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Stalemate of the hydrological master variable? The challenge of implementing environmental flows in the Orange–Senqu basin

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ABSTRACT

In the face of declining rivers globally, the flow regime as the key hydrological determinant for healthy freshwater ecosystems is receiving unprecedented attention. This study investigates the challenge of implementing environmental flows in the Orange–Senqu basin in Southern Africa by assessing progress and its key factors during 1998 and 2013. Based on 22 interviews, the study shows that despite an advanced understanding of e-flows and its requirements, there have been effective implementation actions in only a few river systems to give effect to these e-flow requirements. Ineffective implementing institutions and a challenging basin context are more responsible than largely sufficient policies and legislation.

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Environmental flows; policy implementation; sustainable water management; ecological reserve; transboundary water cooperation; Orange–Senqu basin

Introduction

Environmental flows (e-flows) have evolved as a response to a gradually aggravating crisis of freshwater ecosystems around the world (Harrison et al., 2018). They 'describe the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being' (Arthington et al., 2018, p. 11). So far, scholarship has fallen short in understanding the success and failure of e-flow implementation with a narrow focus on country-specific cases and a lack of comprehensive examination of e-flow implementation within transboundary rivers. Moreover, few studies have paid close attention to the implementation complexities within the basin context, often only focusing on broader institutional aspects.

In this paper, an examination of policy and legislation, institutions and the basin context is conducted to better understand the success and failure of e-flow implementation in transboundary settings. Using the case of the Orange–Senqu river basin in Southern Africa, which is shared by Botswana, Lesotho, Namibia and South Africa, this paper explores progress and asks the following question: What are the enabling factors and barriers that have been most critical in the operationalization of e-flow

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requirements and their subsequent monitoring and management? In particular, the study examines the period between 1998 and 2013, which follows the landmark development of the National Water Act (NWA) (1998) and saw considerable efforts towards integrated water resources management (IWRM) planning and advancements in e-flow work.

The study focuses on policy and legislation, institutions, and basin context as they reveal a complex set of factors that determine the delivery of e-flows. Put differently, it brings together management, engineering, political and economic perspectives to understand e-flow implementation. First, this study examines how governmental water and conservation policy and legislation, as well as environmental safeguards by infrastructure financiers, create an enabling framework for effectively operationalizing e-flows. Second, it looks at the existence and structure, capacity, and political will within governmental ministries and agencies. Third, against the backdrop of the developing country context in which the basin is placed, the study investigates how the design and location of infrastructures affect technical and management steps as well as how conservation incentives arising from healthy freshwater ecosystems or the overuse that gradually degrades them widen or narrow the manoeuvre of decision-makers to support e-flows. In all these aspects, South Africa's great influence within the Orange–Senqu basin requires this study to concentrate on the country's policies and institutions – including its will and capacity to support e-flows basin-wide – as well as its basin development. While a range of studies have looked at e-flow implementation in South Africa (e.g., Hirji & Davis, 2009b), none has performed a basin-wide investigation. The paper advances scholarship by presenting an analytical framework that identifies factors significantly shaping implementation outcomes. Thereby, it contributes to methodological and conceptual insights that aim to further develop an understanding of what determines successful e-flow implementation. The paper draws on a documentary analysis of journal articles, reports and other grey literature by governmental ministries, non-governmental organizations (NGOs) and the basin's river basin organization as well as on 22 semi-structured elite interviews conducted between June and August 2017 with scientists, government officials, NGO executives and consultants from various countries through snowball sampling.

The paper is structured as follows. The first section reviews existing literature to design a nested, multitier framework for analysis of key enabling factors and barriers. The paper then details information on water resources developments, the state of rivers and implementation progress. The results section presents the findings which, despite some basin-wide similarities, highlight that key enabling factors and barriers vary considerably across the three implementing settings. The last section discusses the findings, reflects on the strengths and weaknesses of the analytical framework, and provides policy recommendations for avoiding a stalemate of the 'master variable' before encapsulating conclusions.

Understanding e-flow implementation

The science and methods to assess and implement e-flows have developed considerably over recent decades (Acreman, 2016; Dyson et al., 2008). Characterized by distinct flow patterns and changes, the flow regime comprises the most critical determinant for healthy rivers and was, therefore, coined the 'master variable' (Poff et al., 1997). Growing recognition of the importance of e-flows has prompted many countries and environmental organizations globally to engrain e-flow provisions into water policies, water allocation regimes, and the design and operation systems of water infrastructure (Horne et al., 2017). However, e-flow implementation on the ground – defined as 'a specific pattern of flows released or maintained in a river' (Brown et al., 2020, p. 77) – has often been technically and spatially limited. Where e-flow work goes beyond formulation in policy, challenges remain in integrating policy provisions into operational water management. Moreover, there is a global boom of dam infrastructure projects (Zarfl et al., 2015), most of which are still being constructed without any e-flow assessments being undertaken (King & Brown, 2018).

Multiple reasons exist for why implementation stalls during these steps, which have been investigated by various studies for the South African context (Brown et al., 2020; Dickens, 2007; Hirji & Davis, 2009b; King & Brown, 2010; King & Pienaar, 2011; Pollard & Du Toit, 2011; Qua-Enoo et al., 2006; Quinn, 2012; Ramulifho et al., 2019; Still et al., 2010; Van Wyk et al., 2006). Rather than technical in nature, such as the initial steps to determine e-flow requirements, operationalization and implementation require a political exercise of balancing competing needs, often exceeding available supply. In water-stressed places, e-flows face considerable resistance from water users. Decision-makers can thus be wary of lending support (Le Quesne et al., 2010). Several skilled scientists, moreover, can complete an e-flow assessment and establish technical procedures for implementation within a few months. The success of the latter implementation steps, in contrast, depends on a well-functioning water governance system and on conditions beyond the immediate water domain. This is why they are more complicated and take multiple years for completion, especially in transboundary basins (Brown & King, 2010). In the Orange–Senqu basin, there had been pioneering e-flow work as early as the late 1990s (Brown & King, 2010). Focusing on the period between 1998 and 2013 in particular provides rich knowledge and experience on the successes and challenges of implementation, such as the completion of most of the comprehensive e-flow assessments in the Orange–Senqu – for Katse and Mohale dams between 1998 and 2001; for the Vaal between 2007 and 2012; and for the Lower Orange between 2008 and 2013.

While the above studies demonstrate the challenges of e-flow implementation, only a few analytical frameworks currently exist (Harwood et al., 2018; Hirji & Davis, 2009b; Pollard & Du Toit, 2011). These studies highlight that successful implementation hinges on various interconnected factors at different spatial scales. Sometimes, just a few or a single impactful factor can drive success or failure. Key barriers and enabling factors, furthermore, vary largely between implementation contexts. Hence, there is no one-size-fits-all approach to guide implementation, especially when one considers that there is, in fact, quite an array of approaches that can be understood as supporting e-flows (Le Quesne et al., 2010). Being a collaborative and collective effort, it is also essential to account for the roles of various actors involved in the process (Harwood et al., 2017). These findings make a determinant framework best suited for explaining implementation success and failure. A determinant framework establishes several dimensions with submerged sets of factors, which act as enabling factors and barriers towards implementation outcomes (Nilsen, 2015). Nested, multi-tier analytical frameworks designed for the analysis of socio-ecological systems (Meinzen-Dick, 2007; Ostrom, 2007) are helpful to evaluate the relative importance of these different dimensions and submerged factors, as well as interactions among them, by considering if a factor exists and if its effect is enabling or constraining. This is important to avoid deducing solutions that fail to deliver their promised outcomes because they disregard the complexity and contextualities of the water governance system for which they were designed. In this study, we follow Pahl-Wostl et al. (2012) and use three dimensions (policy and legislation, institutions, and basin context) (Figure 1). We consider these three dimensions most suitable to cluster the factors, which we identified from the research literature as the most important ones for creating an enabling environment for successful e-flow implementation (Table 1, Table 2). In this paper, successful implementation is thus understood as the completion of the five steps displayed in Figure 1 that lead to durable compliance with environmental flows requirements, although we acknowledge that there are various other steps in the process contributing towards this outcome.

