Recycled water – lessons from Australia on dealing with risk and uncertainty


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Abstract

Much can be learned from the numerous water recycling schemes currently in operation in Australia, especially with respect to making investment decisions based on uncertain assumptions. This paper illustrates through a number of case studies, that by considering the contextual and project related risks, a range of business related risks become apparent. Shifts in the contextual landscape and the various players’ objectives can occur over the life of a project, often leading to unforeseen risk and uncertainty. Through a thorough consideration of the potential risks presented in this paper, proponents as well as owners and managers might make better recycled water investment decisions, enhancing the benefits and minimizing the costs of water recycling schemes. This paper presents an overview and discussion of seven key factors to consider when planning a recycling scheme.

Key words: Australia, investment decisions, recycled water, risks, uncertainty

INTRODUCTION

Recycled water has been used in Australia since around the 1970s, predominantly as a means of disposal through irrigation as more stringent regulations came into force to protect sensitive receiving waters. However, with the impact of the millennium drought, which wreaked havoc in Australia during the 2000s, recycled water’s importance as a rain-independent source became valued as one of the options used to fill the growing water supply-demand gap (Hatt et al. 2006; Rodriguez et al. 2009). More recently it has been seen as a means of creating livable urban landscapes, and achieving ‘green’ credentials where a private company provides recycled water within a building/complex for uses such as cooling towers, vertical gardens, toilets and washing machines (Brown et al. 2009; Mukheibir et al. 2015).

Despite its long history of use in Australia, proponents have repeatedly found it difficult to justify the expenditure required for individual recycled water schemes (MJA 2013). They have also found it difficult to unpack the complex range of risks and uncertainties that need to be considered, together with the full range of costs and benefits borne by the various stakeholders involved. During the millennium drought, in particular, many schemes benefitted from financial grants and subsidies, which made them sufficiently viable financially to be implemented. However, since the drought officially ended in 2012 significant government funding is no longer available in the Australian water sector and is unlikely to return in the near future, due in part to the substantial investment in major sources like desalination (Giurco et al. 2014). Hence, if recycling schemes are to play a major role in water service provision in future, it will be essential to improve the means used to identify and assess the potential risks and uncertainties of individual schemes, attempt to predict their potential impacts on costs and benefits, and clarify how these will be borne by various stakeholders.
In Australia, many recycled water guides focus mainly on the technical aspects and associated risks of recycling, taking the Australian Guidelines for Water Recycling (AGWR) (EPHC et al. 2006) as their starting point. Much of the literature published has focused on the technical challenges faced (Foley et al. 2006). However, a detailed investigation of active Australian recycling schemes completed in 2013 highlighted the importance of risks outside the technical realm (ISF 2013a).

Considering these broader risks and uncertainties at the start of a recycling scheme can enable better:

- identification of the risks and uncertainties relevant to the scheme being examined;
- assessment of the likely impact of relevant risks and uncertainties;
- development of mitigation strategies to moderate impacts, reduce costs, and capture benefits;
- articulation of the suite of stakeholders involved throughout the scheme, and how changes in their decisions and actions will affect it;
- identification of which risks will be borne by which stakeholders; and,
- distribution of quantifiable and non-quantifiable costs and benefits more equitably.

This paper uses the research conducted for the Australian Water Recycling Centre of Excellence (AWRCoE) research project (ISF 2013a), and highlights some of the key issues and questions to be considered when planning a recycling scheme. The aim is to attempt to elucidate the risks, uncertainties, costs and benefits that need to be assessed. Every recycled water scheme has its own context, so this paper is intended to help practitioners learn from the case studies. An overview is provided of the case studies, and the risks and uncertainties that need to be considered, as well as the types of questions to be asked. A series of resources developed during the AWRCoE project is publicly available and can be found at http://waterrecyclinginvestment.com.

