APPENDIX 6
BASIS OF ECONOMIC COST COMPARISONS

Contents

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1.0 Purpose

The purpose of this Appendix is twofold: (a) to describe, in generic terms, a methodology to compare piped vs. open channel irrigation distribution networks from an economic perspective; and (b) to present the results of applying the methodology to the two case study investigations.

The Appendix first addresses some conceptual issues, and then lays out a comparative framework. The application of the methodology to the case studies is presented in the last sections, along with a description of the assumptions used in developing estimates of non-capital costs, and the results of the economic cost comparisons.

2.0 Conceptual Issues

There are two possible capital-works scenarios which are discussed in this Appendix – (i) where piped vs. open channel networks are to be compared in a "greenfields" development situation; and (ii) where an open-channel distribution network is currently part of an operational irrigation scheme, and "retrofitting" is envisaged to replace the open channel network with a pressurised pipe reticulation system. The principles underlying an economic evaluation are similar in both cases.

Firstly, it can usually be assumed that the gross, per hectare farm benefits from spray irrigation under either scenario are the same[1]. The key issue for evaluating the two "greenfields" options is to determine the most economically efficient way to supply this water to the farm – either through a network of open channels delivering water to farm turnouts; or through network of pipes delivering the same volume of water at variable pressures (according to turnout location and time), so reducing the need for on-farm pressurization with associated electricity costs, and reducing system water losses. The aim of the evaluation is therefore to compare the total costs of the two options – acknowledging that some of the items included as costs may not be able to be valued in "dollar" terms[2]. For a greenfields site, the piped system will involve greater capital costs than the open-channel system, but this will be partially offset by savings in on-going operations and maintenance costs given that the piped system will supply pressurized water at the farm turnouts. In addition, the piped system will minimise water losses through the distribution network, and result in water savings which means lower water volumes abstracted by the scheme. The preferred

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[1] This assumption may not apply in certain circumstances.

[2] For example, an open channel network may be able to direct by-wash into an associated wetlands area generating positive environmental values which are difficult to monetise.

evaluative approach is therefore to compare the cost differences between the two systems calculating the extent to which the savings in operations and maintenance costs with the piped system (largely through savings in electricity costs) together with the value of water savings, offset the higher capital costs associated with a piped network. Other items (costs or benefits) will also vary between the two options and need quantification where possible.

For the retrofitting option, the comparison is similar, except the objective is to compare the costs associated with continuing the status quo, compared with the costs (both capital and on-going) of retrofitting the system with a piped distribution system. In this case, piping will involve initial capital costs, which will be offset by the savings in electricity pumping costs (since the piped system will deliver pressurized water to the farm turnout), as well as the value of the water savings resulting from the piped system (equivalent to the losses from the existing open channel network). In addition, there will be other considerations to be taken into account, some of which will have a monetary value and some not[3].

The costs items are usually quantified in current prices, so all the costs have the same price datum (such as June 2006). Although most prices will be maintained relative to each other over the life of the analysis period, some relative prices may change due to real price increases – an example of this is the unit price for electricity which many commentators expect will, over the near future, increase faster than the level of inflation. This "real" price increase should be incorporated into the analysis. Similarly, where some prices are dependent on the foreign exchange cross rate to a particular currency (for example, pumps imported from the United Sates), then it is also important to consider how prices might change over the analysis period should the cross rate adjust from what was assumed at the price datum.

Data estimates for costs should be projected over the period of the analysis, and this period needs to be relatively long – probably around 20-30 years – to truly reflect the relative cost differences between the options being evaluated. These cost streams, all at the assumed price datum, need to be "discounted" to a present-value equivalent to assess which option is financially preferable. The results can be subjected to sensitivity analysis to demonstrate the effects of changing the discount rate – for example, real rates between 6 and 10 percent would seem appropriate at present.

As noted above, however, all differences between the options being assessed will not necessarily lend themselves to financial quantification – some items may have "environmental" values which are difficult to quantify. The decision framework will therefore incorporate both financial and non-financial decision criteria.

3.0 Considerations

The following paragraphs detail the individual items that need to be considered in the analysis. The text is written from the perspective of a comparative analysis of a new, greenfields development which has either open-channel or piped reticulation network options, but is equally applicable to a retrofit scenario with some modification.

