# Internalising the environmental costs and benefits of urban water management and supply

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***Abstract***

We briefly consider some of the primary environmental costs and benefits of four primary urban water streams: river abstraction, seawater desalination, waste-water recycling, and stormwater harvesting. We focus particularly on urban stormwater. As a source of water that can simultaneously provide a benefit to society and a benefit to the environment, it presents a novel problem for incorporating their benefits into water supply policy decisions. We discuss a range of mechanisms by which the environmental benefits of alternative water sources such as stormwater can be internalized into water management policy and decision making.

***Introduction***

The dominant source of water to Australia's cities is the impoundment and abstraction of water from rivers draining nearby rural catchments. Urban population growth coinciding with 15 years of dry weather in south-east Australia pushed governments to seek additional water sources for most urban centres. Every coastal capital city has turned to large-scale desalination of seawater as its dominant alternative source of water. Recycling of treated wastewater and harvesting and use of urban stormwater runoff have remained minor contributors to water supplies of cities: in each case only a tiny proportion of the available water source is used.

To date, decisions on water supply augmentation have not fully considered the environmental benefits and costs of each potential urban water source. The dominant approach to water supply has been the centralized capture and treatment of water, followed by its distribution. Where environmental effects have been considered, the primary assumption has been that extraction of water from the environment must have a negative environmental effect that could either be mitigated through a management action (such as the release of environmental flows downstream of a dam) or be accepted as a necessary cost to provide an essential service to our cities.

That (over)-extraction of water from rivers and production of water from desalination plants have negative effects on the environment is well understood, and at least to some extent, has been considered in the commissioning and operation of such water supply systems. However, the environmental *benefits* that arise from using other water sources have largely remained unrecognized. Water sources that supply both a source of water for urban populations and a benefit to the environment present a novel problem for incorporating their benefits into decisions on the commissioning of water augmentation projects, the pricing of water from those projects, and integration of water supply with other aspects of land and water management that benefit from the use of water from those projects.

In this paper, we aim to briefly consider some of the environmental costs and benefits of four primary urban water streams: river abstraction, seawater desalination, waste-water recycling, and stormwater harvesting. Our primary focus will be on the last, because it is a) the largest single source of water flowing through our cities and b) presents serious environmental problems when it is not used (and therefore presents a great opportunity for gaining environmental benefits in its use).

### ***Environmental costs and benefits by water source***

*River abstraction and desalination*

The damming of rivers presents multiple perturbations to rivers and their catchments, but once dams have been built, further impacts can potentially be mitigated through the construction of fish passages to restore connectivity along the stream, and through the release of environmental flows to restore the flow regime downstream.

Desalination of seawater is an energy intensive process: new plants increase demand on an electricity market that is characterized by an undersupply of low-carbon-emission sources, delaying transition of electricity generation to lower emissions. Desalination plants can also cause localized marine impacts resulting from the release of concentrated brine.

Currently, these negative externalities are not internalized and hence when demand for these sources of water increase, these environmental costs increase as well.

For both river abstraction and desalination, their environmental impacts can be reduced most easily by reducing demand on them as urban water sources. Sources such as wastewater recycling and stormwater harvesting provide a very large opportunity to reduce such demand, not only at reduced environmental cost, but potentially at substantial environmental benefit.

*Wastewater recycling*

The recent development of wastewater treatment technologies has been driven primarily by environmental protection initiatives. Today wastewater treatment plants of Australian cities produce effluent of very high quality. Technologies for treating this effluent to potable standard with substantially less energy than seawater desalination are well developed. However, to date, Australian governments have not embraced the augmentation of potable water supplies with recycled wastewater, despite it being common practice in many major cities of the world.

Other than the opportunity costs of failing to reduce demand on more damaging water sources, the environmental costs of not using well-treated wastewater are not large.