**THE CASE STUDIES**

The case studies illustrate a range of recycling schemes with very different scales, characteristics and applications. They vary from a publicly owned system used for a residential green-field site to a privately owned system used for vineyard irrigation. The schemes also vary in terms of operating duration, from as little as a year to over 30 years (when the analysis was undertaken) – see Table 1.

Although the schemes are very different, they provide common lessons and insights about risk and uncertainty, together with the associated costs and benefits for various stakeholders.

Each case study was investigated using a combination of semi-structured interviews for key stakeholders involved in each scheme (some 80 stakeholders in all), and analysis of relevant public and private documentation.

**BROADER RISKS AND UNCERTAINITIES**

It is important to consider more than the technical risks associated with recycling schemes, and take in a much broader range of risks and uncertainties. The case studies revealed a range of other important factors that could introduce additional risks and uncertainties. These factors have been grouped as:

- **Stakeholders** – Who are they? Which are directly involved in the scheme, and which are indirectly involved but still have significant influence or control over the outcome?
Objectives and drivers – What does success look like? What are the drivers and motivation of the scheme?

Supply and demand – What supply is available and what volumes are required?

Treatment – What type of recycling scheme is needed? What level of treatment makes sense?

Scheme approvals – Which approvals processes affect the scheme?

Contractual arrangements – What are the contractual arrangements for implementing the scheme?

Financing – Is the scheme public or private? What are the financial arrangements?

Each of these factors is expanded further in the following sections and aligned with questions to help readers reflect on their own schemes.
**Stakeholders**

It is important to know the suite of stakeholders and their roles in a project from inception to operation, as well as their potential to influence success or failure (ISF 2013a). The value of the stakeholder analysis is in working out whether and why different stakeholders matter. Stakeholder analysis is likely to produce a list of individuals and groups, their number and nature depending on the type of scheme. There may be few or many players, as in the Yatala brewery and Darling Quarter schemes, respectively.

Firstly, stakeholders can be characterized as either ‘direct’ (i.e. internal to the scheme, and bearing direct costs or benefits) or ‘indirect’. The latter may be external – e.g. regulators – who, for example, have no direct financial benefit from the outcome. Mapping the direct and indirect players according to different dimensions provides a clearer picture of how and when it might be important to work with them. The three key dimensions are the stakeholder’s (1) interest, (2) power, and (3) view of the world.

A stakeholder in the top right hand quadrant – see Figure 1 – would have a high interest in the project’s outcome and be a direct player with a high degree of power over the outcome. In this case, the project proponents would be advised to engage and consult with them regularly, and involve them in key governance and decision-making.

If a stakeholder appears in the top left corner – i.e. they are powerful, in relation to the scheme, and need to remain happy with it – it would be important to engage and consult them on their particular area of interest. It might also be useful to consider making efforts to move them across to the top right hand quadrant to increase their level of interest and buy-in.

The level of control and influence of the different stakeholders may change over time. For example, where the developer installs a dual pipe system and passes it on to the local water utility to operate, as in the Aurora scheme. Understanding how each stakeholder’s role might change over time also enables risks and uncertainties to be revealed, together with potential issues that could enhance or undermine the scheme’s success.

The stakeholder’s view of the world – i.e. how they understand the world, and how that affects their perception of risks and, therefore, their beliefs about what sorts of actions are reasonable – is also important to understand. Views and values, for example, about how the world works, and/or whether

![Figure 1](https://iwaponline.com/wpt/article-pdf/11/1/127/381339/wpt0110127.pdf)

**Figure 1** | Stakeholder mapping.
nature is fragile, capricious or benevolent, fundamentally influence people’s assessment of different scenarios – whether something is seen as risky or a worthwhile reward.

Understanding these dimensions, together with the timing of involvement of different stakeholders, may reduce the need to make costly changes to a scheme at a late stage. For example, it may be appropriate to involve scheme operators and managers in the design phase, so that the designs match the operating requirements. This key lesson was learnt in the Darling Quarter scheme, where the treatment contractor consulted with operating staff during the design phase, to ensure that a viable and practical solution was developed as part of the design, build and operate contract (ISF 2013c).

