Frameworks for Water Source Procurement in WA

Discussion paper prepared for the ERA inquiry into competition in the water & wastewater services sector

Prepared for the
Economic Regulation Authority of Western Australia

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Purpose

This discussion paper has been prepared at the request of the Economic Regulation Authority ("the Authority") as input to its current inquiry into competition in the WA water sector. The Authority is examining frameworks for source procurement – a central issue for the WA and other water sectors and one with possible implications for institutional arrangements and the structure of any markets. This paper is not intended to map out a comprehensive framework, nor to analyse market models, but does provides thoughts on a selected range of matters considered highly relevant and commonly overlooked or inadequately factored into water planning.

In particular, we have been asked to focus on the relevance of emerging source planning methodologies, and associated trigger points, that draw on modern *real options principles* in order to point to more cost effective strategy – especially where there are high levels of uncertainty and scope for managing the timing and form of investment flexibly as part of an overall risk management strategy.

ACIL Tasman is working on other related papers for the Inquiry, including an assessment of relevant issues in relation to size and scope economies – and more detailed development of a procurement framework that incorporates the key principles developed here and in other work commissioned by ERA. The collection of papers should be considered as a block because of the tight interactions.

Water Corporation proposal

Water Corporation has proposed to the Authority that primary source planning continue to be conducted by Water Corporation, but through arrangements that would see Water Corporation clearly assume the role of customer and not provider. It does, however, propose for itself a substantial continuing role in identifying the types of projects most likely to be well suited to meeting its needs as customer, and in helping project proponents with alternative approaches to have a fair hearing, including detailed assessment of the implications of the proposed project for the whole system.

Water Corporation is envisaging specifying its requirements in the form of volumes of additional water required within a timeframe – specifying an outcome rather than the means. Specification as a volume/time, rather than as a contribution to system performance, could prove restrictive, especially in respect of some options-based strategies that focus on the flexibility to deliver water rather than the actual delivery of water.

That process of outcome specification is reliant on the ability to model plausible system developments – both demand and actual supply capacity. A crucial issue for procurement planning, especially with consideration of some less centralised models that might allow for broader use of competition, is to ensure that the collective decisions on individual projects – form, size, time, mode of operation and impact on incentives for other possible projects – add to deliver progressive system development that meets the requirements of society and is safe. The relevant economics and impacts relate to how a project affects the performance and costs of the whole system – not the performance of the project on its own. Indeed, normal measures of project perform can and often (even typically) do tend to overestimate, sometimes greatly, the contribution of a project to the system and to underestimate the implications for system costs.

System complexity & diversity

The proposed Water Corporation approach offers one approach to the complex, whole of system task of ensuring that supply can meets demand with adequate *quality*, *reliability*, *system security* and *without excessive cost.*

The task is complex – as Water Corporation argues – and these complexities should not be underrated. Indeed the task has become substantially more complex in recent years as a result of growing awareness of climate change coupled with substantial uncertainty regarding the future pattern of climate change and associated hydrology in WA. It is almost certain that climate change has added to pre-existing drought risks to place added pressure on supplies – less certain is how much, how fast running into the future and from which starting point (current patterns or a 'without drought' variant), and the extent to which it will involve progressive transition vs structural change.

Even without climate change, sophisticated processes are needed to manage other uncertainties, including uncertainty in demand trends, chance variation in rainfall patterns, including deep droughts, and uncertainty regarding future policy settings on matters such as the acceptability of indirect potable reuse (treated wastewater returned to potable supply via discharge into groundwater or dam systems).

An important aspect of the system is the level of *source diversity* – the extent to which supply has access to sources with low, zero or even negative relationship to rainfall patterns. The Perth supply system has been greatly diversified by the Kwinana desalination plant and the announcement that a second plant will now be built. This is on top of the substantial diversification offered by the groundwater sources – while groundwater is rain fed, it offers *both* geographic diversity in the rainfall patterns that feed the total system *and* substantial smoothing over time in the availability of water through its relatively slow rundown and recharge characteristics compared to dams. As the system diversifies, the value of additional source procurement changes – and certainly involves considerations extending well beyond the structure and cost of a procurement project. Planning must take into account the characteristics of the whole portfolio.

System complexity does not always require centralised planning. Markets – from grocery supply chains to gas and electricity – have proven extremely powerful in a range of settings in dealing with volatility and meeting demand despite substantial uncertainties in both supply and demand. However, market failure can be a serious concern – especially in relation to services as basic and essential as water and wastewater.

The range of intangible matters – especially in relation to environmental impacts and limitations on the nature of existing property rights – does urge caution and care in design. Substantial care would be needed in designed a market – other than of the centralised procurement type proposed by Water Corporation. Even centralised procurement can be seriously impeded, especially in a context where price is allowed to have only a very limited role in matching demand to supply, because of relative poor information on user and societal costs associated with non-price restrictions. The present Inquiry will need to address the potential benefits and trade-offs from competing approaches..

Tools for system modelling

Of course, the system planning and assessment tools, currently developed and controlled by Water Corporation, can be expected to have a crucial role to play under almost all institutional and regulatory models likely to receive serious attention during the Inquiry. The fact is that different water sources capable of meeting short term augmentation requirements will have different characteristics and implications for forward costs and options. A sound basis for weighing different alternatives is needed.

In this area, we suspect that there is scope and need for substantial further development of these tools if they are to guide a fair comparison of competing alternatives, or to guide cost effective development of sources by a centrally run process. It seems highly likely that the present tools involve *significant biases*, even within the current system – in line with biases now increasingly recognised most Australian water supply areas. These biases are likely typically to be towards unnecessarily high costs in meeting *supply* and *supply security* objectives.

Key points

Particular points made in the paper include:

- Demands for *system security and reliability* need to be seen as distinct from, and capable of being met in different ways from, demand for *additional water to meet growth* in demand or decline in in-flows.
  - Procurement of extra supply – creating a physical supply buffer – is one means of improving system security and reliability but not the only one.
  - Given the relatively long lead times in the development of serious threats to security in water, security can also be delivered via the capability to bring extra supply to the market fast enough. This can involve investments 'in the pipeline'; options for rapid scalability or variable operating cycles for existing investments; and investment in delivering the ability to contract, construct and commission water supplies with relatively short lead times (readiness options).
- System security as opposed to supply is a key strategy issue for SW WA.
  - Water Corporation modelling indicates that a second desalination plant would not be necessary *if only it were known* that the future would reflect the rainfall patterns of the last 30 years (that still involve a substantial climate shift relate to the earlier 70+ years of records);
    - i.e., that the very poor recent rainfalls involves the impact of a substantial major drought *on top of* a structural shift in climate, rather than reflecting just a further structural shift.
  - Therefore, and as an example of options reasoning, the rationale for the second desalination plant lies in its *insurance value*, not fundamentally in the water it will supply – though there may well be a longer term call on the water to meet future growth.
    - The second plant has a high insurance premium cost attached – planning for such commitment should probe other ways of delivering the needed insurance and the scope for meeting future demand growth, and this could include strategies with might lower up-front cost commitment, but possibly a higher 'excess payment' in the event that the future proves extremely dry.
  - Furthermore, unnecessarily early commitment to a strategy with high and irreversible costs – and this is arguably the case with a second desalination plant with a likely capital cost of $1b – could, under highly

plausible climate change outcomes, prove to substantially diminish incentives for otherwise sound demand management and augmentation measures – and may effectively eliminate a useful role for competition in procurement for a number of years.

  ··· This last point would appear to be of central importance to the current Inquiry.

- Modern options-based methods for planning for cost effective risk management place strong emphasis on *designing flexibility into the procurement process*, even on *buying flexibility* – not just on exploiting the flexibility that happens to be available at the time.
  - Examples are provided where it can be highly cost effective to invest in water sources involving *high unit costs*, but also *high flexibility*, ahead of sources involving much lower (nominal) unit costs but lower flexibility. The higher unit costs are the insurance premium and, indeed, comparing projects on the basis of unit costs can be highly misleading.
  - This is analogous to experience in electricity generation, where a strong role has been found for investment in *flexibility* in the forms of *peaking capacity* and a *shift away from the size economies* of very large plants towards smaller plants introduced to a timeline that better matches actual, as opposed to long-term forecast, growth in demand.
  - Up-front investment in flexibility can and should be viewed as the purchase of insurance against key uncertainties – and may be justified via the scope it offers to limit the risks of excessive overinvestment in large capacity which may prove not to be needed and to support emergency response planning to deal with rainfall developments that fall outside the range of historical modelling.
- Source planning in many jurisdictions – and this appears to include WA – is predicated on an approach that seeks an approximately *least cost strategy under one assumed forward scenario regarding climate change and demand*, coupled with stress testing to ensure that the strategy is robust enough to deal with the assumed 'worst case scenario'.
  - This typically means planning a strategy that is reasonably cost effective in relation to *either the worst case scenario or a highly conservative, low inflow scenario*.
  - Sophisticated statistical methods are often used, including in WA, to account for chance variation in inflow patterns, including chance outcomes worse than those actually recorded.
  - Water Corporation planning currently tracks 3 distinct climate change scenarios – based on actual patterns over the last 6, 9 and 30 years.

    ··· Actually procurement decisions appear to be driven by consideration of both the 6 and 9 year scenarios – both of which are much more pessimistic than the 30 year scenario. The 30 year scenario in turn involves a substantial structural shift relative to the full historical record.

      - As before, a key challenge is whether the recent past is better viewed as another major drought (akin to but worse than the major droughts around Federation and in the 1930s/40s) on top of the structural shift of the last 30 years, or as another structural shift. Both seem plausible, but have very different strategy implications.

  - Ultimately, procurement decisions involve substantial roles for other agencies and the Government, who bring to bear perspectives on unpriced costs and benefits beyond project financial implications, but the needs determination must be heavily influenced by the types of analyses developed by Water Corporation.

- As a general principle, planning based around a near worst case scenario will suggest:

  - The need for capacity to be introduced earlier than would be true on average, generally implying high estimates of expected cost; this cost bias can, to an extent (but not fully), be managed by adapting the timing of the strategy rollout to actual inflows over time (as is done in the current process), but:

  - This approach will also often indicate a *different ranking* of project candidates, as well as a different timing from that likely to emerge from a full options-based adaptive investment process that factors in prospects for less pessimistic outcomes while managing for security and reliability;

      - It is not enough, and could involve very high unnecessary costs, to develop the *structure* (essentially merit order of augmentations) of a strategy based on a near worst case scenario and then to focus only on question of timing.

      - Far more important may be questions of scale, choice of procurement technology and the balance between procurement and demand management.

      - In general, determination of the efficient mix of all these components can only be done using an adaptive strategy that adjusts the sequence, scale and balance over time and that actively invests in creating scope for more effective adaptation over time.

- Near worst case scenario optimisation may have worked fairly efficiently in the past, in a situation where there was little flexibility in procurement options, typically involving new dams that needed to be introduced well ahead of drought in order to be effective.

  - The flexibility now offered by desalination, recycling and even groundwater options – with high levels of scalability and flexibility as to timing, and with scope for modest lead times, seriously challenges this approach.

  - It is quite feasible to add to system security with a 'water factory' that is not yet built and even that has not yet been contracted for.
  - From the time that the improvement in system security has been achieved, it also makes sense to reassess the overall system operating regime – including trigger points for water restrictions – because dams can then be run down to lower levels while maintaining previous levels of system security.
  - At present, it appears that formal modelling of *probabilities of restrictions*, including *total sprinkler bans*, which forms a key part of the advice on which procurement decisions are based, does not allow for *revision of the restrictions trigger points* as new capacity becomes available or the ability to quickly add capacity is created.
    - This strongly suggests that *formally estimated* probabilities of total sprinkler bans are biased upwards, possibly quite significantly. This could give a quite misleading impression of the impact on system security and reliability of proposed new investment in capacity, relative to what might be achieved through investment in boosting readiness to deliver extra water and through soundly based revision of restrictions triggers.
  - Our advice is that Water Corporation would attempt to manage the implications of investments in new capacity that have already been committed, through less formal methods, but this does add to existing concerns that the procurement processes are likely to be biased towards procurement that is earlier, and possibly larger, than could be done cost effectively while still managing threats to reliability and security.
    - Importantly, given the role played by other agencies in overall procurement planning, the way that these probabilities are produced could well shape the character of the planning process in ways that involve a greater likelihood of early commitment to new projects.
    - Given the way that the merit order of investments – type and size as well as timing – can alter, this could also favour committing to projects that would subsequently prove to have been less than efficient as responses to the emerging threats to security.
- The options approach places emphasis on insurance that *limits irreversible commitment to costs that may prove unnecessary*. This suggests, given the current status of the climate change uncertainty, that fresh consideration could be given to a range and possibly a mix of alternative ways of delivering insurance where the irreversible commitment to capital costs is less. The following are examples that should emerge for consideration in a sound procurement framework – they are not recommendations, but rather questions that need to be settled to affirm the cost effectiveness of the current procurement strategy.
  - Planning for later implementation of a higher capacity (or rapidly scalable) desalination that allows deferral – possibly till after good

inflows given the forward inflow uncertainty – of commitment to a high cost project.

- Examples are provided where this proves much more cost effective, even if it risks needing to make a substantially higher cost investment.
- Effectively, this approach *lowers the likelihood of needing to trigger* the investment but *may increase the costs in the event that it needs to be triggered* – an *insurance premium/excess trade-off* that might be cost effective if a substantial lowering in the likelihood of needing to trigger the investment (or substantial deferral of the mean time till triggering) can be achieved.

– Progressive introduction of smaller projects, even with substantially higher unit costs, again as a deferral strategy –even allowing for the possibility of still needing fairly early to trigger the commitment to a large facility. A detailed case study of this option has been provided.

– Reassessment of the regimes for drawing from groundwater, fully recognising any environment and concerns, but also recognising the scope for deferring and possibly avoiding for a long time a substantial new capital cost.

- How do the risks of drawing the groundwater down too low, given current knowledge of these systems, compare to the risks of spending several hundred million dollars unnecessarily?
- Could the former risks be further allayed by a a change to the groundwater regime that allows for longer drawing down at high rates, but also allows for then reverting to an even more conservative level, for a longer period, to assist recovery? Again, while this might trigger a need for even greater investment in capacity later, the trade-off could be highly cost effective because of the prospects for allowing substantial deferral of the large up-front investment while it is still unclear if the investment is needed.

– Careful consideration of the potential value of flexibility options offered through better management of salinity in the Collie-Wellington Basin, with the recent report by the Collie-Wellington Basin Water Source Options Steering Committee pointing to a range of strategies that might fit well into a cost effective adaptive management strategy for the wider system.

– Consideration of the potential role of expanded water trading within an options setting – viewed as a device for deferring much larger capital investments and acquiring the flexibility to better deal with uncertain hydrology, rather than as a permanent and structural shift in water usage patterns.

- The infrastructure cost profile does appear to offer substantial flexibility for cost avoidance under some plausible future scenarios, while offering scope or deferring commitment to a large water factory or similar project.

- Accelerated demand management programs where the costs can be wound back rapidly in the event of useful inflows, thus limiting the extent of irreversible commitment;
  - Again, this could prove highly cost effective relative to up-front commitment to a possibly unnecessary large augmentation project, even if the nominal unit costs of water saved are high. In other jurisdictions, we have examined the economics of pushing demand management measures into regions of nominal unit costs several times the nominal cost of an augmentation project – and concluded that this can be cost effective given the flexibility offered to cap the level of expenditure in the event of useful system recharge.

These strategic options are not new. All have been recognised and assessed within the current processes. However, we are suggesting that a different assessment process – that is less focused on unit costs and more focused on whole of system costs and option value given high rainfall uncertainty – could well lead to substantially different conclusions regarding the most cost effective procurement strategy.

We are not arguing against the specific augmentation initiatives under way. We are arguing that a procurement framework firmly embedded in options principles would have required probing a range of alternatives, within a valuation paradigm that might have led to scope for significant cost savings while protecting system security. In relation to future augmentation decisions, and certainly in relation to the procurement framework and triggers, this type of probing seems to us essential and highly relevant to WA circumstances. We strongly suspect that systematic application to the proposed second desalination plant would suggest some change of strategy as being substantially more cost effective in dealing with the threats.

It is sometimes argued that options methods are not really relevant to systems that are not prone to frequent dam spillages. This reflects an early emphasis we gave to dam spillages in the Sydney catchment (where spillage is a frequent phenomenon) as a clear example of how an options strategy could reduce the substantial costs associated with producing water only to have it lost (as a source of future supply) when the dams spill. However, the principles apply strongly in any context where there is a significant risk that high costs will be incurred accumulating water in the system only to find that it is many years before the water is needed to augment demand. Under the 30-year rainfall scenario, this could well be true of further augmentation of the Perth system. This issue of mismatch between the timing of the costs and the timing of the benefits – and the scope for an options approach to improve the match – is central to the approach and can offer large benefits. The case studies in the report illustrate circumstances in which the savings of this type can be several hundred million dollars in relation to project proposals on the scale of a new desalination plant.

Intangibles

Water procurement decisions almost always involve values well beyond the clear financial values most clearly seen by Water Corporation. This has been reflected in a complex, multi-agency planning process that needs to weigh social and environmental values, and associated political constraints. Even under the current water service supply model, the issues are far wider than input cost sourcing for Water Corporation.

In relation to these wider values, difficult judgments are needed in respect of groundwater management, where information on which to assess impacts can be highly constrained. Transfer of water between regions and uses tends to be controversial – even when done through market transactions. Limitations in the design of property rights can further exacerbate concerns. Commitment to projects to source water in this way can therefore impact on real community values.

Desalination with avoidance or offsets for carbon emissions, and growing evidence of little brine discharge damage, appears to be growing in acceptance in WA – and has been assumed as being the main form of future augmentation. This does not, however, eliminate the scope for other forms of sourcing based on better understanding of groundwater and selective transfers – and recycling and other forms of potable substitution can be expected to play a growing role.

