A Water Sensitive Cities Index to support transitions to more liveable, sustainable, resilient and productive cities

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Abstract
There is growing emphasis globally on the importance of water system services in enhancing a city's liveability, sustainability, resilience and productivity. However, achieving these outcomes, particularly against the backdrop of climate change and rapid urbanisation, requires significant realignment of the how water system services are planned, designed and delivered. Initiating and navigating this realignment is difficult and requires targeted and context-specific guidance. In response, the Cooperative Research Centre for Water Sensitive Cities is developing a new benchmarking tool known as the Water Sensitive Cities (WSC) Index. The WSC Index is designed to facilitate assessment of the water sensitivity of a local municipality or metropolitan city, set targets based on the best available research and inform management responses to improve water sensitive practices. This paper presents results from a pilot study application of the WSC Index, demonstrating the value of the WSC Index as a tool to equip stakeholders with the capacity to monitor, evaluate and ultimately improve their water system practices through the identification and prioritisation of management responses.

Keywords
Indicators; benchmarking; water sensitive cities; sustainable urban water management; transition

INTRODUCTION

There is growing emphasis in science, policy and practice around the world on the importance of water system services in enhancing a city's liveability, sustainability, resilience and productivity. However, achieving these outcomes, particularly against the backdrop of climate change and rapid urbanisation, requires significant realignment of the how water system services are planned, designed and delivered. This realignment must involve moving beyond conventional servicing towards a water sensitive approach, which entails integrated management of the whole water cycle, consideration of water systems as an integral part of the urban landscape, and engagement with citizens as active stewards of a city's water resources and environments (Wong and Brown 2009). A city's transition towards more water sensitive practices therefore requires fundamental shifts in how infrastructure is provided, regulatory and financial frameworks as well as citizen behaviours (Brown et al 2009). Initiating and navigating the changes required is difficult, particularly as existing structures and processes typically reinforce and anchor the status quo (Farrelly and Brown 2011). Exacerbating these challenges is the difficulty in achieving coordinated and aligned action across multiple organisations, even when there are good intentions or policy aspirations. Targeted and context-specific insight is therefore needed to guide strategic initiatives that will support and enable shifts to more water sensitive practices (Ferguson et al. 2013).

In response to this need, the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) is developing a new benchmarking tool, the Water Sensitive Cities (WSC) Index. It aims to support strategic planning and decision-making, foster inter-city learning and enable national governments to assess their cities' urban water management trajectories in relation to other cities. The WSC Index is designed to facilitate assessment of the water sensitivity of a local municipality or metropolitan city, set targets based on the best available research and inform management responses to improve water sensitive practices. It is supported by a web platform that enables visualisations of benchmarking results for a range of audiences, including policy-makers and service providers.

While development of the WSC Index is ongoing, it has recently been applied in a pilot study in an Australian city. This paper presents the results from this case study application, demonstrating the value of the WSC Index as a tool to guide water sensitive city transitions at both the metropolitan and municipal council scale.

METHODS: WSC INDEX DEVELOPMENT

Water-Related Indicators

Indicators play an important role in the assessment of progress towards normative city goals such as sustainability and liveability. They support the dissemination of information, provide a common language for describing the complexity inherent in such assessments, and facilitate effective and clear communication amongst stakeholders with diverse interests (McCool and Stankey 2004). The number of indicators to measure sustainability has proliferated in recent decades, including a wide range designed to assess water-related issues. These are developed across multiple scales, from global scale assessments (e.g. Vörösmarty et al. 2000, Vörösmarty et al. 2012) to municipal level initiatives (e.g. city report cards). As a crosscutting issue, water-related measures can be found in sustainability, urban, governance, vulnerability, resilience and liveability indicator initiatives, reflecting the multi-dimensional nature of water.

Despite the vast array of indicators available, their uptake in practice has been limited, and few are designed to assess or inform the development of long-term policy for sustainable urban water management (Gleick 2003, Brown et al. 2009). Problems associated with current water-related indicator approaches include: (1) narrow focus (e.g. solely on drinking water quality); (2) failure to address the needs of policy and decision-makers; (3) scalar mismatch, particularly between administrative boundaries and flow resources (van der Zaag and Gupta 2008); (4) limited data availability (WWAP 2012), and (5) disconnect between data collection and reporting functions (Hildén and Rosenström 2008, Jesinghaus 2012). To avoid these problems, some scholars advocate for the engagement of end-users during indicator development (Bond et al. 2005; Brenning 2007; Bouleau et al. 2009; Hildén and Rosenström 2008) in order to address the information needs of decision and policy-makers (Dunn and Bakker 2009, Dunn and Bakker 2011).