Objectives and drivers

Having clear and common objectives agreed by the direct stakeholders involved in the scheme is important for success. However, sharing these objectives with indirect stakeholders, as well, is a key ingredient of success, to avoid the risk of partial failure for one or more of the parties involved. Again, attention is needed to this right at the start of the project planning. The objectives for each stakeholder need not be exactly the same, but they must be broadly aligned and not conflicting.

Having common objectives allows direct and indirect stakeholders that may have an influence on the scheme, to see the multiple benefits that it can bring. This enables them to reduce potential barriers, collaborate to solve problems and avoid, or even agree to pay for, potential additional costs. The Darling Quarter scheme provides a good example, where several direct stakeholders worked together and shared the costs of additional equipment to reduce the risk of malodor. There are also examples in which key direct or indirect stakeholders have shifted their objectives and drivers over time, causing difficulties for others. The Aurora scheme illustrates this. The developer responsible for the project went through a merger early in the scheme and shifted its focus from a development with sustainability as a high priority to one with a stronger focus on commercial viability. This had significant financial implications for the other direct stakeholders involved.

Supply and demand

Balancing recycled water supply and demand volumes is only possible on the basis of assumptions about the future. For example, population growth, trends in water efficiency (technology and behavior), climate change, and energy price impacts. There is always uncertainty and a degree of risk that the forecast volumes will deviate from reality.

The higher the uncertainty of the assumptions made, the higher the risk of deviation, often with cost consequences. The most common deviation is where demand is lower than originally projected (ISF 2013j). It could be argued that good planning should include some contingency. However, too much contingency can lead to owners and operators losing money through higher or earlier capital expenditure than was necessary, inability to operate the plant optimally, or additional costs associated with disposing of or storing surplus supply. In the case of ‘take-or-pay’ contracts, someone may be paying for recycled water that they do not actually use – as in the Rosehill scheme.

Possible changes in the assumptions can be identified by looking closely at the supply and demand forecasts, and considering what might cause a change – gradual or sudden – in the volumetric projections. A useful tool for assessing the risks associated with both supply and demand is to consider the potential political, environmental, social, technical, legal and economic influences, using the PESTLE matrix – see Table 2. This tool can also be used to assess uncertainties in the assumptions associated with water quality.

A fluctuating water supply caused by varying rainfall (for stormwater harvesting) or variable sewage flows (sewer mining), indicates a need for onsite storage as a supply buffer. This can take up space, which may either have cost implications or not be available. Equally, the possibility of reduced
supplies must be considered – e.g. reduced stormwater volumes during droughts, or less sewage due to increased water use efficiency or upstream extraction (e.g. sewer mining).

Recycled water demand can be under- or over- estimated in planning, and/or change over the project’s life. It is therefore important to include sufficient flexibility – e.g. a modular approach – to accommodate such changes, so that the scheme can function optimally and remain cost effective.

In several of the schemes, which are effectively underwritten by public utilities, demand has been lower than expected. For example:

• at Aurora, demand rose more slowly than anticipated because housing developments were slower than planned;
• at Rosehill, demand was significantly less than originally anticipated because a key tenant left and was not replaced; and
• at Wide Bay the anticipated level of demand for recycled water never materialized and was affected by seasonality, where good rain made it unnecessary to irrigate saturated pasture.

**Treatment**

In Australia, the introduction of AGWR shifted the focus from prescriptive end-product management to systems-based risk management (EPHC *et al.* 2006). The guidelines recommend that proponents undertake scheme-specific risk analysis, rather than comply with prescriptive standards. While this appears to be a ‘fit-for-purpose’ approach, the challenge is to steer a sensible course between failing to act when action is required and taking action when none is necessary (NHMRC 2011). Lack of action can compromise public health (NHMRC & NRMCC 2011), whereas excessive caution can have significant social, environmental and economic consequences.