An extremely important intangible is the end user costs of restrictions. The current system does not, in most cases, allow the price charged for water services to vary to reflect the system cost of water use – and to use this to derive market information on the user cost of restrictions. Irrigation districts with tradable water rights can deliver quite variable prices in droughts that yield valuable information on user costs of reduced access to water – and help both to post signals as to cost effective augmentation strategy and signals as to where best to direct scarce supplies in the short term. Insight into urban, and especially residential, user costs of restrictions is far more limited. Nonetheless, perceptions of these user costs – especially the costs of deep restrictions, notably a total ban on sprinklers, are central features of the procurement planning processes.

A common feature of using options methods is that it allows for deferral of projects or for reduction in the scale of committed projects. This could be viewed as preserving future options to limit the use of any augmentations, and to limit impacts on intangible as well as tangible benefits. In some cases however, such as the suggestion above of the possible benefits of modification to the groundwater regime, might be viewed as working in the opposite direction – involving a trade-off between tangible and intangible costs and risks – and would necessarily require engagement across agencies, in environmental management. In flagging that possibility, we argue that there may also be scope for offsetting greater short-term use with a drop in longer term use for a longer period.

Comments on market links

An issue with the options approach is the way it adds to the complexity of the analytical task – not intractably but substantially – and in particular in the way that it strengthens the system linkages. It also plays high store on deferral of investment and possibly on intermittent operation of existing investment, when new entrant competition and operation to sell product are traditionally seen as key elements in competitive markets.

These considerations certainly strengthen the case for solid capability being in place to test system impacts and for this being flexibly available to the market. Concern for control of IP could build a case for direct private sector access to the models and methods – having Water Corporation model and test an option in the early stages of development, if Water Corporation has a role in identifying options for augmentation and seeking competitive tender, could well be of commercial concern. There are legitimate issues both of grey areas in attributing ideas and of potential incentives for Water Corporation to want to commercially test the market to supply a given approach once identified – if the testing is made in advance of a formal tender process. This would be true even without an options framework. However, within an options framework the incentives to develop 'clever' strategies that are more lateral in approach are likely to be heightened, and this would probably strengthen concerns for IP.

An important issue is the way that one project entering a market alters the economics – and the option value of – all other projects. As these option values are recognised, the incentives to get in first – possibly sterilising key competitor options – could strengthen counterproductively.

A key feature of the options perspective is the way it suggests thinking more broadly about the services being sought. If the primary function of a project proposal is to deliver system security/reliability rather than current water supply – should more thought be given to how a market might be used to deliver insurance? Who, if anyone, needs to have responsibility for security and how will it be contracted? Is it feasible to have contracts for capability to deliver a project with a very short lead time – possibly including up-front investment in key items on the critical path, development of necessary approvals etc and payment for maintenance of roll-out capability? To what extent are take-or-pay contracts essential relative to capacity and volume contracting. If security services are to be acquired, how should their costs fit in system price regulation?

In relation to central procurement frameworks, the paper suggests strongly that it will be necessary – if such a framework is to be cost effective and to adequately embed the options paradigm and its associated risk management benefits – for the process to seek to contract for the supply of *both* capacity and volume. Furthermore, the price of contracts for capacity should not be set higher than the unavoidable costs of the least cost strategy (costed in an options setting, including risk weighting for likelihood and timing of commissioning and operation) for delivering adequate capacity – in many cases likely to be some form of readiness to deliver infrastructure rather than actual rollout, let alone operation, of new infrastructure.

Finally, in relation to markets, we recognise that willingness to consider greater price volatility in urban water pricing – akin to the volatility now established in some aspects of non-urban pricing – could play a valuable role in opening up a wider set of market and competition possibilities to support more cost effectively matching supply and demand. Cost effective supply-demand matching is a more general, and it would seem appropriate, objective than cost effective source procurement.

We recognise that major change to pricing is unlikely to be a part of early market development, but set out some case study material to illustrate how an options approach to procurement planning can be linked into a new way of assessing the system costs of water usage. This material suggests that traditional approaches to cost and price assessment, including long-run marginal cost, can seriously underestimate the value of demand management that is responsive to system status and pressures for source procurement. We suggest a measure of the system marginal cost of usage – the real time loss of system option value as a result of current consumption – as a useful way of viewing water value in an options-based procurement setting.

1 Purpose

This paper has been prepared to assist the Economic Regulation Authority in its current inquiry into competition in the water and wastewater sectors of Western Australia.

What has been prepared here is a discussion paper that focuses on specific issues in relation to an issue of increasing importance to WA service supply security and costs – that of new source procurement as part of a response to trends in demand and likely trends in rain-fed system runoff as a result of climate change impacts.

The brief for this work requesting a specific focus on the applicability of options-based methods to water procurement in WA, in managing water security as well as supply, and a brief consideration of recent water procurement processes in WA against the backdrop of this options approach. The brief was not specifically about market and competition issues, but there are important linkages that will need to be developed if a sound assessment is to be made of the roles of both options-based tools and competition in water markets.

The paper:

- Discusses key elements relevant to the determination of a framework for source procurement;
  - with particular emphasis on appropriate and cost effective management of the key risks – including threats to *supply reliability* and risks of *excessive, or excessively early, expenditure* – and the potential role of options-based planning tools.
- Flags, but does not develop in detail, some of the key interactions between choices of procurement framework and options for effective use of competition in procurement markets.
- Provides a brief assessment of WA water source procurement processes, outcomes and lessons as they relate to the prospective frameworks and cost implications.

The paper is a discussion paper – and is not intended as a definitive report recommending a specific way forward; in particular, it is not designed to deliver a detailed framework for procurement, though it is intended to guide the process that moves towards a sound framework. In reaching a more definitive position, there will be a need to balance a range of considerations, a number of which are not part of the scope of this paper but are being considered in other commissioned work. This includes linkages into parallel work being done on potential market structures and on size and scope economies in the water and wastewater sectors.

That said, there are elements identified here in the nature of the risk management and procurement problem that need to be recognised within the agreed framework – provided they do not conflict too heavily with other aspects of arrangements for efficient water and wastewater service supply in the future.

A substantial emphasis in this paper is on emerging perspectives on procurement that have not historically been recognised or taken into account. Water planning in WA has, in respect of some of these issues, been advancing rapidly, but a sound procurement framework, well suited to use in the future under possibly different institutional arrangements, is likely to benefit from an even closer scrutiny of some of these issues and their implications.

In particular, reflecting the emphasis in the request from ERA for this paper, much of the paper has been devoted to considering the possible role for a procurement planning framework that more fundamentally incorporates the principles of *options-based planning* to support more cost effective handling of structural risks, especially those attributable to *climate change uncertainty*.

This approach follows from substantial work by ACIL Tasman addressing analogous risks in water procurement planning in several other jurisdictions – and mirrors work on these instruments currently being undertaken by the Water Services Association of Australia. Elements of this approach are already in use in WA, and it appears likely that a fuller utilisation of these methods could create opportunities for substantially more cost effective source planning.

Procurement planning in Australia has emerged in various forms in different jurisdictions – but in almost all cases it has become extremely sophisticated, relying on complex hydrology modelling methods, usually with a probabilistic overlay and increasingly with special provisions to deal with climate change uncertainty. Options based methods require that these systems be used intensively – and probably developed somewhat further.

This paper is directed at an audience that in many cases will not be familiar with these methods. We have attempted to keep the arguments at a level that they can be generally understood, but complexity is at the heart of the problem and some of the arguments require some understanding of probabilistic modelling methods.

ACIL Tasman is working on other related papers for the Inquiry, including an assessment of relevant issues in relation to size and scope economies – and more detailed development of a procurement framework that incorporates the key principles developed here and in other work commissioned by ERA. The collection of papers should be considered as a block because of the tight interactions.

2 Background

Western Australia is the largest state in Australia, spans the greatest range of latitudes and represents a wide range of climate/rainfall patterns – from monsoonal in the north, through Mediterranean in the South-West to extremely dry and even desert conditions across large parts of the inland. There are large areas of groundwater ranging in quality from very good through to hypersaline.

Population, commerce, some aspects of heavy industry and agriculture are heavily concentrated in the South-West, though with significant agricultural activity, including irrigated agriculture in the North. Mining and resource development activities, that form key parts of the growth economy, are spread more widely, with major concentrations of activity around the North-West Shelf gas fields and the Western Goldfields, where nickel and gold mining and processing are major sectors.

This diversity means that there is unlikely to be a consistent approach to water source procurement that is appropriate to all regions – except at a quite generic level of detail. Across the state, primary reliance on sources for water supply services ranges from individual river extractions, small farm dams and roof tanks through irrigation schemes and large scale use of ground and surface water by mining and industrial users through to urban supply schemes drawing on one or more large sources.

The main emphasis in this discussion paper is on predominantly urban – and especially Perth – supply source procurement. However, we have sought to address the general question of why source procurement may be appropriate and how alternative approaches might be compared. Particular attention has been paid to the risk management dimension of the task – if it were not for the uncertainties in relation to future demand and water available from established sources the procurement question would usually be a lot more straightforward, though not necessarily trivial. Choosing between alternatives tends to be driven largely by uncertainties – demand trends, system reliability, environmental impacts of augmentation strategies etc – alongside the evolution of demand management.

The Perth supply system was dominated, particularly prior to last November, by a mix of dam water and groundwater sources that had evolved largely over the preceding century. Compared to other large urban supply regions in other parts of Australia, the level of reliance on groundwater relative to dam water is extremely high. This has tended to create a system in which short term concerns, even in extreme drought, have been less linked to concerns for running out of water and more for concerns for deep restrictions and concerns for possible longer term consequences of needing to draw water at high rates from groundwater.

The traditional approach to source augmentation relied largely on assessing alternatives based on yield and unit cost of supply and seeking to introduce the lower cost sources earliest, moving progressively to higher cost sources. Cost assessment has necessarily involved levels of judgment where there are less tangible dimensions to the different proposals – with issues of water being moved between regions and uses and of environmental impacts – playing a role alongside financial costs. Reflecting the nature of these elements, the process has long involved interaction between Water Corporation (and its predecessors as the major supply utility) and the WA Government.

In recent years, the Perth system has had a major augmentation in the form of the 130ML/day (about 45GL/annum) desalination plant at Kwinana, commissioned last November, and the Government has committed to a second desalination plant, of similar size, at Binningup, probably rated at about 50GL/annum.

It is worth noting that the second desalination proposal is expected to cost a lot more than the first. As before, the best sites have already been used but, also, adding a second desalination plant to a system involves *additional integration costs* as the scope for low cost distribution has been reduced. The first plant can effectively deliver water by feeding it directly into the distribution system and avoiding the need to draw some water from the storages. For a second plant to operate in winter as well as summer will require the ability to shift some of the production up into storage, because of the structure of usage patterns in the system. This has implications for both capital and operating costs.

In combination, the desalination plants account for about a third of Perth demand. In combination with groundwater supplies – which, while linked to long-term rainfall, are much more weakly linked to short-term supplies – these investments should afford a high level of protection for the supply system. In effect, running out of supply is not a central policy challenge – though managing the risk of needing to limit demand in the event of surface storages dropping to very low levels remains.

2.1 Water Corporation position on procurement

The Water Corporation's position on source procurement is set out in some detail in its submission in response to the ERA Discussion Paper, released as part of this Inquiry (http://www.era.wa.gov.au/cproot/5972/28036/20070905%20Public%20Submission%20-%20Water%20Corporation%20-%20Issues%20Paper.pdf). Water Corporation is proposing an evolution of its recent procurement processes, with a strong focus on Water Corporation driving a process designed to best meet what it sees as the needs of Water Corporation and its customers.

The proposed changes would include removing Water Corporation as a prospective competitor in the process. Water Corporation would be likely to provide guidance on the type of project or projects it believes would best suit needs, most probably through the development and ranking of a series of options, but would not itself then bid to supply the projects. Consistent with the broad thrust of its submission, it would be seeking to utilise competition amongst prospective private providers within a procurement process that would be largely managed by itself.

Our early discussions with Water Corporation have certainly emphasised the view that, while Water Corporation has primary responsibility for potable supply in the State, and where source procurement is a central and essential input to this role, then a strong function for Water Corporation in planning, managing and running the process is appropriate.

Clearly some logical possibilities for market structures to be considered by ERA could involve moving away from these assumptions (which have been built into the Water Corporation proposal). Furthermore, Water Corporation has clearly indicated in discussions with us that it still sees significant areas within which further external guidance – particularly in relation to the management of some of the less tangible consequences of procurement strategy – is needed.

More generally, before judgments could be made about the appropriateness of the Water Corporation proposals, it is necessary to develop a clear concept of purpose and of the basis for weighing alternative approaches. We see this as a key function of the procurement framework that ERA is seeking.

The detail of the proposed model is set out in the Water Corporation submission, and we do not reproduce it here. However, key points of emphasis that are relevant to this discussion paper include:

- Significant efforts to balance what were judged to be competing demands for:

- flexibility as to project timing against
- commercial demands for features sufficient to justify the large investments needed in developing a mature proposal, including:
  - certainty that procurement will proceed;
  - level playing field;
  - relatively simple, transparent processes, consistently applied – including in respect of the key trigger points; and
  - reasonable prospects for a good proposal succeeding if the high investment is to be made – characterised as a strong shortlisting process prior to full bids needing to be prepared.

- Reflecting this last point, the need for systems to allow project ideas, especially those that differ substantially from any pre-developed Water Corporation options, to be tested early in the process, and before large investments have been made.
- Likely demands for reasonable clarity on key environmental constraints.
- Specific processes to support the development of concepts not initially identified and ranked by the Water Corporation processes – including access to regulatory and system assessment processes suited to ensuring these concepts gain a fair hearing.

2.2 Options methods in water risk management

Over the past three years, there has been growing attention being paid in Australian water jurisdictions to the potential role of modern options-based methods for guiding the planning and managing of complex infrastructure investment strategies over time. These methods emerged in the 1980s as a response to growing concerns with the limitations and sometimes large bias in the methods widely used at the term. These concerns are generally greatest where two factors come together:

- High levels of uncertainty about important drivers of future investment performance; and
- Substantial flexibility to manage and adapt the strategies over time to changing outcomes in respect of those uncertainties.

A key feature of this approach has been the way it can reduce the *severity of the trade-off*, previously largely unavoidable, between strategies to reduce the risks of excessive investment in water supply, with associated excessive costs, and the resultant implications for greater risk to system security or reliability. Building system reliability and security traditionally entailed largely unavoidable high risks of substantial investment being made much earlier than would subsequently prove to have been necessary, based on actual developments in inflows and demand. These costs were essentially the costs of system insurance.

Of course, flexibility of strategy has long been a feature of water planning. Sophisticated models of system hydrology have long been part of the toolkit used in planning for major water systems, and planning has long been responsive to changes in forward expectations of demand growth. With the emergence of desalination and recycling options for supply, that can operate effectively even in deep drought, flexibility has also entered the timing of the final trigger point for project commitment. However, planning methods have rarely exploited the full opportunities offered by these methods – with their full implications for project form and scale as well as timing.

Key consequences of taking an options perspective include:

- A strong emphasis on the *performance of the portfolio* of supply and demand instruments being used to balance supply and demand, looking at projects from the perspective of their incremental contribution to whole of portfolio performance and costs rather than their stand-alone performance.
- Recognition of the strategic value of reductions in key uncertainties before it is necessary to make large and irreversible commitments to projects that may not be necessary under some plausible futures.
  - Taking this further, there can be strong incentives to invest in gaining better information before commitment – through research and possibly through project deferral.
- Consequently, incentives are created to defer major irreversible commitments to new infrastructure, where this can be safely done – even where this may trigger higher costs under plausible poor inflow conditions – if the infrastructure is not necessarily required under all plausible future scenarios.
  - Effectively this involves moving back from optimising the strategy for dealing with the worst case scenario, and instead focusing on strategies likely to involve lower cost, averaged across the range of uncertainties, but subject to the requirement that the worst case scenario can still be managed affordably.
  - A key example of this approach is creating the opportunity to defer project commitment by planning for a higher capacity project, capable of rapidly recovering production lost as a result of deferral. If such a strategy boosts the prospects for being able to defer the project for a long time, it can prove highly cost effective.
- Again for related reasons, there are strong incentives to design for the use of smaller, but potentially highly scalable, projects rather than deterministic commitment to projects of a fixed scale.

   - This can be highly cost effective, even where the costs of designing and building for scalability are substantially – especially if projects can be scaled up much faster than new projects can be implemented.
- Incentives to consider the potential economic benefits of *adaptive use of new system investments*, such as desalination plants, even once built.
   - This can provide powerful options for managing risks of overexpenditure by allowing for reduction in costs (even at the expense of a rise in unit costs of production) in circumstances where inflows prove better than the worst case scenario assumed. The Sydney desalination plant has been explicitly developed with the intention of using periodic mothballing as part of a cost effective operating regime – even recognising the real costs of mothballing.
- In relation to water supply systems, the use of such an approach almost always has implications for the optimal form of the restrictions regime – with it no longer being sensible to work with restrictions regimes based solely on physical volumes of water in storage.
   - Clearly the ability to bring mothballed desalination capacity into production should *allow for safe levels of storage in dams to be reduced* because of the contribution to system security provided by the mothballed capacity.
   - Similarly, desalination or recycling plants *under construction* will normally imply *lower safe dam level trigger points.*
   - Even *readiness strategies*, entailing the ability to commit to and then deliver a new project fairly rapidly, can allow for safe rundown in dams to *lower levels than was previously safe.*
   - Triggering new commitment to investment because of unacceptable levels of restrictions without reviewing the implications for efficient restriction triggers of projects being built and of projects that could be built quickly would be fundamentally biased towards excessive expenditure.

It is plausible that most, if not all, of these incentives should apply to water procurement strategy in WA. Much of what follows involves the consideration of these matters in relation to the requirements of a sound framework for procurement planning.

