Costing Water Cycle Infrastructure for Sustainable Investment

A. Cullen[1]
[1]Cullen Capital Pty. Ltd., Level 14 50 Queen Street
Melbourne, 3000
E-mail: alan.cullen@cullencapital.com

Decisions related to investment in water infrastructure are frequently supported by cost methodologies such as long run marginal cost, annualised cost and levelised cost. The selection of cost as a discriminator among projects derives from a view of water as an undifferentiated public commodity. Instead of investing for maximum value the objective is to find the "least cost" of delivering water to community demand. Furthermore, the focus is on direct infrastructure costs notwithstanding the profound effect of externalities on the merits of the project.

Even with their limited objectives, these methodologies have serious deficiencies in the scope of data captured, in the explanatory power of the results and in their compatibility with competing public infrastructure projects outside water. For example, annualised cost and levelised cost are methodologies in current use for discriminating between options for investment in water system. The computational complexity associated with making an optimal choice cannot be reduced to these summary equations that guide investment choices in major projects.

There is a need to recognize in any quantification for investment decisions a range of time related and external factors that have crucial impacts on the investment decision. This includes the effects, for example, on housing affordability and the opportunity costs of deferred or foregone public and private investments. Water infrastructure investment must work in conjunction with and seek synergies with other infrastructure projects such as in servicing population growth through greenfields or higher density development. The methodologies for quantitative assessment should be compatible with and be able to be combined with the other planning and infrastructure considerations.

The preferred methodology is founded on investing for value where water has value attributes that are a function of its use and of time. The objective of "highest and best use' for the scarce water resource is preferred to "least cost" delivery. Such an approach would recognize the benefit of delivering water when and in the form that is needed and take account of volatility in supply and demand as risk factors. The focus on value will drive more opportunity for community and private sector participation and will facilitate the integration of water strategies into more complex service models that determine where communities and businesses should best be located and served. Both options valuation methods and cellular automata computations are discussed.

1. DATA CAPTURE AND DISCOUNT RATES

Water is in the forefront of Australian policy challenges and public debate. With public attitudes heated by the underlying fear and uncertainty associated with climate change, the conjunction of drought and increased demand created by rapid growth in economic activity (especially in commodities and increases in household wealth) planning for water infrastructure based on traditional strategies has been perceived by the community as inadequate. One response to the "crisis" is pressure for urgent public investment in mega projects that crowd out other public needs.

These circumstances bring into relief the question of whether the quantitative methods and analysis used to provide decision support for the very large investments and public commitments are adequate for the circumstances of today. These methods need to be evaluated in relation to whether their compass and information content is aligned with the nature of the decisions to be made and on the quality and accuracy of their information content.

The methodologies that dominate the domain are derived from economic theory modified for the special circumstances of water projects. They include economic marginal cost methodologies (short run marginal cost, long run marginal cost, average incremental cost and "levelised cost"). They are designed on the assumption that water infrastructure will be delivered by public monopolies with the objective of delivering water as a "public good" at "least cost". The frame of reference for data and analysis is bounded by the direct project costs and income. Analysis will show that the assumptions and the methodologies have been adjusted to pursue the objectives of cost recovery and stable prices. That is to say that the methodologies are dependent on and fitted to the desired outcomes.

In the modern environment the choice of delivery of water services ranges between aggregations of the private provision of distributed sustainable integrated solutions and large civil projects like dams and desalination plants. With constraints on Government budgets and guarantee capacity for the raising of taxes, and the borrowing of money without compromising credit ratings, there are quantitative restrictions on periodic government capital capacity. Thus there is a need to choose between water infrastructure and hospitals and schools. Therefore, the methodologies need to be generic and not water specific.

For a generic investment analysis a benchmark method would be to calculate the free cash flows associated with the investment (e.g. taking into account actual capital expenditure projected and projecting revenues under sensitivity assumptions) discounted at the appropriate risk adjusted discount rate. The risk adjusted discount rate is the rate chosen to discount the project according to the market pricing of risk associated with the funding and is applied by governments, utilities and regulators in their determinations.

