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BALLARAT'S MESSY PATH TO A WATER SENSITIVE CITY

A LONG TERM INVESTIGATION OF WATER MANAGEMENT IN A CITY

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ABSTRACT

Water security is a vital part of ensuring a sustainable future. This is particularly true for many cities in Australia where relatively low rainfall, population growth and climate change places communities under water stress. The 'Water Sensitive City' is one in which water is drawn from a range of water supplies and that sustainably interacts with its surrounding environment. Every city has a unique water history in which the economic, environmental and social history have impacted on the development of water management. Tracking the evolution of water management of a city and its deviation from a standard pathway can provide information regarding what drives decisions about supply and demand.

Water management in Ballarat has been tracked from the establishment of the first water supply to the city in the 1850's until 2015 using historical records from the local water authority. These records show some key differences between Ballarat's water management history and the Urban Water Management Transitions Framework. This highlights that decisions are a function of the individual situation and circumstances in which a city resides. In particular, the water demand declined from a peak in 1980, well before climatic conditions and severe water restrictions were implemented. Understanding the social, environmental and economic drivers of this reduction in demand may assist in future urban water management decisions. When alternatives are considered, if factors other than economics are considered important, these must be included in the comparative analysis.

Key Words: Water Supply, water demand, urban water, Water Sensitive City, water management, history of water management

INTRODUCTION

The term 'Water Sensitive City' has entered the lexicon of urban water management. It was introduced as the final stage in the Urban Water Management Transitions Framework (Brown et al., 2009), and describes a city where a diverse range of water sources is utilised as part of a sustainable environment. The transitional stages leading to a Water Sensitive City are shown in Figure 1. Interest in Water Sensitive Cities is being driven by higher demand on limited water supplies, which is increasing cities' water stress and placing water security at risk.

The demand for water has increased dramatically during the 20th century. Worldwide domestic water use increased 6-fold, compared to a 3-fold increase in population (Cosgrove and Rijsberman, 2000), with the introduction of hot water availability, flushing toilets, showers, washing machines and garden watering all contributing to this increase in demand as did a reduction in the average number of people per dwelling (Cheruseril and Arrowsmith, 2007; Worthington and Hoffman, 2006).

Climate change is expected to further impact water supply in many areas. Under a climate change scenario, rainfall intensity is expected to increase, with rainfall frequency expected to decrease in some regions (IPCC, 2007): increasing temperatures are predicted to lead to higher evaporation and evapo-transpiration, leading to drier soils and higher water demand by plants (Macinnis-Ng and Eamus, 2009). Further, rivers that rely on glacial and snow melt are expected to experience greater flow variability (Pederson et al., 2013).

The combined effects of increasing demand and climate change has been leading to increased water stress in cities with the United Nations reporting that 2.6 billion people currently lack adequate supplies of clean water and sanitation (WHO, 2015). Additionally 25% of cities with a population over 750,000 are currently suffering from severe water stress (McDonald et al., 2014), and 80% are rated as vulnerable (Padowski and Gorelick, 2014). The demand on groundwater, which is estimated to provide 35% of freshwater worldwide (Chu et al., 2013), is forecast to exceed supply during the next century (Taylor et al., 2013).

To address the problem of increasing water stress in cities, Brown et al. (2009) proposed an Urban Water Management Transitions Framework (see Figure 1) to assist in the transition to more sustainable city water management and, ultimately, to Water Sensitive Cities.

One of the objectives was to provide a benchmarking heuristic for the assessment of a city's water management status, and although some cities may have completed this assessment at a given time, there is little literature available on the transition of individual cities over time. Every city has a unique water history in which the economic, environmental and social history have impacted on the development of water management. Analysing the path of an individual city and highlighting differences from the framework can lead to an improved understanding of what drives water management decisions.

Ballarat – a city in south-eastern Australia with a current population of 102,490 people (ABS, 2015) – was chosen as a case study, allowing the stages of water management to be identified and mapped within the Urban Water Management Transitions Framework. In the present work, we demonstrate the transitions that have taken place in Ballarat through the 20th century and highlight differences to the framework. Of particular interest is the reduction in demand from 1980, well before extended low rainfall and severe restrictions had an impact. This may highlight that the community is making decisions based on a range of social, environmental and economic factors, and understanding these could have a significant impact on the water requirements of a city.