3 Initial comments

3.1 Key issues

Source procurement strategy involves dimensions of *which source* on *what scale introduced* to the system *when* – and of the *operating regime* then attached to the new source as part of the total supply system (recognising that its introducing will usually have implications for the operating regime applied to other supply and demand management components of the while system. The dimensions are not independent. As timing shifts, the most cost effective source, as well as scale of source, can also shift. Indeed, in a growing system choices between a small source early and a larger source later can be real, for reasons flagged in Section 2.2 above. This does mean that sound and cost effective procurement strategy cannot generally take the form of identifying the next source and then simply managing the timing of introduction, based on demand trends and the status of the existing sources.

Water source procurement is just *one of the range of instruments* available – to system planners and/or market participants – in seeking to ensure a sensible and cost effective 'supply-demand balance'. This needs to be done in the context of volatility and unpredictability in both demand and actual supply capacity, and where supply side investments in capacity (recently characterised in WA by desalination plants) are generally fairly lumpy in nature, involving significant steps in *capacity* rather than smooth growth, though often with scope for further scaling up.

This lumpiness is less inherent in some options for managing demand and this potentially has important implications for procurement strategy, suggesting as a bare minimum that a blend of demand and supply-side measures is likely to continue to be better suited to dealing cost effectively with these uncertainties than would a pure supply-side strategy. This is even before taking into account the rising unit cost of system augmentation and the implications of this for the competitiveness of some demand-side measures.

However, there is also scope for delivering flexibility on the supply side that allows for a smooth transition of rising costs associated with increasing access to earlier water. This is particularly true of desalination plants or other forms of augmentation involving high operating costs and can be true of the patterns of operation of the entire system more so than of specific new introductions of extra capacity.

- The presence of short-run flexibility in the rate of extraction from some groundwater sources – even allowing for extraction at rates considered likely to be unsustainable in the longer term – can afford flexibility to defer large new capital investment;
  - Reflecting the comments in Section 2.2, this scope for deferral may have high option value, especially if it provides time in which to assess whether the new capital investment is really needed early.
- Similarly, it is possible to build desalination plants that are scalable in capacity by adding additional modules, providing that inlet and outlet pipe structures have been suitably sized – with some flexibility of this kind being built into the WA desalination plants.

- It is also possible, as was noted earlier and as has been announced in respect of the Sydney desalination plant, to plan for *operating the plant intermittently* – deferring or avoiding operating costs (including any environmental impacts) and under some circumstances this can be highly cost effective.
  - The value of such deferral does not depend solely on risks of dam spillage – as has historically been frequent in Sydney – the opportunity cost of incurring expenditure earlier than later proves to have been necessary can be high enough to justify substantial deferral in this way.
  - The nature of climate change uncertainty in WA, including *possible* climate futures in which, with the two desalination plants there could be a surplus of supply capacity for a significant number of years, again supports the view that the gains from deferral could be substantial.
- Procurement strategy has elements of *quality* as well as *quantity* – and this is again sometimes better viewed as a portfolio, rather than source characteristics question.
  - For example, water quality concerns with sources such as Wellington Dam, with moderately high salt levels, might be addressed most cost effectively through blending with another source to increase the flexibility offered by this established source.
    - Again, it is possible to imagine circumstances in which this could in turn allow the avoidance or deferral of the costs of introducing a larger new source to the system earlier.
  - Reliability and security of supply are additional quality elements commonly of substantial value.
    - Recognising these dimensions as *separate from volume of supply* has proven in several other jurisdictions to be key to the development of efficient procurement strategy, as is discussed further in Section 4.2 below.
- Bringing a new supply source into the system can have the effect of limiting or extinguishing possible future uses of the same source.
  - Transfers of constrained ground or surface water sources from one region to another will raise concerns for the loss of future supply options this could entail for the source region.
    - There can also be concerns where the water is being transferred between sectors – for example, from agricultural to urban or industrial use.
  - Contracting for renewable energy sources as part of a strategy for managing carbon emissions or other environmental impacts will tend to 'cherry pick' suitable sites for the extra generation, extinguishing options for using these sites as part of the supply of wider energy needs in the future.

- The effect can be to push up the future cost of low carbon electricity as a substitute for the existing load by effectively bringing forward the electricity 'merit order".
- Whether this effect is big or small will depend heavily on the nature of the specific merit order – but there is a real opportunity cost – cost of extinguished options – that belongs within the assessment framework.
- Energy pricing that is reflective of this impact on the long run marginal cost of forward energy supply could address this concern directly.
- However, it is arguable that there is currently a mismatch between a water procurement strategy that is required to avoid significant carbon emissions in its energy supply and an electricity market strategy that does not at present factor into pricing carbon emission costs comparable to those driving the water strategy. The two 'procurement markets' are essentially being operated under different valuations of carbon emissions.

3.2 The Water Corporation Proposal

Water Corporation's proposed approach – based on the limited detail so far provided – addresses head-on a series of legitimate concerns with water procurement processes. It recognises that the sound engagement of a competitive market in supply requires commercially attractive processes and incentives. It recognises the need to deliver system solutions – within complex systems – rather than stand-alone projects.

In particular, it provides a process within which any proposed augmentation projects *can* be assessed for their implications for the whole of the system. This is crucial – serious inefficiencies in procurement can, and frequently have, flowed from a planning approach that focuses too heavily on project economics (costs per litre of water delivered from the project) rather than system economics (incremental system cost, implications for forward ability to meet demand and associated risks of either or both of restrictions and the need for further augmentation investment.

Whether the process actively encourages such assessment in a sound manner would depend in part on how Water Corporation expressed its forward requirements. Water Corporation has indicated that it would specify output requirements rather than project form, encouraging competition in ideas to meet this requirement. However, the form of such specification could still play a major role in shaping the types of ideas to come forward – and in shaping the forward economics of water supply. Getting this right imposes strong requirements on the form of the *system assessment processes* that Water Corporation uses and would propose making available to prospective tenders.

For reasons discussed below, we see a potentially serious risk that Water Corporation's output specification takes the form of so many gigalitres of additional supply by a certain date. Additions to supply constitute one of the means of meeting system supply-demand requirements but they are not necessarily the most cost effective way of doing so. A mix of methods can be far more cost effective.

In many cases, there is *technical scope* for substituting between early availability of extra supply and later capacity to deliver a greater level or rate of supply – while still meeting system security and reliability requirements. Whether such substitution is appropriate depends in the relative economics of alternative project opportunities and on the characteristics of the risks to be managed – including climate change risks.

3.3 More general comments

It is unlikely that source procurement processes will ever sensibly be reduced to a 'black box' churning out next increments to the system. High levels of judgment can be expected to apply well into the future, with political, social and environmental as well as economic dimensions. Planning frameworks can be expected to need the capability to bring forward a range of options and associated assessments, and to identify the consequences of changes suggested by wider processes. The same frameworks are likely, nonetheless, to be well-placed to help guide these processes with a better understanding of the true costs, benefits and risks associated with different approaches.

Source procurement strategy cannot logically be separated from demand management strategy as long as the primary concern is with supply meeting demand in a cost effective manner. There can and should be crucial interplay between the entire 'portfolio' of options to better meet demand in the future, with supply-side options being a subset of all options and with the near certainty that a mix of measures will offer the best outcome.

That said, high level procurement planning needs to be tractable, and this will probably involve continuing with some simplifying assumptions. In most jurisdictions we have worked with, high level procurement planning looking several years ahead is typically simplified by focusing on 'worst case scenario' assumption and ensuring that the procurement strategy is capable of dealing with such scenarios. This is a vital part of sound risk management in relation to such an important service.

Difficulties can arise (and have arisen) where these analyses and comparisons of *patterns of investment needed in a worst case situation* become interpreted as the appropriate and safe pattern of forward investment in all circumstances. A lot of the discussion that follows is related to this distinction.

Again, there is a growing awareness amongst water system planners and utilities of the potential for large cost savings, without sacrifice of security, through the development and management of more flexible supply and demand management strategies, especially those that exploit the flexibility inherent in modern water factory technologies, including desalination plants. While awareness is growing, translation of this into the formal planning frameworks is still at a relatively primitive stage in most jurisdictions.

From the perspective of an economic regulator, the potential for better planning methods to deliver significant cost saving, provided the primary objectives of the planning can still be met, is of obvious interest – and goes to the heart of the question of efficient costs of water services. This remains true even where there are market or policy driven requirements in respect of system security.

In an emergency response setting, in which there are looming short term concerns for system security or acceptable reliability levels, priorities will naturally shift towards response to worst case scenarios – but the planning framework should not. A sound framework will recognise and allow for a change in strategy as short-term threats emerge. However, it should do so within a consistent approach to planning in which the main consequence of the emergency setting is to impose fresh constraints on technically feasible options and possibly, as has clearly been the case in SW WA, to challenge the confidence attached to key assumptions regarding future hydrology patterns.

4 The basic objective & challenge

For the moment we separate the discussion from any explicit consideration of overall market structure and competition. We consider the question of what the purpose of source procurement is – or how the objective might be formulated – and the nature of the complications that might impede it being pursued, even by a central planning process. Interactions with market structures are discussed later and are the subject of separate studies commissioned by ERA.

4.1 Why the demand to procure more supply?

Demand for additional water source supply can arise from a range of factors:

- Growth in demand for consumptive use, through population growth or through the emergence of more water intensive usage patterns.
  - Or through growth in demand for supplementation from piped supplies because of lower access to natural rainfall supplies due to short or longer-term demand patterns.
- Reduction in 'normal' levels of supply – of availability of safely sustainable supply from existing systems – as a result of improving knowledge in respect of those systems, associated hydrology and ecosystems.
  - Possibly converted into changed regulatory requirements – for example in respect of river flow regimes.
- Reduction in 'normal' levels of supply as a result of structural shift in hydrology, through climate change trends.
- Changes in the preferences/demands of water users and/or political processes in respect of water supply reliability or quality
- Development and implementation of more sophisticated processes for risk management planning, particularly in relation to risks of structural shifts in key drivers of supply pressures.
  - Of particular importance here is the emerging recognition of the role of modern options-based approaches to investment where there is a high level of uncertainty in guiding more cost effective source planning.

It seems likely that all these factors are present in WA. In several regions, there is strong population and demand growth. Environmental management and regulation is evolving, with particular relevance to the sustainable management of groundwater systems. There is growing acceptance, based in actual experience as well as climate change modelling, of a substantial shift in climate patterns in WA from about the mid-1970s, with growing concerns that the more recent patterns over the last decade could represent a significant strengthening in the trend towards drier conditions. Community experience of several years of restrictions on water usage have led to more detailed specification of tolerable levels of restriction, and to a strong emphasis in WA water planning on avoiding the need for total sprinkler bans. More sophisticated planning methodologies have been developed and are already under serious consideration, including by Water Corporation – including through its participation in a current study by the Water Services Association of Australia of the potential role of real options methods in utility planning processes.

Of course, these pressures for supply augmentation also involve pressures on demand management. With incremental system augmentations generally growing in cost, the cost effective level of investment in demand management can be expected to rise – and the challenge is probably better seen as one of managing the cost effective evolution of both sources and demand management.

Recognising this point is crucial to cost effective source planning. Ideally, supply augmentation and demand management options would be assessed for the combination that delivered desired service functionality at least cost – noting that demand management results in different demands on the service function.

In practice, source planning has tended to involve assumptions regarding per capita demand trends with source augmentation being used to fill any remaining gap over time between supply and demand projections. This is not a true optimisation process. The marginal cost of source augmentation should be a critical determinant of the level of demand management – just as the marginal cost of demand management should influence the supply augmentation requirements.

4.2 Water supply vs supply security

There is a crucial distinction to be made between demand for the *supply of water* and demand to *secure the supply of water*. Historically, the distinction was less relevant, for reasons that relate to the then feasible options for meeting water demands. However, recent developments, especially in relation to desalination and large-scale recycling projects imply that the distinction is now crucial to sound procurement planning – and this need has been intensified by the emergence of climate change uncertainty as a new factor in supply planning.

Failure to take the distinction into account will typically introduce a bias towards excessive expected (ie, probability-weighted) cost in procurement – though the extent of such bias is heavily influenced by local features, including the rate of population/demand growth and the severity of any climate change and severe drought outlook.

4.2.1 Predictable demand and availability

Consider a stylized water supply system in which *demand is growing steadily* and predictably and demand is to be met through the *construction and operation of desalination plants of fixed capacity*. In such a world, procurement planning would be quite straightforward:

- Commitment would need to be made to each new desalination plant to allow it to come into operation in time to keep up with demand growth.
  - Supply capacity would follow a predictable 'step function' pattern, with the requirement that supply capacity always exceed the growing demand.

- The first plant to be built would be the one offering the fixed increment in volume at least cost – and others would be brought in line with a cost-based 'merit order', timed to match growth in capacity to growth in demand.
  - Subject to adequate coverage of any engineering risks, each increment would be introduced on a 'just in time' basis, recognising that earlier commissioning and operation allows for the accumulation of extra water in storage (deferring the time till future source procurement will be needed) but brings forward both capital and operating costs.

Of course the presence of rising costs with each increment could be expected to translate into rising user charges – with implications for demand growth that should be factored into the planning – and this information on rising incremental costs of supply could lead to progressive reassessment of optimal levels of investment in demand management and pricing.

However, in principle, the procurement task would be relatively straightforward. In this system, the *risks of inadequate supply capacity* are effectively managed by introducing predictable increments to capacity, matched to the predictable increments in demand. The *risks of incurring unnecessarily high investment costs* are also managed by the process – through choice of least incremental cost expansions, timed to come into operation as needed.

In effect, adequate supply and supply security objectives are met by the same process and in theory risks of under- and over-investment can both be managed virtually down to zero.

4.2.2 Unpredictable demand

Unpredictability in the rate of growth in demand would not add to the complexity were it not for the inevitable lead times between commitment to construction and commissioning of a new plant. However, given that these lead times are real – a new desalination plant for Perth takes approximately 2 years to build – uncertainty in demand growth does result in a separation between *augmentation definitely needed to meet demand* and augmentation needed to *secure the ability to meet an uncertain demand.*

For example, suppose that growth over the next 5 years will be either 30GL/annum or zero. The system currently has 30GL/annum of excess capacity, based on past planning and the fact that a new plant has just been commissioned. What is the optimal augmentation strategy?

If a decision needs to be taken now, and it is essential that demand be met, then that decision requires commitment to deliver additional capacity to be available 5 years out. It is not known if that capacity will be needed – but the demand for supply security requires the commitment to a desalination plant.

However, if it only takes 2 years to build a plant, then it may be possible to defer the commitment by up to 3 years – indeed it would definitely be excessively costly to build earlier than that. If these 3 years would allow the uncertainty in demand growth to be resolved, then the procurement problem is again relatively easy. If the uncertainty persists beyond 3 years, then a decision would need to be made to procure extra water, even though it may well emerge that the extra capacity is not needed that soon. There is an *unavoidable risk* of *either* being unable to meet demand *or* of incurring supply costs that prove to have been incurred earlier than was, with the benefit of hindsight, necessary to meet demand.

The key thing is that the commitment to build *was necessary to secure supply capacity*. The commitment to the new plant involved the *purchase of system security*. It would be quite inappropriate to look back on the investment and to say that the money was wasted – just as it is inappropriate to look back on an accident-free year and conclude that the car insurance was wasted. Insurance buys security – and there is demand for security as well as for actual water out of the tap. If there is not, then imposing a constraint that requires the system to be secure would be highly inefficient as it would involve excessive costs.

As a general rule, demand trends at least several years out are likely to be fairly predictable under the assumptions here, where inflows are reliable. This need not be the case under more realistic circumstances developed below – where drought restrictions may have been in place for several years and where there is real uncertainty about how far and how fast demand will bounce back if restrictions are lifted. This is, in fact, a key issue in supply planning by several Australian jurisdictions right now. But for moment, assuming steady supply from desalination and now variable usage restrictions, managing demand uncertainty in the short- to medium-term should not create major difficulties.

However, uncertainty regarding longer-term demand does have implications for capacity planning in this world. It may well challenge the assumption that the scale of new plant should remain at current levels – *even if that scale of plant offers the lowest unit costs of production*. The opening up of the electricity market, and the resultant effect in both increasing the volatility of demand as seen by individual suppliers and in reallocating the risks of overinvestment, has led to a fundamental shift in the scale and composition of new entry into the electricity market. These changes have strongly favoured moving to smaller increments of capacity, typically involving *higher unit cost plants*, because of the greater flexibility offered to manage the risks of overestimating longer term demand. The economic gains from using such a strategy, with greater flexibility to limit costs in the event of demand not rising as high as had been expected, can be dramatic.

Carrying this thinking into water could favour reliance on smaller increments in demand or, if this is not feasible or proves substantially more expensive, may place greater reliance in demand management measures better suited to dealing with smaller increments.

This notion of adopting a procurement strategy that focuses on flexibility to deal with uncertainty is central to the ideas developed below.

4.2.3 Unpredictable availability

In most Australian supply areas, especially where there is a large established population base, demand uncertainty tends to be small in relation to uncertainty about inflows in to dams, rivers and groundwater systems. Setting aside for the moment climate change concerns, the dominant factor that has driven most procurement planning over the past century has been the need to deliver a system capable of providing secure supplies in a country characterised by periodic, and sometimes very deep droughts.

In rainfall dependent supply systems, normal planning has long factored in the need to invest in extra capacity to cover periods when inflows will be well below average levels for extended periods. Much of southern Australia has a history of reasonably severe droughts for a few years every decade or so – and rarer extreme droughts of the type seen around the time of Federation, in the 1930s-1940s and again now. These extreme droughts lasted 10 or more years and defined the capacity requirements for secure water supply planning even before concerns with structural shift in climate received their current attention.