Where the investments are to be made by arms of government they cannot be treated as independent projects; they are affected by and likewise affect government balance sheet and income capacity. Segmenting investments into government enterprises does not insulate the political and financial consequences; government would have to step in if water and sewerage services were not supplied. In water matters the government is fully engaged and experiences moral hazard. This has the following implications:

- Boundary conditions must be chosen with care. Thus assumptions and the scope of data chosen have fundamental consequences for choice of investment.
- The starting period for analysis is the earliest point at which investment for any project can commence. Thus if a large project has a long lead time the discounting commences well before significant expenditure is incurred.
- The same investment quantum is used. Consequently, uninvested cash accrues income at the opportunity cost of capital.
- The risk adjusted rate is the weighted average cost of capital for the Government and not the incremental project rate.
- Externalities must be taken into account. This will include the regional economics determined by the spatial location of user populations. Other related infrastructure costs like transport and energy, carbon and environmental impacts and the effect of delay of delivery on third party costs such as the affordability of land need to be taken into account.
- The terminal value of the cash flows and the periodic replacement of capital stock can be taken into account.
- Inflation (including in water pricing) can be embodied in the analysis.

A starting point for any analysis is the choice of data sets and assumptions. There is evidence in the water domain that restricted boundary conditions have led to adverse selection.

The time value of money is a crucial factor in the debate. It is used in Average Incremental Cost and levelised cost formulations. It is used to calculate the Net present Value (NPV) of the Capital cost for the purpose of financing the project. In order to give a perspective on the direct and indirect costs associated with new investment for providing water services for a greenfields development, a new development near Geelong in Victoria was taken as a case study.

Drawing on the data in the Report on "Responsible Water Use at the Armstrong Creek Development" Coombes (2008), and other sources, using an NPV approach, the sustainable integrated system proposed by Coombes was found to be a superior financial and supply solution for the development and was capable of being financed privately.

Water infrastructure as it is currently delivered, is a large civil engineering undertaking with very lengthy delivery times. With the Armstrong Creek development a time lag of up to 20 years was suggested before delivery from the water utility to some developers. Land held back from development because water infrastructure is not delivered has a holding cost. This can be a direct cost to the developer or implicit in price rises in land that is optioned. Based on a weighted average holding cost of 13.5% that was regarded as reasonable at the time for a large developer and other plausible assumptions, at net present value, the cost of delay was in the order of 40% of the cost of land and around 30% of the sale price to the buyers of completed allotments. If the lag were reduced it to 5 years it was 14% and 18%. That is, the delays associated with rolling out traditional water infrastructure have a direct effect on housing affordability of major magnitude.

The same issues apply to the opportunity costs of delaying non-water projects to meet the capital constraints associated with crowding out by giving priority to large scale water infrastructure investment. Scale factors also interact with the time value of money. A large civil engineering approach requires taking long period views and lumpy investments. This compares unfavourably with local treatment where investment can be matched with development sequence. To illustrate this point, if an investment of $100 million is required to service a development that takes 10 years to complete, the centralised solution might require most of the expenditure on holding and treatment facilities to be invested before the development proceeds. Local solutions might be able to be rolled out at $10 million per annum over the 10 year period. At a government borrowing rate of 5.5% per annum there is a cost saving of 25%. If it were a 20 year sequence the cost saving would be 40%.

These issues of capital delays and matching capacity with demand over time have been highlighted and examined by the Rocky Mountain Institute (2004) and White and Fane (2003).

The time related perspectives have not even taken into account market factors where provision of water infrastructure sequence affects market competition and supply and demand. Furthermore, under the integrated sustainable approach water infrastructure is not a constraint on where and when developments are undertaken whether it is greenfields sites or densification of the urban areas.
Housing affordability is but one aspect of the spatial economic issues that result from the constraints associated with centralised delivery of water services. Transport and community infrastructure, business location and employment are some of the major factors to be taken into account. Thus a higher cost water solution might be more than offset by the effect on other capital investments and their outcomes. Unless the water solutions are embedded in a quantitative systems analysis that incorporates all of the elements, the calculations are at best of limited value to the decision makers and at worst misleading. A "least cost" to the water authority might be a highest cost, lowest value when the system costs and benefits are analysed.

