The cost-effectiveness of water augmentation and management: Assessing the Unit Reference Value

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As societies develop, the problem of securing and mobilising adequate water resources to support and sustain economic and social activities increases in complexity. As a cost-effectiveness measure the use of the Unit Reference Value (URV) has become standard practice in South African water resource management and development. It is informative and easy to understand. These two attributes inspire confidence and an ever-greater uptake of its use in evaluating suggested courses of action to be taken by society in ensuring their future. Deviations in how an URV is calculated emerge due to both the diversification of its user base and the dynamic nature of the contexts in which it is applied. Such developments add to the pluralistic framings within which research and decision-makers operate. We provide three sub-types of URV application, and caution against comparing URVs across categories. To mitigate possible confusion, we propose the development of standards/rules for the interpretation of URVs.
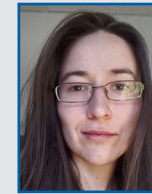
INTRODUCTION

The multifarious use, and even occasional abuse, of research methods and/or indicators are common features within the natural development of science and scientific progress. These multifarious uses often persist due to a resistance to integrative and collaborative learning approaches that emanate from the structure of the various formal and informal institutions involved in knowledge-generating systems (Angelstam *et al* 2013). The gradual entrenchment of indicator adaptations has been cited as the cause for the increase in statistical errors in medical research (Glantz 1980), the development of expensive and ineffective educational practices (Alferink & Farmer-Dougan 2010), private sector underinvestment (Drury & Tayles 1997), and the increase in the incidence of physical injury caused to patients by medical practitioners (Brisson & Brisson 2010). To tunnel through this pervasive resistance requires occasional reflection or, to borrow jargon from systems thinking, *feedback to recalibrate.* The question is, how do we conduct such mental feedback?

One proposed way is a systematic look at the **V**alues (or norms), system **R**ules (or policies), and prevailing **K**nowledge at various stages (i.e. over time) and how that shaped the application, and thus change in and the use of any particular research methods and/or indicators. This model, herein called the VRK-framework, is based on the work of Goddard *et al* (2016), and has been developed for the analysis of contested, complex and cross-scale "problems". It is a very useful framework in the interpretation of the causes of the multifarious use of research methods and indicators, as emerging from the interaction between a universal value for the use of a particular method, and the evidence and practice-based knowledge inequalities between user groups or individuals.

Here we apply the VRK-framework to develop a deeper understanding of why, and how, South Africa's Unit Reference Value (URV) has been used in the recent past, and more specifically, how and why it has undergone various indicator adaptations. The URV is a cost-effectiveness measure developed for use in the pre-planning stages of water resource management and development projects. It assists decision-makers in allocating scarce resources in the most effective way by comparing, in a consistent manner, various water development schemes. Over time, however, the URV has been applied in various settings by an increasingly diversified user base. This resulted in a cumulative series of adaptations to the URV from a diverse knowledge base following the continuous application of it within varied new organisational and environmental contexts. While it could be argued that it would appear that the multifarious use of the URV has

supported useful policy interventions and necessary shifts in the narrative around the management of water resources, there is a risk that it might well be correlated with increased ineffectiveness in water management. This is due to the fact that the adaptations of the URV have remained largely unchallenged. This paper is an attempt to rectify this situation by conducting a critical review, based on the VRK-framework, of the use of the URV indicator in South Africa.

We commence with a discussion on the natural progression of the context within which the URV was developed, and which has also given rise to its multifarious use based on the VRK-framework. Thereafter we take a critical look at the various ways the URV has been calculated, and the implications thereof. This is followed by recommendations with respect to the future development thereof.