[3] For example, an existing open channel network may direct by-wash into an associated wetlands area. Such wetlands may have positive environmental value. Where this open-channel network is to be replaced with a pressurized pipe system this value would be lost, but it may be difficult to quantify this "cost" in monetary terms

3.1 Capital Costs.

The Appendix on Costs (Appendix 5), details the itemised capital costs required for estimating open channel and piped reticulation networks. Pre-construction costs will also need to be included, covering such items as feasibility studies through to final design, contract preparation and tendering, liaison with stakeholders, resource consent and building consent costs, legal fees, etc. These are also described in this Appendix, although some individual items merit separate mention:

3.2 Easement Costs.

It can be assumed that the main, open channel reticulation network will principally run parallel to the existing road network, whereas the piped system, which will be buried at least 1m underground, will be trenched in the most direct routing across farm land with no subsequent adverse impact on farm operations. Formal, legal easements will be required for both scenarios, but the legal costs with creating the easements associated with the pipe network are likely to be less than those associated with the open-channel network, given the lower complexity of the former[4].

3.3 Access Costs.

Where open channels need to cross existing farm land, there will be an impact on access and accessibility, which is only partly defrayed with culvert crossings. While compensation will be paid to farmers affected through purchase of this land, and this compensation will include injurious affects (such as impact on on-farm management and costs), there is little doubt that the piped reticulation system will minimise these effects. In addition it should be noted that land use flexibility may be reduced with an open channel system in that future re-organisation of farm plots and paddocks may be hindered by the network of open channel races, a constraint not imposed with an underground, piped reticulation system.

3.4 Land Purchase Costs.

It is probable that all private land involved in the footprint corridor for an open channel distribution system will need to be purchased by the scheme developer/operator[5].

[4] Survey costs associated with the piped distribution system are also likely to be less than with the open channel network, for similar reasons.

[5] Although some channels will run parallel to the road network, the width of these corridors will mean that typically the width of existing road reserve margins will be too small to accommodate the channels (given road safety requirements) and purchase of adjacent land will be necessary.

3.5 Infrastructure Costs.

Depending on the existing capacity of the electricity network serving the area, it is possible that network upgrading will be required principally to cater for the increased load factors associated with on-farm irrigation pumps. In a situation with a piped supply, and where a significant proportion of water is delivered to the farm turnout under pressure, pumping demands will be reduced and the extent of the upgrades (if any) required to the electricity network serving the area may be also reduced (depending on a number of technical factors such a peak capacity and instant load factors).

3.6 System Operational Costs.

Each system will also have associated operations (covering system operation and control) and maintenance costs – regular maintenance (say annually), periodic maintenance (say once every five years), and extraordinary maintenance (relating to response to extraordinary events such as major floods, power outages, or earthquakes).

3.7 On-Farm Pumping Costs.

Each option will have associated on-farm pumping costs. The open channel system will deliver water at zero head to the farm turnout, and all irrigation water applied will require pumping. Depending on the topography of the command area (particularly the fall from the headrace), location of the turnout within the scheme, and the demands on the system, the piped system will be able to deliver pressurised water at the turnout, which will negate the need to all or part of the on-farm pumping costs associated with the open channel system. The extent of these “savings” will be site specific, as discussed later in this Appendix.

3.8 Water Savings.

The piped reticulation network will have the ability to deliver pressurized water at the farm turnout (so reducing subsequent pumping costs for the on-farm irrigation units), as well as generating water system savings when comparing open channel vs. piped reticulation networks. Water losses in an open channel reticulation network depend on a number of factors (such as the permeability of the channel prism), and can be of the order of 10-30 percent of the water delivered into the network. Given that losses in the piped system will be zero, these water savings can have a significant value – (i) creating the ability to irrigate more area on existing farms through increasing the volumes supplied to individual turnouts; (ii) allowing “extra” water to be sold to new irrigators and again expanding the irrigated area; (iii) abstracting less water from the source supply[6]; or (iv) some combination of the previous three alternatives. In some situations, the value of these water losses may be tempered by the fact that this seepage effectively ends up in groundwater which, in years of low natural recharge, may have some positive value.

[6] All water abstracted from the source supply, such as a river, has an opportunity cost (if extracted) or value (if not abstracted). This results from the fact that this water has other alternative potential uses, either abstractive uses at the same or other extraction locations (for example, potential use by other irrigators), or non-abstractive uses (for example, augmenting in-stream values).

3.9 On-Farm Irrigation Management.

The piped reticulation system may allow a greater flexibility in on-farm water management compared with an open-channel system, depending on whether the open-channel system provides water on demand or on roster. Since the piped system will be on-demand, water will be utilised by irrigators as required, not according to the time when it is supplied, so matching the water demands of the crop. In addition, sumps or on-farm dams will not be required to smooth uniform demand when direct pumping from open-channels is difficult.