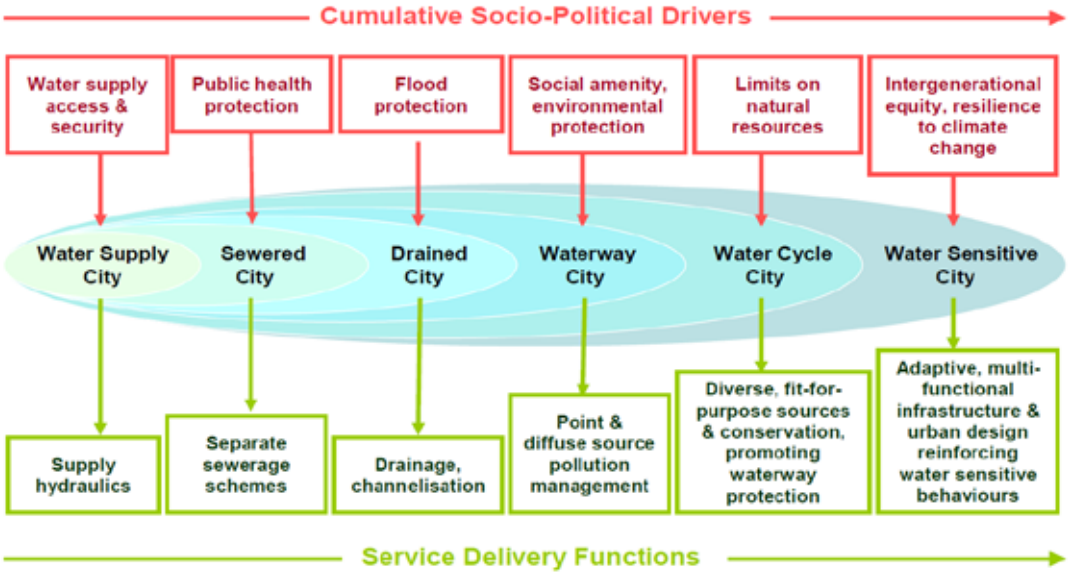

Figure 1. Urban Water Management Transitions Framework (source: Brown et al., 2009)

METHODS

Ballarat: a Case Study City

Ballarat was chosen as case study as many of the issues that have been identified as being important in urban water management have been recorded in the water management history of the city. It is a rural, inland city in South Eastern Australia, approximately 110 km west of the state capital of Victoria, Melbourne (see Fig 2).

The first pastoral settlement was established in the Ballarat area in 1837, with a small community following in 1841. The population dramatically increased following the discovery of gold in the area in 1851. The location was thus determined not by geography or water availability as is the case with many cities, but by the gold discovery. This is a feature shared with other resource-based cities, however it does not necessarily ensure an optimal water supply. Ballarat is located at a relatively high point, and covers the upper reaches of four catchment basins. The majority of the city is located in the Barwon basin where initial water supply was established in 1856, and which receives the majority of waste and stormwater flow from the city. Within ten years of a water supply being established, the catchment in the upper reach of this basin was inadequate, and the first reservoir was constructed in the adjoining Moorabool catchment.

Water stress in Ballarat is expected to increase in the future as the city's population increases by a predicted 40% in the next 20 years (profile.i.d., 2015). Further, the city is in a temperate climate zone, and under a climate change scenario, average temperatures are predicted to increase, and rainfall is expected to decrease and become more variable (CSIRO, 2015). It is currently necessary to source water from more remote basins to maintain supply and this requirement is forecast to increase in the future (CHW, 2016).

As an inland city, there is potential for stormwater capture downstream of the city. As increased urbanisation is expected to result in higher stormwater flows, it may be possible to harvest some of the stormwater flows while maintaining pre-development flows in the receiving waterway. Some housing developments featuring Water Sensitive Urban Design (WSUD) features have been constructed, and a Managed Aquifer Recharge trial completed. While there is some stormwater use for filling recreational lakes and watering public open space, the overall percentage of use is low.