As an example, upgrades to the Western Treatment Plant in Melbourne over the last 15 years were driven by the Port Phillip Bay Study (Harris et al., 1996), which found that the bay was in danger of irretrievably switching from a healthy benthic-driven marine ecosystem, into a plankton-dominated system prone to algal blooms, with substantial loss of amenity and value to Melbourne. To avoid such a catastrophic loss, a target was imposed on Melbourne Water to reduce the annual load of nitrogen delivered to the bay by 1000 tonnes per year. Initially, Melbourne Water aimed to spread the achievement of this target between improvement of the performance of the western treatment plant (which delivered ~3,500 t/y of nitrogen to the bay in the mid-1990s), and reduction in nitrogen delivered in urban stormwater runoff (which delivered a comparable, but more variable, amount of nitrogen).

In the 15 years since, Melbourne Water have been remarkably successful in reducing the loads of nitrogen released by the Western treatment plant: reducing loads by ~2,500 t/y, while simultaneously making the plant a net exporter of electricity, and irrigation water. Wastewater effluent from Melbourne is no longer a major threat to Port Phillip Bay. There is therefore little environmental cost to the bay in not using effluent from the Western Treatment plant. There is, however, an opportunity cost of not using this high quality water for potable use.

*Stormwater Harvesting*

The major threat to the health of Port Phillip Bay remains urban stormwater runoff. Melbourne Water concentrated on reducing nitrogen loads to the bay through a concentrated program of large stormwater-treatment-wetland construction across the city. This collection of wetlands has likely achieved only a reduction of ~100 t/y of nitrogen exported to the bay.

While protection of the currently healthy Port Phillip Bay was a clarion call for action on stormwater runoff; the focus on the bay somewhat overlooked the degraded state of the drains, streams and rivers that flow through the city, mostly upstream of the constructed wetlands. Recent research over the last decade has demonstrated that urban stormwater runoff is the primary degrader of urban streams: rendering them unable to support the 100s of species typically found in healthy streams, or provide ecosystem services, such as the retention and loss of contaminants like nitrogen, that are efficiently retained by healthy streams systems (Walsh et al., 2005). More importantly, we have shown that this doesn't have to be the case: if we retain stormwater in the catchment and use it, or let it infiltrate into the ground, we hypothesize that we can retain healthy streams that could enrich our cities.

Our focus on urban stormwater as a degrader of urban streams has revealed that a primary part of the problem is that there is too much of it. Replacing trees with hard surfaces like roofs and roads greatly reduces the amount of rainfall that returns to the air through the trees. Instead, ~5 times more water runs off a roof or road than would have been the case when the same piece of land was a forest. Water runs off roofs and roads quickly every time it rains, picking up a cocktail of pollutants as it goes, causing frequent flow- and pollution-disturbances to the nearest stream. Not using this excess water carries the cost of lost opportunities for the rivers and streams of our cities being healthy functioning ecosystems.

Using it before it reached the stream would not only protect the streams and rivers, but also:

- much more effectively protect downstream waters such as Port Phillip Bay;
- reduce the risk of urban flooding, with substantial quantifiable savings in infrastructure;
- provide a very large augmentation water source that would allow greater, consistent watering of the urban landscape, providing quantifiable microclimate benefits, with flow-on health benefits to the community.

Quantification of these benefits of stormwater harvesting should be integral to the pricing of this potential augmentation supply, but this has not been done on a large scale to date. Most projects that have been classed as stormwater harvesting have not only failed to quantify such benefits, but have failed to realize them. The dominant approach to stormwater harvesting to date has been abstractions from drains (which are usually drainage lines that were once small streams). Such schemes fail to realize potential benefits because:

- the excess volumes of water running off urban catchments are prodigious once the catchment is large: at best such systems can usually harvest a tiny proportion of the excess water causing problems downstream;

- By taking the water out of the stream, the opportunity has been lost to protect the stream by keeping the damaging stormwater out of it.

This end-of-pipe focus to stormwater harvesting has also resulted in some common misconceptions about stormwater as a resource.