CONTEXTUAL PROGRESSION AND THE GROWTH IN URV THINKING

Introduction

The URV was developed in the 1980s by the then Department of Water Affairs. It was developed as a cost-effectiveness measure that computes the unitary cost of supplying a cubic metre of water at the required assurance of supply, over the portion of the water management or augmentation project's lifespan during which it produces economic benefits for society. In its most basic form the URV is calculated as the discounted present value of the total (capital and operational) lifecycle cost of a water augmentation or management scheme divided by the discounted incremental water availability assured by the expansion of the system and bounded by the projected demand curve until full capacity is reached (Van Niekerk & Du Plessis 2013a). Discounting a natural resource stock such as water is a contested issue (Costanza *et al* 1989). However, the URV has adopted this approach in order to be able to compare, in a consistent manner, the URV ratios of different water development schemes, operating with different time horizons, which have different starting dates, thus avoiding an artificial lowering of the cost of water development by various schemes.

The URV, because of its simplicity in calculation and the ensuing intuitive understanding of the message it is carrying, has become a very powerful indicator with respect to water resource management and development. Over time it has become not
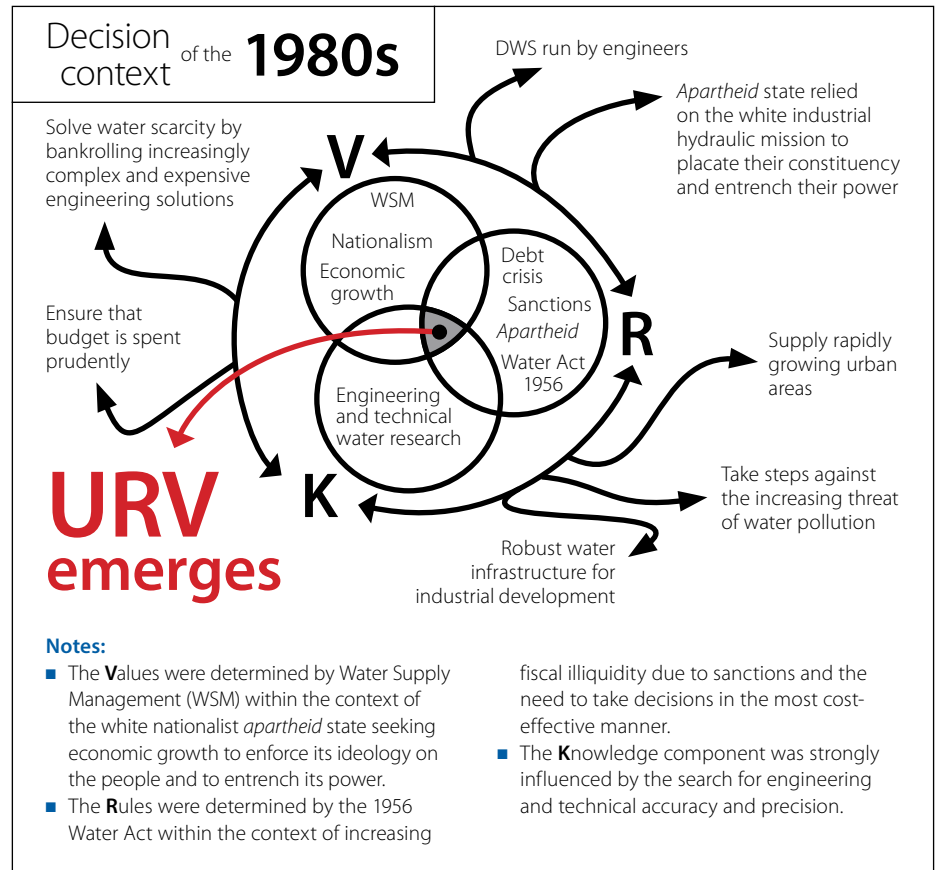
Figure 1 The decision context of the 1980s