In traditional dam-based supply systems, the only instruments for managing these inflow uncertainties were:

- Pre-emptive investment in dam capacity that, most of the time, would seem excess to needs – to provide a bank of water to be drawn on through such droughts;
- Use of drought restrictions to limit 'unnecessary demand' when the threat to security is greatest; and, in the same vein,
- Use of drought pricing – either explicitly, or through significant penalties for breaches of restrictions.

Water trading has been used in same jurisdictions as a way of limiting the costs of restrictions – by allowing limited water to move to where it has the highest short-term value – but this has mainly be in relation to non-urban supplies.

Any sophistication in planning for extreme drought, based on only 100 years or so of hydrological record., will quickly recognise the need to deal with the risks of a drought worse than any in that record. Again ignoring the climate change dimension for a moment, consider the implications of planning for supply in a context where two previous extremely protracted and deep droughts (notionally 1900 and 1940 say) have been recorded. What should be assumed about the sort of drought that needs to 'hedged' by the strategy?

Viewed in its simplest terms, it would be reasonable to conclude that there was probably about one chance in three that the next deep drought would be worse than either of the first two. Greater sophistication (discussed further below) might try modelling the chance form of individual drought events, given what is known of the underlying processes – inevitably producing plausible scenarios where there is a *worse drought than any recorded.* This is a key feature of most modern hydrology modelling, where efforts are made to identify the nature of the underlying stochastic processes and trends that drive the chance-related actual outcomes.

Planning for supply augmentation in this world is much more complex than the above simplified examples. Any strategy, based around *pre-emptive investment in capacity*, which guarantees supply all of the time (including during the hypothetical worse drought than ever recorded) can *almost be guaranteed to carry excess water virtually all the time*, and probably also actual supply greatly in excess of demand virtually all of the time.

This weakness is fundamental to the approach – pre-emptive, high cost extra investment to deal with an extremely rare event must have this characteristic. This is not a criticism if there is no alternative approach available – it simply becomes the necessary cost of adequate insurance – but it is a real cost.

Carrying a spare tyre and airbags in a car involves a guarantee of elevated capital and operating costs for the car, with only modest prospects for these items ever needing to de deployed. This does not mean they are not sensibly carried. The reliability of modern tyres for most users has allowed a rational shift to smaller and more compact 'emergency spares', despite their decidedly poorer functionality in the event of a flat tyre – but has not obviated the case for carrying a spare tyre.

On the other hand, insisting on always carrying a mechanic on board, along with full repair shop, is rarely justifiable even though there is a risk of breakdown where the presence of such facilities on-site would be welcome. The fallback of then calling the local automobile association and accessing an established network of tow trucks and repair stations is likely to be more cost effective, after weighing the risks, for most road users. There is a sensible *balance between pre-emptive and reactive investment*, that is influenced by the nature of the risks and the nature and cost of the options for managing the risks.

As with the example of demand uncertainty, recognition of the characteristics of the risks can lead to important implications for the cost effective form of investment. In particular, the uncertainty regarding timing and depth of these occasional severe drought events strongly favours strategies that:

- Diversify the supply system away from rain-fed supplies, even if this entails somewhat higher expected unit costs of production; and
- Very strongly favours options that are less pre-emptive – that can be introduced in response to drought conditions as they emerge.
  - This opportunity has opened up in a big way with the emergence of more cost effective desalination options.

These elements can greatly reduce the risks of overinvestment – by lowering actual supply volatility in the case of the diversification options and by lowering the likelihood of making a large investment many years ahead of need in the case of drought-responsive investment options.

Of course, if the system in which this uncertainty regarding inflows and supply availability arises is also characterised by very strong demand growth – for example as a result of population growth, then the costs of over-investment are naturally limited or hedged by the fact that the need for the extra capacity, for water as opposed to water security, will emerge in time. This can only reduce, not eliminate these costs but in some jurisdictions the effect can be very important. Perth supply is consistent with this.

4.3 Traditional supply planning approaches

For the moment, we set aside the complexities introduced by differences in the intangible characteristics of different procurement strategies. They are extremely important and we return to them later, but focusing on financial costs provides useful insight to the various broad approaches and how they compare under different circumstances.

Key elements in most traditional planning methods include:

- Development of demand growth projections – commonly in the form of a deterministic growth path, although increasingly this would be accompanied by at least some stress testing.
  - These demand figures will be inclusive of progressive demand management measures, typically resulting in some fall in per capita (unrestricted) demand, but often retaining some rise in aggregate demand.
- Determination of criteria defining the boundary between acceptable and unacceptable levels of system security and reliability; e.g.:
  - Avoidance of the risk of needing to implement a total ban on sprinklers, coupled with acceptable long run frequency of lesser

restrictions (approximating the approach currently taken to reliability planning for Perth supply);

- Ability to meet restricted demand under any repetition of historical rainfall patterns.
- No drought restrictions required at least (say) 95 per cent of the time (possibly with accompanying schedules for the acceptable frequency of deeper restrictions), and chances of the system failing in the sense of there being inadequate supply to meet even the restricted demand being less than 1:8,000 over the next 30 years based on the creation of 'stochastic replica' of past rainfall pattern;
  - These replicas are based on the assumption that past underlying patterns of rainfall persist, but allow for random variations that can create deeper and longer droughts than have so far been recorded.
- Ability to meet restricted demand under an assumed 'worst case scenario' – commonly developed on the basis of the worst year, two years or three years ever recorded, repeated several times;
  - This approach can generate much drier extended runs than would normally flow from the preceding method, though it generally loses any naturally linkage into probabilities.
  - Typically it does not include the worst conceivable case in the sense on no more rain.

- More recently, there has been a need to introduce into the planning a climate change scenario or set of scenarios;
  - Planning in SW WA has recently largely been based on the assumption that a repeat of the last 30 years of hydrology (which was typically drier than the average over the full rainfall record) is a 'best case scenario' and that repetition of the last 9 years reflects a 'worst case scenario', although the past 6 years is also now being used.
  - In other jurisdictions where there is a significant risk, from climate change, of drier future years, the full hydrology record (typically about 100 years) has commonly been retained, but rainfall levels prior to the present drought are sometimes scaled down by a figure reflective of more recent rainfall patterns – either as a base scenario for planning or as part of stress testing of strategy.
    - Replicas are then commonly created by rotating the start year for the series – a device that retains the year-on-year correlation patterns that are linked into severe drought events, but that does allow for bringing forward the timing of severe drought events within the series.
    - SW WA has arguably experienced climate shift earlier and more severely than other jurisdictions and this helps explain the earlier shift towards rejecting the early part of the hydrology record – essentially viewing it as inapplicable to current forecasting. We are

aware that, with continuation of the drought across much of the country, some other jurisdictions have been looking with increasing interest at the approaches that have been developed in WA.

- Development of a suite of options that appear technically feasible and that would allow the reliability and security objectives to be met over time.
- Shortlisting the options to those offering lowest incremental system costs.
  - Typically interpreted as the lowest *levelised cost of system augmentation*, inclusive of capital and operating costs, which should equate to the lowest long-run marginal cost.
  - Most commonly, this is based on the lowest cost under the assumed worst case scenario for planning purposes or some other fairly *conservative scenario* for forward planning purposes.
    - In a WA setting, these appear analogous to the recent 6-year and 9-year hydrology experiences.
    - Crucially, planning appears not to be directed at minimising expected costs, averaged over the range of plausible possibilities.
  - For reasons discussed later, the logic behind this approach appears questionable;
    - the rationale for planning to ensure the worst case and conservative case scenarios are covered and that the associated costs would be affordable seems clear; but
    - the case for seeking to minimise the costs of managing these scenarios before it is clear that the worst case or conservative scenario is either correct or even highly likely is far from clear and would appear to be in conflict with normal risk management and economic planning principles.
- Finetuning the options to allow delivery of any further cost reductions within the reliability and security constraints.
- Producing, as a result, an indicative 'merit order' of projects and timeline for introduction.
- Modifying actual timing of commitment to the next project based on actual system status – possibly deferring the project if there have been good rains and some system rebuilding, for example.
- In circumstances where short-term outcomes prove substantially worse than the range of possibilities that had been allowed for in the planning – a situation that has now arisen in a number of jurisdictions across Australia as a result of the combination of climate change patterns and the worst drought on record in many places – switching into emergency response mode.
  - This can involving moving right outside the previous merit order, and consideration of options – including some not previously considered –

on the basis of volumes that can be accessed quickly enough to avert a major system failure.

- Project cost, and even implications for longer term system costs, tend to take a secondary role until it is clear that there are enough feasible options to deal with the now perceived threat. The rationale for this will generally rest on the assumption that a major system failure of extended duration would entail much higher costs.
- In this emergency mode, previous requirements in terms of system reliability usually go and environmental constraints – such as river flow regimes – are frequently relaxed on-the-fly.

A key feature of the modelling done to support the development of the procurement strategies has been that little if any flexibility is formally taken into account in respect of the commitment to and construction of new projects. Basic investment in the system supply capacity sufficient to deal with future inflow volatility is required to be sufficient to deal with the assumed worst case scenario.

There will be flexibility in demand measures – via formal modelling of usage restrictions, with explicit trigger levels. There is sometimes flexibility in respect of operating regimes – for example, a regime to pump water from one catchment to another may be subject to operational triggers; whether desalination plant is operated can also be subject to operational triggers (as is proposed for Sydney); and in all significant systems there will be reasonably sophisticated modelling of how the general system is operated to meet demands across the system, to mitigate risk of losses from storages prone to spillage etc.

4.4 Stochastic vs deterministic methods

Most of these methods involve some probabilistic or stochastic elements. For example, they may involve simulation to verify the frequency of restrictions – selecting only strategies that offer acceptably low frequencies. The identification of different climate change scenarios has some probabilistic elements in it – but commonly there has been a reluctance to attach actual probabilities to different scenarios. The result is an emphasis mainly on 'worst case scenario' optimisation.

In effect, the methods tend to assume a level of randomness in short run climate outcomes – such as the timing of droughts. Typically, the planning is predicated on such short term uncertainty being handled through the application of usage restrictions, and accepts that the strategy will have associated with it an acceptable *probability of being in restrictions* of various forms.

Historically, supply augmentation for most major urban supply systems depended on the construction of dams and on enough rain after the dam was constructed, and before the water from the dam was needed, to maintain the security of the supply system. Such strategies relied on *large, pre-emptive investment decisions*. Commitment to construction of a new dam is rarely an effective response to a current drought – it represents a response to the threat of a serious future drought.

For ease in understanding the key issue here, consider a situation in which the only uncertainty relates to the climate change scenario and there are two candidates for future climate:

- a 6-year scenario in which the last 6 years of rainfall correctly characterise future patterns; and
- a 30-year scenario in which the patterns over the past 30 years correctly characterise future rainfall patterns, including extreme drought, but also including many years of better rainfall – though still substantially below levels recorded up to the 1970s.

We understand that these two scenarios – if only we knew which – would imply very different forward procurement strategy for SW WA. Under the 6-year scenario, the existing system will move quickly to a point of significant unreliability – characterised by about a 13 per cent chance of total sprinkler ban by 2010/11. On the other hand, under the 30-year scenario, the short- to medium-term prospects for a total sprinkler ban would be almost negligible.

Superficially, this suggests that, if only we knew the reality was the 30-year scenario rather than the 6-year scenario, it would be possible to defer, probably for many years, the need for the Southern Seawater Desalination Plant (SSDP) – that its construction would deliver an asset not needed for many years, involving a substantial capital cost and an on-going operating cost if it were not possible to 'mothball' the facility.

Current planning involves the SSDP being contracted by mid-2008 and coming into production around the end of 2011, with this having the effect of virtually eliminating the risk of a total sprinkler ban in the following year. This provides a rationale for considering commitment to the investment, as insurance – but does not in itself build a total case for such investment.

First up, it should be noted that the cost of the insurance via commitment to the SSDP is potentially high – estimated in May at $955m capital cost. If there were a substantial chance that the 30-year scenario in fact applies, then this would be very expensive.

The plans to operate the plant continuously, using renewable energy, imply a substantial additional cost, though in principle some of this is likely to be technically avoidable – from a utility and end user perspective, the level of operational flexibility and scope for avoiding cost is likely to be linked to the nature of the power contracts. The option to redeploy some of the renewable generation capacity, in the event that continuos supply proves unnecessary, could limit the costs. The aggregate unavoidable cost once committed is, unambiguously, high. Would it be justified?

If the new plant is indeed the least cost way of covering the 6-year scenario risk, the investment might well be (though would not on this basis alone be) justified. A number of questions need to be addressed in reaching this conclusion:

- What is the likelihood of the 30-year scenario applying rather than the 6-year – is there a substantial severe drought element to very recent conditions as well as structural change, or is it all structural change?
- If the 30-year scenario does in fact apply, what are the chances of enough system restoration between SSDP commitment in mid-2008 and commissioning perhaps late 2011 for it to be clearly excessive investment by the commissioning time?
- Why the assumed 3+ years from contracting to commissioning, when Water Corporation has argued in its response to the ERA Discussion Paper that 2 years is sufficient?
- What if contracting were delayed – say 12 months – what are the chances that this would allow for significant further deferral of the project because of useful system restoration and possibly growing confidence in the 30-year scenario?
- If commissioning were delayed by such deferral, would it create greatly elevated risks of needing a total sprinkler ban, or would the knowledge that the plant would soon come into operation be enough to allow the triggering of the total sprinkler bans to be deferred.
  - More generally, do the current trigger levels for the total sprinkler ban adequately take account of the value of the water that will be available from the time of commissioning?
- Would planning for an even larger plant allow the contracting date to be shifted even further out, again lowering the prospects of needing to contract at all?
  - Is it possible that planning for a larger plant to be commissioned later could actually involve lower expected cost? Theoretically, it could.

These questions illustrate how comprehensive acceptance of the probabilistic nature of the problem could lead to very different strategy from an approach based on a decision to accept a particular climate change scenario and plan around that – even if that strategy is accompanied by some adaptation in the commencement timing for the investment. As long as the forward scenario is locked in, it does not focus on the question of whether a strategy that could prove higher cost in dealing with the one plausible, even worst case, scenario could actually be more cost effective in the way it manages climate change uncertainty – including the risk of over-investment.

4.5 Comparing sources – merit orders

The discussion above indicates that merit orders for procurement are usually developed based on estimates of forward levelised cost, which we noted should equate to contribution to long run marginal cost of supply. Conceptually, this is appealing. However, there are serious problems with how the approach is typically implemented. Included here are:

- Where the planning is based on an assumed conservative (low rainfall) scenario, the associated cost impacts will almost always be biased upwards, in the sense of suggesting the need for costs greater than the average costs which will actually emerge.
  - This need not in itself be a major problem, as long as the same scale of bias is involved across all competing sources, and actual strategy and price implications are allowed to adapt to the true outcome, rather than this conservative planned outcome.
  - However, the biases across different sources are almost certainly not consistent for any system of reasonable complexity, with competing classes of augmentation options. The variations can be very large.
  - In other words, if the same exercise were to be repeated with a less conservative scenario – for example, an assessment of the median or most likely scenario – it is highly likely that the sequence of projects would change, not just their timing.
  - We set out later some illustrative case studies that make this point strongly, and show how the differences, and the implications for expected costs, can be very large.
- In practice, merit orders have usually been developed based on examining the project-level levelised costs of alternatives projects to deliver additional water. These levelised costs are often (almost always) not assessed on a consistent basis:
  - Additions to system storage capacity are commonly converted to a unit cost based on the increase implied for sustainable system yield, using the now well-developed tools for modelling performance of a dam-based supply system.
    - These calculations will usually and appropriately, allow for risks of dam spillage, that has the effect of lowering the volumes available relative to inflow levels.
    - In some systems, implications for spillage anywhere in the system may be allowed for, depending on the sophistication of the

modelling done – any such implications are relevant to the calculation of the costs of additional supply capacity.

  … Water factory projects, such as desalination plants, are rarely assessed for the implications they hold for spillages elsewhere in the system – the levelised costs are usually based on volumes produced from the project over time, even though in some systems a high proportion of this production will effectively be lost from the system in the form of additional spillage elsewhere in the system. The bias from this can be very large in some systems – such as Sydney – but is likely to be smaller in systems such as Perth's where spillage, at least from the major storages, appears unlikely.
  … Similarly, demand management measures are typically costed on the basis of the level of substitution for supply from the potable system – for example, each litre saved by a low flow shower head is treated as a litre of additional system supply capacity, even though again system spillage can mean that the effective increase in supply capacity is less – substantially less in some cases.

  – These phenomena are real, and could be highly significant for some WA systems. The scope for seriously distorting strategy – both amongst source augmentation options and between source augmentation and demand management – would then also be large.
  – However, this bias seems likely to be modest in relation to Perth supply, due to the low propensity for spillage.

- Potentially far more serious, especially where there is a high level of uncertainty regarding future rainfall patterns – through either or both of chance droughts and climate change uncertainty – is the scope for serious bias as a result of poor alignment between the timing of when extra supply capacity is delivered and when the extra supply is actually needed to meet then current demand.
  – A large project might tap size economies to deliver 'lower cost' water into the system than would a small project, while being much more expensive as a system solution if the demand for the extra water is slow to emerge.
  – The reality of this effect for the electricity market – and the way that it has shaped procurement strategy in favour of investment capacity that is nominally higher unit cost than could be achieved in other ways through much larger increments – was recognised in Section 4.2.2.
    … There demand volatility and market share were the key drivers;
    … In water in WA, climate change uncertainty may be an even stronger driver of the divergence between levelised cost based on 'production' of supply and levelised cost based on incremental increases in water actually delivered to meet demand, though of course demand uncertainty is also a real feature, especially in regions

where commencement or closing of a major mine can make a dramatic difference to aggregate demand.