Policies and legislation

Without incorporating e-flows into policies and legislation, chances for success are low (Harwood et al., 2018). Policies and legislation set out the overarching objectives and framework for e-flow implementation, for example, by assigning responsible institutions (Speed et al., 2013). Chances for successful implementation are higher where e-flows are written into law and do not only exist in policies (Hirji & Davis, 2009a). Establishing e-flows in transboundary basins requires both international and national legislation. However, as transboundary basins generally lack legally binding agreements that go beyond broad concepts such as 'reasonable harm' or 'prior notification', the national level becomes more specific and important (Dyson et al., 2008). Different types of policies and legislation are relevant to e-flow implementation. Water-management legislation entitles the environment as a legitimate water user and ensures its consideration in allocation decision-making (Harwood et al., 2018). There are meanwhile various cases where environmental policies by donor institutions guaranteed that developers have integrated e-flow requirements into the design and operations of new dams (Harwood et al., 2018). Moreover, the designation of protected areas such as national parks has positively affected implementation as environmental water constitutes a prerequisite for reaching conservation objectives (Hirji & Davis, 2009a)

Institutions

Capable institutions are fundamental to implement and enforce policies and legislation. While there are various actors involved in e-flow implementation in transboundary basins, water-related ministries and local water-management agencies are those mainly responsible for following through on the final steps. The existence and structure of these institutions, their capacity and will to support e-flows are all important for successful e-flow implementation. As Table 2 shows, they have the scope to perform various functions, from establishing and enforcing planning and allocation processes, assessing and determining e-flow requirements, to involving and gaining stakeholder support. These tasks require sufficient staff with ample know-how and skills, which range from performing hydrological modelling to mediating conflicts among stakeholders, as well as securing

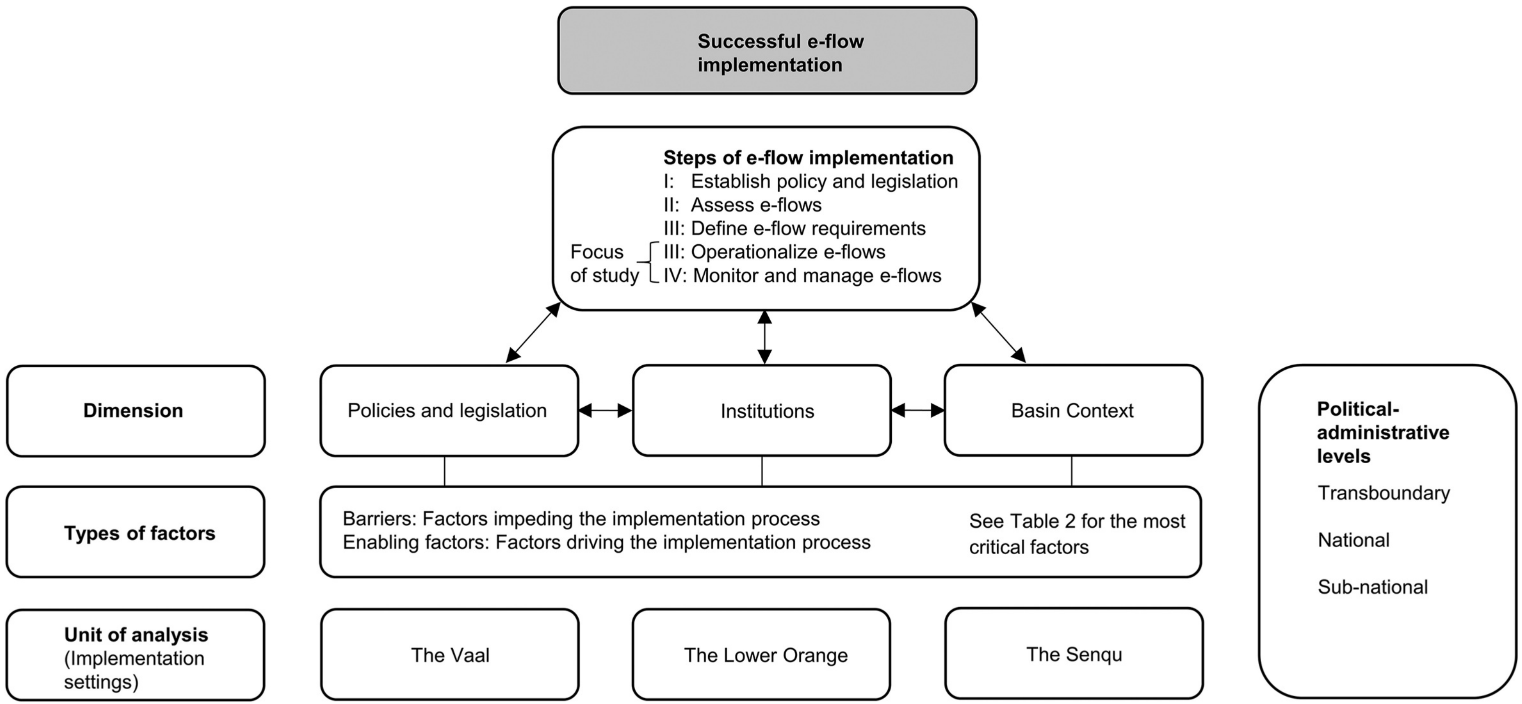

Figure 1. Analytical framework.

Table 1. Characteristics of the three implementation settings based on most recent e-flow assessments.

	Lower Orange	The Senqu	The Vaal
Focus of the implementation setting	Orange Estuary	Katse and Mohale dams	Entire sub-basin
Current ecological state	Largely modified	Slightly modified (before LHWP)	Largely modified or worse
Desired ecological state	Moderately modified (2013)	Moderately modified/ largely modified (2003)	From slightly to largely modified (2007–12)
Flow-related problems	Few floods; pollution through agricultural return flows and mining activities; higher low flows than natural in the dry season, during drought and dry periods	Significant changes of the timing and volumes of river flows through planned Katse and Mohale dams	High pollution through agricultural run-off and uncontrolled sewage discharge; too low or high flows and changes in seasonality
Flow-related measures to reach target	Restore seasonality of flows and decrease nutrient inputs	Provide low and medium flows and high flows (only Mohale)	Improve base flows (decrease or increase as required) and reduce pollution from agricultural run-off, mining and wastewater
State of implementation	Incomplete	Complete	Incomplete
Main water-using sectors	Agriculture, hydropower	Hydropower, urban water supply	Agriculture, industry, hydropower, domestic use, mining
Scale	Transboundary (South Africa, Namibia)	Transboundary (South Africa, Lesotho)	National (South Africa)
Implementing bodies	Department of Water and Sanitation (DWS), South Africa; Namibia	Lesotho Highlands Water Authority (LHWA), Environment Ministry Lesotho, DWS	DWS; Rand Water

Note: The Department of Water and Sanitation (DWS) was originally named the Department of Water Affairs.
Sources: Brown et al. (2020); DWS (2011); and ORASECOM (2014c).

financial resources to execute them (Harwood et al., 2018; Speed et al., 2013). Monitoring capacity is a key factor to understand if e-flows are implemented and effectively improve river ecosystems, as well as to cope with unexpected changes and growing variability due to climate change (Hall et al., 2014). Lastly, the staff needs to understand the importance of e-flows and have the will to implement them, which generally involves additional work and risks. Individuals combining the above qualities have been called 'e-flow champions' (Harwood et al., 2017).

Context

Contextual factors can make e-flow implementation challenging despite the presence of conducive policies and capable institutions. The basin context can compound or enable implementation from a management, engineering, political and economic perspective. For example, a high number of dams not designed to provide e-flows make technical and management steps more complex, generally slowing the process while not allowing to fully restore the flow regime (Richter & Thomas, 2007). This is even more so in transboundary basins where certain decisions require the consent from all riparians (Brown & King, 2010). Another key contextual factor is the prevalence of functional river ecosystems, which can create a conservation incentive that profits e-flow implementation. Water-

Table 2. Summary evaluation of significant enabling factors (✓), barriers (×) and insignificant factors (–).

