INTRODUCTION

In Melbourne’s northern suburbs, there are a number of organisations involved in the provision of urban water services (potable water supply, recycled water supply, sewerage and stormwater management). Yarra Valley Water (YVW) manages the reticulated water, recycled water and sewerage systems. Melbourne Water (MW) is the waterway manager and is responsible for stormwater services when the catchment area exceeds 60Ha, as well as wholesale water and sewerage services. Local councils manage the street-scale stormwater services.

Historically, these organisations have worked independently, focusing on their own responsibilities. To date this has been satisfactory, however, faced with a growing population (expected to reach six million people by 2050) and an environment which is under stress (due to reduced water storages as a result of drought, ever increasing greenhouse gas emissions, and a Bay that is highly sensitive to the discharge of nutrients), a new approach is required to ensure the best holistic solution to provide maximum community benefit is identified.

In order to define where new developments can occur and to limit urban sprawl, the Government created an Urban Growth Boundary (UGB), which encompasses the city. Within the UGB, there are four major development fronts, one of which is the Northern Growth Area (NGA), covering an area of 9,500ha, which will ultimately contain 90,000+ residential homes and 1,050ha of employment land (see Figure 1). Providing water, sewerage and stormwater services to this area is estimated to have a net present cost over 25 years (borne by water utilities, Councils, land developers and property owners) of between $1.3–1.7 billion depending on the solution adopted.

To ensure the best holistic solution is identified, a methodology was developed to measure the performance of a number of different servicing options against a set of Integrated Water Cycle Management (IWCM) objectives developed in consultation with key stakeholders as follows:

• Reducing potable water consumption – relieving the pressure on climate-dependent sources such as dams and deferring non-climate-dependent augmentations such as seawater desalination;

• Reducing the volume of treated effluent discharged to Port Phillip Bay and receiving waterways – Port Phillip Bay has a finite capacity to receive and naturally treat nitrogen;

• Improving stormwater quality – the addition of pollutants (such as nitrogen, phosphorus and suspended solids) degrade waterways;

• Reducing stormwater runoff frequency and volume – reduces waterway erosion and protects aquatic ecosystems (Fletcher and Walsh, 2007);

• Maximising the volume of stormwater/rainwater that infiltrates into the groundwater table – returning base flows to pre-settlement levels.

The methodology then relates the overall performance of each option to its total community cost to derive a ratio that can be used to indicate its value (environmental) for money.

With the world’s population forecast to grow from six billion people to nine billion people by 2050 and with most of these people living in cities, the challenge of providing services in a more sustainable and integrated way is certainly not unique to Melbourne, and methodologies such as this one may be useful in assisting similar future processes.

DIFFERENT LEVELS OF IWCM PLANNING

In recent times, water practitioners and town planners have had differing opinions regarding what IWCM actually is. IWCM planning takes place over an extended period of time, constantly evolving throughout the planning cycle as more information about future land uses becomes available. As such, a number of key decisions (such as whether or not recycled water will be provided or what areas of land need to be set aside for key infrastructure) are made at various different points in time.
It is imperative to ensure the outcomes from the various levels of IWCM planning are complementary, while providing developers and customers with as much choice as possible. Figure 2 illustrates the various levels of IWCM planning which take place within Melbourne.

**METHODOLOGY**

At the commencement of the investigation, YVW and MW collaborated to develop six options (described in Figure 3) for detailed analysis. Three of these options can be classified as “integrated”, meaning they address all of the key IWCM objectives previously listed. The remaining three options represent a more traditional approach in which the IWCM objectives are prioritised (with some often not addressed at all – predominantly those objectives relating to stormwater runoff frequency and volumes).

The options chosen were selected to represent the extremes of what is currently possible (and assumes that any other alternate options would fall somewhere in between). Although the extreme options are unlikely to be implemented exactly as they have been defined, they do provide guidance as to what future work (if any) may be required to hone in on a preferred option.

The options investigated were compared using the following methodology:

1. The sewerage, potable water, recycled water and stormwater systems were all hydraulically modelled to size the required infrastructure (at both the catchment, development and allotment scales).

2. Based on the outputs of the hydraulic models, the environmental impacts specifically relating to the key IWCM objectives were quantified – namely energy and water consumption, nutrient concentrations, runoff volumes and frequency, and base flow volumes.

3. A Common Evaluation Framework (CEF) was developed, based around a set of sub-measures, to measure the achievement of the IWCM objectives.

