocations, again leading to the reduction in the price of water entitlements.

In contrast, if there are no changes in utility charges, but there is an exogenous increase in prices for traded allocations, this should make entitlements more attractive to hold as an investment.

Converting from irrigated to non-irrigated farming

Some irrigators may respond to changing water prices and economic circumstances by ceasing irrigation activities and undertaking non-irrigated activities (box 6.3). Converting a farm from irrigated activities to dryland activities means not only changing outputs and the physical inputs to the crops produced, but also changing the mixture of the capital and labour employed on the farm. For example, some dairy farmers in the GMW district have changed to dryland livestock production and sold their water entitlement. The sale of the water entitlement provided cash.

There may also be a cashflow advantage when selling a dairy herd and purchasing other livestock. After allowing for taxes, the cash could be used to retire debt, or fund investments both on and off the farm.

Box 6.3 **Sale of irrigated land and water entitlement — is the whole more than the sum of the parts?**

Separation of water entitlements from land means irrigators can sell their water entitlement without selling the farm. However, there are suggestions that selling an irrigation farm with an adequate water entitlement may result in a higher overall price than selling the two assets separately (Bjornlund 2001).

Most farms are not sold on a 'walk-in walk-out' basis where the land, livestock, plant and other farming assets are sold as one package. Rather, the land is sold, and then there is a public 'clearing sale' where the livestock, plant and moveable assets are sold. As a water entitlement is a moveable asset, it could be expected to achieve its highest price at a public auction, such as a 'clearing sale'.

Examination of advertisements for the sale of irrigation farms shows that the two assets (land and water entitlement) continue to be advertised as a package in most cases. This implies that either the sale of the farm and water entitlement as one unit is perceived to result in a higher overall return than the sale of the two assets separately, or that there may be additional transaction costs in selling land and water separately.

There are several explanations for the possible differential:

- The market for water entitlements is relatively 'thin' — there are few trades observed. A purchaser buying a land and water entitlement package can be certain of their total investment. However, an intending irrigator who purchases land only will have to attempt to purchase water entitlements in a market where there may be few sellers. A pessimistic purchaser could over-estimate the cost of purchasing water entitlements, and therefore reduce the price they may be prepared to offer for land.
- An irrigation farm sold with an adequate water entitlement is a functioning farm. As such, the farm may be valued as a 'going concern', including irrigation and related infrastructure. On the other hand, an irrigation farm sold without a water entitlement cannot function as an irrigation farm, and prospective purchasers may discount the value of the irrigation and related infrastructure (Bjornlund 2001).
- The demand for water on some irrigation channels is close to the supply capacity of the channel. If an irrigator leaving the industry sold their water entitlement to other irrigators on the same channel, the purchaser of the land could then have difficulty obtaining capacity on that channel, even though they could purchase a water entitlement. Conversely, there are some channels where there is little demand for water. The sale of an entitlement from such a channel may make it uneconomic for a utility to continue operating the channel. Once a channel is closed, it may be costly to reopen.

6.3 Summary

- In the long run, prices received in competitive industries are expected to cover long run average costs, including a ‘normal’ profit to owners of the business. Consequently, any significant decrease in long run costs will eventually be passed on to the consumer.
- In the long run, some irrigators will respond to increased water prices by changing outputs. Physical constraints to changing outputs include the topography of the farm, soil types, water availability, and climate. Other constraints may include capital availability, type of tenure for land, the supply reliability of irrigation water, access to markets and regional infrastructure, and taxation.
- If a large number of irrigators move from one activity to another, the change may affect commodity prices received in both the activity they leave (prices may go higher) and the one they enter (prices may go lower).
- While the determinants of the price of rural land are complex, the potential profitability of the activities that can be carried out on that land are an important factor. Any change that reduces the long run profitability of irrigated activities will tend to reduce the price of that land.

APPENDIX

A Previous Australian estimation studies

Many studies have estimated the demand for water, in a number of different contexts. This appendix discusses a number of studies from Australia that are primarily concerned with the demand for irrigation water.

Estimates of the derived demand for irrigation water are based on the value of water as an input into agricultural production. This value is dependent on the value of the agricultural output, and hence the estimation process gives a schedule that represents the value of the marginal product for water.

There is considerable variation among the approaches used to estimate water demand. Among the most significant differences are:

- the scale of the optimising decision maker (either relatively homogeneous sub-regions or individual farms)
- the time horizon (short, medium or long run models).

Models also differ on the geographic region on which the analysis takes place. The region considered will determine the dominant agricultural industries.

The irrigation water demand relationships that have been estimated by nine different studies are compared in table A.1 by the own-price elasticity of water that were observed. All the studies are on regions within the Murray-Darling Basin.

In all cases it was found that demand is very inelastic at low prices. In fact, the majority of studies estimated that demand was (nearly) perfectly inelastic for prices from $0 to $20 or $55 per megalitre. This means that, for price rises within these ranges, the quantity of irrigation water used will not change.

The responsiveness (elasticity) of demand increased for higher price levels. Those studies that reported elasticities over a number of price ranges all found this increase, to the extent that most water demand functions where found to be elastic (greater than 1) at the highest price range considered.