only standard practice to calculate the URV for all water-related projects, but also mandatory within the context of any fiscal and budgetary process to motivate for financial or other resources. This natural progression with respect to the use and popularity of the URV coincided with a radical change within the political-social-economic and ecological context within which it has operated. We analyse this change at the hand of the aforementioned VRK-framework.
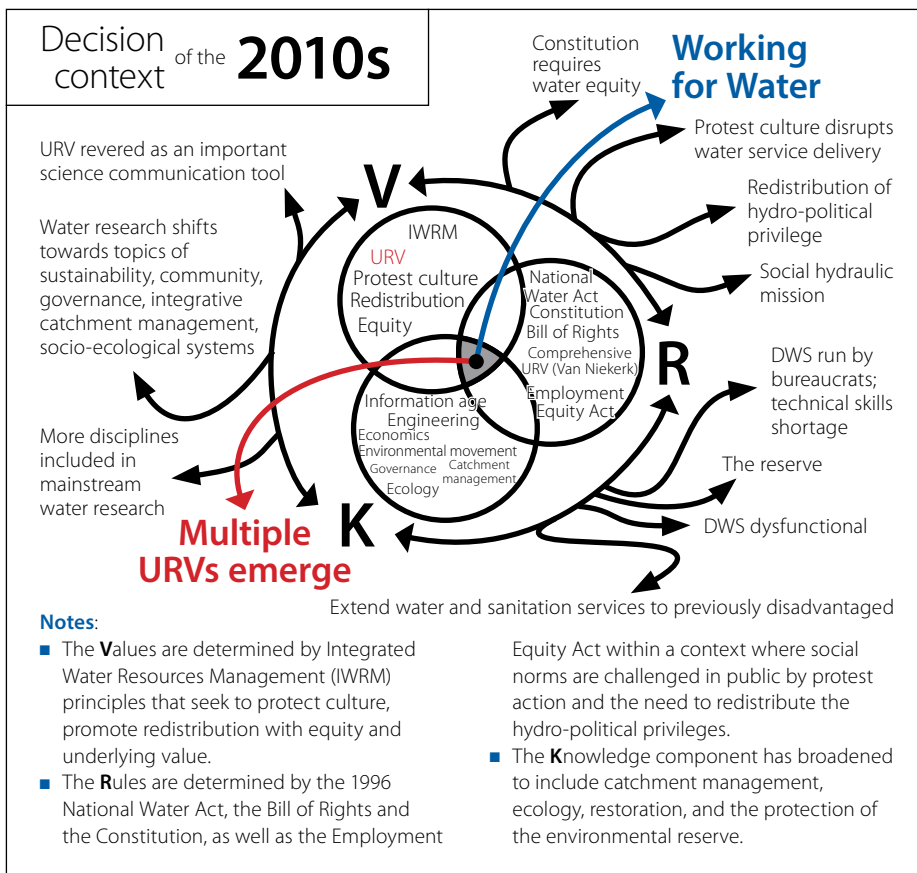
Cross-temporal analysis of the context of water resource management

Goddard *et al* (2016) proposed a values, rules and knowledge (VRK) framework with which to understand how a societal system of decision processes affects the manner in which a particular problem is addressed. We apply this framework to the South African decision-making context for water resource management, comparing a model of its state in the 1980s when the URV was developed (Figure 1) to a model of its current state (Figure 2).

In the 1980s water resource management was governed by Water Act No 54 of 1956. This Act required government to consolidate existing water legislation, and thus restructured the Department of Irrigation to form the Department of Water Affairs (DWA). The DWA had to ensure that there

was sufficient water supply to support South Africa's growing social, economic and industrial development initiatives (Tempelhoff 2017). In addition to this drive towards the heavy capitalisation of the country, it took place within the context of a very unstable internal and external political economy. Thus, there was a need to manage water resources more effectively and to secure internal water security through water supply management (WSM) (Lowenberg 1997). This led to a very dominant supply-side policy focus and water research. This produced engineering and technically based solutions (Siebrits *et al* 2014). With the DWA chiefly the technocratic territory of engineers, plans for the expansion of water supply to cities and areas of industrial development were focused on increasingly complex and costly transfer schemes (Turton & Meissner 2002). The URV was developed to assist in selecting the most cost-effective option first. This context is vastly different from that prevailing since the 1994 democratic elections and the rapid development of a natural resource management agenda – elements that have shaped the world of the current decade.