- There can also be a serious issue of bias because of uncertainty about future policy settings in respect of policies that have a major effect on shaping investment.
  - For example, most jurisdictions in Australia have not yet moved to accept direct potable reuse – return of treated wastewater to dam or groundwater systems – as an acceptable technology. There are both psychological and public health dimensions to this – though it is arguable that the public health risks of indirect potable reuse by households, a common and often much higher cost alternative strategy, are substantially greater. Nonetheless, it is appropriate that this technology be approached cautiously.
  - However, it also seems reasonable to argue that there is a good chance that the technology will become acceptable in the future – and possibly in the near-term. SE Queensland has already committed to its acceptance. It is quite possible that groundwater recharge, which is undertaken in a range of overseas locations, will prove acceptable ahead of return to dams.
  - Consider a rooftank or centralised indirect potable reuse scheme that is being considered and that, under current policy settings, looks to be a serious procurement option in the near term. It will involve substantial capital costs – tanks, dual pipes and plumbing etc – but assessed over say 25-30 years it appears competitive.
    - However, any decision to allow direct potable reuse in the next several years could have the effect of making a lot of this rollout investment look unnecessary – effectively stranding the assets. They would probably still be used, but the investment pattern would look decidedly expensive.
  - Under some circumstances, the same arguments night be applied to desalination investment, especially as its project costs rise with the need for greater integration expenditure (mimicking the integration expenditure needed for direct potable reuse).
    - The lower energy demands and treatment costs for wastewater relative to seawater (once captured at a treatment point) could challenge the economics of the desalination investment – effectively making such investments exposed to the risks of a policy change.
  - Risks, including policy change risks are real and cannot necessarily be avoided. However, serious propsects for a policy shift of this kind should in principle increase the competitiveness, as 'next cab off the rank' of projects with lower up-front commitments to capital costs, even if they have higher operating costs and through-life costs assessed on a 20-30 year basis. The risk-weighted costs may be a lot lower.

Reflecting these effects, it is *not possible to safely converge* on a sound procurement strategy by starting with an assessment of the relative ranking of projects on the basis of relative project costs and then adjusting the timing of introduction, starting with the lowest project unit cost and working up. Such an approach will almost certainly *not yield the lowest present value of necessary system augmentation* and operation over time – and plausibly it may prove to be seriously wrong.

In fact, while merit orders can be useful concepts to provide an idea of how the system is likely to develop over time, there is a flaw in the reasoning that assumes a merit order can be developed and treated as a dispatch order for procurement – when there is substantial demand and inflow uncertainty. The real merit order will actually be the outcome of the procurement planning process rather than an input to it – and the ranking of the projects as well as the timing needs to be a function of the way the inflow and demand scenarios actually emerge.

Unit cost-based merit orders can work well in areas such as electricity dispatch, from sunk capital investments in operating generation capacity. Here, there is high flexibility for individual generators to vary levels of dispatch and the primary need for thermal generators is to cover the short-run marginal cost of operation. This is not true for hydro generators, who must take into account loss of option value, in the form of water in storage, from current generation – but such generators are able to bid into a market mainly shaped by short-run costs of other generators. In relation to decisions on major system augmentations, the approach has serious deficiencies. This is despite the strong tendency for supply options, and demand management measures, to be described and compared in terms of project levelised cost under a steady state operating regime that cuts across the principle that the major reason why early augmentation is being considered is to ensure the *flexibility* to deal with plausible threats to security, rather than a guaranteed need for ongoing supply. Growth trends may imply a near-guaranteed future demand for the extra water – but the role of discounting in defining levelised cost and assessing future cost implications means that a lot of caution is needed where some plausible scenarios imply that growth, as opposed to security, demands may not arise for some years.

Importantly, the above points reemphasise the value of investment in flexibility, especially through deferring high up-front costs that may not prove appropriate given plausible future developments.

4.6 Procurement as a dynamic programming problem

The earlier comments regarding the need to handle political, environmental and social, as well as economic, dimensions remain highly relevant. The high levels of uncertainty remain a constraint on what can be done. However, it may be helpful to stand back and ask what the objective of a sound, economically based procurement strategy might be. Here we attempt to provide a formal statement of problem – recognising that the above constraints mean that actual implementation will be subject to a range of other processes.

We presume there is a broad interest in ensuring supply adequate to meet demand, with acceptable levels of security and reliability. We assume there will be a willingness to use drought restrictions or incentives (price or otherwise) as part of the machinery for achieving this objective – on the basis that occasional restrictions, or voluntary adaptation of behaviour to posted incentives, are likely to be cheaper than purely meeting all demand all the time (at least under current end user pricing policies). In most markets it is assumed that optimal outcomes involve movements in both supply and demand.

An existing water system seems likely to need to evolve over time to meet a mix of demand growth and climate trend, and it needs to incorporate the capacity to deal with plausible chance variations in rainfall and inflows – including periodic deep droughts.

We further assume the desire to avoid unnecessary costs, and to ensure that the costs are 'affordable' under all plausible scenarios. These costs should include intangible and user costs as well as supplier costs.

Given the earlier discussion (and the examples set out in Section 5 below) we need to allow for the fact that actual costs will not be deterministically set – actual patterns of investment and operation will be adapted in the light of then available information.

So an early question needing to be addressed is that of what is meant by costs and by cost containment. The normal literature of both economics and risk management recognises several approaches:

- Minimising expected costs – costs averaged across the range of plausible futures.
  - This would generally be the present value of the expected costs, discounted to reflect the opportunity cost of funds – and this concept is built into the practice of focusing levelised costs.

- Minimising the maximum exposure (minimax) – minimising the costs that would arise under the worst case outcome. Again these would normally be discounted costs.
  - For the reasons discussed above, this might be viewed as approximating the nature of current planning in a number of jurisdictions.
- Minimising expected costs, subject to the constraint that the worst case outcome is affordable.
  - Further refinement would allow for a damage function, rather than just a cost function, in which the level of damage rises as affordability becomes a problem – with the objective of minimising the expected damage.

The second of these is probably the easiest to implement and it is not surprising that variants on it are mainstream. It allows the difficult and potentially contentious judgments regarding the range of plausible futures and their likelihoods to be avoided – the focus is purely on the bad end of the range. It rarely in fact works with a true worst case scenario – such as the rain stop and stay that way – but instead operates with subjective devices for translating historical experience into credible extreme possibilities.

WA now relies heavily on stochastic manipulation of *very recent* experience – currently modelling based on the last 9 or 6 years. The prospects of such a short time series, within an extreme drought, being representative of the future range seems very small but as an approach to conservative planning it has some appeal given the detailed examination of climate trends that has occurred. Other approaches – such as endlessly repeating the worst 1, 2 or 3 years on record – have been used in other planning processes. As a device for planning very short term emergency response they have some rationale in conservatism, while still being highly subjective and usually highly pessimistic (taking into account the implied *chain* of apparently low probability events being used).

However, while these processes may make some sense as a way of determining a worst case scenario for planning purposes, the rationale for seeking to minimise these costs – or indeed the costs of any conservative assessment of future inflow prospects – is difficult to see. Logically, the other two approaches – expected cost minimisation (possibly with affordability constraints) or expected damage minimisation would seem far more defensible. The community has a broad portfolio of interests and could generally take the view that is risks are reasonably diversified – and the more this is true, the more it would favour expected cost.

If the task is seen as either *expected cost* or *expected damage minimisation*, then the problem is essentially a dynamic programming problem. The objective is to minimise the expected value of a time series function (present value of forward costs), subject to constraints and subject to uncertainty. If the nature of the uncertainty could be expressed mathematically, the problem becomes theoretically tractable. The focus of the solution will be on *decision processes* for implementing investment, *not on deterministic investments* over time. The task is to identify the decision process – the logic and rules that trigger what investment to bring in when (including regular updates of current status and forward options) – that satisfies the constraints under all scenarios and that delivers or at least approximates the *lowest expected present value.*

Real options principles introduce a further possibility to the range of objectives, in which the concept of expected value is recast to take into account the concept of probabilities adjusted for risk attitudes. In effect, it can imply modification to the discount rate (to a risk-free rate) and a change in the probabilities used – and these changes can be soundly grounded. This reflects the classic Black-Scholes principles for valuing and managing investments in financial options, and has been extended to include physical (ie, 'real') options.

However, we do not develop this extension further here – instead focusing on more traditional risk-adjusted, adaptive decision processes (including decision trees that have been used over many years). This approach can be more transparent and easier to communicate to key stakeholders, and can provide more natural and accessible insights into ways to improve the value of the decision process.

What the next section does is show how this admittedly theoretical discussion can be made very real to highlight potentially large biases in any planning process that does not, at least approximately, come to grips with some of these issues. It also points to the fact that it is possible to develop a decision process that does factor in major structural (and chance) uncertainties – at least to highlight the implications these have for sound strategy. Application of these approaches to real procurement challenges in other jurisdictions has led to the identification of large excessive costs being produced out of existing planning processes.

Some of the issues in relation to how such an approach might be embedded in a more competitive market setting are discussed briefly in Section 7 below.

5 Options–based procurement – Illustrative examples

To provide a more concrete feel for these concepts, the following sets out a relevant but highly stylised example of how risk balancing can deliver large benefits. It deals with the costs associated with strategy that entails a substantial risk of overinvestment as the means of securing supply. We start with a particularly stylized example, to illustrate the underlying principles, and then develop it into a more realistic example.

To set it in context, we are starting with the proposition that, under Water Corporation's 30-year scenario, no further system augmentation would be needed for some years. However, under a 6-year scenario, a substantial block of additional supply appears to be needed soon; the investment would be insurance.

Do we commit to that block, or is there scope for providing the insurance in other ways that limit the up-front and irreversible commitment to a big block of capacity that may not be needed? Logically, this could include:

- Accepting the risks of possibly needing to work key groundwater sources (such as the Nungara Mound) hard for longer than had been planned, but still only for a finite period – exchanging one risk for another by possibly allowing long term deferral of a large project.
  - Effectively, the strategy would buy some time during which new information may emerge to allow substantial deferral or change in the form of the investment strategy.
- Probing within a system options setting the range of flexibility options offered by the strategies recently identified by the Collie-Wellington Basin Water Source Options Steering Committee, in their report to the Minister for Water resources, for deriving greater value from the Basin water resources.
  - A key issue with these resources is a level of salinity that greatly limits usage flexibility.
  - The report identified a series of options for managing the salinity level – options that could emerge as far more attractive assessed in an options setting than in a project setting.
    - This appears more likely given the relatively low up-front capital costs, suggested in the report, for some approaches – to be compared with a desalination project with substantial irreversible capital cost that is again directed at a form of salinity management.
- Consideration, again within a system options setting, of the strategic function of expanded water trading – as a source of security and flexibility rather than as a long-term primary source of growth supply.
  - Our understanding, based on Water Corporation indications of likely costs – of the order of $1.50 *project* levelised cost for steady operation at about 20GL/annum (as cited by Marsden Jacob Associates) – suggests that it *might* stand up well, on a pure utility financial cost basis, compared to additional desalination.
    - The smaller scale, and the relatively low capital cost estimates (understood to be of the order of $200m in pipe costs) also suggest

possibilities for cost deferral and flexibility that would warrant exploring in a whole-of-system options setting.

We have not sought to model these possibilities explicitly. In the context of a discussion paper produced quickly, we have adapted some options modelling undertaken elsewhere to illustrate the key points and the potential magnitude of key effects, as they may relate to future augmentation decisions.

5.1 Illustrative example 1 – Flexibility vs nominal unit cost

Consider the following simplifying assumptions:

1. Inflation adjusted discount rate of 6 per cent.
2. A supply system faces one of only two possible hydrology futures:
   - There has been a once-off structural drop in inflows due to climate change, lowering average inflows from now on by 30% and triggering a medium-term need for supply augmentation to meet demand of 100GL/annum; or
   - There is a trend towards drier conditions, dropping average inflows by 30% across the next 30 years, and creating a need for average supply capacity to grow by 4GL/annum, leading to the same demand for extra supply 25 years out.
3. Two schemes are available for addressing supply augmentation needs:
   - One big project (recycling, desalination etc) that will deliver 100GL per annum of extra supply.
     - Capital cost of $1b
     - Operating cost of $100m/annum
     - Levelised cost of water delivered from the project of $1.87
   - A progressively scalable parcel of augmentation options, each component offering an additional 4GL of production of water, each with:
     - Capital cost of $60m
     - Operating cost of $6m
     - Levelised cost of water delivered from each project $2.81 (ie, 50 per cent higher than the big scheme)
4. The schemes can be implemented instantly, and the financial assessment is done over 25 years with no residual values – clearly a gross simplification, but it helps to make the point.

Note that these scalable projects[1] each involve unit costs, *measured relative to water produced*, that are 50 per cent higher than the single large scheme. It is possible that an extra 100GL per annum is needed 'immediately' – and if we knew this were the case, then building the single large scheme would make good sense.

However, if in reality the inflows are going to decline progressively, then it would be possible to address the rising need for water through progressive implementation of the smaller schemes – this package of schemes offers the option to delay and phase in progressively, in response to the emerging requirement.

In this situation, it turns out that the second scheme involves little more than half the cost (in present value terms) of the first scheme – meeting the supply requirement at a system cost of $859m less than that implied by building the large scheme. In this situation, one small scheme is brought in each year, to match the growing demand for water. Under these circumstances, the assumption of no residual values would be biased strongly against the use of the smaller schemes (it ignores the value of some near-new schemes 25-years out), yet the calculations still strongly favour these smaller schemes with much higher unit costs of production.

The source of these gains lies in the misfit, under the gradual decline scenario, between the timing of project costs and the timing of system needs. Large costs are committed early and most of the production is not needed for many years – rather like the old problem with needing to build dams decades before they would likely to be needed, in order to ensure they have water when the water is needed.

The extent of potential cost savings suggests it could be worth wearing a substantial additional cost, in the event that the climate change is really a structural shift rather than a trend in return for access to these potential savings. In a sense, it suggests the insurance against this structural shift risk might take the form of a policy with a high excess attached if there is a serious chance the policy may not be needed.

The *flexibility* inherent in the package of small schemes, includes the *options to delay* a lot of the cost elements. Because of this, it is possible to avoid the risk, inherent in the first scheme, of committing to a large, high cost scheme only to find that the system demand pattern does not match the new supply capacity –

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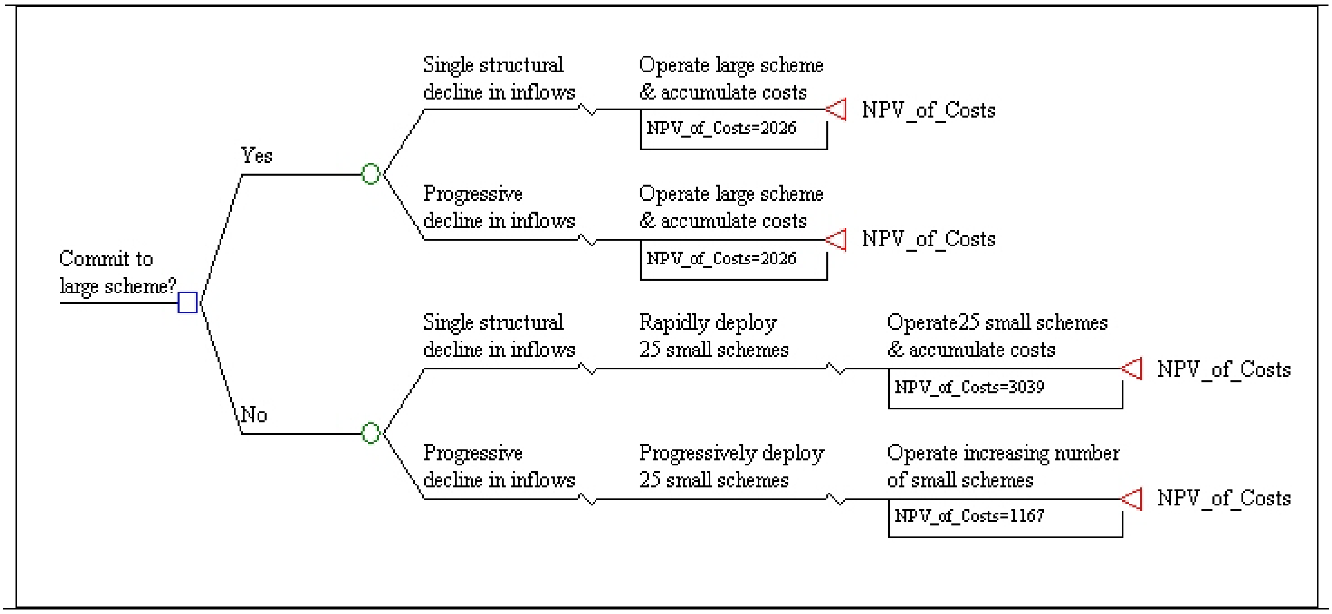
1 These projects are specified here as a homogeneous group of identical projects to demonstrate important principles. They are not intended to reflect specific options available to Victoria, where a more realistic characterisation would involve choice between a few large initiatives and a diverse mix of smaller initiatives spanning a range of approaches to reducing supply pressures.

the risk of overinvestment. The value in these deferral options lies in the assumed scope for determining how much demand there will be each year in time to roll out additional capacity if needed. It is possible to defer both operating and capital costs, and the benefits of this are appropriately accentuated by the financial discounting.

The problem lies with the chance the change is structural – and the need for an affordable fallback if the large scheme has not been committed. Under the simplified assumptions used here, the fallback could include later committing to the large scheme but wearing a risk of tighter constraints, or harder use of groundwater etc. It could also include the much greater flexibility to bring forward some of the smaller schemes – providing scope for dealing with intermediate scenarios..