Dimension		Factor	Lower Orange	Vaal	Senqu
Policies and legislation	Water-management-specific	A framework for water planning in policies and legislation	✓	✓	×
		A legal basis for regulating water allocations	✓	✓	×
		Reallocation and trading mechanisms	✓	✓	×
	E-flow specific	Legal recognition of e-flows as a priority user	✓	✓	×
		Legal status or mandate enables setting and regulation of target water flows and levels for the environment	✓	✓	×
Institutions	Water-management specific	A robust planning and (re)allocation framework	✓	✓	×
		Stakeholder engagement	–	–	–
		Monitoring and enforcement of water abstractions, dam release rules, and impoundments	✓	✓	✓
		Funding for all water-management functions and various processes	–	–	✓
	E-flow-specific factors	Awareness of key stakeholders about the importance of and will to implement e-flows	–	–	×
		Consideration of e-flow requirements in water planning and management	✓	✓	×
		Staff with technical know-how and a scientific understanding to manage e-flow assessments and guide implementation	✓	✓	✓
		Individuals with above-average skills and motivation ('e-flow champions') at all governance levels	×	✓	×
		Sufficient data to track compliance and adjust management	×	–	✓
		Sound methodologies, standards and guidelines and decision-making tools for e-flow assessments and implementation	✓	✓	✓
Basin context		Conservation incentive comprised of socio-economic dependence on rivers and ecological value	✓	×	✓
		High hydro-infrastructure development	×	×	✓
		Density of water users and established allocations	×	×	✓
		Support of e-flows by the public and decision-makers	–	–	–
		Socio-economic conditions and development (e.g., poor access to water services)	×	×	✓

Note: The results for the Senqu concern only e-flow work related to the Katse and Mohale dams.

dependent users can have considerable political clout. The level of support for e-flows can depend on the benefits gained from an intact flow regime (e.g., for tourism) (Still et al., 2010) and the appreciation of its value (Garrick et al., 2017). Intact ecosystems with high biodiversity levels equally create conservation incentives as the need for protecting them legally is generally higher (Harwood et al., 2018). In contrast, overdevelopment of water resources confines the manoeuvre of decision-makers to support e-flows. Regulating water use, and especially (re)allocating water to the environment, involves substantial political risks and high costs, especially in water-scarce regions. The consequence is often limited political will that delays and stalls the implementation process (Dyson et al., 2008). Lastly, the developing country context strongly influences e-flow implementation. While various structural challenges including under-funding and weak institutions generally make policy implementation in developing countries more intricate, there are also opportunities, such as the availability of donor funding to support e-flow work (Hirji & Davis, 2009a).

E-flow implementation in the Orange–Senqu basin

The Orange–Senqu is among the largest river basins in Southern Africa. It rises in the highlands of Lesotho and runs 2300 km westwards to discharge into the Atlantic Ocean. The 850,000 km^2 catchment stretches across Lesotho, Botswana, Namibia and South Africa. Hydro-climatic conditions in the basin are marked by an uneven spatial distribution of precipitation, from 1800 mm in the east to less than 50 mm in the western parts. Summer rainfalls are erratic and change from year to year, making run-off highly variable. The Orange–Senqu basin is among the most heavily engineered basins in Africa. The river system accommodates at least nine inter- and intra-basins transfer schemes and more than 30 major dams. Most of them store and supply water for irrigation while only a few generate hydropower. The high development resulted in the bulk of water resources being allocated to human uses (Orange–Senqu River Commission (ORASECOM), 2014a).

South Africa dominates water-related variables affecting the flows of the Orange–Senqu. It contributes a large share of the total run-off while having high levels of water use compared with the other riparian states (Figure 2). South Africa also holds considerable economic and political power (Mirumachi, 2015). Botswana's and Namibia's roles in e-flow implementation are limited, given their low contributions to run-off and having limited water use. Additional institutional factors limit Namibia's role in implementing e-flows. Among the most impactful ones are that the border it shares with South Africa runs along the northern bank of the Lower Orange, thus giving Namibia no equal access to the river (Earle et al., 2005). While Lesotho's water use is equally insignificant, it plays a crucial role due to substantial run-off generation within its territory (ORASECOM, 2014a).

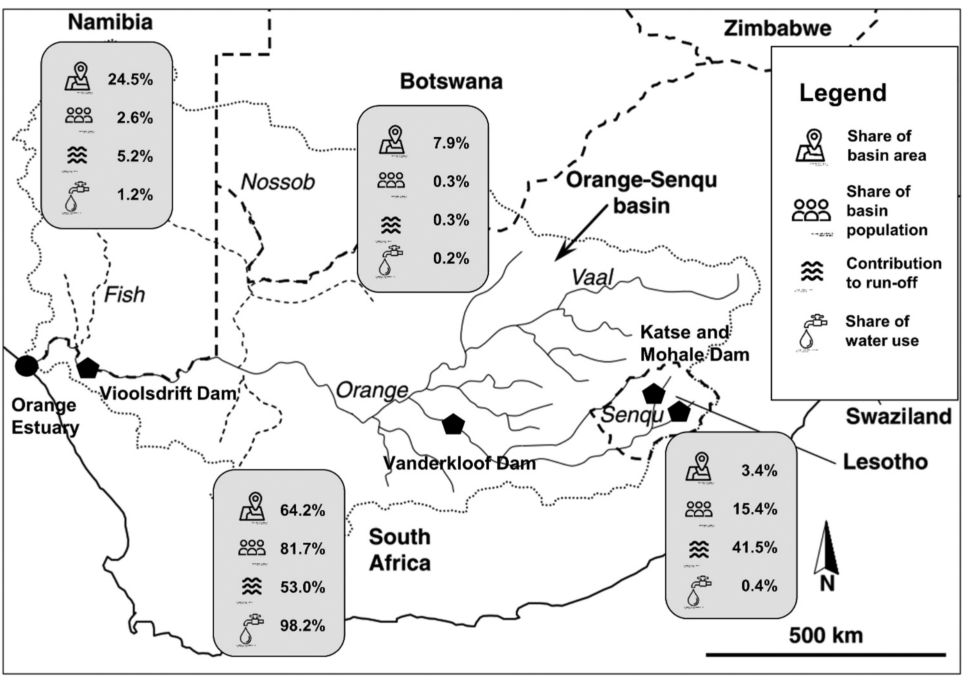

Figure 2. The Orange–Senqu basin with major tributaries.
Sources: Adapted from Kistin and Ashton (2008); data from ORASECOM (2014a).

Not only is the Orange–Senqu a large transboundary river basin, but also there are distinctive sub-basins – the Lower Orange, Senqu and Vaal – which are important to understand e-flow implementation. The advanced state of and distinct challenges to implementation make these three sub-basins (as highlighted above) particularly instructive cases for analysis. E-flow implementation has focused on the Lower Orange as opposed to the Upper Orange, because the high conservation value of the estuary is of concern to the tourism industry and national park authorities (ORASECOM, 2014a). To identify key enabling factors and barriers, the analysis takes flow-related problems and measures to accomplish e-flow requirements into account, besides other important aspects in the three implementation settings (Table 1).

The following gives an overview of the three sub-basins.

The Senqu

The Senqu is dominated by the Lesotho Highlands Water Project (LWHP), the world's largest international water transfer. It will eventually comprise a total of seven dams that convey water from Lesotho to the Gauteng region, South Africa's economic powerhouse. This study only considers the first two, Katse and Mohale River developments (Phase I). E-flow interventions began in 1998 when Katse Dam neared completion. Before LHWP, all rivers were in a slightly modified condition (ORASECOM, 2014c). The project's treaty signed by South Africa and Lesotho determined that the two dams were to cut river flows by more than 95% (ORASECOM, 2014a). An e-flow assessment was conducted, which formed the basis for negotiations between the governments of South Africa and Lesotho, the World Bank and the Lesotho Highlands Development Authority (LHWA) and resulted in increases of downstream dam releases by 300–400% (Brown, 2008).

