

# WATER RESOURCE MANAGEMENT

## using water options to meet environmental demands

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- In an unregulated river, water reaches floodplain and wetland environments during high flow events that usually occur in wetter years. Managed flows that replicate the timing of these naturally occurring events have the potential to deliver desired ecological benefits at the lowest cost.

- ABARE has developed a model to evaluate the use of options contracts to provide water for environmental purposes. The Murrumbidgee River options model (MROM) can be used to evaluate a range of investment and management options to increase the natural and productive value of irrigated agriculture and the riverine environment. A key purpose of the framework was to provide a better understanding of the tradeoffs between consumptive and environmental water demands in the Murrumbidgee River.

- The results indicate that an options contract written against irrigators' announced allocations could be used to provide water for the environment at a substantially lower cost than government purchase of general security entitlements. Further, irrigators can retain their permanent entitlement as a hedge against the risk that the pool of water resources available to irrigators will decline in the future.

### Introduction

The Intergovernmental Agreement on the 2004 National Water Initiative sets out three desired objectives for the management of environmental

water (Commonwealth of Australia 2004). These are to:

- identify the actions and associated benefits sought within the riverine environment,
- empower managers with authority and resources to achieve these actions and benefits, and
- provide these benefits cost effectively.

One of the key actions in the southern Murray Darling Basin is to reconnect river systems with the wetland environments of the flood plains in a manner and with a frequency to deliver a number of ecological benefits. Some of these benefits include maintaining native floodplain vegetation, promoting waterbird breeding and providing nutrients to maintain fish populations.

The natural link between these environments was through flood events that now occur much less frequently in this highly regulated river system. One means of reconnecting the floodplains with the river is through the use of targeted releases to create or augment high natural flow events. These events would have occurred naturally in seasons with above average inflows in winter and early spring.

While the volume of releases required to inundate wetland environments will depend of the desired frequency and duration of the event, the opportunity cost of those water resources will be lower in seasons with above average winter or spring inflows. In high flow years, both the volume of releases required to supplement

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inflows and the value of lost agricultural production will also tend to be lower.

This seasonal difference in the costs of diverting water between agricultural and environmental use is why trading is seen to be an important aspect of cost effectively managing environmental flows. While the primary focus has been on the temporary transfer of water from environmental allocations to irrigation use in periods where water supplies are relatively scarce, there is also the potential for irrigators to transfer water to the environment in periods of relative abundance.

Trade in water entitlements between irrigators can have an important role in mitigating the costs faced by irrigators if water is sourced from consumptive use for environmental management (Goesch and Heaney 2003; Heaney et al. 2002).

In this paper, the benefits of trade between irrigators and the environment are examined in the context of the timing of environmental and irrigations demands. The results draw on a case study of the Murrumbidgee River. A model of the Murrumbidgee River system is described and used to explore how the timing of providing environmental water affects both the volume and the cost of the transfer.

## The environment as a water trader

The transfer of water from irrigators to the environment could take the form of an option. Irrigators could enter a contract to sell the part of their allocation that is in excess of a specified level. For example, an irrigator holding a licensed annual entitlement of 100 megalitres could write an option to sell any allocation announced above 90 megalitres. In years with limited water resources, this threshold may never be reached but in other years, up to 10 per cent of their entitlement may be transferred to the environment. Hertzler (2004) refers to this type of instrument as an exotic option, differing from a financial option in that the quantity is a random variable as opposed to price.

A water option is also different from a financial option in that the option covers the temporary use of a renewable resource. The entitlement to the ongoing flow of returns from that

resource is retained by the irrigator writing the option (Michelson and Young 1993).

The timing of the option within the season also needs to be considered. The timing of the option will affect the timing and volume of water available for environmental management, the cost and the demand for storage infrastructure. For example, an option written at the start of the irrigation season could provide water to meet current environmental objectives. Here, the length of time that the option can be exercised is an important feature, as the environmental releases may need to be timed to match periods of high flows. Alternatively, an option written late in the season could be carried over in storage for use in a subsequent season.