4. For each option, raw sub-measures scores were calculated. Scores out of 100 were assigned as follows:
   - 0/100 – poor performance – a step backwards from current practice.
   - 50/100 – current best practice – meets currently documented standards and which could be enforced today.
   - 100/100 – world’s best practice – eliminates or minimises impacts to levels which are deemed to be within the carrying capacity of nature.

5. Each of the sub-measures were assigned a weighting using the Analytical Hierarchy Process, which is a mathematical technique for organising and analysing complex decisions developed during the 1970s (Saaty, 2008). This scoring process involved assigning a single vote to each stakeholder group for each pair of sub-measures. Sensitivities were captured to measure the impacts that differing stakeholder opinions had on the end result.

6. Raw sub-measure scores and sub-measure weightings were combined to calculate “weighted sub-measure scores”. For each option, these weighted sub-measure scores were added together to obtain an overall option CEF score.

7. For each option, the Total Community Net Present Cost (NPC) was divided by the CEF overall score to calculate a "community value" ratio. Preferred options were those with the lowest NPC per unit of CEF overall score.

Several supporting pieces of work were undertaken as part of the investigation to provide surety around some of the assumptions being used. This work is described in the following sections.

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**Figure 2. Hierarchy of IWCM planning in Melbourne.**

**Figure 3. Options investigated.**
CALCULATION OF PRE-DEVELOPMENT RUNOFF DAYS

A number of the CEF calculations involved comparisons with the pre-settlement number of runoff days – that is, the number of days in which rainfall on the catchment exceeded the available soil storage levels and resulted in surface runoff to the local waterway.

Given that the NGA has been extensively farmed and cleared over the past 100 years, it was difficult to calibrate the stormwater model (MUSIC) and confirm that it was returning realistic results. As such, a reference catchment with similar rainfall, topography, soil type and vegetation (matching vegetation maps produced by the early explorers) was found and analysed for the purposes of calibrating the NGA model parameters.

The Surrey River catchment located in south-west Victoria was chosen. This catchment has gently sloping topography with primarily basaltic clays and is characterised by its grassy woodlands, much like the NGA pre-settlement. The catchment also had reliable streamflow and meteorological data available over an extended period of time.

By comparing historical flows in the Surrey River against rainfall and evaporation data (ensuring only years where the annual rainfall was within 15% of average rainfall for the NGA were selected), it was possible to calculate that there were approximately 35 naturally occurring surface runoff days per year. This is reflective of the unique soil conditions and is significantly higher than the MUSIC model estimates (six runoff days per year), which is more typical of a more free-draining soil present in the south-east of Melbourne.

ASSESSMENT OF THE IMPACT OF RAINWATER TANKS ON KEY STORMWATER ASSET SIZING

In order to determine whether any of the key stormwater infrastructure (i.e., pipes, wetlands and retarding basins) could be downsized as a result of using rainwater tanks, a separate hydraulic modelling investigation was undertaken (Ward, 2011).

Several rainwater tank configurations were tested against a number of rainfall events recorded over the past 70 years – of varying intensities (from a 1 to >100-year average recurrence interval) and durations (from 35 minutes to 1,860 minutes). These configurations included a traditional rainwater tank design with a high level overflow and a modified rainwater tank with a controlled overflow halfway up the tank (set to empty the top half of the tank volume over a 24-hour period).

The investigation concluded that although the modified rainwater tank configuration provided reductions in retarding basin size for certain shorter duration and intensity events, there were no significant savings evident for the lower intensity but longer duration events, as the tanks were unable to empty quickly enough to provide any meaningful additional storage capacity.

Despite the inability to downsizing the retarding basin assets, stormwater...
pollutant modelling found that the use of rainwater tanks on each allotment resulted in a significant reduction in downstream (development scale) wetland sizing of up to two-thirds. These savings were subsequently incorporated into the financial analysis.

RESULTS AND OUTCOMES

When the CEF sub-measure weightings were applied to the raw sub-measure scores, the chart in Figure 4 was created. This chart highlights the sensitivity of the options to the sub-measure weightings extracted from the scoring process. Using a sporting analogy, the non-integrated options “are more like specialists than all-rounders”, and subsequently do well when their specialty receives a higher weighting and poorly when it receives a lower weighting.

CEF overall scores were then divided by the Total Community Cost (represented as a NPC) to calculate a “community value” ratio (see Figure 5). This ratio effectively measures how much each CEF overall scoring unit costs the community (i.e. $M of NPC to achieve one unit of CEF overall score) and is not dissimilar to a traditional financial cost-to-benefit ratio.