The Lower Orange

The Lower Orange stretches from the point where the Vaal joins the Orange to the Atlantic Ocean. Irrigated agriculture occupies vast stretches of the Lower Orange and accounts for 90% of the water taken from the river. Releases made for agriculture and hydroelectric power from the basin's two largest dams, Vanderkloof and Gariep, have negatively affected the seasonality of flows. Due to upstream development, discharge is only 60% of its natural volume (ORASECOM, 2014a). For these reasons, but also because of non-flow-related causes, the estuary's ecological condition has been continuously degrading, now being largely modified. It has therefore been placed on the Montreux List, which includes Ramsar sites – wetlands of international importance – undergoing adverse changes.

The Vaal

Water resources management in the Vaal has been for many years geared towards expanding Gauteng's economy, the economic hub for South Africa. Named the 'hardest working river' in South Africa, the Vaal provides water to 45% of the country's population and to 60% of the economy (DWS, 2011). It harbours large extractive industries and power stations producing 90% of South Africa's electricity. Together, these uses account for half of the water demand within the basin (ORASECOM, 2014a). Table 1 shows that most rivers in the Vaal are in a poor ecological state today. This leaves only a few that still qualify for restoration. Here, measures to achieve e-flow requirements largely focus on reducing pollution. Water quality problems are nowhere greater in South Africa than in the Vaal (ORASECOM, 2014a), with salinity levels within the river often dominating the rivers management regimes.

Findings

This section presents an evaluation of the key factors following the analytical framework, along the three dimensions of policies and legislation, institutions, and the basin context that have shaped e-flow implementation outcomes, which Table 2 summarizes.

Policies and legislation

Nowadays, all riparian states except Botswana have environmental policies and legislation that make reference to e-flows to some degree. However, legal provisions for e-flows followed considerably later in Lesotho and Namibia, in 2008 and 2013, respectively (Brown et al., 2020). In the Vaal and the Lower Orange, South Africa's policies and legislation are most important to e-flow implementation. In South Africa, several policies and legislation recognize environmental water needs. South Africa's NWA, which was established in 1998, may be the most important legal piece because it stipulates that ecosystem and basic human needs, together called 'the Reserve', have the highest legal priority among all water users in allocation decision-making. A reserve is hence viewed as the most effective legal mechanism for ensuring e-flows (Harwood et al., 2018). E-flows have also been translated into key policies, such as the National Water Resources Strategy 2nd Edition. Overall, the policies and legislation make necessary provisions for nearly all the required conditions presented in the analytical framework, from issuing and regulating water rights and licences to ensuring re-allocations to the environment. Additionally, e-flows are considered in important policies and strategies at the transboundary level although these have a less clear standing than laws and regulations. While in place, the question is whether e-flow policies and legislation are robust enough to enable successful implementation on the ground.

The interviews revealed that the e-flow policies and legislation are subject to several weaknesses. While it is generally believed that the Reserve in South Africa is a priority use by right, interviewees pinpointed that the NWA does not provide an explicit statement for this. It is therefore a policy position that is not legally enforced. This gives the DWS or water agencies a way to prioritize other water uses in decision-making for water allocation and can theoretically lead to poor consideration of e-flows. Interviewees also highlighted weaknesses in policies relating to dam operating rules, which are confirmed in the literature. Supposedly, dam operators in South Africa have loopholes to avoid integrating e-flows in dam operating rules (Brown & King, 2012; Hughes & Mallory, 2008). While it is difficult to evaluate the effect of these weaknesses, interviewees still considered the policies and legislation in South Africa sufficiently robust. These observations coincide with the literature. South Africa's freshwater policies and legislation are generally considered world-leading and progressive (Bourblanc, 2015) and have contributed to successful e-flow implementation on some rivers (Hirji & Davis, 2009b; Le Quesne et al., 2010). Failure of or delays in implementation in the Lower Orange and Vaal stem from incapable institutions rather than from the weaknesses in policies and legislation.

In contrast, when e-flow work started for Katse and Mohale dams, Lesotho lacked any environmental policies and legislation, including those supporting e-flows. This posed a great challenge to the implementation process. In the negotiations surrounding the planning of Katse and Mohale dams, scientists had to take up the role of legitimizing e-flows (Brown & Watson, 2007). The successes in the Senqu case stem from the national policies and legislation of South Africa and the internal environmental policies and safeguards of the World Bank that it has to follow when financing infrastructure projects (Brown et al., 2020; Hirji & Davis, 2009b). Despite its low overall investment, the World Bank insisted on carrying out an e-flow assessment as a precondition for its engagement in the project (Horta, 2005). The primary reason for this was the internal environmental assessment safeguard policy, according to one of its studies (Hirji & Davis, 2009b). This view is also shared by Brown and Watson (2007) who emphasize that only the World Bank, and, to a lesser degree NGOs, acted as watchdogs, ensuring the project's outcomes were environmentally and socially sound.

Institutions

The Orange–Senqu basin has a high level of institutional development, marking it out from many others in Africa (Mirumachi, 2015). Most vital for e-flows among transboundary institutions is the ORASECOM, the river basin organization. Essentially, it has enabled otherwise absent yet fundamentally important coordination of basin-wide e-flow work, like ensuring the integration of e-flow requirements into key planning documents and through stimulating dialogue among the riparian states on e-flows issues. National water institutions are, however, responsible for operationalizing e-flow requirements. Given that it has only an advisory role, the ORASECOM has little influence on the enforcement of dam re-operations or on the regulation of abstractions, which are processes that are key to the e-flow implementation steps this study analyses. Moreover, the asymmetric power distribution among the riparian states undermines ORASECOM's ability in effectively supporting e-flow implementation at the transboundary scale. Interviews pointed out that due to its considerable power advantage, and position within the basin, South Africa does effectively control operational e-flow implementation. The interviewees highlighted that the border between Namibia and South Africa is a significant barrier to this. The absence of the legal right to the river impedes Namibia from drawing on mechanisms to enforce its hydro-political interests through transboundary water cooperation or international water law. This, for example, weakens the position of Namibian conservation actors in pursuit of protecting the estuary.

The failure to restructure South Africa's water governance system has impaired implementation in the Vaal and Lower Orange. Stipulated in the NWA, South Africa had planned to establish catchment management agencies (CMAs) to decentralize water management (King & Pienaar, 2011). However, the process has experienced extensive delays and of the initially 19 CMAs only two are operational today (Water Research Commission, 2020). In recent years, the DWS initiated steps to appoint a governing board for a third CMA, the Vaal CMA, which has been legally established. These considerations were subsequently superseded by further discussions within DWS towards a combined CMA to manage the entire Orange and Vaal system. Several interviewees, among them one former DWS employee in the lead of establishing the CMAs, deemed the effect for e-flow implementation considerable. This is because legally only a CMA can develop a catchment management strategy, the planning instrument that would guide water resource management. This means that there has been a water-management area planning vacuum in these water-management areas that would have had to guide e-flow implementation, as well as other supporting functions. While there are regional DWS offices that manage and evaluate e-flows, the national office holds the key responsibility. The interviewees considered the centralized authority as disadvantageous, as there is limited capability to respond to local challenges, such as involving local water users and gaining their support.

South Africa has a large community of skilled e-flow scientists and practitioners, which has been vital to carrying out the technical e-flow work professionally across the basin (Bourblanc, 2015). Over recent decades, this community was taking up a frontrunner position in developing methodologies for conducting and implementing e-flow assessments. Hirji and Davis (2009b) note that South African experts substantially contributed to successful e-flow implementation in the region, including Lesotho. While the methodologies designed to conduct e-flows face certain technical and conceptual issues, the interviewees viewed them as sufficient. The same applies to technical procedures established to facilitate the implementation of e-flow requirements (e.g., South Africa's system to classify rivers). It appears that despite certain weaknesses, methods and technical procedures have had an overall positive effect.