The prevailing context in the current decade is illustrated in Figure 2. Supply-side interventions were becoming costlier to implement just as the government, having been limited in their access to credit in

Figure 2 The decision context of the 2010s

The figure contains the following text:

Decision context of the **2010s**

Working for Water

Constitution requires water equity

URV revered as an important science communication tool

Water research shifts towards topics of sustainability, community, governance, integrative catchment management, socio-ecological systems

More disciplines included in mainstream water research

V

IWRM
URV
Protest culture
Redistribution
Equity

National Water Act
Constitution
Bill of Rights
Comprehensive URV (Van Niekerk)
Employment Equity Act

Information age
Engineering
Economics
Environmental movement
Governance Catchment management
Ecology

R

K

Multiple URVs emerge

Protest culture disrupts water service delivery

Redistribution of hydro-political privilege

Social hydraulic mission

DWS run by bureaucrats; technical skills shortage

The reserve

DWS dysfunctional

Extend water and sanitation services to previously disadvantaged

Notes:
- The **V**alues are determined by Integrated Water Resources Management (IWRM) principles that seek to protect culture, promote redistribution with equity and underlying value.
- The **R**ules are determined by the 1996 National Water Act, the Bill of Rights and the Constitution, as well as the Employment Equity Act within a context where social norms are challenged in public by protest action and the need to redistribute the hydro-political privileges.
- The **K**nowledge component has broadened to include catchment management, ecology, restoration, and the protection of the environmental reserve.

response to their policies, was growing more reliant on the expansion of the water supply to support the needed growth of economic activity. In such an environment, the application of cost-effectiveness analysis to eliminate the costlier supply interventions early in the planning process was developed.

In post-*apartheid* South Africa, the policy of government is not one of expanding the water supply to support economic development, but rather of extending water services to the areas that were beyond the jurisdiction of the DWA under *apartheid* (Schreiner 2013). Integrative Water Resource Management (IWRM) had replaced WSM as the dominant paradigm, but the successful implementation of its policies and interventions has been questioned, and even failed (Ashton 2000; Denby *et al* 2016). The most widely held belief for its failure is that the persistent levels of poverty and high-income inequalities, which were carried over from the 1980s, limit the successful implementation of IWRM (Movik *et al* 2016). Water research is increasingly dominated by ecologists and economists as focus has shifted away from engineering and technical solutions towards concepts such as sustainability, governance, adaptation and management (Siebrits *et al* 2014). The URV is thus adapted and used as a science communication tool (Blignaut *et al* 2010; Mander *et al* 2017). A decision to fund the Working

for Water (WfW) programme, which was made in 1995, had a positive impact on both the livelihoods of local communities and the availability of water, and has additionally promoted advances in biological control, raised conservation awareness, enacted legislation and promoted research (Binns *et al* 2001; Van Wilgen & Wannenburgh 2016). The expansion of water delivery services is frustrated by a growing protest culture (Tapela 2012) and the Department of Water and Sanitation (DWS) is evaluated as being in a state of dysfunction, lacking technical personnel, institutional capacity and funding to perform maintenance on water infrastructure (Ruiters & Matji 2015).

Comparing two epochs

The difference in social-political-ecological and institutional context between the 1980s and the current decade can hardly be greater. The 1980s were characterised by technocratic, success-seeking precision with a well-functioning and engineer-driven government department focused on water supply management to uphold a specific ideology of exclusivity and privilege. The current decade, however, is characterised by an inclusive, pluralistic and eco-anthropological ideology focused on integrated water resource management within the context of a hollow, and often failed, state (Morokong *et al* 2017).

It is in this latter context that multiple URVs emerged to assist and inform decision-makers.