This approach offers two advantages. First, there is no need for the environmental manager to hold a permanent water entitlement if the water is only required in wetter than average years. The outlay required to gain access rights to water for the environment is the price of the option, which will be substantially lower than the capital cost of a permanent entitlement.

Second, irrigators retain their permanent water entitlements. A permanent water entitlement is a natural hedge against the risk that the pool of water resources available to irrigators will decline in the future. Such a decline might result from a longer term reduction in rainfall and catchment runoff, or the sovereign risk that government will reallocate water resources to the environment, for example. Irrigators holding a permanent entitlement will at least be partially compensated for reduced water access by an increase in the average value of their remaining entitlement.

## Murrumbidgee River options model

The Murrumbidgee River options model (MROM) was developed at ABARE to evaluate a range of investment and management options to increase the natural and productive value of irrigated agriculture and the riverine environment. A key purpose of the framework was to provide a better understanding of the tradeoffs between consumptive and environmental water demands in the Murrumbidgee River.

MROM has four integrated components or modules. The first component is a hydrological representation of flows in the Murrumbidgee River and its principal tributaries.

The second component simulates the physical operation of storage and delivery infrastructure to meet irrigation and other consumptive requirements, as well as environmental objectives.

The third component is an agronomic representation of crop water requirements, yields and production.

The fourth component, the agricultural production and returns module, allocates available land and water resources to irrigated agricultural production enterprises to maximise expected returns.

These components are considered in more detail in the following sections.

In addition to the main model components, there are environmental demand nodes to represent environmentally important wetlands and billabongs along the Murrumbidgee River flood plain. Natural and induced flood events can connect these wetland environments to the river system to support a range of ecological processes. While these processes are not explicitly represented in the model, the frequency and the duration of these events can be specified as flow management objectives (Hillman 2004). The comparative environmental benefits of different flow regimes, however, are outside the scope of this model.

A schematic diagram of the model is provided in figure A. More detailed information on MROM can be found in Beare, Heaney and Hafi (2004).

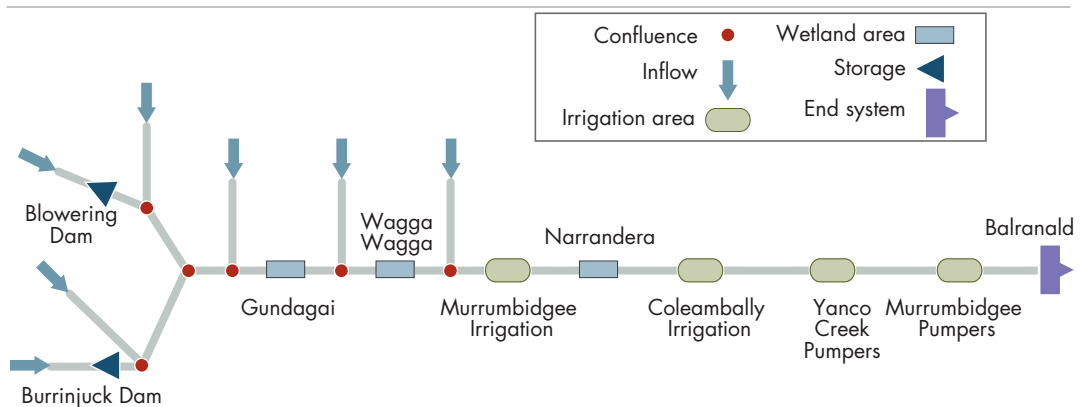
### Hydrology module

The MROM hydrological and river system management module draws heavily from the New South Wales Department of Infrastructure, Planning and Natural Resources' (DIPNR) Integrated Quantity, Quality Model of the Murrumbidgee catchments (IQQM).