Operationalization of e-flows on the ground fails in many cases because institutions lack capacity, a challenge which is well recognized (King & Pienaar, 2011; Quinn, 2012). These capacity concerns are also relevant to ORASECOM that currently has a small staff complement. The DWS and the CMAs, where they exist, are constrained by an insufficient number of staff with the necessary technical know-how and financial resources. Consequently, as another interviewee remarks, implementation often stalls after the DWS executed e-flow assessments carried out by consultants. Limited capacity has various consequences for implementation. Interviewees remarked, for example, that it makes it challenging to prosecute illegal water use which exacerbates the problems regarding compliance with e-flow requirements. Moreover, information about river conditions, such as discharge levels, and thus the state of e-flow implementation, emerged as a critical barrier from the interviews. The interviews revealed that a key reason for this deficit is a roll-back of monitoring. Consequently, there has been increasingly limited data available to inform various aspects of implementing and managing e-flows.

While institutional capacity in the water sector is generally a larger challenge in Lesotho than in South Africa, e-flow implementation during LHWP Phase I profited from several advantages that root in the nature of new dam projects. While Lesotho's Environment Ministry involved in the e-flow implementation had no in-house capacity and expertise to conduct and implement e-flow assessments, they were brought to the project by South African experts (Hirji & Davis, 2009b). Compared with South African cases, there was a local agency – the LHWA – responsible for e-flow implementation. Moreover, there were only three parties (the two national governments and the World

Bank) involved in the negotiations surrounding e-flow implementation. In the same processes in the Vaal, there are many more users with stakes involved, increasing interest in a limited resource and potential for conflict. Additionally, the project character implied that funding for the whole e-flow implementation process was included in the financial planning, as pointed out by an e-flow assessment expert involved in LHWP II.

Among all institutional factors outlined in the analytical framework, unsupportive governmental staff may be most significant in explaining the failure or significant delays of the process. Two interviewees, both having conducted various e-flows assessments in the region, share the view that many people with relevant decision-making power regarding e-flows have not accepted the concept and refuse to support it. High-level governmental staff consequently allocate insufficient resources to e-flow implementation, conjuring up the aforementioned capacity deficit, while dam managers, for example, are hesitant to integrate e-flow requirements into dam operation rules, as Hirji and Davis (2009b) point out, for example, in the case of LHDA. A former DWS employee noted that generally there is a limited understanding of the socio-economic costs and benefits associated with e-flows, which can affect the willingness of staff to implement them. These findings align with international trends as highlighted by Le Quesne et al. (2010). The same interviewee also remarked that the water institutions in the Orange–Senqu have lacked an e-flow champion, a critical success factor in other cases as outlined in the analytical framework.

Basin context

The high number of dams, their unfavourable location in some cases, as well as designs unfit for restoring e-flows have strong impacts on e-flow implementation from a technical and managerial perspective. When e-flow interventions started in the late 1980s, the Senqu had not been impounded by dams while the Lower Orange and Vaal had already been heavily engineered. A higher level of development makes the implementation process more complex (e.g., as releases from multiple dams need to be included in modelling exercises), as pointed out by a hydrologist of the DWS, and extends its completion time. All dams in the basin, except Mohale, were constructed before e-flows were considered in water resources planning. Thus, Mohale is the only dam in the basin equipped with the structural design components, such as outlets, to make releases that can mimic naturally diverse flow patterns (not only base flows). The location of Vanderkloof Dam poses a particularly severe barrier to improving e-flows in the estuary. The dam is the closest to the river mouth – albeit being 1500 km away from it – and therefore controls the flow regime of the entire Lower Orange. This long distance, however, makes it impossible to accurately regulate e-flow requirements for the river stretches most downstream. Consequently, a re-regulating dam 150 km away from the river mouth is under consideration. Such a dam comprises the only means to reverse the unnatural flow dynamics according to the interviewees. All these aspects of water resources development render implementation more complex, expensive and compound the restoration of certain elements of the flow regime outlined in Table 1.

In all three cases, outcomes of the e-flow work are heavily influenced by strong economic imperatives. Incentives to protect freshwater ecosystems differ, from being relatively low in the Vaal to being high in the Lower Orange. Prior to Katse and Mohale, Lesotho's undeveloped rivers were in a good ecological state (ORASECOM, 2014c). The dam-related consequences for 150,000 downstream livelihoods were critical for triggering an international outcry and conducting an e-flow assessment (Brown, 2008). Simultaneously, there were strong interests to develop the rivers. The project's water transfers were to underpin 60% of South Africa's future gross domestic product (GDP) and yield 5% of Lesotho's state income (Rousselot, 2015). Both states consequently tried to minimize the impact of e-flow requirements on the available yield for use (Brown & Watson, 2007). Conservation incentives in the Vaal are generally low. Due to ecological degradation, the DWS (2011) considers only a few river features to warrant protection while only a small population directly relies on their ecosystem services (DWS, 2011). The Vaal River is primarily managed to sustain economic activities, for example, by engineering flow dynamics to control economically damageable pest outbreaks, as two interviewees stated. Reliance of the local economy on a functioning estuary, including tourism and fishery, remains low (ORASECOM, 2014a). The key enabling factor, as several interviewees remarked, is its high ecological value and protection status (e.g., as a Ramsar site). The resulting conservation incentive has nonetheless not prevented its decline. In all three cases, conservation incentive tends to be outweighed by the basin's powerful economy, which has a high and growing demand for water but encompasses limited activities with direct dependence on a functioning river providing some level of ecosystem services.

Over-allocation of water in rivers is a key challenge in large parts of the Orange–Senqu and compounds re-allocation to restore e-flows. It mainly concerns rivers of the Vaal and Lower Orange. As water allocations pre-date e-flow assessments and the legal requirements there-of, additional water resources are required to implement e-flows. At a basin scale, water allocations to sustain e-flows need to be doubled from the volume currently designated (ORASECOM, 2014c). To this end, the basin-wide management plan (ORASECOM, 2014b) envisions a broad range of measures, including increasing the system yield, improved operating rules and improved demand management. It will also be necessary to re-negotiate allocations. Several interviewees confirmed existing literature (Dyson et al., 2008; Molle & Wester, 2009) in that this re-allocation process, in which 'Compulsory Licensing' is the main instrument, has been politically challenging and implemented only in smaller systems. This is because current water users resist changes to their licenced allocations, while re-allocations can cause significant economic damage. Interviewees portrayed stories in which its enforcement often depends on decision-makers having to mandate the demolition of illegal dams or the prosecution of powerful mining companies for unlawful water pollution, political risks they attempt to avoid, especially during election times (Bourblanc, 2017). Re-allocation of currently unused licences, a more feasible option politically, is hampered by information about who owns these and has required extensive and legally challenging studies regarding these allocations and what is actually being used. Consequently, implementing e-flow requirements in parts of the Vaal and Lower Orange is limited to optimizing dam operating rules as long as no additional water is available.

Finally, the developing country context and history of the basin strongly affects the ability to gather support for e-flows from politicians and society. Interviewees pointed out that the immense pressure for development and tackling structural challenges dominates politics in Southern Africa. Healthy rivers, therefore, receive low priority on the political agenda. In South Africa, this plays out in that the central government offers limited institutional support and financial resources to protect freshwater ecosystems. Another barrier arises from yet hugely unequal access to basic water services. Caused through water politics of the apartheid government, it has remained vastly unresolved (Van Koppen & Schreiner, 2014). Water allocation thus becomes more challenging politically as decision-makers can face resistance if they support e-flows over prioritizing promises for change (Swatuk, 2010). A low appreciation of and misperceptions about e-flows, such that e-flows pose a threat to development, further complicate the political debate (Dickens, 2007; Van Wyk et al., 2006). While e-flow implementation is always challenging in water-scarce places, structural challenges impede progress in developing countries. On the upside, e-flow work benefits considerably from foreign assistance, including that received by ORASECOM. Brown et al. (2020) estimate, for example, that international donors fund 43% of e-flow assessments in Southern Africa.