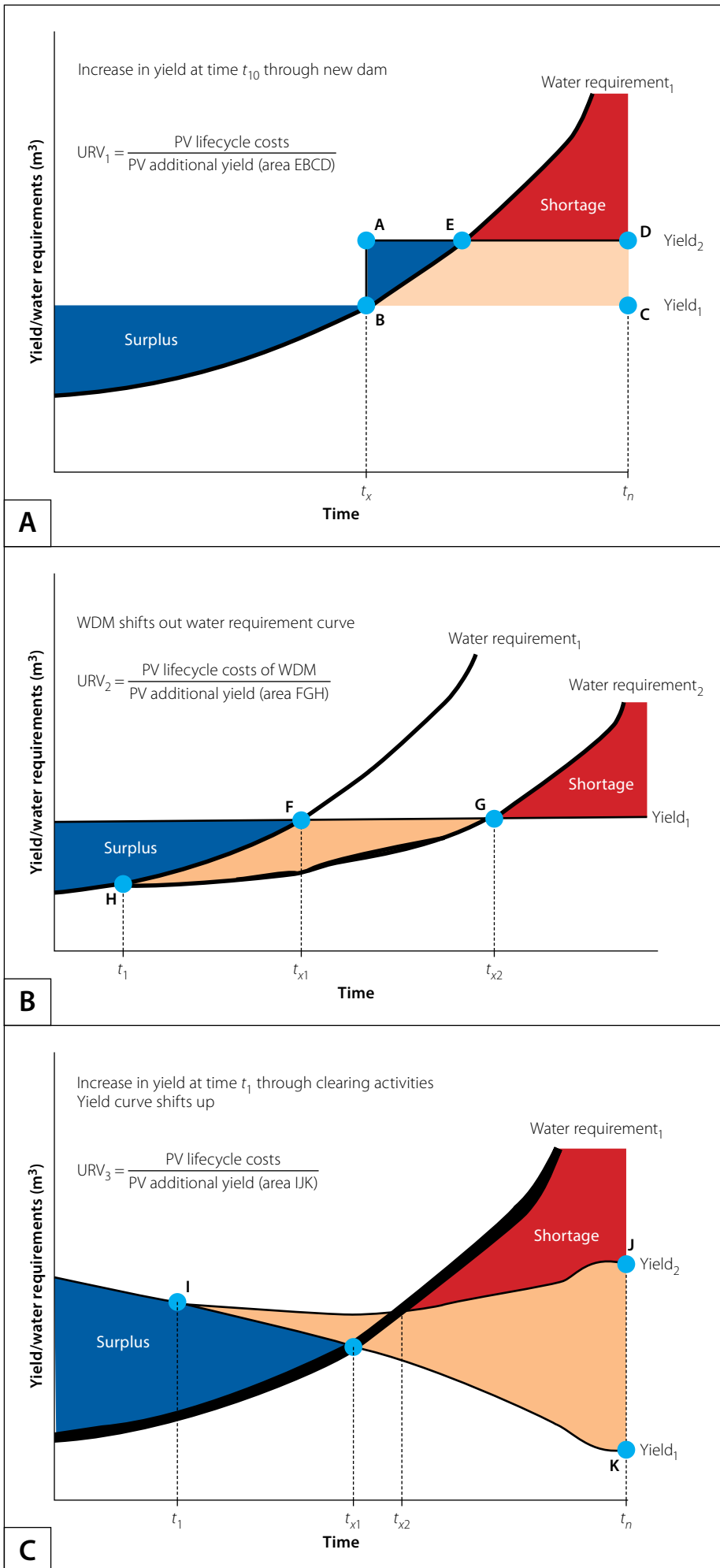## ADVANCES WITH RESPECT TO CALCULATING THE URV

Introduction

The URV is, essentially, a knowledge-generating tool. However, due to the contextual changes as described above, it became widely distributed for use across a broad number of organisational, sectoral and disciplinary boundaries. This made new applications possible that were not considered at first, or even deemed possible. Originally, in the 1980s, calculating a URV required one to take into consideration discounted lifecycle costs, projected water demand, the yield of the existing system including water transfers, and the incremental yield provided by the project being evaluated. The boundary of the problem is extended by the comprehensive URV to include an analysis of how each system's water demand and supply vectors vary over time and with respect to each other in the case of evaluating transfer schemes between two systems. In recent years, due to the multifarious use of the URV, the definition boundary has changed to exclude some core components of the original URV calculation, while expanding to include new components. A process, referred to above as indicator adaptation, occurred.