The dilemma here can be shown graphically in a decision tree, as follows:

Figure 1 **Structure of illustrative options-based investment decision**

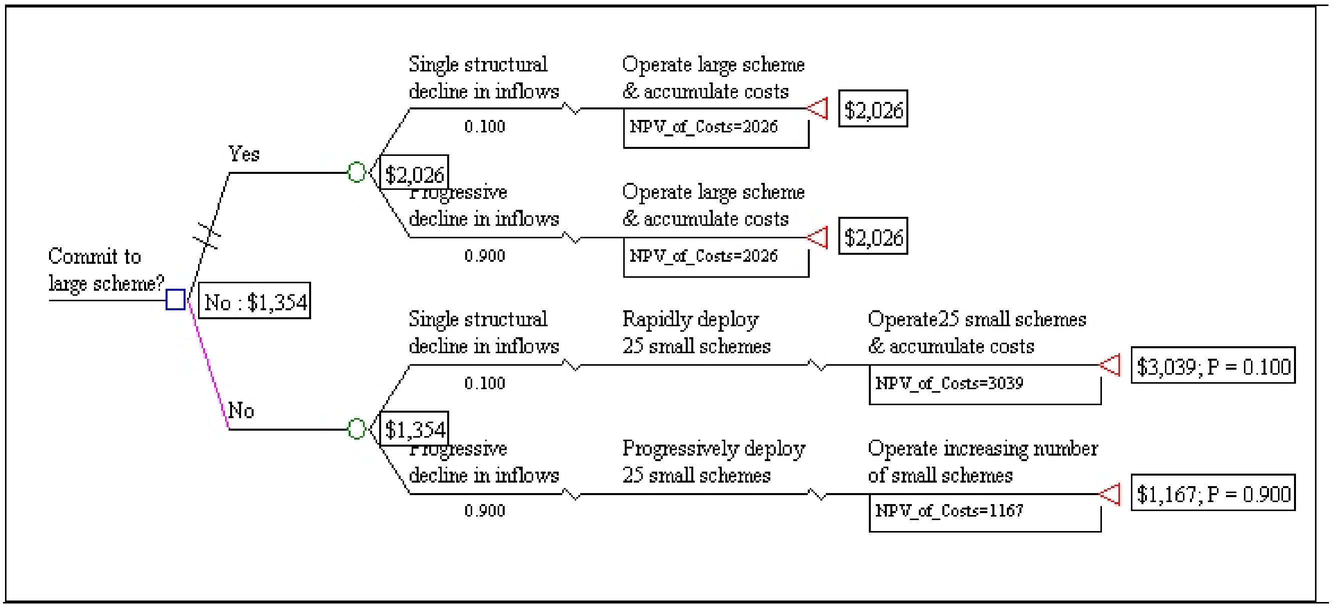


The challenge lies with an uncertainty to be resolved in the future regarding how fast inflows are declining, represented by the circle that splits into the two scenarios. Committing to the big scheme definitively deals with the supply uncertainty *and* locks in costs of $2,026m, the present value of capital and operating costs.

If, instead, reliance is placed on the small schemes, the pattern of investment and the cost is uncertain. It is possible that the costs will be almost halved and also possible that the costs will be higher – by 50 per cent. Whether this is a smarter strategy depends heavily on the likelihood that there has been the one major structural shift – the greater the likelihood, the more attractive the big scheme strategy.

If the objective were to minimise the expected (risk-weighted) cost of delivering a secure system, it is possible to assess the break-even probability of the single structural decline. If it is less than 46%, then the more flexible strategy based around small schemes outperforms the 'king hit' strategy. If the likelihood of this sudden, as opposed to trend, decline is low, then the potential savings are large and the risk shrinks rapidly. The following chart shows a solved version of this decision tree in the situation where we assume that the probability of a structural shift, as opposed to a trend decline by 30 per cent, is only 10%.

Figure 2 **Cost minimising strategy for options-based investment**



Under this assumption, the model shows an 'optimal' decision in favour of the progressive/flexible strategy, with an expected cost of $1.35b relative to the fixed cost of $2.03b for the alternative – an expected cost saving of $672m, for the same level of system security. It does involve a 10 per chance of paying more, and that could be interpreted as the cost of the insurance.

Another way of looking at this is that access to the flexible strategy creates *option value* for the planning process of $672m – an opportunity for a net saving of $672m. This figure is less than the $859m mentioned earlier – because of the non-zero possibility that there has been a large structural shift relative to the recent 30 year hydrology experience. As the likelihood of this structural shift rises, the net gains fall.

However, if there is a potential value, this raises the question of whether it might be worth investing, possibly investing a lot, in creating an option of this kind if it did not already exist. It is this process – of probing the possibilities for responding to threats, identifying scope for flexibility in managing costs, and opportunities for increasing the flexibility through strategic investment that lies at the heart of a sound procurement planning process. It is not a mechanical algorithm for ranking strategies, but rather a firmly based paradigm for exploring opportunities to better manage risks and to create greater value.

The two strategies are quite different – and not just in respect of expected costs. The 'big project strategy' is largely deterministic – easy to explain, every one can see where the water is coming from and how it meets demand in all circumstances, straightforward, if painful, to budget etc. The latter is far less predictable (in the more realistic case of ongoing uncertainty for several years), but the potential gains are large. The two cannot be separated – the very flexibility that delivers the expected cost savings also delivers the lack of cost predictability – however, it is quite reasonable to have a well defined process, even without certainty as to the outcome from the process, where that process can be viewed as highly cost effective.

This example provides a simple illustration of an options modelling methodology brought to bear on a planning problem. The model is well-defined and yields insights even if we do not know the probability that a structural shift has occurred. Having developed a model that captures the mechanism through which the flexible strategy might offer value, the same model allows calculation of the circumstances in which the flexible strategy might be preferred. This in turn creates a clear agenda for the ongoing planning process; in many cases it will prove a lot easier to agree on whether the probability is greater or less than a given figure (in this case 46%) than it will be to agree on a point estimate. The strategy may allow a robust conclusion in favour of, or opposed to, the large project strategy without there being any agreed probability estimate on the table.

This last point is important to the current processes – the nature of the uncertainties is very different from the probabilities that emerge from simple replication of past patterns, with past frequencies being used to infer future probabilities. One of the lessons of recent rainfall experience has been that past patterns can prove poor predictors of actual events. There is, and will remain for a long time, a lot of subjectivity in weighing these risks and likelihoods, and the approach we have used keeps these issues explicit and allows for robust decisions to be made even where there is a lot of remaining uncertainty – including about probabilities.

As an aside, it is possible to reassess the levelised cost of the single large project under the assumption of progressive demand growth – but to base the assessment on additional system demand supplied rather than water produced from the project – recalling that on the latter basis the levelised cost was $1.87/kL. Based instead on *incremental system demand supplied*, the levelised cost is $5.88 and this really is the better measure of the economics of the water from the project under this trend change scenario.

This is the price that would have to be charged for each kL of extra system demand satisfied by the scheme – and makes the point that levelised costs based around project output can be highly misleading when planning and ranking options. The comparable figure for the progressive roll-out strategy remains at its previous level – $2.81 – reversing the 'ranking' implied by the levelised costs. This comparison also drives home the point that the merit order for projects – the ranking as well as the timing – is heavily dependent on the scenarios, even if based on unit costs rather than incremental system costs.

5.2 Illustrative example 2 – Designing for flexibility

The above example is particularly stylised, in order to set down a basic methodology and to draw out some important messages about the potential value of flexibility. The example assumed that a once and for all time choice needs to be made, up-front, between the big, low unit cost of production scheme and a sequence of smaller increments.

If that assumption were necessary – so that a choice in favour of the flexibility would imply locking into high unit cost of production projects for all time – then a lot rests on what is assumed regarding the probability of a one-off structural shift vs a longer-term trend. The above initial assumption of a 10 per cent chance of the structural shift certainly favours strongly the small project approach. Indeed, the above analysis of the break-even value for this probability (46 per cent) may offer enough room to move. That said, in the context of an unprecedented run of extreme dry years, it would not be surprising to find people suggesting that the probability of the sudden structural shift is even higher than the 46 per cent figure, in which case the analysis is not fully conclusive.

As before, we would urge caution about being too pessimistic about trends from within what is likely to be a serious drought – even if one intensified by climate change. As was argued earlier, even without climate change, there would have been good odds that this drought would be worse than any previously recorded – because the record is so short, with very few deep droughts. If we add in clear indications of climate change, captured by assuming future patterns will at least reflect the last 30 years better than the last 100 years, then these prospects are greatly increased – without any assumption of structural change beyond that implied by working with the 30-year assumption. The modelling relates to the question of further structural change that implies that the experience of the past few years is more indicative of the future than is an assumption that there will be a progressive trend, over the next 25 years towards a further 30 per drop. This is not obviously excessively optimistic, if used as part of a decision process that effectively manages both possibilities.

In many cases, the choices need not be that stark – there can be scope for taking a middle path in a way that further improves the risk management – in the sense of lowering the risks of making a high cost commitment that proves unnecessary. This approach, where accessible, represents sound investment strategy and risk management, and can lead to a substantially more robust conclusion as to the best decisions to be taken early.

To illustrate this, we develop an extended version of the above options model, where this now incorporates the option to defer commitment to the large plant, at a cost. Not proceeding with the large plant now does not rule out such an investment indefinitely. Indeed, a key purpose of the options strategy will be to avoid excessive costs due to construction that is unnecessarily early, rather than the avoidance of such construction *per se*. In this case, there are plausible climate conditions in which construction of the large plant is likely to be cost effective – but there are potentially large benefits if it is possible to ascertain if such a future actually applies before making an irreversible commitment to the large project.

In the first year, we build only a small plant – to buy time[2] – after which we resolve the uncertainty (think about wet 2008 vs repeat of 2006), and on the basis of this are able to choose between progressive rollout and building one big plant. Clearly this strategy adds to the nominal cost of the big plant, if that is the way you go – but in fact it lowers the NPV of costs by delaying the big investment. Much more striking are the gains if it turns out that there is no need for the big plant.

This more sophisticated strategy – which can in turn be further enjanced through a rolling decision rule – eliminates the risk of ever having to make the biggest investment envisaged in the simpler example above – that of finding yourself building lots of high cost small plants up front. This is a key aspect of the risk management.

Again to keep this illustrative example relatively simple, we model the case where the uncertainty as to whether the change is structural or trend in nature will be resolved over the first 12 months. This could just as easily be modelled

2 This could be viewed as analogous to commencing the process of building a contingency reserve as insurance against a plausible climate outcome.

as 2 years or 5 years, and with relatively minor addition to complexity the model could be further extended to allow not for the resolution of the uncertainty, but for a significant reduction in the level of uncertainty. The basic consequences are broadly similar, in the way they inform strategy.

In reality, there is scope for a different of form of resolution to apply – but one that again reinforces the value in delay where possible. If there is a chance of the drought breaking, and bringing with it significant recovery in dam levels, then there is option value in delay where possible. This will be true even if there has been a structural shift in climate – as long as the recovery in dams and groundwater levels means that expenditure on a large project can safely be deferred for some time. All these effects can be incorporated into models of this type fairly easily. The structure presented here is designed to illustrate the approach and the nature of some of key implications.

Figure 3 and Figure 4 are analogous to Figure 1 and Figure 2 above; Figure 3 shows the structure of the revised options strategies, while Figure 4 presents the 'solution'.

Figure 3 **Structure of revised illustrative options-based investment decision**

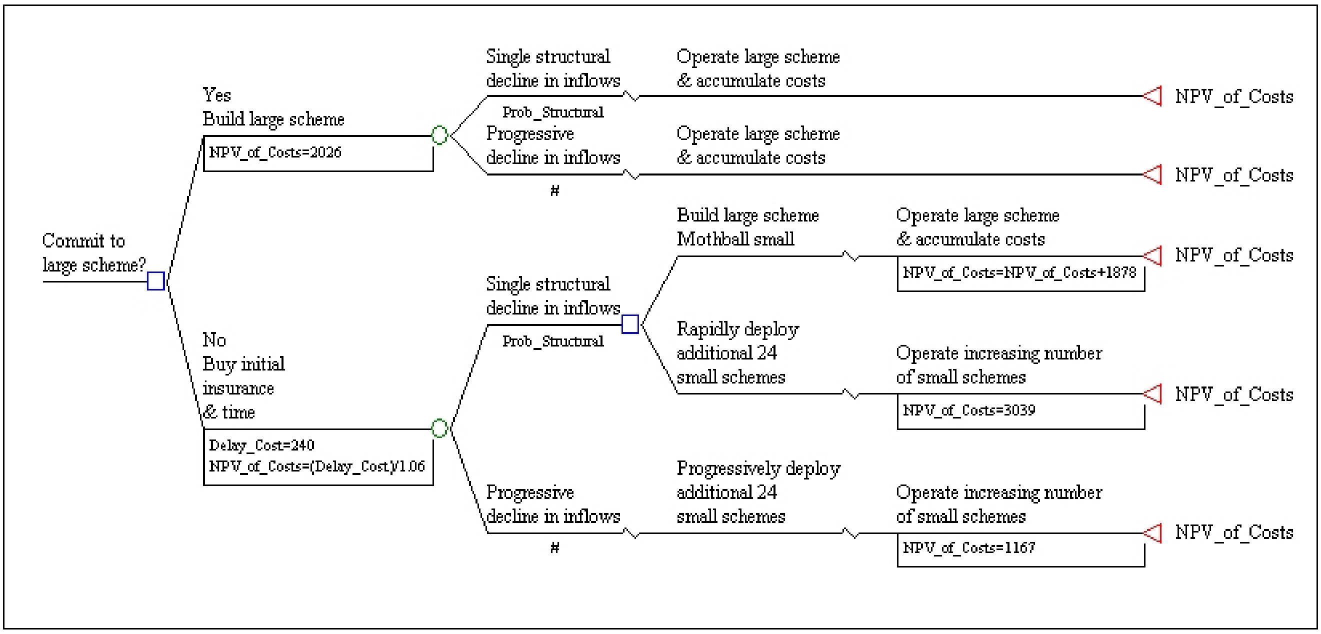
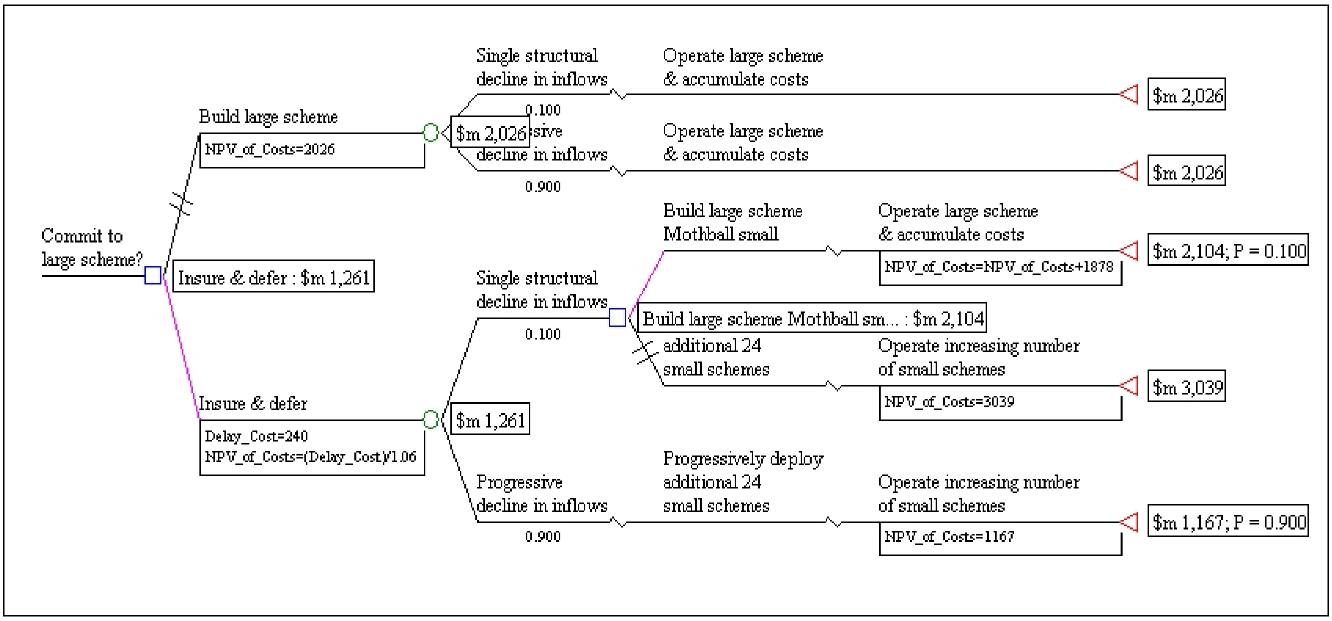


Figure 4 **Revised cost minimising strategy for options-based investment**



Two key changes have been introduced to the structure of the problem:

- Allowance is made for a decision, after 12 months, as to whether then to build the big plant or not – if this commitment was not made up-front.
- We have allowed for elevated costs in dealing with the risks of the structural change where the initial response is not to build the large plant.
  - We have allowed for a relatively high unit cost response strategy for the first year, that manages the demand threat, and have assumed that this involves a larger commitment than the cost of a single small project.
    - Notionally, to illustrate the value of high-cost insurance, we have assumed the up-front cost would be four times the cost of a single project, and would be 'written off' in the event that the big project proceeds later.
    - This might involve 4 small projects, or one or two small projects accompanied by, for example, accelerated demand management or tighter (and higher cost) restrictions, and may include development of a large scheme readiness strategy – with these costs viewed as the cost of insurance against the chance that the change is trend, not structural.

The effect is to introduce the option to choose a $240m commitment up front, possibly followed by the large project, or by a rolling sequence of smaller projects, *depending on the later review* of the nature of the climate change. Note that the large project has been deferred by at least 12 months, which provides a small offset, in terms of a reduced NPV of costs, in the event that the project still proceeds.