Average daily travel times from the IQQM model were used to route flows between the reaches in the model. DIPNR also provided simulated daily flows from 1976 to 2003 for seven aggregated inflows to the Murrumbidgee system. These data were used to estimate the seasonal patterns, as well as the spatial and temporal correlations in stream inflows, rainfall and evapotranspiration. These patterns were used to generate stochastic dam and tributary inflows, and crop demands. Droughts were also incorporated into the baseline and the annual likelihood of a drought event was assumed to be 10 per cent with a random reduction in unregulated inflows of 35–70 per cent.

The model hydrology operates on a daily time step where simulated inflows are routed according to travel times between reaches of the river, infrastructure constraints, including storage and channel capacities, operational rules managing releases from Burrinjuck and Blow-

## A Schematic diagram of the Murrumbidgee River Options Model



ering dams, offtakes to the main irrigation areas and overbank flows to wetlands.

### Operational module

Operational rules were developed to prioritise and allocate available resources between competing uses including environmental requirements, irrigation, and urban, stock and industrial use. The rules are intended to reflect water sharing arrangements set out in the catchment management plans for the Murrumbidgee Valley and the Murray Darling cap diversions for consumptive use.

Within the modeling framework, water allocations to irrigators are announced monthly from August to February. After deducting environmental and nonagricultural water requirements, the balance of water resources held in storage, plus minimum expected future inflows form the basis of the announced irrigation allocation.

Storage release rules were developed to maximise irrigator returns subject to environmental and other release requirements. The rules minimise the likelihood of a severe constraint on delivery capacity that can arise when storage levels at Burrinjuck Dam are not sufficient to meet peak season irrigation demands.

### Agronomic module

Within the model there are three horticultural crops: citrus, stonefruit and grape vines. There are four winter crops: canola, lucerne, pasture, and wheat. Summer crops include: cotton, lucerne, maize, rice, pasture, and vegetables.

Given the current allocation of land to different cropping activities and initial soil moisture levels, the agronomic component of the model calculates:

- daily crop irrigation water requirements,
- daily soil moisture based on estimated evapotranspiration, rainfall and applied irrigation water,
- cumulative plant moisture stress levels and associated yield losses,
- rice ponding levels and yield losses associated with maintaining active pond levels, and
- irrigation orders, accounting for field and delivery efficiency as well as channel capacity constraints.

Crop irrigation requirements are based on pan evaporation, stochastically generated from historical data at Griffith, and monthly crop requirements published by the FAO (Doorenbos and Kassam 1979). Field requirements were calculated on the basis of individual crop application efficiencies. Irrigation offtake requirements were calculated on the basis of off-farm delivery efficiencies. In the model there is no explicit distinction between high and general security water entitlements. However, irrigation requirements for horticultural crops were given first priority in the presence of any constraints on delivery.

Soil moisture was calculated as a function of current soil moisture, crop moisture requirements for each crop, rainfall and applied irrigation water, subject to a constraint on soil moisture holding capacity. Soil moisture levels falling below the maximum soil moisture deficit were accumulated for each crop to determine cumulative moisture stress. Yield losses were then imputed against a maximum potential using the ratio of accumulated moisture stress to total crop moisture requirements and a crop specific yield reduction factor published in Doorenbos and Kassam (1979).

Initial rice pond target depths and soil saturation requirements were used to determine rice water requirements at the start of the growing season. Irrigation orders were then placed to meet any positive requirements to meet the current target. Initial orders for all other crops were set to fill the existing soil profile and then meet expected evapotranspiration requirements for the balance of the growing season.

### Agricultural production and returns module

The crop allocation module is designed to derive the best allocation rules for land and surface water resources in agricultural production given current land availability and announced surface water allocations, and the uncertainty associated with water allocations, rainfall and crop evaporative demands.

The model allocates resources by considering a sequence of short, intermediate and longer term planning decisions. The short term planning considers planting and water allocation decisions

for a specific season: spring, summer or autumn. The intermediate term planning considers the interdependence of these short term decisions within the irrigation year (August–May). For example, water allocated to finish winter crops in the spring is no longer available for summer crop use. The long term planning decision considers the allocation of land and water resources between irrigation years.