WSC Index Development Process

The development of the WSC Index aims to address key deficiencies described in the previous section: (1) it takes a broad perspective; (2) it engages with industry, policy and decision-makers throughout the development process to ensure their needs are met; (3) it is applied at the metropolitan and municipal council scale—the frontline of water management—where water-related data is most readily available (Norman et al. 2012, Dunn et al. 2014). The WSC Index is being developed iteratively through prototype, refinement and pilot testing phases. This has involved close engagement with CRCWSC industry partners to create a product that is functional, useful and presents clear benefits, as well as being reliable and scientifically robust.

An in-depth literature review revealed there are few existing tools to assess the multiple dimensions of a city's water sensitivity or inform appropriate management responses. As such, a prototype framework for the WSC Index was developed, drawing on relevant existing indicators and supplemented with emerging knowledge from CRCWSC research. The prototype was trialled with two municipal Councils in Australia. This provided insights to inform a subsequent phase of refinement and enhancement, which focused on reducing the number of indicators, clarifying indicator descriptions and developing the conceptual basis for analysing the indicators through a number of different frameworks that would support the development of management responses. The WSC Index was then pilot tested in three case study locations within a single metropolitan area in Australia (one case at the metropolitan scale and two cases of municipal Council areas) in order to validate and further refine the WSC Index and benchmarking process. The final phase of development and testing (forthcoming) will focus on further developing the WSC Index to identify and prioritise management responses for the pilot case studies.

Indicators and Analytical Lenses

The WSC Index has multiple aims: To provide a communication tool for describing key attributes of a water sensitive city; articulate a shared set of goals of a water sensitive city; provide a global benchmarking for a city; measure progress and direction of progress towards achieving water sensitive city goals and assist decision-makers prioritise actions; define responsibility and foster accountability for water-related practices. It comprises 34 indicators, which represent important attributes of a water sensitive city across social, technical and ecological domains. These indicators are organised under seven thematic goals for water sensitivity (see Table 1). Scoring for each indicator is qualitative, with a rating from 1 to 5 assigned according to the description that best fits the city's current situation. Table 2 provides an example of an indicator rating descriptions.

Three analytical frameworks support interpretation of the indicator scores and provide insight into the management responses that should be prioritised to advance water sensitive practice: (1) city-states, (2) principles of water sensitive practice, and (3) water sensitive outcomes.

City-State Continuum

The Urban Water Transitions Framework (Brown et al. 2009) identifies evolving socio-political drivers and service delivery functions as six distinct developmental states that cities move through in response to society's expanding objectives for urban water management. These form an embedded continuum, culminating in the water sensitive city (Figure 1). The city-state continuum provides the first analytical lens, based on the calculated percentage of indicator scores that are above or equal to the threshold values associated with each idealised city-state.

Principles of Water Sensitive Practice

The water sensitive city concept is underpinned by three distinct sets of practices that deliver important services (Wong and Brown, 2009). *Cities as catchments*, in which all the available water resources within an urban footprint are considered valuable. This includes sewage, rainwater, stormwater and groundwater, and infrastructure systems integrate both centralised and decentralised technologies to utilise these resources at different scales in fit-for-purpose applications. *Cities providing ecosystem services*, in which water infrastructure and the urban landscape are designed both functionally and aesthetically. These integrated systems provide multiple benefits, including stormwater treatment, flood protection, heat mitigation, ecological health and landscape amenity. *Cities with water-conscious citizens and communities*, in which people appreciate the many values of water, feel connected to their local water environments and engage in water sensitive behaviours. Organisations and professionals that influence water management exhibit policies and practices that lead to water sensitive outcomes. These practices form the second analytical lens, based on the average score of the indicators that are associated with principle of practice.