Comparing like with like means not only starting the time value process at the same time but also comparing like quanta of investments. If a small or sequential project is to be compared with a large project the earning capacity of the uninvested portion of funds needs to be included. This is well known in the formula for the Modified Internal Rate of Return (MIRR) calculations. In the MIRR calculations the return provides for investment of the unused funds at a suitable return such as a cash rate investment. This means that the smaller or sequential project would be credited with the return on the cash not used as a residual of the larger investment amount. It is a way of capturing the opportunity cost.

The choice of risk adjusted discount rate is a significant issue, although not as important as capturing all of the relevant costs. What is the opportunity cost of capital for the government? The government has two sources of cash: taxpayer equity (in the form of taxes and charges and retained earnings), and borrowings. On a balance sheet basis the Victorian Government has equity of 94%and debt of 6% in 2008 for on budget activities. The rate on equity is the opportunity cost of investment by the taxpayer if the government were not investing on the taxpayer's behalf. The government might choose not to make a market return thus providing transfer pricing but the appropriate return is market based. Water authorities in Victoria typically use the Capital Assets pricing method (CAPM) applied by the Victorian Productivity and Efficiency Commission to establish equity and debt rates. However, they apply the gearing of the business unit (ranging around 50% gearing for water utilities) not whole of government to calculate the Weighted Average Cost of Capital (WACC) that is the blended rate of return for different components of capital like debt and equity. In a whole of government choice for a capital expenditure the gearing would be much lower and the WACC consequently much higher.

Another way of approaching this is to consider the cost of capital rationing. If the government were to build both a dam and a hospital though borrowing it could reduce its credit rating from (say) AAA to BBB and thus raise its **whole** cost of borrowing by (say) 1%, not simply the project cost as is currently applied. If this is attributed to the decision to build the dam then the borrowing cost of the dam is raised by a substantial multiple of the credit spread. While the WACC analysis is preferred this brings home the fact that capital rationing has a cost. The free cash flow analysis that we use as a benchmark would apply projected new capital expenditure that in the case of a dam would be relatively low but would account for the loan amortization schedule separately. This is particularly important as bank loan amortisation periods are now considerably shorter than effective life calculations for large projects.

The implication of the foregoing analysis is that conventional government project analysis understates the cost of projects that depend upon the underlying credit of government and favours business units that use high gearing even if not economically or socially efficient.

The treatment of inflation in water methodologies is usually applied by seeking a real discount rate achieved by deducting the Reserve Bank target inflation rate. Is it reasonable to apply an economy wide inflation index or should it be related to indices more reflective of costs associated with the provision of this type of infrastructure? The inflation index for costs should be construction specific as it aims to represent construction and not household expenditure in real terms.

The discussion thus far has focused on the inputs into predictive quantitative models to support decision making by governments and their agencies. It turns now to the common models.

It can be stated at the outset that the politics of water have been focused historically on keeping prices low and stable. This gives an incentive to water authorities to seek those goals through a "least cost" approach to capital expenditure. Later in this paper it is suggested that the focus should be value. However, it can be observed that least cost is from the viewpoint of the water provider and ignores whether its decisions increase cost on others. Both demand and supply can be volatile as a result of stochastic events. For example, in rural areas the water users are agriculture, forestry, mining, other industries, town populations and the environment. The system where water is a factor of production is a stochastic system where weather, interest rates and commodity prices are random variables and where asymmetric information between central managers and irrigators and users in water management (Hughes 2009) also leads to randomness. Figure 1 below shows how favourable currency and interest rate movements have contributed to increased rural production despite the drought and thus exacerbated the demand for water. Thus pressure on water resources would be expected to be most severe when water resources are depleted but commodity prices for both agriculture and mining are high, and interest rates and currency values are low (a position that we have been experiencing). Conversely, relatively plentiful water would not be sufficient to help the rural economy when the financial market variables are all in the wrong direction. Thus the notion of regularity in annualised calculations is open to question.