Designing the appropriate level of treatment will depend, firstly, on what users need and when, and secondly on source water quality. Perceptions of risk are key in setting treatment levels, as they can lead both proponents and regulators to be over-cautious. The introduction of the AGWR, with its
risk-based approach, has unintentionally encouraged a cautious approach in setting treatment levels, despite the protection offered by end-use control points and risk barriers. These higher levels of treatment are not always better, and have associated higher cost and energy implications.

Matching treatment levels with demand

In many of the schemes, treatment levels exceed customer needs (ISF 2013k). This is driven partly by the difficulty of providing a range of water qualities to meet different requirements for various end-users – e.g. in Rosehill – and in predicting the quality of water needed by potential future customers. In Wide Bay, for instance, a treatment plant producing high quality recycled water was built to supply a potential future demand that has not yet arisen, resulting in more expensive equipment, and higher energy use and costs than required by the current end users. One way to prevent this is to negotiate on-site treatment for those requiring specific higher levels of treatment, allowing a lower quality product to be supplied to the majority of others. This reduces treatment costs for most of the recycled water supplied. Also, taking a modular approach enables upgrading later, when demands for higher quality arise.

Matching treatment levels to public health risk

Developers’ and regulators’ perceptions of public health risk can drive treatment levels up beyond those recommended in the AGWR. It is clear that a perception remains that ‘best quality’ rather than ‘fit for purpose’ water is required to mitigate potential health risks, which often adds unnecessary additional energy requirements and costs. Reputational risk, where developers are concerned with lower quality water and/or associated amenity disruptions, has also led to higher levels of treatment, for example at Darling Quarter. On the other hand, a pragmatic approach was adopted in Roseville, where the council considered that public health risks were low, and so the water is not disinfected before irrigation or toilet use.

Treatment technology risk

A number of technological performance issues can be of concern, especially if this is the first time that the proponent has ‘worked with’ recycled water. A robust assessment of source water quantity and quality, and associated consistency, will avoid the later addition of processes to the treatment train. Using tried and tested treatment processes ensures that the plant functions effectively for a specific application (i.e. it will treat the source water, producing the water quality required). The AGWR suggests that treatment processes be validated prior to operation of the water recycling scheme. This is a positive approach, which shifts the focus from end point monitoring to process barriers and their operational monitoring. This could save costs in future when more treatment systems have been pre-validated (Muston & Halliwell 2011).

Scheme approvals

In Australia, as elsewhere, there is a range of approvals processes relating to different jurisdictions, arrangements and applications (Power 2010; ISF 2013l; Mukheibir et al. 2015). There is ambiguity around the need for formal and informal approval from multiple agencies, and sometimes there are gaps in the regulations. For example, New South Wales’ metropolitan councils currently do not need to seek approval for schemes that they implement themselves, which means that they have no official regulator. A recent review of the NSW Water Industry Competition Act (WICA) includes
recommendations for closing this anomaly (IPART 2013). Such difficulties have often caused approvals processes to take far more time and resources than originally anticipated.

The recent drive to tighten approvals processes, and the shift to a risk management approach through WICA (IPART 2008) and AGWR, have resulted in some ambiguity for existing and new proponents seeking approval for recycled water schemes. The regulators’ desire to move to a risk management approach – with limited staff and regulatory resources – while proponents aim to do so with limited guidance, available skill levels and time, has produced a capacity gap in the sector. Regulators like the NSW Office of Water are now trying to find ways to address this, through more streamlined processes and provision of additional resources to guide proponents.

**Contractual arrangements**

The evolving nature of the recycled water sector and the many ways in which schemes can be set up, require that contractual arrangements are considered carefully. Roles and responsibilities must be clear, to minimize potential conflict when plans fail (ISF 2013). Negotiating contracts takes time and can cause added financial stress for those involved, if they have not allowed long enough.