3.10 Improved Water Quality.

Open races systems can involve significant problems in water quality, with leaves, grass and algae in the race system affecting farm pump operations. In addition, the temperature of the irrigation water generally increases over the length of the reticulation system increasing the potential for algal contamination and the costs associated with filtration systems. Contrast this with a piped reticulation network where water quality is preserved at the level it was at the network intake.

3.11 Environmental Effects.

Open races systems do provide amenity and environmental benefits in terms of fish habitat, and refuge/breeding areas for wildlife. It is also possible to provide recreational opportunities within an open-channel network. These opportunities are forgone with the piped system.

3.12 Public safety costs.

Any open channel distribution network introduces aspects of public safety, even with fenced channels and grills over culverts. Despite such precautions, there always remains the possibility of accidents and even drowning with such a large body of water – involving stock and/or humans. A further consideration is that piped systems do provide the opportunity to provide pressurized water for fire-fighting with public safety benefits.

3.13 Methodology and Evaluation

The recommended approach for evaluation is to quantify all the implications of the two options (open-channel and piped) over an agreed analysis period (such as 20-30 years), recognising that some components will have an impacts every year (e.g. comparative pumping costs), some will only appear periodically (e.g. maintenance), and some will not be able to be valued in monetary terms (e.g. environmental values). These non-monetary items need to be described and quantified in as much detail as possible, because even through they cannot be priced; they are still important values and components of the decision framework.

It is then recommended that all components which can be valued in dollar terms are “discounted” to a present value, using a range of “real” discount rates[7] (say between 6% and 10%). This Present Value (PV), together with the list of non-priced effects, form the basis for the decision on which option is preferred.

[7] Since all unit prices will be in terms of a constant price datum, the discount rate will not include an allowance for inflation. As such, it will be “real”, as against “nominal”, and differs from interest rates prevailing in the market

It is possible that in some situations, a comparative evaluation from a private perspective (i.e. such as that of a group of farmers, for example), will yield a different result than an evaluation undertaken from the community's perspective. This is likely when considerations have different "values" from a private compared to public perspective. Examples are where seepage looses in open channels reticulation networks have groundwater recharge value – the benefits of which do not accrue to the irrigators in the scheme under consideration, but to irrigators drawing from other sections of the aquifer (which are benefits to other private individuals), or to wetlands, river flows and lake levels (which are public benefits). Similarly, where a piped system will result in water savings, these "savings" may be traded (which are private benefits), or source abstraction quantities reduced (higher river flows could augments in-stream values which are public benefits). Each situation studied will vary in this context, but it will be important to isolate where individual components have values that will differ whether perceived from a private or public perspective.

4.0 Economic Cost Comparisons of Pipe and Open Channel in Case Studies

The technical analyses and capital cost estimates of the detailed case studies are given in Appendixes 2, 3, 4 and 5. These sections combine results from these analyses with non-capital cost estimates to provide the economic cost comparisons.

The economic cost comparison between pipe and open-channel options follows the generic methodology outlined above, with the common assumptions applicable to each case study summarised below:

- All prices are in constant 2006 dollars;
- The analysis period adopted is 30 years;
- Base capital costs are "best estimates" and include commissioning costs but exclude physical contingencies[8];
- The options are compared in discounted cash flow framework over this period with real discount rates of 6, 8 and 10 percent; and
- Real electricity prices are assumed to rise by 1 percent annually over the next 10 years.

This generic framework is then applied to each case study as follows.

4.1 CPW Case Study

The sub-area adopted in this case study covers a gross command area of 36,000 ha. The specific assumptions[9] applicable to the economic analysis of this case study are as follows:

- Implementation extends over 5 years, with the first 2 years devoted to resource consenting and initial preparatory work, and the subsequent 3 years to civil work;
- Commissioning costs add 3 percent to capital costs and are spread over years 5 of the implementation period and into Year 6, the first year of operation;

[8] Physical contingencies would need to be included as part of detailed project costings.
[9] The estimates of the cost of non-capital costs and recurring annual costs have been based on analyses of similar projects and discussions with operational schemes; and on the specific features of the case study investigations.