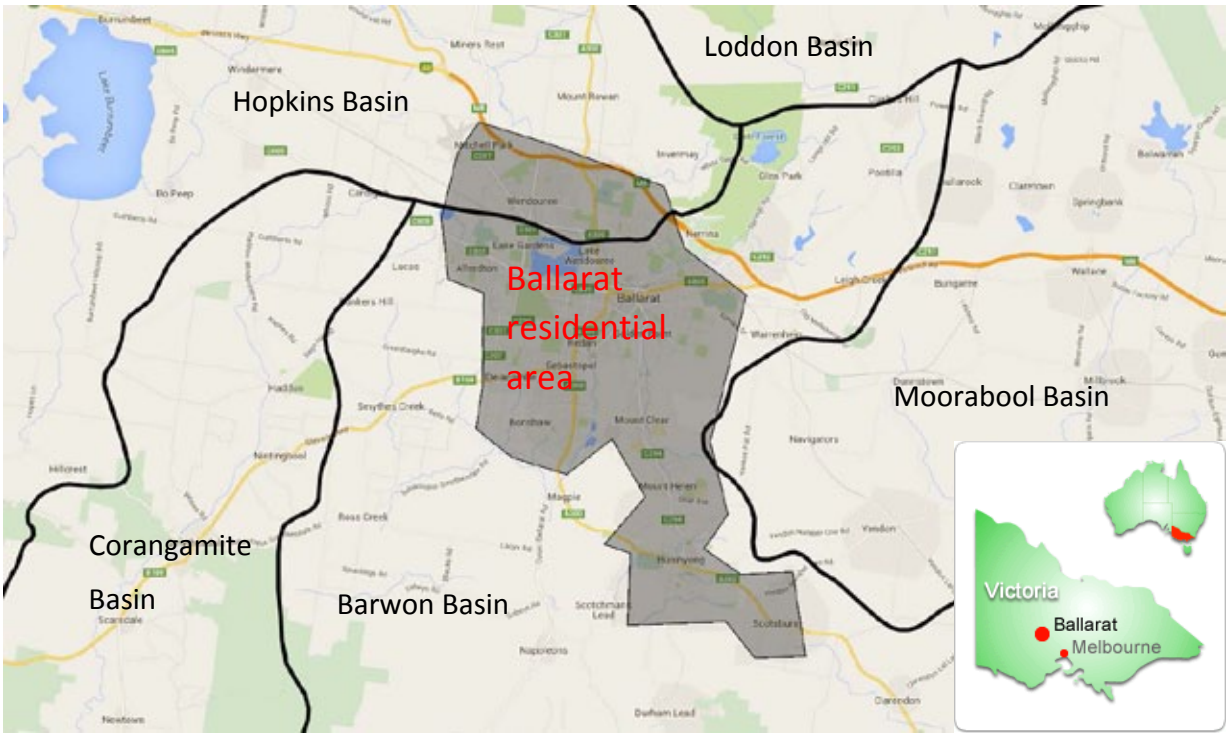

Figure 2. Ballarat and surrounding catchment basins

Water Use: a Common Understanding

The understanding about water use is clearly described in a quote from the Melbourne Water website which states that "Melbourne's water use has varied over the years, from the high consumption of the 1980's to the water-saving efforts during the 1997-2009 drought" (Melbourne Water, n.d.)

This is consistent with Ballarat where the 2013 water plan uses 1990's data as the baseline as it is considered representative of the pre-restriction period, with continually increasing water use. The Millennium Drought placed significant pressure on supply and required restrictions to match supply and demand. As restrictions and water reduction campaigns remained in place, permanent water saving methods were encouraged such as the installation of rainwater tanks, low flow shower heads and dual flush toilets. When restrictions were lifted, the water use did increase, but not to previous levels.

This commentary reflects the lived experience closely enough to have become an accepted truth. Collection of the data was expected to reveal this pattern, and become the basis for determining water requirements and the potential for savings in future work.

Data Collection

The current urban water authority - Central Highlands Water - holds archives of the Annual Reports of water services from 1882 onwards. From these, we obtained data and information relating to the amount of water supplied, number of water connections, sewer flows, number of the sewer connections, reservoir levels, water rates, domestic and non-domestic water use and timing on the imposition of restrictions.