Developers often depend on agreements with utilities to either source sewage or discharge waste from a treatment plant. They are needed to provide long-term security for water quantity and/or quality for the developer, as a basis for investing in a water recycling scheme. Equally, the utility must be sure that it can commit to providing the source water. The well-negotiated, long-term arrangement set up with SA Water at Willunga is an example in which contractual arrangements for multiple parties have worked well.

Some contractual arrangements guarantee revenue from recycling scheme end-users or retailers who are contractually bound to pay a set amount, whether they use the recycled water or not (‘take-or-pay’ agreements). These can impose unfair financial burdens – e.g. in Rosehill, where Sydney Water must purchase the recycled water from the operator, even though demand has declined.

**Financing**

In the past, many Australian water recycling schemes have received federal and/or state grants, either directly related to recycling and/or to the users of the recycled water. This funding has assisted in driving some recycling schemes, where they might not have proceeded without it. Other schemes have been able to negotiate favorable arrangements, such as long-term, free supplies of high quality, treated water.

It is now clear that neither situation is likely to continue (Maywald 2013). Significant government funds are no longer available for the Australian water sector and are unlikely to return in the near future. Rather, according to Maywald, government’s role will be to ‘provide incentives and freedom for industry to innovate’ in urban water. Widespread state and federal government targets for recycling mean that utilities are also looking for opportunities to meet their performance targets.

The most significant thing to note from these studies and others (Watson et al. 2015a; Watson et al. 2013b; Byrnies 2014), is that calculating the costs and benefits of recycled water is complex (Mitchell et al. 2007; MJA 2013). The many parties involved in recycling schemes often have different views and approaches, when looking at costs and benefits, which can lead to conflicting and confusing results. The schemes investigated here demonstrate that, whilst some costs are direct and fixed, many others and essentially all of the benefits associated with recycled water schemes can be:

- **indirect and difficult to measure** (e.g., the business value to an operator/retailer of a successful move into small-scale recycling systems);
- **imprecise** (e.g. a utility’s costs in adapting its business processes to include the provision of a new, recycled water service);
- **uncertain and variable** (e.g. lower than expected take-up of recycled water due to end-users not seeing value in the intended benefits);
• contingent on future scenarios outside the providers’ control (e.g. a contribution to potable water availability during a drought, but the decision by a state government to construct a desalination plant that reduces that benefit); and,
• disperse (e.g. the real value of a scheme may assist in underpinning an entire regional economy).

The further benefit of deferred capital expenditure on large, centralized systems due to recycling schemes, is routinely excluded from investment proposals because it is only noticeable at an aggregated scale. For example, those responsible for a scheme may obtain a twofold benefit: it may reduce the load on the sewage network and treatment plant, while also reducing demand on the potable water supply system and associated networks. Such broader benefits can save millions of dollars, by delaying or obviating network or system upgrades, but are rarely monetized or captured in recycling scheme analyses (Watson et al. 2013b). The cumulative effects of multiple individual recycled schemes on a specific water and/or wastewater system are typically unrecorded.

UNCOVERING THE RISKS

Based on the case studies examined and the seven factors identified above, a series of trigger questions (see Table 3) has been developed to assist direct and indirect stakeholders to develop a recycled water scheme. They are best used at the planning stage, to uncover the potential risks, uncertainties, costs and benefits. The set is not exhaustive but provides a good starting point for broader thought in relation to technical issues, and includes a broad perspective of risks, uncertainties, costs and benefits.

CONCLUSIONS

Although the AWRCoE research project only investigated a small number of case studies, they were specifically chosen to cover a wide range of schemes with very different scales, characteristics and applications, as well as business models and durations of operation. The method of investigation, analysis and synthesis has enabled a wide variety of issues to be uncovered. This has yielded a suite of fact sheets and papers that provide different ways to access details and lessons from each case study. These stories and associated lessons are a ‘must read’ for any proponent embarking on a recycled water scheme.