Short term decision making involves, for each season, allocation of budgeted land area between alternative crops, allocation of budgeted surface water quantities between months, and for each month between a number cropping/pasture enterprises. Intermediate term decision making in the model involves allocation of surface water available at the beginning of an irrigation year between spring, summer and autumn.

Long term decision making involves the allocation of land for summer crops to be irrigated during the current irrigation year, winter crops that will be planted in the current irrigation year but completed in the next irrigation year, and a decision on carrying some of the surface water allocated for the current year over to the next year if it is profitable. The land allocation decision between irrigation years is subject to a requirement of short fallow, which means land planted to summer (winter) crops is not available for planting crops in the next autumn (summer).

The model takes into account, the economic value of the remaining surface water allocation and land resources carried over to next season. At each period (irrigation year, season or month), decisions are made to equate the expected net benefit from allocating resources over the remainder of the current period and the expected net benefit from saving the resources for the following period.

The model is formulated as a stochastic dynamic programming problem in MATLAB. There are number of fixed exogenous parameters, including crop prices, production and harvest costs, crop water requirements, yields and yield loss functions, delivery charges, pumping costs, and water use efficiency levels. The model solves for each irrigation area over a discrete range of land availability and water allocations. The discrete grids of land and water resources

along with the solution values at each grid point are then incorporated into the fully integrated MROM simulation model. This solution matrix is then used to interpolate land and water planning decisions for land areas and water allocations that fall between grid points.

### Implementation

The fully integrated version of MROM was developed in Extend (version 6), a software package designed specifically for the purpose of simulation. Within the model interface, it is possible to observe stream flows at various locations, storage levels and releases from storage, and met and unmet irrigation order. Within an irrigation area, it is possible to monitor soil moisture balance and moisture stress for each crop as well as budgeted and actual water use. Model parameters are documented and stored within an integrated database with each run of the model being associated with a unique database.

Many of the model parameters, including water allocations, capacity constraints, and climatic conditions such as the likelihood of a drought can be changed by model users. Other parameters are fixed but are included in the database to maintain ready access to the assumptions made in developing the model. Summary outputs from the model are written and stored in a database that can be accessed within Extend or externally as an Excel workbook.

A fixed random seed was used to ensure that stochastically generated inflows, pan evaporation and rainfall were identical for each simulation. Each simulation was run over a 50 year time horizon, with model outputs recorded as simple annual averages. Net present values were calculated using a discount rate of 5 per cent.

## Evaluating the use of options to trade water to the environment

In this study, alternative scenarios were developed to evaluate the use of options contracts to provide water for environmental purposes. An option could be provided whereby the environmental manager (in the case of the Murrumbidgee, the New South Wales Government) could

acquire water for environmental management from irrigators at a prespecified price and conditions of access. This contract could take the form of an option to transfer an irrigator's announced allocation, at a specified time, above a certain defined threshold of allocation percentage.

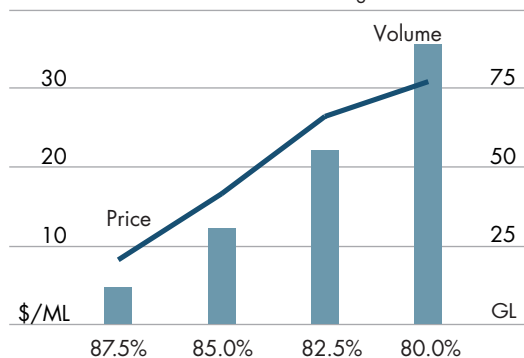
Here, the contract provides for the transfer of that proportion of an irrigator's 1 August allocation that is above a threshold, say 85 per cent of the irrigator's licensed entitlement, at a specified price. The environmental manager could negotiate an option fee (the price for the right to the option itself), which would be paid to the irrigator even if the option was not exercised. For its part, the environmental manager would have the right to exercise the option if the announced allocation exceeded the nominated threshold.