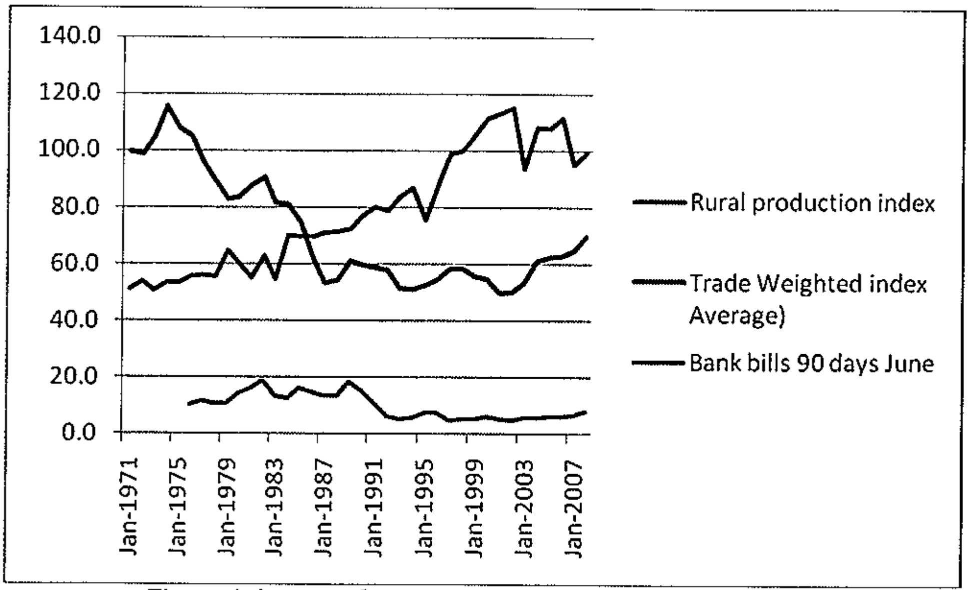


Figure 1: Impact of currency and interest rate movements

Capital expenditure on water infrastructure investment is non-linear with sharp singularities associated with large new projects.

2. QUANTITATIVE METHODS

These facts pose very significant challenges for setting price for both recovery of investment and equity for consumers. The water industry has unsuccessfully sought to resolve these issues through modifying economic models of marginal cost pricing. Given the large fixed cost component, it would have appeared that short term marginal cost would establish the market price. This, however, would have meant that cost recovery would not occur since the average cost would be higher for a very long period of time. It would also lead to difficulties at singularities as infrastructure reached capacity and substantial investments were made to augment it.

For these reasons it was abandoned and costs were "smoothed" by taking a very long time frame and treating fixed costs as variable providing a "long term marginal cost". However, this did not take account of the timing of investments and revenues and thus could not discriminate between projects that have different profiles and sizes and promoted underpricing where consumption was deferred. The next adaptive step was to establish Average Incremental Cost and "levelised cost" to take into account the sizes of projects, the pattern of demand and expenditure and the time value of money. The objective behind "levelised cost" methodology is laudable. It is desirable to discriminate between capital expenditure options of differing size and with differing time scales. It is essential to consider time values and scale economies. The levelised cost defined in White and Fane (2003) is:

$$\mathrm{LC} = \frac{\sum_{t=0}^{t} C_t/(1+r)^t}{\sum_{t=0}^{t} S_t/(1+r)^t}$$

Where C_t is the cost (capital and operating) of the option in year t and S is the saving in volume of water in year t and r is the real discount rate.

White and Fane (2003) focussed the numerator on water demanded not "safe yield" and broadened the use of this measure of conserved cost to also include demand supplied and conserved.

What is common to all formulations is that they seek to establish a summary statistic that predicts which option is least cost and establishes a constant unit price that would enable cost recovery. Each formulation is an **average**. The dangers of using averages are well known and that is the case for all of the methods.

The numerator is the Net present Value (NPV) of the costs.