Water Sensitive Outcomes

As a city becomes more water sensitive, its capacity to deliver liveability, sustainability, resilience and productive outcomes increases. These four outcomes provide the third analytical lens for interpreting the indicator scores of a city. *Liveability* refers to the capacity of the water system to deliver a high quality of life for people, and includes outcomes such as thermal comfort, aesthetics, amenity, social connection and a healthy environment. *Sustainability* refers to the ongoing capacity of a city's water system to provide services for current and future generations. *Resilience* refers to the capacity to maintain the delivery of water system services as conditions change and in the face of acute and chronic disturbances, through adaptation and/or recovery. *Productivity* refers to the capacity of the water system services to generate economic value, either directly or indirectly. These four water sensitive outcomes form the third analytical lens, based on the weighted (High, Medium, Low) average score for the indicators that are associated with each outcome.

Table 1. WSC Index goals and indicators

Goal 1. Ensure good water sensitive governance	1.1 Knowledge, skills and organisational capacity
	1.2 Water is key element in city planning and design
	1.3 Cross-sector institutional arrangements and processes
	1.4 Public engagement, participation and transparency
	1.5 Leadership, long-term vision and commitment
	1.6 Water resourcing and funding to deliver broad societal value
	1.7 Equitable representation of perspectives
Goal 2. Increase community capital	2.1 Water literacy
	2.2 Connection with water
	2.3 Shared ownership, management & responsibility
	2.4 Community preparedness and response to extreme events
	2.5 Indigenous involvement in water planning
Goal 3. Achieve equity of essential services	3.1 Equitable access to safe and secure water supply
	3.2 Equitable access to safe and reliable sanitation
	3.3 Equitable access to flood protection
	3.4 Equitable and affordable access to amenity values of water-related assets
Goal 4. Improve productivity & resource efficiency	4.1 Maximised resource recovery
	4.2 Low GHG emission in water sector
	4.3 Water-related business opportunities
	4.4 Low end-user potable water demand
	4.5 Benefits across other sectors
Goal 5. Improve ecological health	5.1 Healthy and biodiverse habitat
	5.2 Surface water quality and flows
	5.3 Groundwater quality and replenishment
	5.4 Protect existing areas of high ecological value
Goal 6. Ensure quality urban space	6.1 Activating connected green - blue space
	6.2 Urban elements functioning to mitigate heat impacts
	6.3 Vegetation coverage
Goal 7. Promote adaptive infrastructure	7.1 Diversify self-sufficient fit-for-purpose water supply
	7.2 Multi-functional water infrastructure
	7.3 Integration and intelligent control
	7.4 Robust infrastructure
	7.5 Infrastructure and ownership at multiple scales
	7.6 Adequate maintenance

Table 2. Example indicator rating descriptions

Goal	1.	Ensure good water sensitive governance
Indicator	1.2	Water is key element in city planning and design
Ratings:	1:	Water policy and management beyond essential services are rarely considered in matters of urban planning.
	2:	General policy on sustainability is in place but there is a lack of focus on integrated water system planning.
	3:	Urban water policy acknowledges the role of integrated water management planning and water system planning coordination between organisations occurs, often led by a single agency or department.
	4:	Urban water policy acknowledges the role of integrated water management planning and some collaboration between organisations occurs. Contingency planning are routinely used and incorporate methods such as scenario planning to deal with uncertainty around issues such as population growth and climate change. Monitoring and evaluation of planning is in place.
	5:	Water system planning is fully integrated in urban planning and design. Cross-sectoral collaboration to water system planning is mandated in official policy and included in statutory planning frameworks. Contingency planning are routinely used and incorporate methods such as scenario planning, robust decision making and exploratory modelling to deal with uncertainty around issues such as population growth and climate change. Monitoring and evaluation of planning is in place. Urban design guidelines address the critical role of water in achieving liveability, sustainability, resilience and productivity goals. Strategies and plans are explicitly adaptive.