The MROM simulation tool was used to estimate the expected yield and cost of writing the option for a range of thresholds. The expected yield of the option is across the total licensed entitlement for the Murrumbidgee Valley and, as such, represents the maximum volume of water that could be obtained at each nominated threshold. The thresholds under consideration are 80, 82.5, 85 and 87.5 per cent of the total licensed entitlement. The price (or cost) of the option is the opportunity cost of forgoing the water from agricultural use — that is, the amount that the irrigator would need to receive to be at least as well off after the option was exercised. The cost is based on the assumption that the option is exercised in full when the threshold condition is reached. The findings are summarised in figure B.

If announced allocations on 1 August are 80 per cent of the licensed entitlement, the volume of water available for the environment would be around 90 gigalitres at a price of \$30 a megalitre. This is equivalent to about 4 per cent of licensed entitlements. Conversely, if announced allocations were 87.5 per cent of licensed entitlement, the average volume of water available for the environment would be 10 gigalitres at a price of around \$12 a megalitre. Importantly, this price is well below that of purchasing a general security entitlement of an equivalent yield. This was estimated to be around \$46 a megalitre a year.

## B Expected yield and cost of a 1 Aug option to sell water to environmental manager

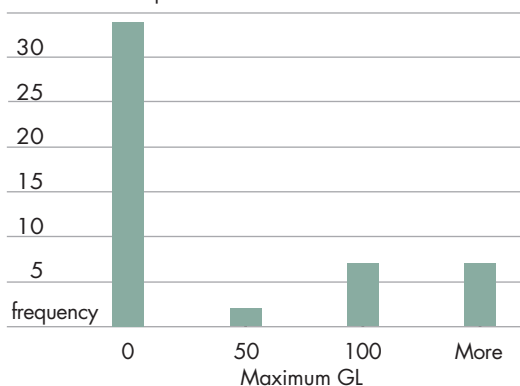
where announced allocation exceeds a range of fixed thresholds



The distribution of the volume of water transfers under an option with an 85 per cent threshold is shown in figure C. Data are shown for transfer volumes of 0 (that is, beneath the threshold), 50, 100 and more than 100 gigalitres. While the option has an expected annual yield of around 30 gigalitres, the 1 August threshold was not reached in the majority of irrigation seasons. The results indicate that the option could be exercised in about three out of ten irrigation seasons. Of the options that could be exercised, about half were for transfer volumes that were in excess of 100 gigalitres, with the majority of the balance being between 50 and 100 gigalitres.

## C Distribution of annual options for sales of environmental water

at an 85 per cent announced allocation threshold



## Concluding remarks

This case study provides a clear indication that while there are competing environmental and consumptive demands for water, the nature and timing of these demands are, in some sense, complementary. Establishing institutional arrangements that allow water trade between irrigators and an environmental manager when seasonal conditions are favorable can substantially reduce the opportunity costs of sourcing water to meet environmental demands. This accords with the findings of Michelson and Young (1993) who concluded that water options written by irrigators has the potential to secure urban water supplies during drought while maintaining agricultural returns.

The transfer of allocation to the environment during times of relatively abundant water supplies will minimise the value of lost irrigated production as well as any flow-on disruptions to the processing and service sectors beyond the farm gate. In other words the opportunity costs of obtaining environmental water will be lowest when the timing of purchases matches the natural pattern of flood events that connect the river system to the flood plains.

An options contract written against irrigators' announced allocations is only one way to establish trade between irrigation and environmental demands. However, there are three advantages of using this approach to meet environmental demands. The first is that irrigators can retain their permanent water entitlements. Permanent water entitlements are a natural hedge against the risk of a future decline in the pool of water resources and provide a more secure setting for irrigators, and others, to make investment decisions.