While recycled water has been used in Australia since the 1970s, it has often relied on government grants and subsidies to provide sufficient financial backing for proponents to invest. Recycling schemes are all unique but this paper illustrates that there are common factors to be considered well beyond the narrow technical realm of available guidance materials. Those that center around stakeholders, objectives and drivers, supply and demand, treatment, approvals, contractual arrangements and financial arrangements are equally, if not more, important. All must be considered when planning a scheme, including the implications of how they might change over time. This will ensure that as many of the risks, uncertainties, costs and benefits as possible are laid out clearly for the benefit of all, and allow mitigation measures to be built into the planning process for the scheme’s general benefit.

If both large- and small- scale recycled water schemes are to be included in the portfolio used to fill the urban water supply-demand gap, assist in increasing agricultural productivity, and capture benefits associated with wastewater reduction and resource recovery into the future, things need to be done differently. The capacity to identify and assess the wide range of potential risks and uncertainties of schemes, attempt to predict their potential impacts on costs and benefits, and clarify how these will be borne by stakeholders, must be improved.
Table 3 | Questions to assist in uncovering broader risks and uncertainties

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<th>Risk and uncertainties</th>
<th>Trigger Questions</th>
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| **Stakeholders**       | • What did the stakeholder mapping reveal for each stage of the project? Who are the direct and indirect players? What are their roles and responsibilities? Who should be engaged with and how?  
  • Which internal stakeholders can be engaged at the start – especially technical and operational partners? When should other internal and external stakeholders be engaged to reduce risks?  |
| **Objectives and drivers** | • What is the common objective/vision shared by all stakeholders for the scheme?  
  • How might a change in leadership or values in the organization influence what is possible?  
  • How might a shift in an influential stakeholder’s objective/vision affect the scheme?  |
| **Supply & demand**    | • What could affect the source water quantity upstream?  
  • What will be the response to changes in source water quantity?  
  • What will the customer-base look like in the medium- to long-term, and how will this affect demand?  
  • What are the consequences of over- or under-estimating demand?  
  • How can the scheme be phased to accommodate these potential changes?  
  • What contingency plans are in place?  |
| **Treatment**          | • What could affect the source water quality upstream?  
  • What will be the response to changes in source water quality?  
  • How might the water quality requirements of end-users change?  
  • What are the consequences of over/under treatment for end-users?  
  • Would a supply of differentiated quality suit the objectives and demand profile?  
  • How does the planned treatment level match the end-user risk?  
  • How can the level of risk be reduced through means other than treatment?  
  • What if the treatment technology does not perform? Are the technological components tried, tested and validated? Is technical support readily available?  
  • How will non-health risk issues (odor, noise, truck movements) be addressed?  
  • What contingency plan is in place to deal with a technical treatment failure?  
  • How resilient is the treatment process to changes in influent quality, quantity and demand?  
  • How has equipment obsolescence been addressed?  |
| **Approvals**          | • What approvals processes apply to the jurisdiction for this specific application? Who can give formal approval versus informal approval/advice?  
  • How can varying interpretations within and between regulators be managed?  
  • How can lengthy approvals processes be managed?  
  • How might the approvals processes or regulators change over time? How will this be dealt with?  |
| **Contractual arrangements** | • What business security do the contracts provide?  
  • What level of flexibility do the contracts allow, to accommodate future changes in circumstances?  
  • How will long-term, binding agreements affect the scheme’s future financial viability?  |
| **Financing**          | • What are the broader costs and benefits for the scheme? To whom do they fall, and when?  
  • How does the financing model take account of the range of costs and benefits?  
  • What grants, funds, other public or private entities are available to assist in financing the scheme? For example, are there funds available that are not directly relevant to recycling but have a similar aim?  |

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