We note that in 1956, meters were installed to record the total amount of water supplied from the reservoirs. Prior to this, the total amount of water was recorded as the summation of all the metered supplies. A correction could have been made to allow for this change; however, the small variation did not substantially affect our results or conclusions, so the raw data has been reported. We also note that there was no direct data available for domestic and non-domestic water use between 1956 and 1995, so rates and revenue information was used to estimate domestic and non-domestic water use during this period. The accuracy of the data met the requirements at the time, and while metering technology may have improved, data errors are not considered to be significant compared with the overall changes in water use.

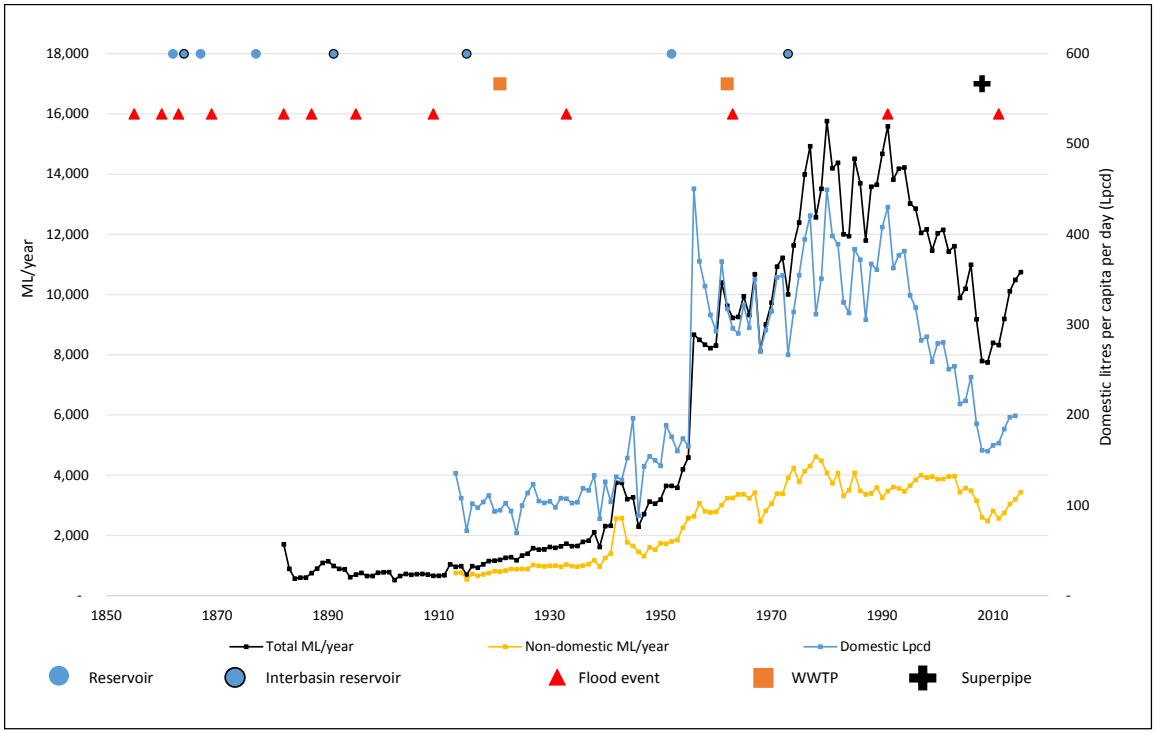

Figure 3. Ballarat Water Consumption 1855–2015

In Australia, decimal currency was introduced in 1966, and all currency has been converted to Australian dollars. Similarly, imperial measures, in this case, gallons for water supply, were used up until 1974, which have been converted to SI units (litres) that have been used since.

Population data was sourced from census information (ABS, 2015; Victorian Government, 1881, 1891, 1901), which was collected at 10-, 12-, 7- or 5-year intervals over the period. Linear extrapolation between census dates was used to determine the population in non-census years and enable calculation of water use per person. Other information affecting water management including rainfall (BOM, n.d.) and flooding (Flood Victoria, 2015) was also collected.

From the above sources, we established a continuous data set of Ballarat water management information since 1882.