The URV's many faces

All the applications of the URV use the same definition with respect to costs, namely the numerator (i.e. the total capital or establishment costs plus the ongoing management and operation cost over time, discounted over the anticipated lifespan of the project). There are, however, at least three different interpretations with respect to the calculation of the denominator. We elaborate on these three below, labelling them URV1, URV2 and URV3 (as illustrated in Figure 3).

1. URV1 (the original version, see Figure 3: Panel A): The denominator is the additional water yield of a water development scheme bounded by a water requirement curve (Van Wilgen *et al* 1997; Larson *et al* 2001; Hosking & Du Preez 2002; Van Niekerk & Du Plessis 2013a, 2013b; DWS 2014; Blersch & Du Plessis 2017).

2. URV2 (URV1, but adapted for water demand management, see Figure 3: Panel B): The denominator is the additional structural water yield surplus, or

Figure 3 URV subtypes

simply the "water saved" in response to demand-side management interventions (Joubert *et al* 2003; De Lange 2006; Hoffman & Du Plessis 2008; Mckenzie & Wegelin 2009; DWA 2011).

3. URV3 (URV1, but adapted to accommodate environmental management such as rehabilitation and the clearing of invasive alien plants, see Figure 3: Panel C): The denominator is the ability to increase either water yield or base flow in a system, irrespective of direct human consumption of that additional water for water services (Marais & Wannenburgh 2008; Blignaut *et al* 2010; Preston 2015; Vundla *et al* 2016; Mander *et al* 2017; Morokong *et al* 2017; Nkambule *et al* 2017). It is used particularly where, due to uncertainty regarding the extent to which increased base flows will enhance the capacity of water infrastructure to meet societal demands, or indeed in the absence of such infrastructure for a river system all together, it has become the practice to forgo the consideration of a water requirement.

In literature, all three these methods, irrespective of the way in which the denominator is being defined and calculated, are called URV. This has the potential to lead to misguided outcomes and erroneous, and even inefficient, water resource management advice. The impacts of these three different ways of calculating the URV will be discussed at the hand of Figure 3, within the context of hypothetical examples.

Example URV1:
- **Context:** In Figure 3: Panel A, water demand increases over time and the water requirement of the system exceeds the water yield it can provide at time t_x. A water project that becomes operational at time t_x, and provides additional water yield (shifts out yield curve 1) of size A-B for

the rest of the economic life of the system until time t_n.

- **Denominator:** The URV used to evaluate the water project is concerned with the cost-effectiveness of the water project in enabling the system to meet its water requirements, and it discounts the hatched area (the area demarcated by EBCD) that is bounded by the system's projected water requirement curve.

Example URV2:

- **Context:** In Figure 3: Panel B, the water requirement of the system exceeds the water yield it can provide at time t_{x1}. Some water demand management measurements are implemented at time t_1, lowering the projected water requirement curve (shifting it down) and ensuring the system can meet its increasing demand for water until time t_{x2}. The system gains water surpluses (unused capacity) and delays the onset of future shortages.
- **Denominator:** The URV used to evaluate the water project discounts the hatched area (the area demarcated by FGH).

Example URV3:

- **Context:** In Figure 3: Panel C, the water requirement of the system exceeds the water yield it can provide at time t_{x1}, due to the spread of invasive alien plants (IAPs) which reduce runoff. In anticipation of future shortfall in the system's capacity to provide sufficient water, clearing of IAPs commences at time t_1 and continues for the economic life of the system until t_n. Like other supply-side interventions, the yield curve is shifted upwards improving the system's ability to meet its increasing demand for water (by $t_{x2}-t_{x1}$ years).
- **Denominator:** In this case, the URV used to evaluate the water project discounts the hatched area (the area demarcated by KIJ). Here the total additional yield provided by the intervention is taken as measure of effectiveness, irrespective of whether or not this additional yield will be used in the system. This is in contrast to the example given in Panel A in which only the additional water bounded by the water requirement curve is used to evaluate the cost-effectiveness of the intervention.