- Resource consenting expenditure for the open channel option occurs over years 1 and 2 of the analysis period, and involves an investment of 5 percent of base capital costs spread equally over the 2 years– the piped option involves an expenditure of 85 percent of this amount;
- Legal costs for the open channel network are assumed at 4 percent of base capital costs, equally spread over Years 1 and 2 – expenditure for the piped system is at 40 percent of this amount;
- There are no additional infrastructure costs (such as upgrades to the electricity network) associated with either option;
- The open-channel system will require the canal footprint to be purchased;
- The pipe system will require easements to be established over the reticulation footprint, the costs of which are reflected in legal costs.
- The open channel network assumes the purchase of 280 ha of land for the canal footprint, and another 22 ha of land for other minor works, or a total of 302 ha. The pipe scheme assumes 164 ha of land for land easement, with no land purchase;
- The compensation price for land purchase is $15,000/ha.
- Operational costs for both systems are $16/ha;
- Pump R&M is assumed at 3 percent of capital cost;
- Pumps are replaced after 15 years assuming 3,000 operating hours per year. With the open channel system, all 305 pumps are replaced at year 15. With the pipe system, 57 turnouts do not require pumps. Of the remaining 248 turnouts, pump replacement is programmed between years 15 to 25 depending on average usage/load.
- System maintenance costs for the open channel system are $15/ha and for the pipe system $12/ha.; and
- Water “savings” with the piped system are assessed at 20 percent of the water that would be required at the headrace of the open-channel network. This water has a “value” of $4,600/ha and is “sold” in the 2 years following scheme commissioning.

The results of the analysis with these assumptions are shown in Table 1.

Table 1: Central Plains - Open Channel vs Pipe

	Present Value Cost ($ millions)
Open Channel System	
6% discount rate	162
8% discount rate	132
10% discount rate	110
Piped Distribution System	
6% discount rate	118
8% discount rate	102
10% discount rate	90

This analysis indicates that the piped distribution system holds promise to be a cheaper option than the open-channel system, when evaluated over a 30 year analysis period. Although the piped system is about twice as expensive in terms of base capital costs ($123 million vs $64 million), the lower operations costs with the piped system because of the pressurised water delivery reducing on-farm pumping costs, together with the value of the water savings generated from the piped system, result in a lower-cost alternative when viewed over the longer term.

In terms of sensitivity analysis, this result is robust across all three discount rates. In addition, sensitivity testing indicates that:

- Should there be no real increase in the price of electricity over the analysis period, there is negligible change to the results because the “value” of these savings do not start to occur until after Year 6 and then only escalate at 1 percent annually for 4 years;
- Should the value of the water “savings” be negligible, then the two options become comparable in present value cost terms at the higher discount rates (8 and 10 percent);
- Should capex costs increase by 20 percent, the piped option still remains the preferred option in terms of the present value of comparative costs; and
- If pump operating costs increase by 20 percent, there is only a small change to the results, and the comparison remains similar.

4.2 ALIS Case Study

The sub-area adopted in this case study is described in Appendix 4, and covers a gross command area of 4,083 ha and supplies water to 3,200 ha. The specific assumptions applicable to the economic analysis of this case study are as follows:

- Implementation extends over 4 years, with the first year devoted to resource consenting and initial preparatory work, the subsequent year to preparatory work followed by two years of civil work (Years 3 and 4);
- Commissioning costs add 3 percent to capital costs and are spread over years 4 of the implementation period and into Year 5, the first year of operation;
- Resource consenting expenditure for the piped system occurs in year 1 of the analysis period, and involves an investment of 2 percent of base capital costs;
- Legal costs for the piped network are assumed at 1 percent of base capital costs, equally spread over Years 1 and 2;
- There are no additional infrastructure costs (such as upgrades to the electricity network);
- The pipe system will require easements to be established over the reticulation footprint, the costs of which are reflected in legal costs;
- The pipe scheme assumes a network layout involving land easement, with no land purchase;
- The piped system will “release” for sale that area of land which currently forms the footprint of the open-channel network– it is assumed that 30 ha of this land will be sold in Year 5 at $15,000/ha.;

- Operational costs for both systems are $16/ha (in other words, no operational costs savings are assumed);
- Pump R&M is assumed at 3 percent of capital cost;
- Pumps are replaced after 15 years assuming 3,000 operating hours per year. With the open channel system, all 27 pumps are replaced at year 15. With the pipe system, 8 turnouts do not require pumps. Of the remaining 19 turnouts, pump replacement is programmed between years 15 to 25 depending on average usage/load.
- System maintenance costs for the open channel system are $15/ha and for the pipe system $12/ha (in other words, the pipe system has a maintenance cost saving of $3/ha.); and
- Water "savings" with the piped system are assessed at 20 percent of the water that would be required at the headrace of the open-channel network. This water has a "value" of $4,600/ha and is "sold" in the 2 years following scheme commissioning.