Table A.1 **Elasticities from various models of irrigated water demand**

Study reference	*Observed own-price elasticity ($\mathcal{E}$)*			*Price range for $\mathcal{E}\approx 0$*
TERM-Water (PC estimates using Wittwer 2003)	short run:		-0.08	
	long run:		-0.10 – -0.15	
Hall (2003)	linear:	$0–$100	-0.11	
	quadratic:	$0–$100	-0.14	
Jayasuriya, Crean and Hannah (2001)		$0–$38	-0.02	$0–$37
		$38–$47	-0.72	
		$47–$77	-0.82	
		$77–$98	-3.52	
Pagan et al. (1997)	short run:	$10–$30	-0.03	$0–$40
		$30–$50	-0.19	
		$50–$70	-2.81	
	long run:	$10–$30	-0.04	
		$30–$50	-0.25	
		$50–$70	-3.01	
Collins, Hall and Scoccimarro (1996)		$0–$28	0.00	$0–$28
		$28–$38	-0.14	
		$38–$50	-0.20	
Hall, Poulter and Curtotti (1994)		$20–$80	-0.99	$0–$20
Mallawaarachchi, Hall and Phillips (1992)		$12–$37	-0.34	na
Read, Sturgess and Associates (1991)	short run:	$0–$55	0.00	$0–$55
		$55–$70	-1.15	
	medium run:	$0–$55	0.00	
		$55–$70	-1.65	
Briggs-Clark et al. (1986)		$4–$21	-0.13	$0–$20
		$21–$42	-0.65	
		$42–$51	-3.80	
		$52–$58	-14.1	

[a] Where elasticities were not explicitly presented within a study, they were calculated from the reported demand functions.

Table A.1 (continued)

Region / Industries	*Comments*
Irrigated industries in the southern Murray-Darling Basin	• Computable General Equilibrium (CGE) model of Australia examining regional impacts using ABS statistical divisions in the Murray-Darling Basin, and remaining states. • Linear and quadratic programming models of irrigated agriculture in the southern Murray-Darling Basin.
Lachlan Valley (NSW)	• Based on NSW Agriculture existing regional economic model of irrigated agriculture • Five production zones
Murrumbidgee Irrigation Area / onions, carrots, rice, wheat, soybeans, canola, lucerne and sub-clover; with long run opportunities in winegrapes	• Parametric linear programming model of region • Short run — capital constrained • Long run — may involve adoption of new (water saving) irrigation technologies (on-farm storage and drainage reuse systems) and/or new enterprises requiring significant capital investment such as permanent horticulture
Southern Murray-Darling Basin	• No interregional trading • Short run estimates • Water demand is more elastic if output prices fall.
Southern Murray-Darling Basin / rice, tree and vine crops, and pastures for dairy and prime lamb production (cotton in one region)	• Spatial equilibrium model, linking 18 regional linear programming sub-models by a model of the river system. • Short run — no incorporation of capital (or structural) adjustment in response to rising water prices.
Murrumbidgee Irrigation Area / citrus and wine grape	• Programming model of a farm • Long run — 20 year time horizon, for behaviour of investment in water saving irrigation technology
Northern Victoria – Goulburn and Murray irrigation systems	• 14 relatively homogeneous sub-regions, each assumed to be managed as a single profit-maximising entity, under hypothetical ‘average’ climatic conditions • Short run — breeding livestock and capital constrained • Medium run — capital constrained
Murrumbidgee and Coleambally Irrigation Areas / 36 cropping (27 irrigated, 9 dryland) and 8 livestock activities	• Regional Linear programming model • Short run — capital constrained, but water use may change through alternative cropping patterns and varying the number of irrigations per crop

A longer time horizon also increases the responsiveness of water demand. The two studies that permitted flexibility in farm decision making by allowing changes in the numbers of breeding stock (medium run) or investment in new irrigation capital (long run). This is because the longer time horizon provides more options with which to address the rising price of water, and thus more avenues to decrease consumption of this costly resource (box A.1).

Box A.1 **Long run and short run modelling**

Pagan et al. (1997) conducted a study to compare long run and short run models of irrigation water demand. Parametric linear programming and ordinary least squares regression analysis were conducted over a $0 to $70 per megalitre price range, to determine demand relationships in an unregulated market. They built on the model of Jones and Fagan (1996) which functions at the region level, for the Murrumbidgee Irrigation Area — Yanco and Mirrool Irrigation Areas, centred on Leeton and Griffith respectively.

The model seeks to maximise the regional financial gross margin from cropping and pasture. Crops include onions, carrots, rice, wheat, soybeans and canola, while lucerne and sub-clover are used for grazing sheep or hay production and sale. This maximisation occurs subject to crop and livestock price data (three-year farm-gate averages) and variable cost and yield data from previous Murrumbidgee Irrigation Area evaluations specified for different farm types.

In the long run model, farmers may adopt new (water saving) irrigation technologies such as on-farm storage and drainage reuse systems, and/or new enterprises requiring significant capital investment such as permanent horticulture — these are all adjustment opportunities that are beyond a farm's short run resources. Perennial horticultural crops are represented by wine grape plantings that require high security water entitlements. Such entitlements are sold at a premium.

Responsiveness of water demand was found to be less elastic in the more constrained situations since not all adjustment options are considered.

A notable characteristic of the estimated demand functions is their stepwise form. These steps arise because reductions in water use usually occur at threshold prices where a farmer is induced to change a discrete variable such as the choice of irrigation technology or the mix of crops.

Existing models were based on a yearly time frame and use average statistics for rainfall. This type of research hides the seasonal variation that water demand experiences throughout stages of crop development or other agricultural processes. It also masks the effect that uncertainty of rainfall can play on farmer decision making. In addition, as Hall, Poulter and Curtotti (1994) noted, where price and water flows are considered to be known with certainty in models, water security cannot be considered.

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