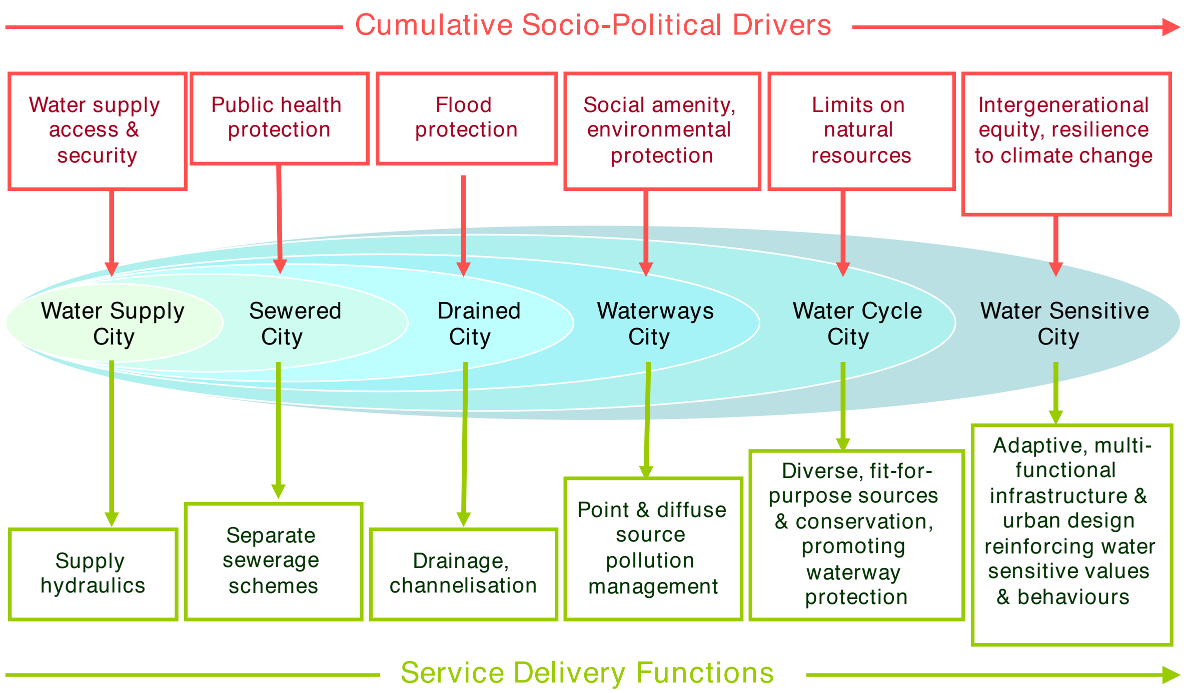

Figure 1. City-state continuum of the Urban Water Transitions Framework (Brown et al. 2009)

METHODS: CASE STUDY APPLICATION

The pilot study for the WSC Index has involved its application to three case cities from the one Australian city: the metropolis itself (M) and two embedded municipal Councils (C1 and C2) with significantly different geographic, demographic, socio-economic and development characteristics. The cities have been de-identified for this paper as the research is still preliminary. The pilot study was conducted from February to July 2016, and aimed to test and validate the framework and functionality of the WSC Index relative to four aspects of value: reliability, usability, usefulness and transferability. Data for the pilot assessments were collected through a participatory workshop in each case city. Since the WSC Index assessment is based on geographic area rather than organisational responsibility, participants represented a range of stakeholder organisations with a role in the delivery of the city's water system services, including the municipal Council, water utility, government departments with recreational and environmental responsibilities, and others (N=25 for M, N=20 for C1 and N=19 for C2).

The workshop process took participants through a three-step method for scoring each indicator: (1) live polling to gauge individual participants' perspectives on the score for the indicator in question, (2) interactive discussion to uncover evidence and justification to inform the indicator's score, and (3) reach consensus amongst the participants on the score to be assigned. The live polling used a bespoke web-based tool that participants accessed through their mobile devices to score 1-5, the collective results for which were then showed in real-time. These results were then discussed, evidence identified (e.g. policy documents, organisational materials, expert views) and consensus achieved. Approximately 15 minutes was allocated for each indicator and in order to cover all 34 indicators in one day, two concurrent sessions were facilitated; one for biophysical indicators and one for socio-political indicators. This also allowed participants to concentrate on scoring indicators most relevant to their expertise and interest or knowledge. Participants uncertain on their ability to score certain indicators could abstain from the poll, however this option was rarely taken up and all participants were involved in the discussions.

The validity of the indicator scores was tested through an exit survey of the workshop participants, asking how closely the results matched their expectations for their city's performance. 92% of the participants (M: 23 out of 25, C1: 20 out of 20, C2: 15 out of 18) responded that the results were somewhat or very similar to what they expected, which gave confidence in the accuracy of the scores. A likely explanation for the 8% of participants who felt the results were very different to their expectations is that many of the participants in C2 were only advised the day before the workshop that they would be participating. This meant there was minimal time background discussions and preparations in advance of the scoring and so some people may have been unfamiliar with some of the concepts discussed in the workshop.