Discussion

The study shows that particularly the final steps of delivering e-flow requirements through water allocations and dam operating rules still prove challenging to move forward in the Orange–Senqu basin, as was the case one decade ago (Quinn, 2012). In this study, results show that in the period 1998–2013 ineffective implementing institutions and a challenging basin context are more responsible for failure than unsupportive policies and legislation, although we outlined considerable differences between the implementation settings. Overall, the key barriers do largely compare to those in other

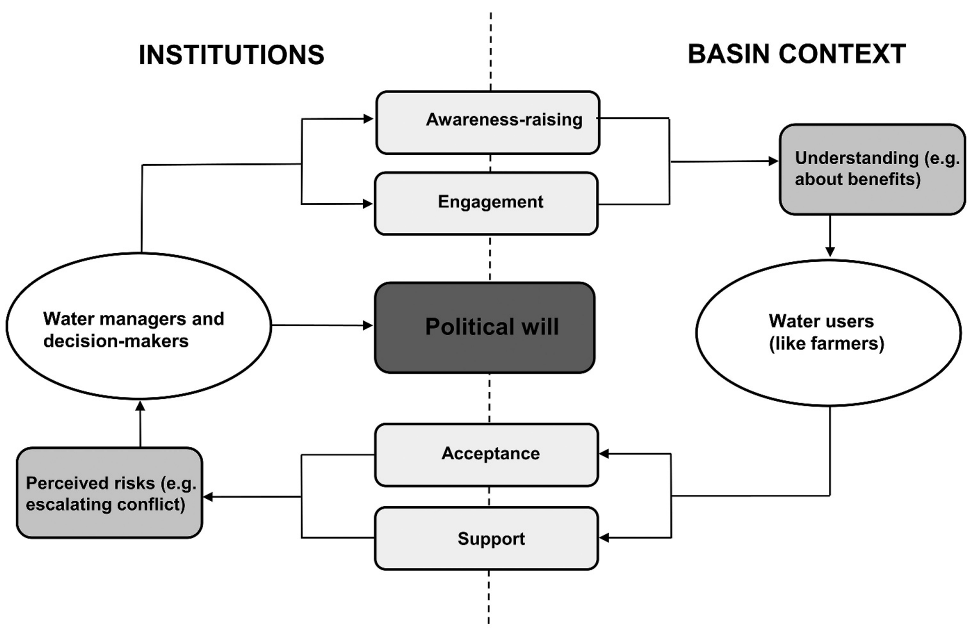

Figure 3. The beneficial relationship between effective implementing institutions and supportive water users at the local level as a prerequisite for political will to implement e-flows.

studies, with political will possibly ranking highest (Hirji & Davis, 2009b; Le Quesne et al., 2010), and relate almost equally to the areas of water management and e-flows. Concerning institutions, there are several strong enabling factors, including the advanced integration of e-flows into basin-wide planning and regional technical know-how. Considering South Africa, the main institutional challenge may reside with the lack of local-level representation, financial resources, data, skilled staff and political will. The interactions between several of these institutional barriers and lack of political will are particularly important to explain e-flow outcomes in South Africa (Figure 3): Low capacity, and especially poor local-level representation, limit options for collaborating with and gaining the support of local representatives. This, in turn, can be viewed to undermine the willingness of water managers to support implementation. Pahl-Wostl et al. (2013) consider these bottom-up governance structures most important for implementation. Furthermore, the basin context poses strong barriers which often seem to outweigh the enabling factors that emerge from it, even where the conservation incentive is very high, causing a gradual decline of various rivers in the basin. This confirms other studies in that 'it is never too early to get started' (Brown & King, 2010, p. 107), but also that slow or failed e-flow implementation can contribute to irreversible ecological degradation, as some Vaal rivers prove. Looking at its transboundary nature, South Africa is the upstream member with not only the largest part being within its boundaries, but also economically generates the largest benefits from the basin, therefore also having the ability to substantially affect basin-wide e-flow work. Our findings show that transboundary e-flow work is advanced but ORASECOM's impact on the final steps is relatively low. Besides the reasons already pointed out, including South Africa's hydrohegemony (Mirumachi, 2015), there is a need to also rethink the role of ORAESCOM, and river basins organizations generally, for e-flow implementation. This pertains particularly to the basin-scale as the primary management unit, especially in over-engineered basins like the Orange–Senqu where water management is rather organized around resource demands than river boundaries (Muller, 2019).

The findings of this study have to be reflected against developments in the sphere of e-flows that have occurred since 2013. While e-flow assessments for most major rivers were completed in South Africa before 2013, with progress having decreased in subsequent years, implementation proceeded to the next implementation steps in some instances, such as agreeing on e-flow requirements. E-flow implementation also advanced in Lesotho. Besides Katse and Mohale dams, e-flows are delivered and monitored for Metolong Dam on the South Phuthiatsana River since 2014. Compared with the years before 2013, however, e-flow work in the basin, and especially in South Africa, has slowed down. The Lower Orange, where it is still unknown if dam releases comply with e-flow requirements, reflects the general situation of many rivers in the basin, for which e-flows are still not being delivered (Brown et al., 2020). This slowdown in implementation progress is not exclusive to e-flows with the momentum propelling reform and key outcomes encapsulated within the NWA in 1998 having gradually diminished across the water sector due to a range of institutional challenges faced by the DWS (Nyam et al., 2020).

The empirical findings underscore the value of utilizing nested, multi-tier frameworks to explain the barriers and enabling factors of e-flow implementation. Three elements of our framework warrant reflection. First, we were able to identify the most important factors in each of the three dimensions of policy and legislation, institutions, and context, and qualitatively evaluate how these dimensions compare against each other in terms of their relevance for e-flow implementation. Despite common challenges to rank factors precisely, we could identify key actions necessary to advance future e-flow work. Second, the comparison of the three cases illuminated large differences between implementation settings. For example, safeguarding the estuary will depend much on constructing a re-regulating dam, adjusting base flows at Vanderkloof Dam, and the ability to formally protect South Africa's section of the estuary. Conversely, controlling pollution from agricultural run-off and discharge of untreated wastewater are most essential to improve water quality for the Vaal rivers. These differences underscore the need for context-specific, multiple-scale analyses at scales below the sub-basin level and beyond the watershed. Third, we demonstrated why consideration of the basin context is indispensable for explaining e-flow outcomes. One can maximize investments to make policies robust and institutions effective, but if the basin context is overly constraining, these efforts might be futile. So, while water-sector institutions themselves are barely able to influence contextual factors, understanding which ones matter, and where, can help to inform policy and management (e.g., by identifying priority areas for e-flow restoration that promise high implementation success). Moreover, recognizing the need for bottom-up, polycentric approaches, as outlined earlier, more nuanced stakeholder assessments than in this study are needed. Such a detailed assessment may result in targeted engagement and communication needs and actions and has value as an integral part of the analytical exercise. An integrated stakeholder assessment ideally considers the level of the individual, given mounting evidence that proves the critical role highly skilled individuals have in shaping implementation success regarding e-flows as well as other water-related policy aspects (Renner et al., 2018).

The empirical findings also suggest from a practical perspective several key interventions necessary to avoid a stalemate of the master variable. Action is urgently needed as growing water demand and climate change will further stress freshwater ecosystems (Grafton et al., 2013) while interdependencies between water, food and energy intensify across Southern Africa (Conway et al., 2015). First, despite some recent developments such as a review process of National Water Policy in South Africa (DWS, 2013), there remain policy and legal weaknesses that need redress. The legal position of the Reserve as a priority user in the NWA needs strengthening while only more stringent provisions in dam policies will ensure consistent integration of e-flows into operating rules. South Africa is likely to continue to develop the basin's water resources in its interest. To effectively restore the flow regime at the basin scale, it will be key to empower ORASECOM through granting it authority beyond its current advisory role. Second, there is significant demand for institutional reforms and capacity building. Without advancing the CMAs in South Africa, improved management regimes being implemented is unlikely, including the development of the catchment management strategies, a task that is inherent to the CMAs. The DWS has refined the number of CMAs and has had these legally established, and is also working on the process to establish the governing boards after which the institutions can be operationalized. Nevertheless, progress has been slow since the release of the 2013 revised policy statement (Water Research Commission, 2020). This does mean that it will take time before catchment-level planning processes in support of e-flow implementation will be affected. Similarly, implementation will hardly advance – no matter how robust the governance system – without significant investments in under-funded implementing institutions, including ORASECOM. Finances of the DWS have deteriorated over recent years, affecting contracts and projects, including those of cost-intensive e-flow work (Claymore, 2017). Lastly, any institutional and policy change ultimately hinges on shifting mindsets of high-level decision-makers in water-management institutions. Largely unaware of the sweeping socio-economic implications a stalemate of the master variable would entail, there is still a strong sentiment towards engineering solutions despite a growing discourse on the importance of nature-based solutions (Bourblanc, 2017). However, the needed transition does require a civil society that more actively pressures governments to better safeguard freshwater ecosystems.