RESULTS

The total water use in Ballarat is presented in Figure 3 (black line) along with water use per person (blue line) and non-domestic demand (yellow line). Five distinct phases have been identified. Each of the time periods discussed has been identified as corresponding to a transitional phase described in the Urban Water Management Transitions Framework presented by Brown et al. (2009). These phases involve a low water use initial period as water supply was established (pre 1920), a gradual increase as the distribution network was extended, and drainage and sewer were established (1920 – 1940), a dramatic increase as the city became fully connected (1940 – 1980), the reduction of water use corresponding to increased environmental awareness (1980 – 2000) and further reduction due to reduced rainfall and associated restrictions (post 2000).

The building of infrastructure such as reservoirs from the 1860's, waste water treatment plants (for treating sewage) and the 'superpipe' (2008) (a diversion pipeline from a distant catchment) are also shown in Figure 3, as are recorded flood events.

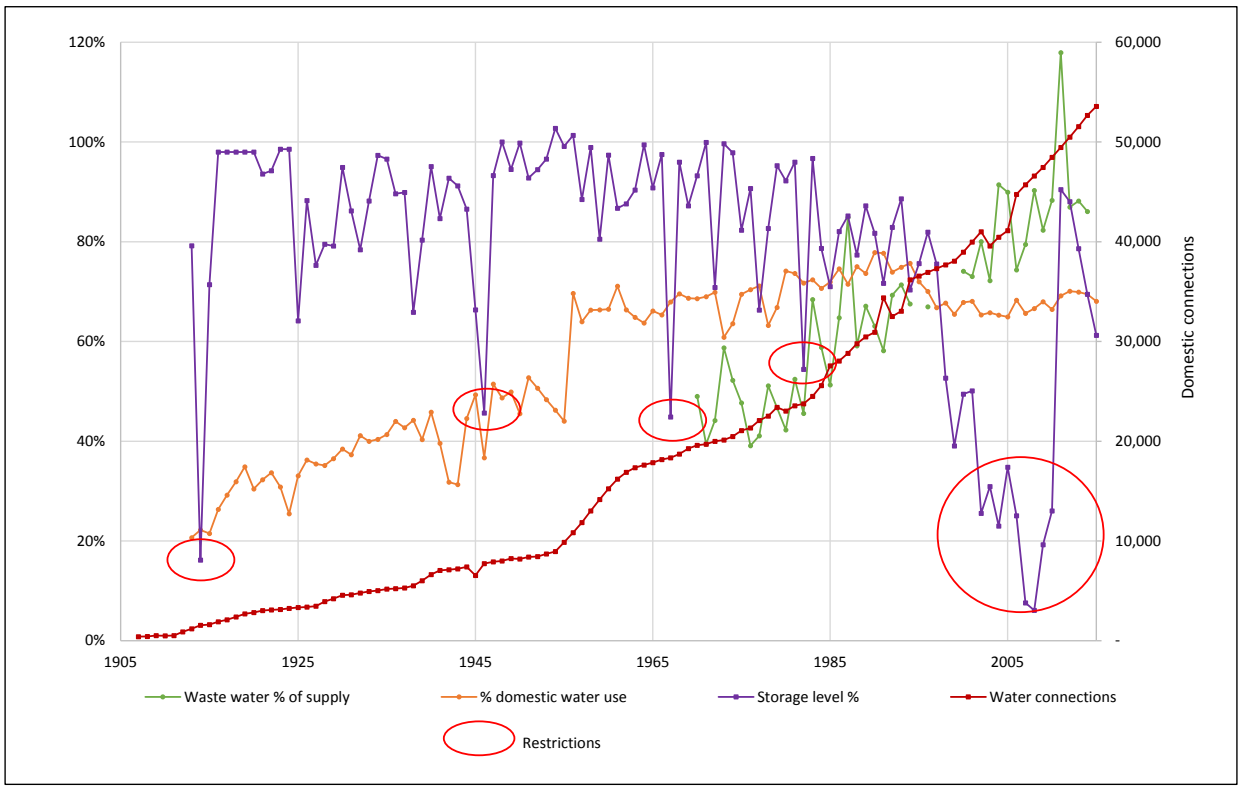

Figure 4. Ballarat Water Supply and Domestic Connections 1905–2015

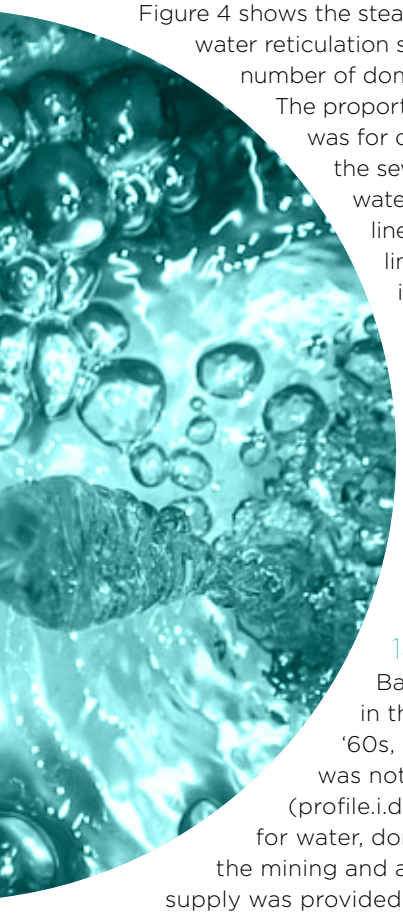

Figure 4 shows the steady expansion of the Ballarat water reticulation system as indicated by the number of domestic connections (red line). The proportion of total water used which was for domestic supply (brown line), and the sewer flow as a proportion of total water supply are also shown (green line). The water storage level (purple line) has been highlighted to identify when water restricitions were imposed and the impact of the Millenium Drought on Ballarat's water supplies. Despite increased storage volume, there was less water available to Ballarat in 2008 than at any other time since 1913, demonstrating the reality of water stress in a developed city in a temperate climate.

1850s–1920

Ballarat's population exploded in the gold rush of the 1850's and '60s, and reached a peak in 1868 that was not reached again until the 1970's (profile.i.d., 2015). This led to a demand for water, domestically but particularly in the mining and associated industries. The initial supply was provided as a public standpipe, then from 1882, when metered data first became available, was divided into mining, manufacturing and free supply. In 1907, towards the end of the gold mining period, the first domestic connections are recorded, and metered data becomes available for domestic supply from 1913. While water use did not alter significantly during these years, enhancing the security of supply required the construction of additional reservoirs. Six reservoirs were constructed during this period; three within the Barwon basin, in which most of Ballarat city is located and into which waste water drains, and three in the adjacent Moorabool basin. These were at an elevation that enables gravity supply to the city.