The denominator (safe yield or water consumption and saving) in volumetric terms is summed over the whole period (whether or not discounted) and unrelated to unit cost in any one period. In Levelised cost formulae it is discounted.

White and Fane defended the use of a discounted volumetric variable in the numerator on two grounds:

1. "It is therefore reasonable to discount this quantity over time in order to account for consumers' time preference for consumption." In addition, they chose the capital charge rate for the capital stream as the discount rate for the volume without justification.

Since growth will come from new consumers and since for economic reasons consumers may choose to save rather than consume water the case has not been made why this time preference exists. If the water volume is a proxy for revenue then the financial discount rate is plausible.

2. "the levelised cost is equal to the 'income' per unit that would need to be received from each unit of supply, for the project to 'break even' in present value terms."

Volumes would need to rise at the financial discount rate very year on a regular basis at the constant price to produce this result. The pattern of costs and volumes would have to be invariant. The artificiality of this in an environment of stepped tariffs and irregular demand is evident.

Similar criticisms could be made when using annualised cost in the numerator. In that case the denominator would need to be constructed as a constant annual volume under time discounting.
The numerator (annualised cost) is not a sequence of actual costs but a financial amortisation schedule for financed costs based on an assumed project return to capital.

Therefore, simply in financial terms, the methodologies cannot deliver a robust unit price profile with which to compare one project with another.

The summary statistic ignores the external capital financing costs and opportunity costs associated with the pattern of demand. A dam will have high initial costs and build its revenues over the long term. Therefore, users will make a small contribution to cost recovery using the levelised cost price in the early stages and there will be substantial capital and opportunity costs to be considered. Tanks on the other hand more closely match demand and supply and therefore have lower external capital financing and opportunity costs. Very large projects with long time frames to justify them necessarily reduce the capacity of financial markets to absorb them and require Government to be responsible. In addition the infrastructure might have a significant terminal value e.g. a dam. In a very long defined term this might be discounted to a point of not being material but for rigour should be included.
There are a number of ways in which levelised cost can be altered by policy. For example, changing the time period will alter the fixed cost spread as a variable cost per annum. Changing the sequence of drawing on the asset will make an alteration. For example, if a desalination plant were to be used as a base generator instead of a reserve generator thus ensuring full capacity throughout its life it might present a lower levelised cost than a more efficient asset because of the demand factor in the denominator.

Given its restricted scope, its artificiality, its rigidity and its averaging approach the method conveys little practical information, can be misleading and can be directed by choice of assumptions to specific outcomes. It leads to the conclusion that it has little and unreliable information value for decisions on choice of infrastructure option. That is, the computational task cannot be reduced to this level of simplicity without a loss of meaning.

A discounted cash flow approach using scenarios and taking account of volatility of inputs would provide richer and more relevant information. Through separating the cash flows into operational, investing and financing the optimization of different pricing profiles can be accomplished for which the summary statistic is of no value. A better outcome can be achieved by predicting price progression through fitting the prices profiles required to reach revenue and cost neutrality or such other policy stance as might be required. Those price profiles would enable comparison of different options and scales.

Water, like petrol, is a very emotional issue for the community. From observation it appears that consumers react more to the delta than to the absolute level. Thus the desire for price stability is well founded. This does not mean constant prices but the avoidance of sharp increases. Pricing revolves around the recovery of costs from users and has led to the ranking of projects on a "least cost" basis using the formulae described above. Under the discounted cash flow analyses various smoothed price trends can be incorporated having regard to steps in the "indivisibility of capital" expenditures.

The focus on cost and "least cost" is a legacy of a public sector investment history focusing on large and therefore publicly funded projects. It has been demonstrated that the quantitative support for least cost rankings can be profoundly misleading. It is said that "one gets what one pays for". It ought to be axiomatic that investments will be made to generate the highest value rather than on the basis of least cost. The discussion now turns to investing for value.

3. EFFICIENT INVESTMENT IN WATER SUPPLY

Efficient water supply would enable demand and supply of water to be matched at each point of time. This is the case for water conserved where there is a perfect match, a close match with water tanks and a poor match with large sources like dams and desalination plants. In the sequence of drawing on water sources, the consumers would draw first on savings, second on tanks and then on large sources.