RESULTS

This section presents the results for the three pilot study applications of the WSC Index: Metropolis (M), Council 1 (C1) and Council 2 (C2). Benchmarks for an idealised Waterways City and Water Cycle City are also shown to provide a reference point for interpreting the pilot results. The average score for each of the seven goals in the pilot cases is presented in a radar chart in Figure 2, visually highlighting the relative performance of each city and in comparison to the idealised reference cases. The indicator scores for the three pilot cases are then analysed through the three analytical lenses embedded in the WSC Index tool, as presented in Figure 3.

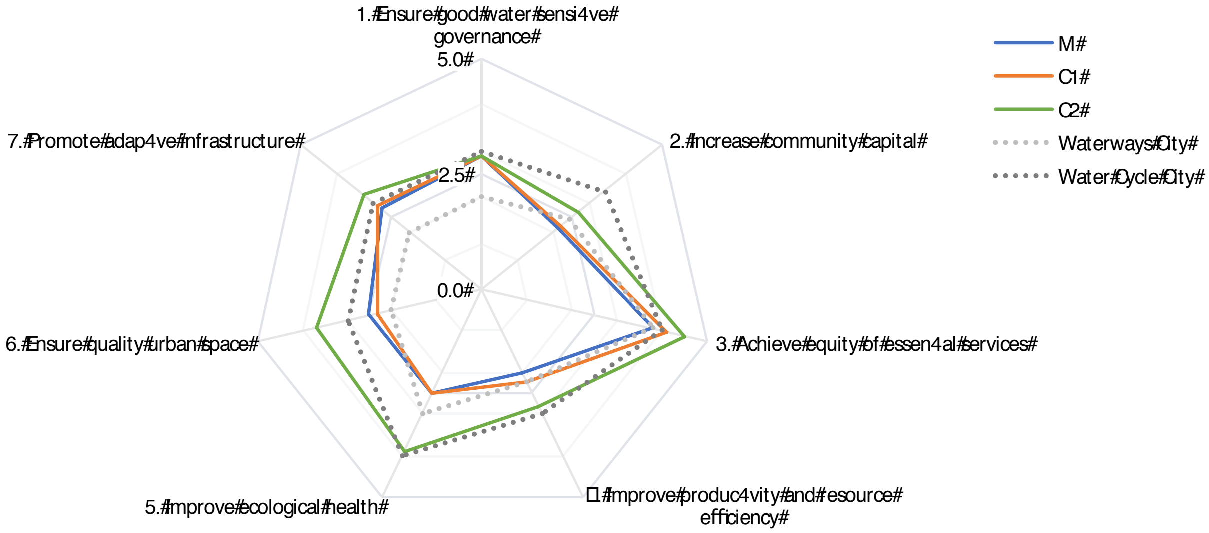

Figure 2: Average goal scores for pilot study and reference cases

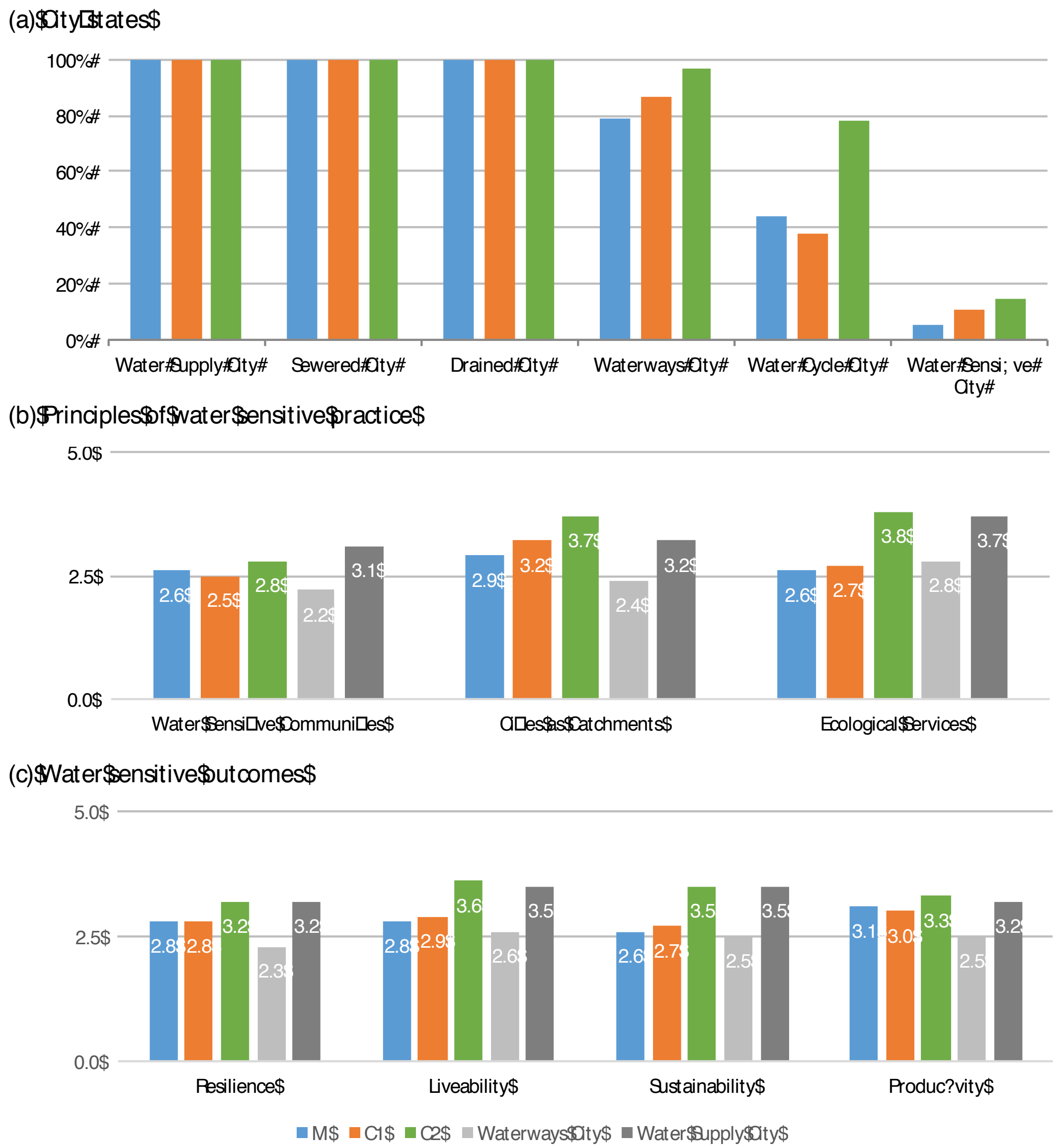

Figure 3. Pilot study and reference case results represented through the three analytical lenses

DISCUSSION

Figure 3a shows that all three pilot cases have fully achieved the *water supply*, *sewered* and *drained city* states and are in various points of transition towards the more aspirational city states. Progress towards the *waterways city* is strong (M=79%, C1=87%, C2=97%), reflecting the presence of a significant river in the region that is valued as a key landscape, recreation and environmental asset, as well as strong institutions that undertake integrated planning for the river corridor and implement significant initiatives for the protection of waterway environments. Reasonable progress towards the *water cycle city* (M=44%, C1=34%, C2=78%) reflects the presence of integrated water systems that rely heavily on groundwater and, recently, managed aquifer recharge schemes. The metropolitan utility operates a large scheme that recharges groundwater with recycled wastewater and some individual municipal councils (including Council 2, resulting in the high benchmark observed in Figure 3a) operate local recharge schemes with stormwater resources. These schemes are supported by an institutional setting that has relatively advanced governance and regulation, consistent with elements of the *water cycle city*. Progress towards the *water sensitive city* is still limited for all three cases (M=5%, C1=11%, C2=15%); examination of the individual goal scores other two analytical lenses provide insight into the management responses that would most effectively advance water sensitive practice.