A lack of adequate drainage was a major issue during the mining boom. Sluice mining created very high sediment loads, choking downstream waterways which exacerbated flooding, an issue that was not resolved until 1915 (McBride, 1916). Drainage within the rapidly expanding city was also an issue, leading to the construction of the bluestone gutters and channels in the 1880's, which are still in use today. Reports of flooding through historical notes and media outlets shows eight examples over 60 years. One of the most significant, the 'Great Flood of Ballarat' in 1869 (The Argus, 1869) caused the death of at least two people, and was one factor in the justification for Gong Gong reservoir, constructed in 1877 (CHW, 2016).

During this time, the establishment of a reticulated water supply but the lack of sewerage and the frequency of flood events, meant that Ballarat could be described as a Water Supply City.

1921–1940

Metered private connections grew steadily in the period between the wars while there was little change in population. By 1940, the city's population of around 40,000 people had been relatively stable for 60 years, and Ballarat now had 6000 domestic water connections. The expansion of water reticulation and initiation of a sewerage system in 1923 had significant impacts on water management in Ballarat during this period. Total water use doubled due to the deployment of more connections, but water use per person and per connection remained unchanged.

Given the establishment of the drainage system, though an incomplete sewerage system, Ballarat during this time could best be described as existing in the second stage of the framework – a Sewered City. We note that Ballarat's water management status deviates from the theoretical framework, which suggests sewerage implementation tends to precede drainage.

1941–1980

A dramatic increase in demand occurs between 1941 and 1980 during a time of population growth and increased standards of living as expected. During this period, Ballarat experienced a 6- to 7-fold increase in total water use, and per capita water use tripled. The growth in post-war Australia (the baby-boom and migration) (ABS, 2015) is reflected in the growth of the Ballarat population. Availability of water was increased due to provision of additional reservoirs, and complete reticulation and universal connections to the sewer were provided. These changes, combined with changes in technology, resulted in increased water consumption.