Conclusions

The purpose of his study was to explore the factors that determine the outcomes of e-flow implementation in the Orange–Senqu basin. While policies and legislation have had an enabling effect, it has found that ineffective implementing institutions and an intricate socio-economic basin context are responsible for the inability to realize the final steps of e-flow implementation. We have presented a way forward to prevent a stalemate of the master variable, a task that is not insignificant noting the complexity of the challenges that exist. However, even in severely water-stressed contexts and under politically intricate situations the water community has witnessed remarkable 'ecological turns' being mastered in recent decades, such as the restoration of South Africa's over-developed Crocodile River (Harwood et al., 2017).

It is important to acknowledge that successful implementation is more than 'seeing the right amount of flow moving down a river', and as such progress in the Orange–Senqu basin is quite considerable despite the basin's complexity. At the same time, the Orange–Senqu has an enabling environment for e-flow implementation that, while not being ideal, is substantially more advanced and robust than in many other large global rivers such as the Nile (NBI, 2021). This underscores the achievements made in the Orange–Senqu basin, but also the considerable challenge for freshwater biodiversity conservation in many other global basins in developing countries where nascent e-flow work might be jeopardized by an ongoing hydropower boom or increasing water demand.

For the future of many river basins in developing countries, a critical question in need of being addressed is how we can accelerate e-flow implementation under conditions that will remain far from ideal. To this end, testing the analytical framework allowed to define priorities for follow-up studies and paves the way for further conceptual and methodological developments. These learnings comprise a valuable addition towards building an analytical framework that can facilitate comparisons across different basins and contexts, a precondition for further exploring of what determines successful e-flow implementation at a global level.

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References

Acreman, M. (2016). Environmental flows – Basics for novices. *Wiley Interdisciplinary Reviews: Water*, *3*(5), 622–628. https://doi.org/10.1002/wat2.1160

Arthington, A. H., Bhaduri, A., Bunn, S. E., Jackson, S. E., Tharme, R. E., Tickner, D., Young, B., Acreman, M., Baker, N., Capon, S., Horne, A. C., Kendy, E., McClain, M. E., Poff, N. L., Richter, B. D., & Ward, S. (2018). The Brisbane Declaration and global action agenda on environmental flows (2018). *Frontiers in Environmental Science*, *6*(45), 169–178. https://doi.org/10.3389/fenvs.2018.00045

Bourblanc, M. (2015). The South African 'ecological reserve': A travelling concept. *Politikon*, *42*(2), 275–292. https://doi.org/10.1080/02589346.2015.1041674

Bourblanc, M. (2017). State transformation and policy networks: The challenging implementation of new water policy paradigms in post-Apartheid South Africa. *Water Alternatives*, *10*(2), 303–321. https://www.water-alternatives.org/index.php/alldoc/articles/vol10/v10issue2/357-a10-2-7/file

Brown, C., Campher, D., & King, J. (2020). Status and trends in eflows in Southern Africa. *Natural Resources Forum 2020*, *44*(1), 66–68. https://doi.org/10.1111/1477-8947.12190

Brown, C., & King, J. (2012). Modifying dam operating rules to deliver environmental flows: Experiences from Southern Africa. *International Journal of River Basin Management*, *10*(1), 13–28. https://doi.org/10.1080/15715124.2011.639304

Brown, C., & King, J. (2010). Environmental flows in shared watercourses: Review of assessment methods and relevance in the transboundary setting. In A. Earle, A. Jägerskog, & J. Öjendal (Eds.), *Transboundary water management: Principles and practice*. Routledge.

Brown, C., & Watson, P. (2007). Decision support systems for environmental flows: Lessons from Southern Africa. *International Journal of River Basin Management*, *5*(3), 169–178. https://doi.org/10.1080/15715124.2007.9635317

Brown, C. (2008). *Let it flow: Reducing the Legacy of Dams*. www.irn.org/files/en/africa/Lesotho-water-project/let-it-flow-lessons-Lesotho.html .

Claymore (2017, May 2). *Mokonyane's department of water and sanitation bankrupt*. Report. The South African. https://www.thesouthafrican.com/news/mokonyanes-department-of-water-and-sanitation-bankrupt-report/

Conway, D., Archer, E., Deryng, D., Dorling, S., Krueger, T., Landman, W., Lankford, B., Lebek, K., Osborn, T., Ringler, C., Thurlow, J., Zhu, T., & Dalin, C. (2015). Climate and Southern Africa's water–energy–food nexus. *Nature Climate Change*, *5*(9), 837–846. https://doi.org/10.1038/nclimate2735

Dickens, C. W. S. (2007). Obstacles to the implementation of environmental flows. *In: Proceedings of the Conference on Adaptive and Integrated Water Management*, 1–13. https://www.newater.uni-osnabrueck.de/caiwa/data/papers%20session/H2/DICKENS%20Flows%20FINAL%20Paper.pdf

DWS (2011). *Classification of significant water resources in the upper, middle and lower Vaal water management areas 8, 9, 10: Water resource analysis report*.

DWS (2013). *National water policy review*. Approved Water Policy Positions.

Dyson, M., Bergkamp, G., & Scanlon, J. (2008). *Flow: The essentials of environmental flows* (2nd ed.). IUCN. Reprint IUCN 2008.
Earle, A., Malzbender, D., Turton, A., & Manzungu, E. (2005). *A preliminary basin profile of the Orange/Senqu River*. University of Pretoria.
Garrick, D. E., Hall, J. W., Dobson, A., Damania, R., Grafton, R. Q., Hope, R., Hepburn, C., Bark, R., Boltz, F., De Stefano, L., O'Donnell, E., Matthews, N., & Money, A. (2017). Valuing water for sustainable development. *Science*, *358*(6366), 1003–1005. https://doi.org/10.1126/science.aao4942
Grafton, Q., Pittock, J., Williams, J., Connell, D., Jiang, Q., Kompas, T., Davis, R., Fu, G., Warburton, M., Udall, B., McKenzie, R., Yu, X., Che, N., Lynch, A., Norris, R., Possingham, H., & Quiggin, J. (2013). Global insights into water resources, climate change and governance. *Nature Climate Change*, *3*(4), 315–321. https://doi.org/10.1038/nclimate1746
Hall, J. W., Grey, D., Garrick, D., Fung, F., Brown, C., Dadson, S. J., & Sadoff, C. W. (2014). Coping with the curse of freshwater variability. *Science*, *346*(6208), 429–430. https://doi.org/10.1126/science.1257890
Harrison, I., Abell, R., Darwall, W., Thieme, M. L., Tickner, D., & Timboe, I. (2018). The freshwater biodiversity crisis. *Science*, *362*(6421), 1369–1371. https://doi.org/10.1126/science.aav9242
Harwood, A., Johnson, S., Richter, B., Locke, A., Yu, X., & Tickner, D. (2017). *Listen to the river: Lessons from a global review of environmental flow success stories*. WWF-UK.
Harwood, A., Tickner, D., Richter, B., Locke, A., Johnson, S., & Yu, X. (2018). Critical factors for water policy to enable effective environmental flow implementation. *Frontiers in Environmental Science*, *6*(37), 1–7. https://doi.org/10.3389/fenvs.2018.00037
Hirji, R., & Davis, R. (2009a). *Environmental flows in water resources, policies, plans and projects, case studies (report No. 48871)*. The World Bank.
Hirji, R., & Davis, R. (2009b). *Environmental flows in water resources, policies, plans and projects, findings and recommendations (report No. 48743)*. The World Bank.
Horne, A. C., Webb, J. A., Stewardson, M. J., Richter, B. D., & Acreman, M. (Eds.). (2017). *Water for the environment: From policy and science to implementation and management*. Elsevier. https://doi.org/10.1016/C2015-0-00163-0
Horta, K. (2005). The World Bank's Decade for Africa: A new dawn for development aid. *Yale Journal of International Affairs, Winter/Spring*, *2006*, 1–8. https://heinonline.org/HOL/LandingPage?handle=hein.journals/yaljoina1&div=31&id=&page=
Hughes, D. A., & Mallory, S. J. (2008). Including environmental flow requirements as part of real-time water resource management *River Research and Applications*, *24*(6), 852–861. https://doi.org/10.1002/rra.1101
King, J., & Brown, C. (2010). Integrated basin flow assessments: Concepts and method development in Africa and Southeast Asia. *Freshwater Biology*, *55*(1), 127–146. https://doi.org/10.1111/j.1365-2427.2009.02316.x
King, J., & Brown, C. (2018). Environmental flow assessments are not realizing their potential as an aid to basin planning. *Frontiers in Environmental Science*, *6*(113), 1–8. https://doi.org/10.3389/fenvs.2018.00113
King, J., & Pienaar, H. (Eds.). (2011). *Sustainable use of South Africa's inland waters (Report No. TT 491/11)*. Water Research Commission.
Kistin, E. J., & Ashton, P. J. (2008). Adapting to change in transboundary rivers: An analysis of treaty flexibility on the Orange–Senqu River Basin. *International Journal of Water Resources Development*, *24*(3), 385–400. https://doi.org/10.1080/07900620802127325
Le Quesne, T., Kendy, E., & Weston, D. (2010). *The implementation Challenge: Taking stock of government policies to protect and restore environmental flows*. The Nature Conservancy and WWF.
Meinzen-Dick, R. (2007). Beyond panaceas in water institutions. *Proceedings of the National Academy of Sciences*, *104*(39), 15200–15205. https://doi.org/10.1073/pnas.0702296104
Mirumachi, N. (2015). *Transboundary water politics in the developing world*. Routledge.

Molle, F., & Wester, P. (2009). River basin trajectories: An inquiry into changing waterscapes. In F. Molle & P. Wester (Eds.), *River basin trajectories: Societies, environments and development* (pp. 1–20). CABI.

Muller, M. (2019). Scale and consequences–the limits of the river basin as a management unit. *Water Science and Technology: Water Supply*, *19*(2), 618–625. https://doi.org/10.2166/ws.2018.109

NBI (Nile Basin Initiative). (2021). *State of the River Nile Basin Report 2021*.

Nilsen, P. (2015). Making sense of implementation theories, models and frameworks. *Implementation Science*, *10*(53), 1–13. https://doi.org/10.1186/s13012-015-0242-0

Nyam, Y. S., Kotir, J. H., Jordaan, A. J., Ogundeji, A. A., & Turton, A. R. (2020). Drivers of change in sustainable water management and agricultural development in South Africa: A participatory approach. *Sustainable Water Resources Management*, *6*(4), 1–20. https://doi.org/10.1007/s40899-020-00420-9

Orange–Senqu River Commission (ORASECOM). (2014a). *Orange–Senqu River Basin Transboundary Diagnostic Analysis (Report No. 002/2014)*

Orange–Senqu River Commission (ORASECOM). (2014b). *Integrated water resources management plan for the Orange-Senqu River Basin. Report No. 019/2014).*

Orange–Senqu River Commission (ORASECOM). (2014c). *Consolidation of environmental flow requirements: Integrated water resource management plan for the Orange–Senqu River Basin (Report No. 016/2014).*

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(39), 15181–15187. https://doi.org/10.1073/pnas.0702288104

Pahl-Wostl, C., Arthington, A., Bogardi, J., Bunn, S. E., Hoff, H., Lebel, L., Nikitina, E., Palmer, M., Poff, L. N., Richards, K., & Schlüter, M. (2013). Environmental flows and water governance: Managing sustainable water uses. *Current Opinion in Environmental Sustainability*, *5*(3–4), 341–351. https://doi.org/10.1016/j.cosust.2013.06.009

Pahl-Wostl, C., Lebel, L., Knieper, C., & Nikitina, E. (2012). From applying panaceas to mastering complexity: Toward adaptive water governance in river basins. *Environmental Science & Policy*, *23*, 24–34. https://doi.org/10.1016/j.envsci.2012.07.014

Poff, N. L., Allan, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B. D., Sparks, R. E., & Stromberg, J. C. (1997). The natural flow regime. *BioScience*, *47*(11), 769–784. https://doi.org/10.2307/1313099

Pollard, S., & Du Toit, D. R. (2011). *Towards the sustainability of freshwater systems in South Africa: An exploration of factors that enable or constrain meeting the ecological reserve within the context of integrated water resources management in the catchments of the Lowveld (Report No. TT 477/10)*. Water Research Commission.

Qua-Enoo, A. B., Schendel, K., & Quinn, N. (2006). South Africa's reserve: Challenges and recommendations for implementing sustainable development policies. *Journal of Environmental Assessment Policy and Management*, *8*(1), 61–83. https://doi.org/10.1142/S1464333206002311

Quinn, N. (2012). Water governance, ecosystems and sustainability: A review of progress in South Africa. *Water International*, *37*(7), 760–772. https://doi.org/10.1080/02508060.2012.741999

Ramulifho, P., Ndou, E., Thifhulufhelwi, R., & Dalu, T. (2019). Challenges to implementing an environmental flow regime in the Luvuvhu river catchment, South Africa. *International Journal of Environmental Research and Public Health*, *16*(19), 3694. https://doi.org/10.3390/ijerph16193694

Renner, T., Meijerink, S., & van der Zaag, P. (2018). Progress beyond policy making? Assessing the performance of Dutch–German cross-border cooperation in Deltarhine. *Water International*, *43*(7), 996–1015. https://doi.org/10.1080/02508060.2018.1526562

Richter, B., & Thomas, G. (2007). Restoring environmental flows by modifying dam operations. *Ecology and Society*, *12*(1), 1–12. https://www.ecologyandsociety.org/vol12/iss1/art12/

Rousselot, Y. (2015). Upstream flows of water: From the Lesotho highlands to metropolitan South Africa. Territorialities and hydropolitics in Southern Africa. *Journal of Alpine Research*, *103*(3), 1–16. https://doi.org/10.4000/rga.3023

Speed, R., Yuanyuan, L., Le Quesne, T., Pegram, G., & Zhiwei, Z. (2013). *Basin water allocation planning: Principles, procedures and approaches for basin allocation planning*. UNESCO.

Still, D. A., Dickens, C., Breen, C. M., Mander, M., & Booth, A. (2010). Balancing resource protection and development in a highly regulated river: The role of conjunctive use. *Water SA*, *36*(3), 371–378. https://www.ajol.info/index.php/wsa/article/view/210949

Swatuk, L. (2010). The state and water resources development: A tale of two South Africas. *Water Alternatives*, *3*(3), 521–536. https://www.water-alternatives.org/index.php/alldoc/articles/vol3/v3issue1/114-a3-3-4/file

van Koppen, B., & Schreiner, B. (2014). Moving beyond integrated water resource management: Developmental water management in South Africa. *International Journal of Water Resources Development*, *30*(3), 543–558. https://doi.org/10.1080/07900627.2014.912111

van Wyk, E., Breen, C. M., Roux, D. J., Rogers, K. H., Sherwill, T., & van Wilgen, B. W. (2006). The Ecological Reserve: Towards a common understanding for river management in South Africa. *Water SA*, *32*(3), 403–409. https://www.ajol.info/index.php/wsa/article/view/5266

Water Research Commission (2020). *The reluctant roll-out of catchment management agencies: Assessing the key risks and consequences of delays in finalising institutional arrangements for decentralised water resource management*. Report No. 2943/1/20.

Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L., & Tockner, K. (2015). A global boom in hydropower dam construction. *Aquatic Sciences*, *77*(1), 161–170. https://doi.org/10.1007/s00027-014-0377-0