Of the three pilot cases, Council 2 is benchmarked as the most water sensitive across all goals and analytical lenses. The average goal scores in Figure 2 show that in particular, Council 2's performance for *Goal 5 Improve ecological health* and *Goal 6 Ensure quality urban space* is higher than the Metropolis and Council 1, which is also reflected in a significantly higher benchmark for *ecological services* principle of practice (Figure 3b). Figure 3b shows that Council 2's benchmarked principles of practice were above the *water cycle city* reference case for *cities as catchments* and *ecological services*, but not for *water sensitive communities.* This indicates that to make further progress towards the *water sensitive city* state, management responses should target the associated goals, particularly *Goal 1 Ensure good water sensitive governance* and *Goal 2 Increase community capital.*

In contrast, Council 1 and the Metropolis would progress further along the city-state continuum by management responses that target the *ecological services* (Figure 3b), which is currently the only principle of practice that benchmarks below the reference case of the *waterways city*. *Goal 5 Improve ecological health* would be particularly important to focus on in order to increase their average score of 2.5 to the *waterways city* reference benchmark of 3.0 (Figure 2). Figure 2 shows that Council 1 and the Metropolis would also benefit from management responses with a particular focus on *Goal 2 Increase community capital*. While their overall benchmark for the *water sensitive communities* principle of practice was above the *waterways city* reference score (Figure 3b), it is clear from Figure 2 that their performance *Goal 1 Ensure good governance* is markedly better (2.9), almost meeting the reference benchmark of 3.0 for the idealised *water cycle city* case.