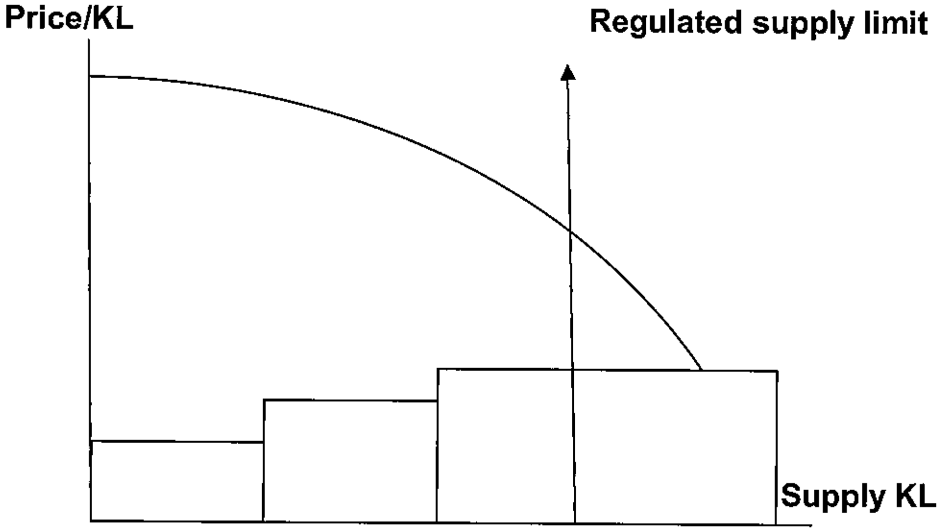
The LC calculation does not take into account changes in the capacity to supply from an investment over the life of the investment. Volatility needs to be considered. When considering efficient investment an objective is to evaluate the risk that demand and supply will not match leading to an overinvestment or underinvestment in the source of supply. For example, Coombes & Barry (2009) have calculated the relative performance of dams and tanks under conditions of climate change and seasonal variation.

4. INVESTING FOR VALUE

The industry debate has focused on cost as is common for public sector projects although some price signals are embedded in the demand function. However, it would be superior to relate costs of investment to value of water. Clearly value is changing as is pricing. The value approach would also be able to take account of the value of unused reserves. Value is a better driver of investment decisions than cost. It is also consistent with water trading markets. In a market with regulated pricing and supply it also enables transparency in transfers of value. The subject of valuing water especially where most supply is not freely traded is a complex one. In this discussion it is only possible to open up lines of inquiry and make high level suggestions on methodology.

One way to calculate value would be to regard water supply as a series of options for water supply under different tariffs over a supply period, calculating value though options pricing models such as the binomial options pricing model. We can readily regard the consumption of urban water as a series of annual options with the fixed charge as a premium and the exercise price being the variable charge. However, especially under conditions of rationing, what is the value of the water consumed? This requires calculation of the clearing price at which demand and supply would match given the volatility of both demand and supply and taking into account sustainability of supply. This can be established using probability methods as has already been extensively done in predicting demand and supply.
Taking this approach will enable a better understanding of value created for the community, of the social transfers of value, of the opportunity cost of conserving supply and of the premium for

catastrophe protection. The following Figure 6 shows in illustrative form an urban domestic supply profile. The curved line is the demand curve for water in a free market. The boxes represent the payments made to the water authority under a stepped tariff for amounts supplied (not including the fixed charge). The vertical arrow relates to the constraints placed upon supply by the Water Authority to conserve water.