Second, the purchase of an options contract allows governments to acquire environmental water without having to make the initial capital outlay to purchase entitlements, or to have to manage those entitlements once purchased.

Third, an option offers environmental managers a greater degree of certainty in planning releases and lower transactions costs than operating in the temporary trading market for water allocations.

There are other environmental demands for water that do not necessarily match the timing of natural flood events. However, it may still be possible to acquire water through an options contract and then store it for later release. For example, if an options contract were used to source water for the Snowy River, it would be necessary to store purchases, or borrow against expected purchases, within the Snowy Hydro-electric Scheme

There are, however, a number of questions that need to be considered when designing an effective contract. First, a clear understanding of the desired environmental outcomes is needed to assess the expected timing and level of water demand.

Second, the conditions and price of the option will need to attract a sufficient number of irrigators or other agent(s) that are willing to write options to meet those demands. This problem has, in part, been analysed by Hertzler (2004) who examined the price-quantity relationships of an option triggered by random variation in supply as opposed to price.

Third, there is a need to identify other institutional arrangements required to facilitate or enhance the effectiveness of trade. Again, these arrangements might include infrastructure access rights to store purchases for later release. Finally, the contract specifications and the uptake of the option will have a major influence on how effectively a contract can be used to source environmental water requirements. This is an area for further research.

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ABARE Outlook 2005 Conference

Session: Water Resource Management

Investment in Infrastructure

Wednesday 2<sup>nd</sup> March

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**Synopsis:** Since the mid 1980's, but specifically since the 1994 COAG agreement there has been a move throughout Australia to a more commercial approach to the ownership, pricing and management of water supply and irrigation infrastructure. This has occurred in concert with a range of similar reforms to other public utilities and service providers in the areas of urban water, gas, electricity, rail, public transport and even telecommunications and postal services. A number of financial issues are now confronting the large irrigation providing "group-schemes" who collectively distribute most of Australia's irrigation water. The key challenge now facing a number of these companies, state utilities and other providers is the move from a more efficient break-even business to an entity that recognises the value of the infrastructure assets employed. Murray Irrigation Limited is a private company, based in Deniliquin in NSW, diverting up to 1.9million Megalitres annually from the Murray River. In this paper I will attempt to discuss some of the infrastructure management and pricing issues confronting our company. In its simplest form the issue relates to the conflict for Directors and other managers of Irrigation infrastructure caused by the relatively high value of assets employed (and their replacement) and the vulnerability of users to even modest water supply price increases. The contemporaneous issues of taxation, The 100 year drought sequence, falling key commodity prices, deregulation, the Living Murray Initiative and the National Water Initiative (NWI) all impact on just how managers view the infrastructure employed in delivering water to irrigators.

## **1. Background to Murray Irrigation Ltd. In the context of Infrastructure ownership and management:**

Murray Irrigation was formed in 1995, primarily as a result of irrigator unrest regarding water delivery prices (in the NSW Murray water shortage, Caps and cut-backs were not really issues in 1994!). The Primary license is held by the private company with 2400 shareholders owning bundled shares and water entitlements in proportion to the water rights issued progressively by the State Government since 1932. The 750 000Ha area is serviced by 4000Kms of earthen supply channels and 1000 Kms of storm-water drainage and more than 22 000 assets to deliver up to 1 600 000 million MLs of water, entirely by gravity. The asset valuation is difficult (i.e. what market value?) but are estimated to be c \$400m. Governments recognised the massive investment needed to refurbish and modernize the irrigation regions and saw the autonomy model as one that could achieve the joint aims of taking a failing asset off the State Treasury books, and achieving a key CoAG aim of separating the natural resource manager from the water retailer. In the final negotiations a dowry was paid by governments to the new Company recognising the refurbishment needed to bring the system back to a reasonable level of repair. The dowry was also paid on the basis the new company would contract to set aside funds (i.e. create a sinking fund) during the dowry period for long term refurbishment when the 15 year dowry period ends.