Two key conclusions compared to the earlier model:

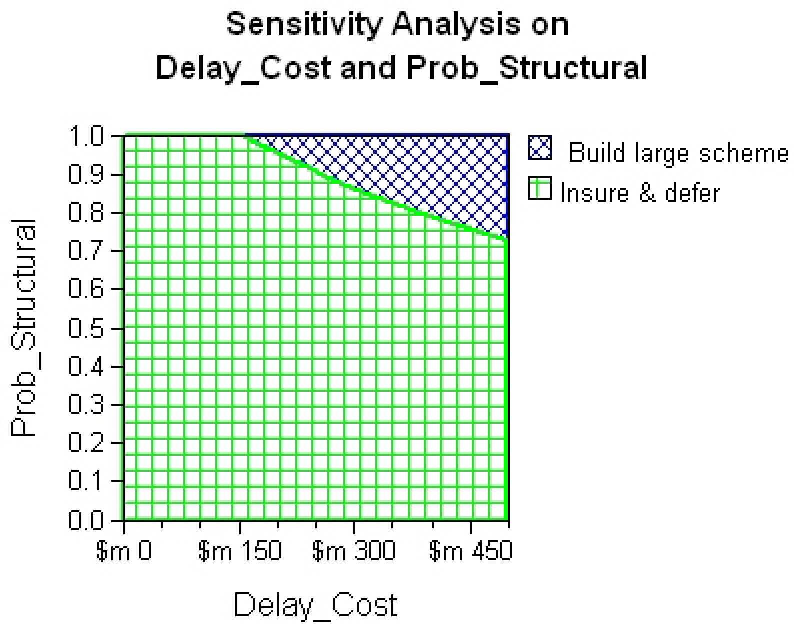
- the expected cost has dropped from $1,354m to $1,261m, a saving of $93m, pushing the option value (comparison with the single big project costs of $2,026m) up from $672m to $765m; and
- the 'worst case' outcome has dropped from an outlay of $3,039 to an outlay of $2,104, now only $78m more than the outcome from moving straight to the large scheme, even after factoring in the $240m cost of insurance – because the gains include the benefits of deferring a large capital cost.

These changes are quite dramatic – and illustrative of real opportunities that can be derived from this type of readiness approach. The modelling strongly suggests that, even with a substantial 'insurance premium' to be funded, the worst case downside in choosing the more flexible options – from actively investing in buying flexibility – is small, while the upside is even greater than before.

Indeed, it is again possible to assess the breakeven value for the probability of a structural shift as opposed to a trend – and the value has now risen from the former 46 per cent to 92 per cent. If the chances that we need to manage a declining trend in inflows, rather than a one-off structural shift, were greater than only 8 per cent, then the analysis would favour making the investment in the more flexible strategy. This would support a quite robust conclusion in favour of flexibility rather than large project/low project unit costs of production.

Taking this type of reasoning even further, it is possible to probe the probability/cost of insurance trade off. The following chart shows the combinations of values attributed to the cost of insurance (variable Delay_Cost), and to the probability that the change is structural rather than trend (variable Prob_Structural) that would support decisions in favour of the large scheme of the insurance/deferral approach to investing in flexibility.

Figure 5 **Illustrative strategy trade-offs**



This example illustrates the key drivers of readiness value – in the potential to defer costs and to better align costs with benefits – and it illustrates the values could be large.

With a low enough (but still substantial – over $150m) cost of insurance, the flexible strategy proves dominant *irrespective of the probability that the climate change is structural*. As the cost of insurance rises, that probability becomes increasingly significant – but the constraint is still quite demanding, based on the current state of hydrology and climate change modelling.

The NSW Government, in announcing its move away from a fixed commitment to a desalination plant in favour of a desalination readiness strategy, estimated the savings in *expected costs* to be conservatively greater than $900m – compared to the costs of moving immediately on a scalable desalination plant. This figure[3] reflected only the benefits of deferring capital costs. Incorporation of the benefits of deferring also unnecessary operating costs, and the costs of carbon emissions and brine discharge, and the lost option of adopting more efficient desalination technology in the future, would

[3] We note that those calculations were based on the use of a system trigger of dams falling to 30% of capacity, the strategy announced by the Government when it supported the readiness strategy. The Government later committed to the plant when the dams were approaching 33 per cent, but had not reached 30 per cent. The dams fell no lower an by 20 September 2007 were at 59 per cent – suggesting at worst that it would have proven possible to defer the very large investment by a number of years, with cost savings of some hundreds of millions of dollars. The intention remains to operate the plant flexibly within an options-based framework.

support a higher figure again. Comparing to a large, non-scalable plant (of the size of the upper scalable limit of that which emerged from the planning) would have resulted a much higher saving again – well over twice the quoted figure of $900 million.

Of course, that reduction in expected costs was *not guaranteed* to reduce costs. It was predicated on there being an assessment of good prospects of the drought breaking before the trigger point for the desalination plant was reached. Dam levels subsequently fell close to the suggested trigger level, and while they have since risen without first reaching the trigger level, these patterns have altered the data on which adaptation of the strategy can sensibly be based.

The modelling work that underpinned those cost estimates was more complex that in the above illustrative examples, but there were strong structural similarities. An analogous options model was used, modelling desalination within a portfolio that included a wide range of DM and recycling measures. The probabilities were themselves inferred, and applied within a Monte Carlo framework, based around several thousand stochastic realisations of possible forward rainfall patterns and dam levels (starting with dams at severe drought levels); these analyses were further accompanied by stress testing of particular climate change scenarios. These are valuable enhancements to the options modelling approach – but do not detract from the underlying sources of value illustrated by this and the earlier example.

6 Water Corporation system modelling

In the context of a brief discussion paper, we have not attempted to probe in detail and assess the Water Corporation processes for procurement planning. However, we have held some preliminary discussion with Water Corporation, were previously briefed in some detail on approach to forward capacity planning and have examined the model, provided to the Authority by Water Corporation, that models system status and restrictions under a range of synthetic inflow scenarios developed out of the past 6, 10 and 30 years of hydrology.

Based on these considerations, along with the ideas set out in the earlier material, there are a number of observations worth making and questions that arise. We consider these relevant to consideration of appropriate procurement frameworks for WA.

As has already been flagged, actual procurement decisions involve stakeholders, and decisions, extending beyond Water Corporation. Importantly though, the processes now being used to plan strategy would, under Water Corporation's proposal, be available to prospective tenderers in the future to assist with the development of a proposal.

First and foremost, the current process is highly centralised, and based around whole of system planning. It has demonstrated an ability to factor in new possibilities as proposed by others – with the Harvey Water trade being the most frequently cited example.

This is just one example of the substantial flexibility that does exist in the present system. While the Water Corporation model for assessing likely future needs and timing is formally fairly deterministic, in practice the approach to trigger point determination (on supply projects at least and, they have argued, on restrictions levels) is flexible.

However, they appear, based on our current understanding of the processes, not to be operating with a full options approach:

- Specification of outcome requirements in the form of volume and timing, as opposed to contributions to system security and reliability, where possibilities might involve measures other than volume and timing, is likely to limit the access to proposals that might be more cost effective.
- The processes appear not to yet adequately reflect the economics of mismatch between timing of expenditure and timing of need – with the unit costs quoted for projects looking likely to be very low relative to expected levelised unit costs per unit of additional system supply or other appropriate system measure.
- Planning is based around a conservative indicator scenario for climate change, and the role of plausible wetter futures (though still a lot drier than the historical record) appears limited in shaping adaptive strategies that seek to maximise the value of the flexibility.
- For related reasons, it seems unlikely that these processes deliver least expected cost outcomes, subject to security and reliability constraints. There is an implicit objective function being used that appears difficult to rationalise other than that it poses a problem that is relatively easier to solve.
- It seems likely that the system modelling could benefit greatly from a serious reassessment of the role of restrictions within a diversified system that includes desalination, desalination scheduled to come on line in the future and a range of readiness options. This almost certainly implies a significant reshaping of the formal restrictions regime and could well suggest that the necessary probabilities of triggering total sprinkler bans is well below current estimates.
- Water Corporation has in place most of the pieces needed to move to a fuller options-based planning paradigm – and to support wider market processes in undertaking appropriate assessments of system impact. Some further development of the systems would be needed.

- A key issue is the implied need to confront explicitly the question of how likely it is that very recent experience is truly indicative of future trends. This is somewhat subjective and controversial. However, without such a process, the analysis above clearly indicates that even the concept of cost-effective investment in procurement is not well-defined.
  - The Water Corporation approach essentially resolves this dilemma by assuming (implicitly) the recent experience is a good pointer to future patterns – and much better than, for example, the 30 year (or, we suspect, even a 15 or 20-year pattern). This treats the recent experience as a non-drought event.
    - We emphasise that it is the approach, not Water Corporation, that embodies this assumption.
  - While this does deliver a tractable problem, the cost implications of the assumption being false appear great enough to justify serious review of the assumption.

7 Impact of premature commitment

The illustrative case studies in Section 5 clearly demonstrate that, under reasonably plausible conditions that bear some affinity with – but do not match precisely – actual conditions in SW Western Australia, premature commitment to a substantial procurement project can entail large costs with little benefit in the form of heightened system security or availability of water to meet growth demands. In one sense, this is *the* key consequence of using a framework that, in this sense, is biased towards earlier than necessary investment. If it is to occur earlier than necessary, it also involves the risk that it will turn out to have been the wrong project – and not simply the right project wrongly timed – but the impact is essentially the same. The present value of the expected costs of meeting service standards will have been higher than necessary – with this flowing into expected charges for services that are higher than would have been necessary.

Of course, there may be some social and/or political benefits in governments being seen to have acted pre-emptively and decisively, given the greater complexity of the rationale for a less deterministic options strategy – with effective communication being both difficult and being suggestive of indeterminacy in leadership. Communities that feel threatened – and it would be fair to say that SW Western Australia feels threatened by climate change and its implications for water supply – often respond positively to assertive leadership in addressing the concerns. A 'successful' pre-emptive strike against a possible enemy can be popular – especially if it eliminates any determination of whether the possible enemy was in fact an actual future enemy without the pre-emptive strike. We restrict our attention here to more narrowly defined economic costs and benefits – inclusive of environmental and social impacts of actual water outcomes, but exclusive of these political dimensions.

Within this narrower focus, a number of additional ways of looking at the possible impact of a procurement framework that is prone to early commitment to substantial projects may be of value.

7.1 Impact on economics of alternatives

Early commitment to a lumpy asset such as a substantial desalination plant, especially (as appears to be the case with both the commissioned and proposed desalination plants) if planned only for *continuous operation*, risks unnecessarily restructuring the economic incentives for a wide range of alternative measures that might otherwise we packaged to offer a far more cost-effective strategy.

For example, assume the second desalination plant proceeds and that, over the next two to 3 years, the drought breaks and conditions return to the relatively dry (but not constant extreme drought) pattern seen over the past 30 years – in fact, even a somewhat drier scenario would perform similarly.

In this setting, even continued application of the Water Corporation approach to modelling system security would progressively converge on the conclusion that there is a short- to medium-term surplus of water in the system. There would be benefits in this – groundwater and wetland systems proceed to recover. Certainly the threat of deep restrictions would be pushed well back – and indeed the strategy of early, pre-emptive investment would probably lead to the assumption that deep restrictions would never be needed. While the incremental cost of the additional water would be quite high, the averaged cost seen by most water users would probably be at a tolerable level and the outcome could prove quite popular. There is no question but that it addresses head on short-term security and longer-term demand growth concerns. If the price impact appears modest – and *it is not widely recognised that the price impact was unnecessary* – there is a good chance the strategy would be well-received.

Nonetheless, in this world of more than adequate water supply, the economic incentives for demand management and for accessing alternative procurements of supply would have dropped dramatically. The same Water Corporation modelling would be pointing to the lack of threat – and quite rightly the advice would be to defer the costs of demand management and supply augmentation measures – even where these involve much lower costs than the then sunk fully attributed costs of the desalination plant.

This response to the sunk costs would be appropriate. However, unless and until those costs are truly sunk it is important to ask if this is the outcome being sought. What if it leads to avoiding low cost, progressive demand management and supply augmentation measures – only because a much larger cost has already been sunk. The strategy is not lower cost – it is just organised in such a way that it is lower avoidable cost.

These incentives that could be depressed include:

- Incentives for building greater water efficiency into housing design;
  - Governments could of course still regulate for these standards, but the fact is that the presence of the sunk costs and excess capacity do lower – probably substantially – the efficient level of such investment.
- Similarly, the *efficient level of restraint* on actual water use – from length of shower, through garden watering to industrial usage patterns – will be lowered.

Were it possible to move back from continuos operation of the desalination plant to discretionary operation as has been proposed for the Sydney desalination plant, the incentive effects change somewhat. Under this assumption, some of the costs are no longer fully sunk – with there being the option to avoid the operating costs, less any costs triggered by an intermittent operating schedule. This would create an opening for some very low cost options still to be attractive relative to operation of the desalination plant – but their would remain a very large disincentive associated with the sunk capital costs.

7.2 Impact on competition opportunities

Importantly from the perspective of the present Inquiry, there is another (closely related) set of incentives that would be altered – and suppressed – that go to the heart of competition opportunities in water.

Should it emerge, from the commitment to the second desalination plant and the emerging experience of the climate change impact, that the IWSS has adequate supply for many years to come – then again the economic incentives for demand management and for provision of new sources will be greatly depressed and pushed out in time. These are the very incentives likely to support competitive markets in procurement.

The commitment of $1b to a second desalination plant could well turn out to have rendered trivial or irrelevant, for a substantial period of time, the opportunities for tapping into serious competition in supply and demand management. While we are aware of a view that procurement accounts for only a small portion of water supply costs – suggesting that this may not be a big loss – we would urge caution. First, as was noted earlier, this seems likely to be less true of future water supply than of past water supply, as the emphasis moves to increasingly costly procurement options. Secondly, in a world in which one desalination plant has just been commissioned, and a second one costing $1b in capital and with substantial operating costs, has just been announced, the absolute value of the costs involved seems pretty substantial.

Again, if the costs are truly sunk, and if it emerges that there is a 'surplus' of supply (whether through poor procurement processes or through good luck on climate change), it may well prove inappropriate to move early to develop procurement markets – because they could not justify early establishment costs. Markets justified on the basis that they could lower procurement costs have little value where there is no demand for procurement.

This need not, however, imply that the present world – in which there is only one desalination plant – would be improved by adding the second plant at a cost of $1b. As above, this situation will have arisen at high, but irreversible cost. Under the less pessimistic, but still serious, climate change scenarios, the cost of the second desalination plant could well prove a lot more expensive than the cost of an alternative strategy, more fundamentally incorporating options principles. This could be particularly true if a competitive market, facing appropriate incentives to discover and deliver more cost effective ways of managing the risks, could be engaged.

All of this is, of course, predicated on their being a lower cost alternative strategy that delivers adequate security.

8 Wider observations on central procurement

Against the backdrop of the discussion in Sections 6 and 7, it is worth considering how a central procurement model might approach the problem of managing both system security and actual requirements for water through a competitive tendering process – and how the opportunities suggested above for options-based planning methods might be effectively built into the process.

Working through detailed market structures is beyond the scope of this paper. We are working through some of these issues in other work being done for ERA, including our separate study of size and scope economies in the water sectors – and separate work has been commissioned from NERA on possible procurement market structures. However, some observations relevant to these matters are provided here because of the need we see for trying to ensure a procurement framework that allows the economies offered by the options paradigm to be realised.

It seems most unlikely that a competitive procurement process based *solely* around competing and contracting for *projects* to deliver specified extra system supply at a point or points in time, or to source water 'dispatch' from existing sources, can deliver a *portfolio of procurement actions* that is *cost effective over time* in the sense developed above. The concept underpinning such a market is in conflict – though not necessarily in unavoidable conflict – with the flexibility that lies at the heart of the options approach.

If a competitive market is (as we believe it should) to deliver *both* water and water supply security, and if the balance required between these two is likely to vary over time (with demand growth and better understanding of climate change and long term hydrology possibilities), then it would seem that the procurement process will need to be able to post *incentives for both forms of service*. Various ways of achieving this could be considered, including:

1. Entering the market to buy both services – with willingness to contract for *capacity* as well as for *supply*.
2. Entering the market to acquire only supply, but allowing the market to set very high prices for supply in a situation where there is a serious threat to security, posting strong incentives for pre-emptive investment to be able to exploit these opportunities.
3. Entering the market to acquire capacity and then allowing the system operator to manage the dispatch, with agreed arrangements for paying the suppliers of the capacity.

An analogous situation arises in electricity markets, where there is a requirement to ensure capacity to meet demand peaks, as well as to manage normal dispatch from existing capacity. Two broad models predominate, approximating approaches 1 and 2 above:

- WA is an example of an electricity market where the market management function seeks contracts for both capacity and supply.
  - Where there is a perceived looming problem of possibly inadequate supply, contracts are offered to cover the standing costs of bringing new capacity into the market – essentially the operator as opposed to the tenderer accepts the risk of over-investment.
  - However, the contracts are only written at a price reflective of assessed *least cost ways of delivering the minimum needed extra capacity* – typically the capital costs of a new peaking station which has low capital (unavoidable) but high (but avoidable) operating costs.
  - Tenders to deliver capacity in another form – for example an intermediate load station – can be accepted, but this would require the proponent to accept the risks in respect of capital costs over and above those of a peaking station of equivalent capacity.

      - ⋯ The proponent would then need to seek to cover these higher costs through actual dispatch at prices above the marginal costs of operation.
  - Actual dispatch from existing capacity is separately managed.
- The National Electricity Market (NEM, which does not include WA) does not offer a separate market for capacity.
  - Instead, it allows the Value of Lost Load, the maximum wholesale price that can be paid for actual supply, to rise much higher than in the WA market – $10,000 per MWh vs $150.
  - Prospects for accessing such price peaks, and the scope these offer, even with low levels of dispatch, to recover a substantial capital investment, post incentives for pre-emptive investment in capacity – and, indeed, for electricity businesses to seek to offload these price risks through contracts for supply that can further encourage new entry.
  - These incentives are strong – VoLL events occurring less than a quarter of a per cent of the time can account for half of gross generation revenues across a year – and prices well-short of VoLL can still impose very high costs.

In the electricity market, these extreme peaks can occur relatively frequently but are typically of short duration.