The total value of water supplied is the area bounded by the curve and the supply limit. Of this value the authority receives the amount in the rectangular areas plus the option premium while the consumer has the balance. In option terms the consumer will be "in the money" when the demand and supply curve is in excess of the exercise prices. It can be seen clearly from the chart that the regulation of water supply might entail substantial transfers of value by the community to private users. The equity of these transfers and their role in driving consumption behaviours has a role in determining the quantum and volatility of demand e.g. the relationship of water demand to wealth. In standard options terms the water authority has written and the consumer has purchased an American call option with a premium at the fixed charge and an exercise (strike) price at the variable charge times the quantity to be supplied. An American call option allows the exercise of the option at any time during the option period and a European option only allows the exercise at the option expiry date. The quantity to be supplied might be taken as the regulated limit or a series of smaller quantity options be purchased some of which might expire worthless as being beyond the regulated limit. The current market value (the area under the curve) would be based on consensus expectations at the time of purchase of the options as the market is forward looking. The value of the options could be calculated using multi-period binomial options pricing methods. The ability to value water in a standard framework provides the opportunity for better information to inform investments.

In order to accommodate population growth in urban centres, choices need to be made about increasing density or developing greenfields and between multiple options from water savings to dams. Water infrastructure and management represent a key driver in the decision. Substantial tradeoffs between private and public wealth creation are involved. In order to make transparent the flows and stocks of value associated with the investment it is desirable to think of water not in terms of its volumetric components but as having value attributes that vary according to place and end use. In the grid system that extends from the precinct to the source of water and waste water treatment it is possible to tag each connection with its financial attributes deriving from its relationship to water ("cellular automata" as described by Wolfram (2002) in "A New Kind of Science" and to generate computations over this value map that optimise investment in the grid and in water efficient management. This approach would enable a combination with transport, power, and other major factors in urban planning since it adopts a methodology that can deal with irreducible, complex computational challenges.

5. CONCLUSIONS

The profoundly complex trade off decisions that have to be made by governments for major projects require quantitative methods that convey high quality decision support. The current methods used to evaluate water infrastructure projects are open to question. There has been a presumption that water infrastructure is a public commodity, has large economies of scale and that, therefore, governments can supply it more cheaply due to the time period for recovery of costs and the large scale of financing. This has been supported by hiving off water projects to government utilities, using project costing metrics and summary numbers based on an interpretation of the application of economic marginal cost theory to water. Large water projects are not "off balance sheet" for government. Moral hazard overrides any quarantining. Capital funding for these large projects displaces other use of limited government funding capacity. This requires establishing a discount rate based on whole of government leverage rather than project leverage and bringing to account a range of externalities associated with the investment.

The quest for a summary statistic to rank projects and assist price formation has its most recent form as "levelised cost" or "average incremental cost". The various current approaches are averages based on restricted conditions. They are artefacts that do not convey any useful information for the twin goals of "least cost" construction and pricing for cost recovery. The application of discounting cash flows to the operating, investing and financing patterns taking into account volatility and fitting pricing profiles is the method that is likely to produce the most valuable information for decisions. Investing for "least cost" might result in "least value". The focus of investment is normally upon maximizing value and this should be the aim of government. Establishing value enables optimization to be used in a consistent framework across the government sector and enables the financial and social consequences of transfers of public assets to be identified. Therefore, a valuation approach to water investment is proposed for which options pricing methods can provide an appropriate approach. Another direction of promise is to conceive of water grids and cells in terms of value rather than volumes of water and to construct cellular automata to generate optimisation models. This has the prospect of enabling other infrastructure elements like transport and energy to be combined in the computation.

6. REFERENCES

Coombes, P.J. (2008). "Responsible Water Use at the Armstrong Creek Development: Analysis of Integrated Water, Stormwater and Wastewater Options." Bonacci Water

Coombes, P.J. and Barry, ME. (2009) "The spatial variation of climate, household water use and the performance of rainwater tanks across Greater Melbourne" WSUD 2009, Western Australia.

White and Fane (2003) "Levelised Cost, a general formula for calculations of unit cost in integrated resource planning" Water Supply Vol 3 No 3 pp185-192, IWA Publishing

Hughes, Neal (2009) Management of irrigation water storages: carryover rights and capacity sharing ABARE Conference Paper 09.2

Rocky Mountain Institute (2004) "Valuing Decentralised Waste Water Technologies" Rocky Mountain Institute

Wolfram, S. (2002) "A New Kind of Science", Wolfram Media