Analysis of *water sensitive outcomes* in Figure 3c shows that the three pilot cases score above the idealised benchmarks for a *waterways city* in each of the categories, even with the low *Goal 5 Improve ecological health* score for the Metropolis and Council 1 shown in Figure 3b. The majority of indicators under *Goal 5 Improve ecological health* contribute to *liveability* and *sustainability* outcomes, however, indicators that are scored more highly under the other goals compensate for the low goal score. Council 2's higher score for *Goal 5 Improve ecological health* and *Goal 6 Ensure quality urban space* goals is shown to result in significantly higher *liveability* and *sustainability* outcome benchmarks (Figure 3c).

Further insight on appropriate management responses would be gained by examining the individual scores within each goal to assess which particular indicators should be prioritised to achieve the city's local objectives. However, this is beyond the scope of this paper due to space limitations.

CONCLUSION

The analysis presented in this paper highlights the insights that can be gained through application of the newly developed WSC Index for guiding action to support and enable shifts to more water sensitive practices. It is too early in the tool's development and testing to fully assess the value of the individual analytical lenses embedded in the WSC Index but the pilot case study results are promising. Using the WSC Index as a benchmarking tool equips stakeholders with the capacity to monitor, evaluate and ultimately improve their water system practices through the identification and prioritisation of management responses. This capacity is essential to the goal of realigning the planning, design and delivery of water system services to enhance the liveability, sustainability, resilience and productivity of our cities.

The city-state continuum lens of the WSC Index has created significant interest amongst the CRCWSC's industry stakeholders, reflecting the fact that the water sensitive city concept has become well established in Australia and the water sector is deeply engaged in the challenge of how to enable the transition to more water sensitive practices. The WSC Index provides a basis for city entities to characterise their current status against the ideal of the water sensitive city and identify their position against the city state continuum. This has created more intense and more widespread interest in the concept and brought a focus to the inherent desire of each city to improve its status. Although the WSC Index is not yet fully developed and has had no external promotion to date, a number of other cities not already engaged in its prototype development and pilot testing have expressed interest in applying the tool to inform their strategic planning.

Liveability, *sustainability*, *resilience* and *productivity* have been incorporated as an analytical lens to enable the outcomes of interventions, particularly infrastructural investments, to be differentiated. It is expected that city entities (such as municipal councils) will be interested in assessing the benefits of their water system services in terms of these outcomes. Narrowly-focused interventions often fall into the trap of achieving one outcome while leading to potentially unintended negative outcomes as by-products. For example, a city may strengthen its resilience to future uncertainties in drought conditions through investment in high-energy centralised solutions (such as desalination) without exploring the sustainability benefits that could be gained through using alternative water resources (such as harvested stormwater) and liveability benefits from infrastructure that is distributed through the landscape (such as biofilters). It is anticipated that the *water sensitive outcomes* analytical lens would reveal that such a scenario could lead to a high score for *resilience* but low for *sustainability*, *liveability* and *productivity*. Ideally, strategic interventions are expected to concurrently improve a city's rating across each of these four outcome areas.

During the pilot testing process, stakeholders have expressed strong interest in the *water sensitive outcomes* results. The next stage of the WSC Index tool's development will focus on providing the means for a city to set targets and model management action scenarios, which will provide further opportunity to explore the utility of this lens, as well as the *principles of water sensitive practice* lens. The pilot results reveal that the results for this practice lens may provide clearer identification on the nature of interventions to be adopted in improving the water sensitivity of cities. This finding will be explored upon the WSC Index's further development towards a tool that cities can use to inform the development of a strategy for transitioning to a more advanced city-state, whether expressed as a location on the city-state continuum, implementation of water sensitive practices, or the delivery of liveability, sustainability, resilience or productivity outcomes.

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