The results of the analysis with these assumptions are shown in Table 2.

Table 2: ALIS replacing open channel with pipe reticulation.

	Present Value Cost ($ millions)
Piped Reticulation System	
6% discount rate	4.5
8% discount rate	5.0
10% discount rate	5.3

This analysis indicates that the piped distribution system is likely to be more expensive than the open-channel system it replaces when evaluated over a 30 year analysis period. The capital costs of the piped system are such that they cannot be offset by the savings in operations costs (reduced on-farm pumping costs), together with the value of the water savings generated from the piped system.

In terms of sensitivity analysis, this result is robust across all three discount rates. Using the 8 percent discount rate as a comparative benchmark, the base case PV of cost for retrofitting is $5M. If capex is reduced by 20 percent, this falls to $2.9M and if capex falls by 40 percent, the PV of cost falls to $0.8M. If water sales revenue increase by 20 percent, the PV of cost in the base case falls from $5M to $4.7M. In the case where opex cost savings are increased by 20 percent, the PV of the cost falls to $4.5M.

The sensitivity of the result is therefore very heavily dependent on the capital cost of the retrofitting. Appendix 5, section 10.8 details one approach to reducing the capital cost by altering the risk assumptions. If this capex is transferred across to the above analysis, the assessed PV of cost for the retrofitting option decreases from $5M in the base case (at a discount rate of 8 percent), to $1.6 M.

4.3 Comparison of Results

It is informative to list some of the reasons why a piped reticulation system is apparently more cost-effective in the Central Plains scenario, whereas retrofitting a piped system into the ALIS may be less attractive from an economic viewpoint. In this regard:

- The piped network for the CPW scheme involves a base capital cost of around $3,400/ha compared with that for the ALIS at just under $4,100/ha. This is a result of the different layouts (with ALIS being a longer, narrower layout with only some of the properties supplied) and the ALIS design criteria to supply at a minimum head of 42m. Layout, however, appears to have a comparatively dominant impact on scheme cost.
- The CPW scheme has higher on-farm pumping operating cost savings for pipe versus open channel than ALIS because: (a) ALIS has a lower system capacity, with less flow being supplied to each property; (b) ALIS has a lower target pressure to be supplied; and (c) ALIS has lower electricity costs.
- The piped network for the CPW generates on-farm pump operating cost savings compared with the open channel option of around $160/ha compared with the ALIS of just under $100/ha. The CPW figure results from relatively high energy cost values for both options subtracted, whereas the ALIS figure results from a modest energy cost of the limited pumping from races at present, to the piped option where energy costs are zero, because of the high delivery pressures.

4.4 Additional Considerations

It is emphasised that the economic analysis above is only part of the comparative evaluation – other aspects (both perceived benefits and costs, but parameters which cannot be quantified in monetary terms), need to be included in any comprehensive comparison. The extent to which each of these issues will apply, and the weight given to each, will vary with individual circumstances, but the following table lists some of the factors that should be also canvassed in any comprehensive comparative evaluation of the options.

Table 3: Additional Considerations

System	Additional Potential Comparative Benefits
Open Channel Reticulation	Allows augmentation of lowland streams (although piped schemes can allow direct augmentation)
	Provides additional groundwater resource for potential abstraction
	Provides additional groundwater for dilution of leachates
	Creates potential wildlife habitats
	Provides more equitable on-farm pumping costs across the command
	Provides opportunity to collect and utilise by-wash
	Easier to expand in the future
	Creates opportunity for amenity and recreation benefits on waterways
	Provides for easier implementation through the improved “bankability” which attaches to lower capex.
Piped Reticulation	Reduces potential for water mixing with cultural and bio security implications
	Reduces need for rostered water delivery systems
	Provides pressurized water for fire-fighting
	Reduces access disruption to farm operations from channel bridges, culverts and fences
	Increases land use flexibility without channels dissecting paddocks
	Provides higher water quality at farm turnout
	Reduces need to discharge excess flows after stoppages
	Easier to measure scheme flows
	Reduces issues in health and safety
	Increases scheme security
	Reduces risk of water contaminants
	Less exposure to real price rises in energy costs
	More socially acceptable to wider community
	Reduces visual impacts
	Provides potential potable water supply
	Is perceived to be a more “sustainable” use of resources

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