Firstly it is often argued that stormwater harvesting is impractical because the storage requirements are prohibitive in a typical urban setting. This misconception also arises from the perspective of water supply planning for security of supply. Certainly if you were to design stormwater harvesting system for 100% supply security, then very large storages are required. However, there is no reason that an augmentation supply needs to be a secure supply 100% of the time. If you design to maximize yield rather than supply security, much smaller storages are required to achieve, say, 80% of the yield that would be achieved with 100% reliability. For example, we have shown that a 5000 L tank on a typical suburban house can provide 70% of the household's typical demand.

Secondly, it is often dismissed as an unreliable 'climate-dependent' water source in the same class as river abstraction. While stormwater runoff is obviously dependent on rain, it is a much more reliable source than river runoff, because runoff from roofs and roads is not dependent on antecedent dryness. A 15 mm rain event on a 1 ha forested catchment at the end of a dry February is unlikely to produce any runoff, as the dry soils and water-stressed trees would take up all of that water. In contrast a 1 ha roof under the same storm would produce ~145,000 L of runoff. The costs of not using that runoff are manifold.

***Internalising externalities in urban water***

There are a variety of other features of the current urban water pricing institutions that contribute to the low use of stormwater as a ready source of supply. The lack of scarcity value in current urban water pricing and the 'invisible' costs of water restrictions mean that stormwater has not competed on an equal footing with traditional sources. It has therefore been seen as too 'costly'. The preference for large-scale augmentations has also marginalized potential decentralised supply options. Decentralised solutions also have the potential to vastly reduce the costs of transportation. Water is heavy and in certain areas can be costly to transport; yet the current pricing system does not reveal or properly account for these cost differences. An urban water institution that recognises this heterogeneity in cost would incentivise local decentralised solutions where transportation costs (including fixed and marginal costs of transportation) are high. An institution that fully accounts for these costs and internalises values would be likely to encourage greater use of stormwater.

Addressing these barriers directly through pricing would increase the efficiency of the urban water supply system and likely result in an increase in use of stormwater. However other mechanisms may be appropriate to specifically address the environmental externality; and ensure that the environmental benefits of using stormwater are internalised. Like many environmental problems there are several policy mechanisms that can be considered. These mechanisms could operate at various scales and include command and control regulation (such as building and planning standards), public works for stormwater retention, or private/householder stormwater retention. Ideally the chosen mechanism would account for the specific features of the problem. Most importantly it would recognise the heterogeneity in costs and benefits of stormwater retention at various locations and across scales. One way to 'price' this externality is for government to provide positive incentives to households. Another is to undertake streetscape works. One mechanism that allows you to achieve the greatest environmental benefit with the lowest cost across these types of projects is an auction. We have designed and implemented two pilot auctions for an outer urban catchment of Melbourne (Nemes et al 2010).

The Little Stringybark Creek auctions include:

- joint consideration of public works and private actions across scales;
- a metric to compare the benefits of interventions across and within scales;
- an environmental procurement auction to reveal and minimise the cost of private interventions; and
- An endogenous reserve price to select the optimal portfolio of investments.

The auction assumes that society bares the responsibility for the environmental externality. Other mechanisms, including regulation and externality pricing could also ensure that the benefits to society are captured.

**Table 1. Summary of some of the environmental costs and benefits associated with the use of water from different sources**

| | **Environmental costs of use** | **Environmental benefits of use** |
|---|---|---|
| River abstraction | Disruption to environmental flows, connectivity of streams and fish movement<br>Impact associated with infrastructure | |
| Desalination | Impact of brine<br>Impact associated with energy consumption<br>Impact associated with infrastructure | |
| Wastewater recycling | Impact associated with infrastructure | Reduced risk of degradation of coastal waters |
| Stormwater harvesting | Impact associated with infrastructure | Improved health of rivers and waterways<br>Reduced risk of degradation of coastal waters<br>Reduced urban flooding risk<br>Urban microclimate benefits |

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