In addition, two significant events that had a temporary effect on the water use occurred during this time. The first was in 1940 when a number of military camps were established in Ballarat. The water use within these camps peaked in 1942, when they made up approximately 10% of the total metered water supply of the city.

The second was in 1956 when the Olympic rowing events were held at Lake Wendouree in Ballarat.

During this year the water required for the lake increased substantially. Further, there were two years in which water restrictions were imposed due to a reduction in supply (1945 and 1967), but in the year following the lifting of restriction demand returned immediately to that expected.

Two additional and larger reservoirs were constructed during these years. In 1980, the forecasted annual water demand for 2015 (given the expected increases in population and usage) was 31,040 ML (Knowles et al., 1984), more than double the amount of water used in 1980.

During the latter half of this period, when both the reticulated water supply and sewer were connected to all homes, the sewer flow was typically 50% of total water use, suggesting external water use, which would not be transferred to the sewer, was around half of the total. With the expansion of the sewer to all homes, in addition to the reticulated supply and drainage system, at this time Ballarat was described as a Drainage City.

1981–1999

Despite the forecasts of growth in water demand, the usage of water in Ballarat peaked in 1980 and then began to decline. Water restrictions temporarily assisted in reducing the demand for water in 1982, although such measures have been previously shown to have only short-term effects. Although there was adequate water availability at all times after 1983, the city's water use stabilised, and then began to decrease, with a per capita decrease of at least 20% between 1980 and 1999.

The 1982 drought that prompted the introduction of water restrictions may have helped establish the idea that fresh water is, in fact, a scarce resource: an idea assisted by awareness campaigns such as 'Don't be a Wally with water'. Legislation requiring dual flush toilets on all new toilet installations was also implemented in 1984 (Melbourne Water, 2016). Residential allotment size also began to decrease from the 1980's with subdivisions becoming more common; however the existing housing stock resulted in the average of residential allotment size changing slowly.

Water quality and the impact of sewage treatment on downstream waterways became the focus of reporting during the 1980s. Although no additional water treatment plants were required in Ballarat, upgrades to the facilities improved the water quality of discharge. The sewer flow as a percentage of total water flow increased during this time, indicating less water was being used outside the home.

The reduction in water use, which suggests the introduction of a level of awareness of water as a finite resource, together with the priority given to the quality of the discharge from waste water treatment plants, shows it is reasonable to describe Ballarat during this time as a Water Way City, where the impact of the city on the surrounding environment is a consideration.

2000–2015

After the year 2000, water management has been dominated by a changing climate. A number of years of below average rainfall commenced in 1996, and by 2000 water restrictions were implemented. At this time, unlike previous periods of water restrictions, the restrictions remained in place for a number of years and became increasingly severe until 2008 when additional water became available and restrictions were eased. We note that although water restrictions had a significant impact on water use, the long-term trend in reduced water use began many years before restrictions were imposed. Between 2000 and 2008 per capita water use dropped below the longer term trend which appears to be constantly downward from 1990 to 2014, although it may now have stabilised at about 200 L per person per day.

The local water authority promoted water saving measures during the period of restricted supply. This included campaigns encouraging the installation of low-flow shower heads and dual flush toilets. External water use was disallowed for a number of years, which led to gardens with lower water requirements and the installation of domestic rainwater tanks. The sewer flow as a percentage of total water supply increased continually over the period of water restriction, supporting the idea that external water use was reduced:

it is now less than 20% of the total water use in Ballarat. Non-domestic water use was also targeted through a water reduction in industry program. Further, a program to capture and reuse stormwater for external use within the city was undertaken: the most prominent example of which was the supply of water to Lake Wendouree. The water reduction measures were still in place when the unrestricted water supply again became available, and these may have hastened the longer term trend in reduced water use.

During this time, local water supplies were not able to provide adequate water for the city of Ballarat, so a 'superpipe' was completed, enabling the transfer of water from the northern Victorian irrigation district to Ballarat. This pipe forms part of the integrated water network around Victoria, which allows inter-basin transfers to achieve optimum allocations, and is now relied upon to meet the forecasted water demand for the next 25 years.