In water, the corresponding 'peaks' – extreme droughts – may arise at intervals of decades rather than months. Furthermore, the earlier discussion of the options paradigm suggests that pre-emptive commitment to new capital investment can be unnecessarily costly, especially if readiness strategies could be effective. Developing an effective and cost effective procedure under the NEM approach looks likely to be very difficult – though there may be scope to evolve towards this approach.

The capacity and supply contracting model looks more promising as a starting point. If we accept the principal that the price offered for new capacity should reflect the *least cost way of achieving that capacity*, then it might well be that the appropriate price for extra capacity – given the key uncertainties – could be the irreversible costs of establishing and maintaining a set of readiness options. These could include design work, obtaining and maintaining necessary approvals and possibly active investment in components of the proposed project that are driving the minimum deliver time.

Readiness options also include strategies such as holding desalination capacity without the operating costs of actual production, in the form of an operational desalination plant that is not operating all the time – in line with the model proposed for Sydney. Such a strategy does entail real costs – but it also entails the avoidance of real costs and can be highly cost effective, even in systems not prone to periodic overflowing. We believe that the case studies in Section 5, and especially in Section 5.2 are strongly suggestive of opportunities in relation to the IWSS for significant savings, at least while present levels of uncertainty regarding the precise impact of climate change on hydrology persists.

The procurement process, supported by sound portfolio options modelling, could express a willingness to pay a price for capacity augmentation in which the incentives for early or excessive investment are contained to the minimum needed.

As near-term threats to security rise, the lead times of most readiness options will loom as constraints on the effectiveness. It will become necessary either to *exercise the options* – to undertake the commitment to building the extra physical capacity – or to identify an alternative source of new capacity within the lead-time constraints.

Designing such a process effectively involves determining the *trigger point* for the exercise of the readiness or other options for ensuring adequate capacity – but it is crucial to recognise that the process involves evolution in the nature of the project to be triggered, as well as in the timing of that triggering. At any point in time, the settings are specified to minimise expected forward costs of meeting service requirements. In this way, a central procurement process that actively acts to acquire both capacity and supply could be designed to embody a sound options-based approach to planning and assessment of projects, and trigger points designed to manage the risks of investment that is too early or of the wrong form.

Establishing and maintaining the capability to undertake rolling analyses of portfolio options within this options setting would be a key responsibility of such an entity.

The Water Corporation proposal focuses on the third of the approaches set out above – relying on its role in operating the system to then derive adequate supply from the acquired capacity. However, if it were to capture the cost economies suggested by approach 1 above, the form of the services it seeks to acquire would, we believe, need to be carefully specified to allow readiness options to be considered and the assessment processes would need to be capable of weighing the value of such proposals for the scope they offer for more cost effective matching of supply to demand.

9 The role of price in procurement

One issue not covered in detail in this paper has been the potential role of the price mechanism in procurement. Section 8 does examine the role of price in delivering capacity as well as dispatch in the National Electricity Market – but also sets out reasons for caution in translating that mechanism directly into water.

ACIL Tasman has undertaken substantial work in a number of jurisdictions on the relationship between options-based procurement planning and the effective system cost of water use. In an options world, in which a readiness option has been identified and the trigger point for commitment to substantial investment is approaching, any consumption of water brings forward the trigger point and increases the probability of needing to trigger the investment before, for example, a drought breaks. In these circumstances (as in the extreme peak market setting in electricity), the true cost imposed on the system by consumption can rise rapidly as system storage (or other measure of capacity to meet demand) drops. Every glass of water drunk adds to the expected cost of the system augmentation.

In most mainly urban jurisdictions, there remains substantially political sensitivity regarding the possibility of considering price fluctuation – especially end user price fluctuation – to become a key part of the supply-demand balance. There is generally acceptance that prices may need to rise – typically to reflect an estimate of long-run marginal cost (LRMC), which in many areas has risen as a result of climate change and current drought pressures.

However, LRMC does not reflect the real time costs imposed on the system by water usage – and end user contribution to demand response in times of system stress is based mainly on the use of restrictions. Prices that rise when water is scarce, and fall as it becomes less scarce, could be viewed as a generalised form of restriction. They could also be interpreted as an implementation of NWI principles in respect of pricing that is fully cost reflective.

It is worth noting that consumptive pool non-urban water access arrangements, where temporary and permanent trades are allowed, do approximate pricing at the real time cost of consumptive use of the water. This occurs because of the way the value of access rate varies depending on volumes available, and the way that allocations are determined. The dramatic rises in the prices paid for water during the present drought – for example in the Murray-Darling Basin – has illustrated these effects starkly.

9.1 Illustrative example

We accept that radical change to pricing policy is unlikely to be an early component of at least urban water market development in WA. However, we also recognise that evolution of arrangements that include price as part of the market definition could underpin a much richer set of options for engaging with markets – demand as well as supply side – in managing the supply-demand balance more cost effectively.

Reflecting this, we include below some material that more clearly illustrates the way that an options-based approach to procurement planning could be meshed with a price-based approach to demand management. The link is essentially the loss of system option value that flows from consumption – a loss that varies depending on the status of the system in real time and the scenarios for future break in drought conditions etc.

The example is stylized, and the modelling work was developed in a different context (hence inclusion of a larger than proposed for WA desalination plant), but it serves to illustrate the key concepts – and to assist in this incorporates several simplifying assumptions.

9.1.1 Assumptions

We consider a water supply system for a major urban centre. Storage capacity is greater than 3,000GL, but the system has been in drought for some years, and is now at one third of capacity, and falling. In the real world, actual levels would vary seasonally and based on chance rainfall, but we ignore those effects for now (though they can be incorporated without interfering with the logic). This system is in steady decline, at the rate of 400GL/annum and will continue to do so until the drought breaks (or new supply is brought in).

What is uncertain is when the drought will break. To keep it simple, we assume the time till the drought breaks follows an exponential statistical distribution, with *mean time till it breaks* this late into a deep drought of 18 months. However, it could break tomorrow, or in 5 years time or more.

Once it breaks, we assume the dams fill and that the system then remains reliable until the next deep drought, that we assume commences 20 years after this drought commences (20-year cycle between deep droughts and we assume the next deep drought will certainly need extra capacity).

Consideration was given to building a desalination plant, at a capital cost of $2b. This plant will safely see the system through the drought, even if it persists indefinitely.[4] However, the risk assessment has indicated that the decision on whether to build or not can *safely be deferred* till the dams get down to 450GL – and still be commissioned in time (this is desalination with a short

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[4] This is a pretty strong assumption given the depletion rate and the capital cost. In reality, a substantially higher capital cost, plus operating costs, could be needed be needed for desalination on this scale, and the plant would probably be made scalable and operated intermittently. Scaling up the capital cost figures would similarly scale the unit cost figures cited below.

lead time!) The planners recognise the *value of the option to defer* commitment, and plan a readiness strategy – to be triggered at 450GL.

The effect of moving from pre-emptive build to a readiness strategy creates two cost savings:

- A guaranteed saving as a result of the delay in construction implied – even if the drought does not break, it will be almost 1.4 years before the plant needs to be built.
  - On a $2b investment, this immediately implies a reduction in the NPV of $178m at a 7% discount rate.
- Potentially a much greater saving because of the possibility that the drought will break before the trigger point, and the plant will then be able to be deferred by 20+ years, till the next deep drought, with an NPV saving, if this proves possible, of $1.5b.

These are the factors underscoring the benefits of an adaptive readiness strategy, rather than pre-emptive build.

We now add a twist, in the form of a one-off shock to the system of 100GL of extra consumption this year. The shock is large – but only to make it visible in the chart that follows. We actually analyse a much smaller one-off shock – it could be any short-term consumption decision (down to a glass of water) – or, indeed, a system leak in excess of the normal level.

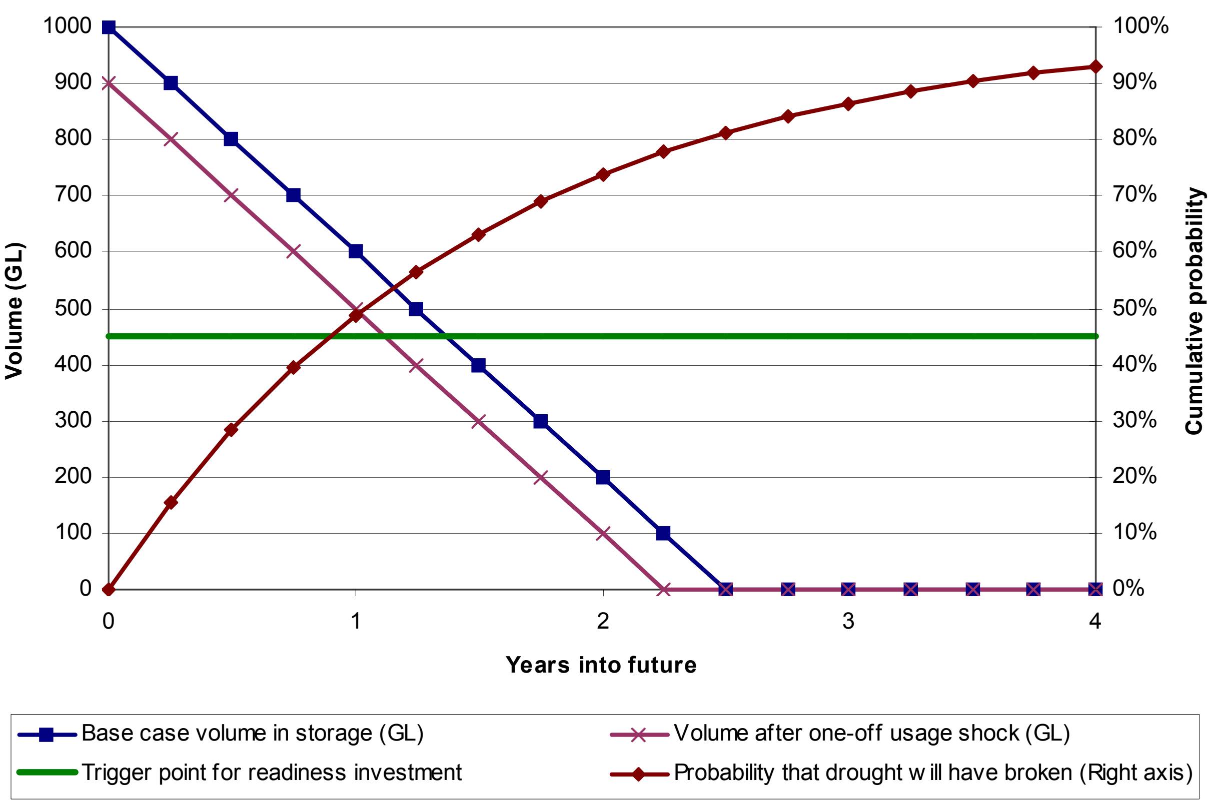
The effect of this shock is to drop the storage by 100GL. From that point on, depletion occurs at the same rate as before – we are dealing with a one-off shock, not a sustained change in the demand trend.

9.1.2 Structure

Figure 6 illustrates these effects. The system depletion curves, with and without the one-off usage shock are evident. The trigger point for the desalination plant is shown as a horizontal line at 450GL – and it is clear that the effect of the one-off shock is to advance the time till the desalination option will need to be triggered, unless the drought breaks first. The advance is from 1.375 years down to 1.125 years, a reduction of 3 months, precisely consistent with a shock of 100GL when depletion is occurring at a rate of 400GL/annum.

Figure 6 also shows the cumulative probability distribution of the time till the drought breaks. This distribution has a mean value of 2 years, starting this late in a deep drought. The probability of the drought breaking in the next 12 months is then just under 50 per cent – with a 92 per cent chance of it breaking in the next 4 years.

Figure 6 **Illustrative system depletion features**



9.1.3 Implications for system option values

From this we can infer the probabilities of the system hitting the trigger level before the drought breaks, both without and with the one-off shock.

- Without the shock, the trigger is hit in 1.375 years, and the probability of the drought breaking before then is 60 per cent.
- With the shock, the trigger is hit after only 1.125 years and the probability that the drought breaks in time falls to 53 per cent – making early construction 7 percentage points more likely, and in that case it will be more expensive, in NPV terms, because of the need to build 3 months earlier.

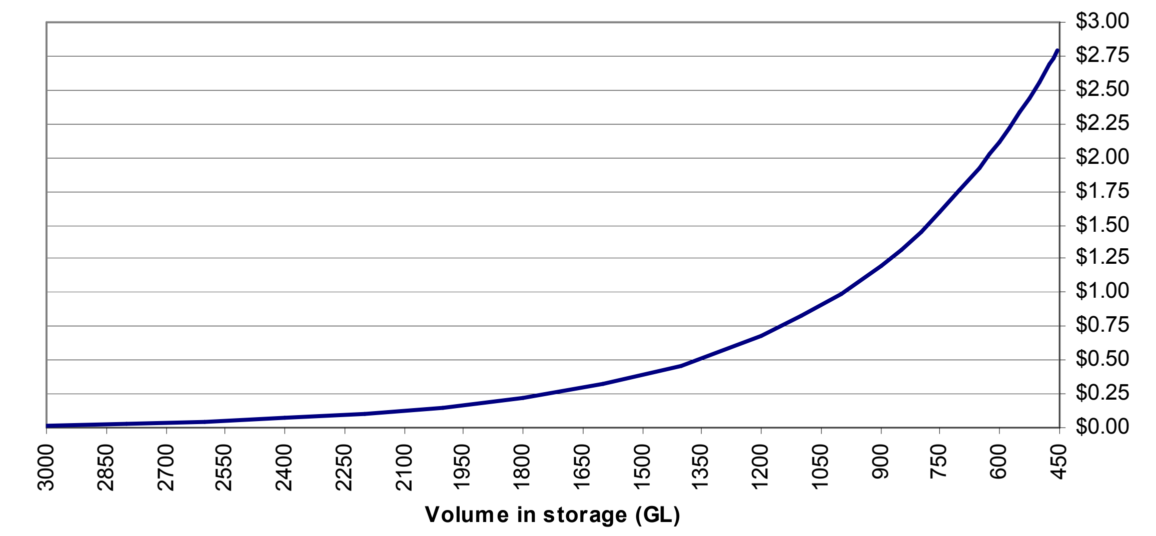
If all these factors are combined into an assessment of risk-weighted costs, incorporating the chance of the drought breaking, and if so deferring the desalination plant by 20 years, we get the following results:

- Without the usage shock, the expected costs of the readiness strategy are $1.04b, based on the 7 per cent discount rate.
- With the usage shock, the costs are $1.15b.

The one-off consumption shock has *added $110m to the expected cost of ensuring system security through the use of the readiness strategy*. This is made up of a small component due to the way the one-off shock advances the time till depletion in this drought, plus a large component attributable to the 7 percentage point chance that the shock will result in a need to build the desalination plant during this drought when this cost would otherwise prove to be deferrable for many years. $110m for the sake of an up-front usage shock of 100GL translates to a unit cost of $1.09. This is a cost *over and above* any pre-existing assessment of LRMC, and is attributable to the price shock. This measures only the value of the lost options extinguished because of the one-off consumption.

These calculations can be done for different starting levels of water in storage. They are unexciting if the starting level is below the trigger point, but reveal a pattern of rising value of lost options as you approach the trigger point.

Figure 7 **Changes in value of lost options as the trigger point is approached**



We have used this options model, but worked with a much smaller one-off shock of 1GL, in developing Figure 7. This model has been used to estimate the unit cost of the one-off usage shock across a range of starting levels and these are plotted in Figure 7. Not surprising, for good dam levels the option value is small – though under our assumptions it will be positive as long as the dam is not spilling. As levels fall – and therefore the time before the trigger level would be reached should the drought continue is reduced – the costs rise, and rise substantially. The earlier comment about the size of the capital costs and the size of the capacity needed is relevant here – with plausible desalination costs, the top option values could be very much greater.

However, a key point to make here is that the unit costs of a one-off consumption shock within a drought – measured as the loss of forward option value of water stored in the system or equivalently the increase in expected costs of securing the system – can easily exceed the *nominal levelised cost of production* from the next tranche of capacity to be brought into system. Indeed, these costs can easily be several times that nominal levelised cost of production. Note that this estimate of lost option value does not include the costs usually factored into short-run marginal cost, including delivery pumping and treatment costs. These costs are additional and should be factored into any assessment of the true cost to the system of water usage.

The terminology *nominal levelised cost of production* is carefully chosen here. Under our assumptions, once the drought breaks there would be no need to operate the desalination plant till the next serious drought. This could allow 'mothballing' for extended periods, with substantial savings in costs – but the effect would be to push up, possibly a lot, the levelised cost of production from the plant. This would be quite rational and the assumptions that lead to this conclusion are not in themselves contentious. For many systems, intermittent operation of desalination is likely to make good economic sense – and has been clearly flagged for Sydney desalination should the plant be built. In a spillage-prone system like Sydney's the case is very strong, but even in other systems the effect of discounting is commonly going to strongly favour an adaptive strategy that only uses desalination capacity intermittently. Unit costs may be higher, but system costs should be a lot lower under a wide range of plausible circumstances.

The above assumptions actually imply a levelised cost of water from the desalination plant, if operated continuously, of just on $1/kL, assuming annual operating costs of around 10% of capital costs. This figure is low and suggests that the option values in Figure 7 could easily be substantially higher than is shown if continuous operation is planned. However, the figure is perhaps more realistic under an assumed intermittent operating cycle determined by the adaptive management strategy.

We note that the levelised costs of the proposed second desalination plant for WA are currently estimated to be of the order of $1.90/kL. Parameter estimates consistent with this cost would roughly double the estimated loss of option value from consumption.

In other contexts, we have defined this measure of loss of option value as a result of a unit of current consumption as the system marginal cost of usage (SMCU) – and argued for its consideration as part of an overall water pricing regime, that would still incorporate core equity and public health measures.