DISCUSSION

The process of calculating a URV is a platform which supports the development of synergies to create new knowledge on a project by project basis (Siedlok & Hibbert 2014). Above the line sits Economics/Finance, below the line sits Hydrology, Engineering and Ecology – and the URV analysis requires the inclusion of components from each. The emergence of a multifarious use of the URV, as seen in the previous section, can be explained by applying Argote and Miron-Spektor's framework (Argote & Miron-Spektor 2011) for organisational learning. In each instance the URV tool was shaped through use to accomplish the objectives of the new user for the purpose of the adopting organisation. For example, the URV was adapted for use in evaluating IAPs and motivating for their removal. The diffusion of the URV tool across multiple organisations predisposed users to have and acquire divergent evidence and practise base knowledge endowment. This made the emergence of several distinct URV deviations a sure thing, as the concepts of cost-effectiveness or accompanying graphing techniques were lost during the translation of the tool between organisations, or were discarded over time.

By viewing the URV through the VRK and organisational learning frameworks, we conclude that, since its emergence in the 1980s, the use of the URV has succeeded to influence value systems and operating protocols at a societal level. Politicians and researchers are aware of, and wish to entrench, its usefulness as a science-management communication tool, hence the repeated use of the URV. The URV is also a point in analysis around which synergies occur, encouraging those who engage with it to be exposed to a more holistic view of a particular subsystem. Owing to changes in the decision context of South African water management, an influx of researchers from a broadening set of academic disciplines expanded the experiential and practical knowledge stock embedded within the original definition and use of the URV. Unfortunately, it is also potentially misleading, as it is, essentially, not the same indicator given the different definitions used for the denominator.

Given the externality benefits produced by the URV, any aim to address the multifarious use of it must not inhibit any freedom in the ease with which it can facilitate communication between scientists and managers, or allow for innovation that comes from moving the problem boundary. Context is thus important and valuable, and additional rules imposed on its calculation must serve the pluralistic operational context. The co-habitation of the three URV formulae used, however, provides sufficient space for such a pluralistic environment.

CONCLUSION

The Unit Reference Value (URV) has been used in South Africa for more than 30 years, initially by water engineers, and later hydrologists, economists and ecologists alike within a drastically changed social-political-ecological and institutional context. As a cost-effectiveness measure it is highly informative and intuitively easy to understand – both aspects that generate further support for its use. Over time however, the multifarious use thereof has led to various ways in which researchers calculated its denominator, to the extent that, effectively, the results across the different types of URV measures cannot be compared without some discussion and distinction. This does not imply that the new developments have been wrong. Rather, they have added to the pluralistic context within which research and decision-makers operate, and is a good reflection of the current and emerging debates.

To mitigate against possible confusion and to avoid the misinterpretation of the results, we recommend the following:

- The introduction of naming conventions for different URV subtypes, namely URV1, URV2 and URV3, as per the above categories thereof. This would force URV users to make type-for-type comparisons and reach conclusions that can be supported from the theory, and which would make type-for-type comparisons possible. This will interact with the values and knowledge components to self-regulate further expansion.
- The redefining of the appropriate measure for all the URVs as "the unit cost to reduce future water shortage, or to enhance water security, using measure 1, 2, or 3" – that will be applicable in most interventions.
- That URV users provide, not only a formula or description of the URV calculation according to the type they are reporting on, but also a diagram illustrating what the effectiveness measure is that they are calculating. This would imply that users will engage with many of the principles underlying the URV and potentially be a point of learning between individuals that could reduce knowledge inequalities.

Within a world of increasing complexity, scarcity and dynamic change, the development of simple and effective indicators to assist in decision-making is of high value. The URV is one such an indicator. Here we propose three changes in the conventional use of the URV metric that should facilitate dialogue within the water resource management space, while improving the

nuances with respect to its use within various different contexts.

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