The long-term reduction in per capita water use, which resulted in a reduction in overall water use; increased awareness of water as a limited resource; and the use of alternative water supplies indicate that Ballarat at this time can most likely be considered a Water Cycle City, or at least, well on the way to achieving this status

DISCUSSION

The Urban Water Management Transitions Framework describes a relatively linear path through different phases of urban water management. While different phases can be distinctly seen in Ballarat's progression, they do not necessarily match with those described. This highlights the messy nature of history and development.

The reduction in water use from 1980 was unexpected. While researchers have expressed concern about the low level of implementation of alternative water supplies and the decisions taken to supplement local surface water, this data indicates communities have been responding to messages about the need for water conservation for an extended period.

Development Compared to the Framework

The conceptual model of the Urban Water Management Transitions Framework describes a city which first establishes a water distribution network, then sewerage followed by drainage before taking into account the surrounding environment and managing the Integrated Urban Water Cycle. While this representation describes the transitions that typically occurs, the data from Ballarat indicates that things occurred in a different order. Drainage was a particular issue for the newly developed gold mining town so resources were directed toward this issue. Conversely, while water supply was first established in the 1860's, sewerage was a lower priority and did not commence for more than 60 years.

Similarly, from the 1980's, a strong awareness of the environmental impacts of water, and particularly waste water, can be seen. As Ballarat has many indicators representing a Water Cycle City it may be expected that strong environmental considerations would therefore impact later water supply decisions, favouring wastewater recycling or stormwater reuse options. However, when the local surface water supply was inadequate, an inter-basin transfer, the goldfield's superpipe, was constructed. The security of the water supply and certainty of the outcome were favoured over more innovative solutions.

These examples highlight that while general trends may be visible, individual cities often make decisions based on their unique circumstances and consultative processes between different stakeholders. Responses are to local needs and situations rather than being in step with an overall philosophy. This is consistent with the findings of Furlong et al. (2016) who describe this process in water management, but also reference a seminal work by Lindblom (1959) which describes planning more generally as 'the science of muddling through'.

While decisions made at any time may be rational and based on the unique circumstances, they will however depend upon the criteria used for completing the comparative analysis. In Australia since the corporatisation of the water authorities in the 1990's (Furlong et al., 2016) this has primarily been an economic assessment.

Table 1. Factors impacting water use decisions

Category	Factor	Example
Social	Legislative	Requiring new residences to include dual flush toilets
	Awareness	'Don't be a Wally with Water'
	Lifestyle	Residential block size and garden type
Environmental	Climate	Rainfall and water availability
	Sustainability	Impact on rivers
Economic	Pricing	Water rates

Other considerations may be included as a hurdle, such as having an acceptable Environmental Impact Statement, but cost has been the ultimate determinant between options. In this case study, alternatives to the superpipe were rejected due to the higher cost, with no accounting for externalities or ecosystem services. Comparative analysis of factors other than cost is required to provide improved information so better informed decisions can be made.

Factors Impacting Decision Making

Despite the common belief that water use had continued to increase up until restrictions in 2001, peak water use in Ballarat occurred in 1980. Apart from short term restrictions, which previously had little long term impact on demand, there was unrestricted water availability. The factors which have influenced consumer water demand are not necessarily those which the authorities have used to estimate the required supply. The range of factors that influence decisions have been grouped under the Triple Bottom Line categories of social, environmental and economic in Table 1, and the impact of these on the water demand in Ballarat will be the subject of future work.

CONCLUSION

This case study of Ballarat illustrates the messy path followed in the evolution of water management within a city. While a relatively linear path such as that described by the Urban Water Transitions Framework may be a useful summation of the general process, individual cities will make decisions based on their particular needs and situation.

When various water supply options are considered, hurdle criteria are often used to generate a short list. Following this, a comparative analysis is done, and typically an economic assessment is used for this. If other factors such as environmental impact are considered important, they need to be part of the comparative analysis if the best possible decisions on resource management are to be made.

The decrease in water demand in Ballarat from 1980, well before major long term restrictions were in place, indicates a better understanding of the factors that drove water use decisions by the community, and this could be significant for the future of urban water management decisions.

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