As Figure 5 shows, Option 3 does not have the highest overall CEF score but does have the best “community value” ratio – in simple terms it is $3.15M cheaper per unit of CEF score than the next best option (Option 4). The results highlight the deficiencies of a traditional Triple Bottom Line (TBL) approach, which attempts to consider financial, social and environmental measures in parallel:

- Traditional TBL models often artificially reduce the weighting given to community cost and fail to recognize the commercial reality of how business decisions are made. They can also recommend options that do not necessarily represent value for money (i.e. an option may meet all of the desired objectives but have a huge cost and be selected over a much cheaper option that only falls slightly short of meeting all the desired objectives).
- The community value ratio for the “do nothing” option represents a reference point against which alternatives should be compared. Theoretically, this reference point represents “current practice” (not to be confused with current best practice) and before considering alternatives, they should at least have a matching or better ratio.
- The option with the highest community value ratio will not necessarily have the highest overall CEF score. Often in traditional TBL models, there is very little difference in overall option scores but large variations in community cost. This is certainly the case in this investigation, with Option 3 having a CEF overall score of 66.33 and a Community NPC of $1,482M, and Option 4 having a CEF overall score of 67.38 and a Community NPC of $1,721M (a score difference of 1.05/100 but an NPC difference of $239M).

Additional outcomes of the study, which will be used to inform the next level of IWCM planning, include:

- The design of bio-retention systems is critical, particularly when installed in areas with clay soils where the evapo-transpiration rate is much greater than the infiltration rate all year round. Systems must be of a manageable size, be aesthetically pleasing, and require minimal operations and maintenance input.
- The lowest cost option for meeting the stormwater performance objectives in Melbourne’s north does not involve the use of rainwater tanks. This investigation indicates that bio-retention systems are a more cost-effective solution for disconnecting impervious surface areas from the formal stormwater system (through a combination of evapo-transpiration and infiltration).
- The performance of rainwater tanks is very “area-specific”. In this study, average reliabilities were between 52–81% depending on household size (with 100% of the roof area connected to the tank and annual rainfall of 596mm). This means that reductions in the size of the potable water network (or recycled water network depending on how the tanks are backed up when empty) are not possible without the installation of some form of off-peak tank top-up system.
- The use of rainwater tanks to supply hot water services in parallel with the supply of recycled water for non-potable uses (toilet flushing, clothes washing and outdoor uses) can reduce per capita imported water to 60L/person/day (30L/person/day less than a recycled water only solution).
- In water supply systems where energy-intensive supply sources such as desalination will ultimately play a major role (such as Melbourne), the use of recycled water to substitute non-potable uses can result in a reduction in greenhouse gas emissions in comparison. Based on recent data, recycled water production and supply consumes approximately 1,600kWh/ML compared with an estimated 2,100kWh/ML for potable water, which includes a mix of desalinated water and dam water. In comparison, it is not uncommon for a typical household rainwater tank system to use around 2,500kWh/ML.

CONCLUSION

The key outcomes of the investigation for Melbourne’s North were as follows:

- All preferred options – whether it be the best traditional option (Option 2) or the best integrated option (Option 3, which is illustrated in Figure 6) – involved local

![Figure 6. Schematic diagram of the best “integrated” option.](image-url)
treatment and recycling. As a result of this investigation, YVW is planning for all new developments within the NGA to be required to provide the necessary recycled water reticulation assets and connect to the local recycled water system provided by YVW – enforced using Clause 56 of the Victorian Planning Provisions, which define the conditions that are associated with the sub-division of land.

- Alternate water sources should not compete against each other. This investigation has shown that multiple sources can be used in a complementary way without negating their own unique benefits. As the water balance indicates, the area is an overall “net water producer”, with the annual volume of rainfall and wastewater far exceeding total demand.

- It is possible to implement stormwater retention measures, which achieve the desired runoff frequency outcomes. The exact configuration of these solutions is area-specific, however they will be distributed across a range of scales (i.e. allotment, street and public open space).

- Given the difficult soil conditions in the NGA, agreed solutions to manage stormwater runoff frequency and volume will be challenging to find. One possible alternative is to undertake large-scale stormwater harvesting with the aim of producing drinking quality water (this is currently being tested at a pilot scale by YVW at its Merrifield Stormwater Harvesting Project, which is jointly funded by the Australian Government).

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**REFERENCES**