## **2. The key Infrastructure Management/ownership principles of the new Murray irrigation Ltd in 1995.**

- There would be no rate of return charged to users for the assets employed, but rather a sinking fund for the long term maintenance of the infrastructure.
- Any profits or dividends would only be paid to irrigator/shareholders as a cheaper future water supply price.
- Any needed modernisation would be funded through annual charges to irrigators.

- There would be a single price for water delivery to all farms within the 750 000 Ha area (expressed as a fixed and variable charge per entitlement owned or megalitre used)
- As far as possible there would be a universal service standard. Even if a customer wanted to pay more there would only be one standard of service.
- Priority for projects would be given to projects that assisted in reducing water losses.
- Any Supply-system water savings created through improved water management infrastructure would be socialized to benefit the announced allocation to all shareholder/irrigators.

### **3. The key issues now:**

- The NWI is demanding that permanent water trade be opened up- if there is significant trade out of our region there are serious infrastructure issues.
- In the case of private companies and State owned Corp's the directors realise it may be appropriate to apply a rate-of-return to each of the employed assets to ensure better fund- allocation/asset management/replacement criteria and general decision making by the Boards responsible for these systems and their assets.
- In a new *unbundled* model, there may be shareholders in future with no interest in our delivery infrastructure for water delivery, and likewise there may be infrastructure owners without an interest in water supply- Effectively infrastructure or water owners simply looking for a rate of return on their investment (Wheat Board B-Class shareholders do not care too much about the return per ton to wheat growers if they do not grow wheat?)
- The establishment of an infrastructure trust may be one solution- with annual dividends payable from a (modest) rate of return.

- Further modernization is now needed to enable a more flexible and responsive irrigation supply system.
- The 100 year drought has bitten hard. The company's funds and that of its shareholders are stretched.
- Residual tax issues are hurting Murray Irrigation Ltd. Post June 2004 tax issues have been largely resolved

- 4. Dividends policy/Pricing dilemmas:** The directors recognise the need to develop a model consistent with commercial principles, the problem is that there appears to be universally a failure to recognise the value of the assets employed in group schemes throughout Australia. When a farm is valued there is a land value, increasingly a water value, and sometimes, the farm improvements and infrastructure are also part of the value. The assets that are employed to get the water to the farm through a group scheme are ignored- possibly because the works were rarely paid for by the current occupant, they were considered part of the whole, and they were never separately charged for- except in terms of a unit, fixed or volumetric water charge. Increasingly as farmers think of transferring and separately valuing their water entitlements, the separate value of the infrastructure needs to be considered.
- 5. What cost recognising the cost of assets?** In simple terms the concept of implementing a rate of return on Irrigation Company distribution assets, even at modest levels will increase water prices in our case by circa 100%. (i.e. say 7% on 400m = \$28m p.a. OR even 7 % on "new" assets= c \$ 10.0m pa). In the event the current users remain the owners (and are not able to sell water or units of infrastructure) and that the ownership is distributed proportionally to water entitlements this may not be as severe as first envisaged as a large proportion of the dividend will be paid to the same users who are the owners. Any surplus would be reinvested in their supply company, presumably in other income earning assets. In the event units of ownership in the infrastructure are progressively traded to non-

users and the dividends paid accordingly a number of issues arise. The ability to sell the water out to another group scheme or licensed supply point with lower infrastructure charges (possibly subsidized by Governments) will become a serious equity issue.

6. **The National Water Initiative and Infrastructure management:** The NWI has indicated that rates of return should be applied on assets employed in both Urban **and** Rural water users. Even assuming there is a recognition sunk assets are not part of any rate-of-return regime as Governments and other infrastructure providers modernize, invest and rationalize their irrigation storage and supply systems commercial principles will be increasingly relevant- (think of changes in the last twenty years in Gas, electricity, telecommunications etc). The original issues of rural development, nation-building and drought proofing will increasingly take a back seat.
7. Models under review
8. Conclusion- Investment in Infrastructure: