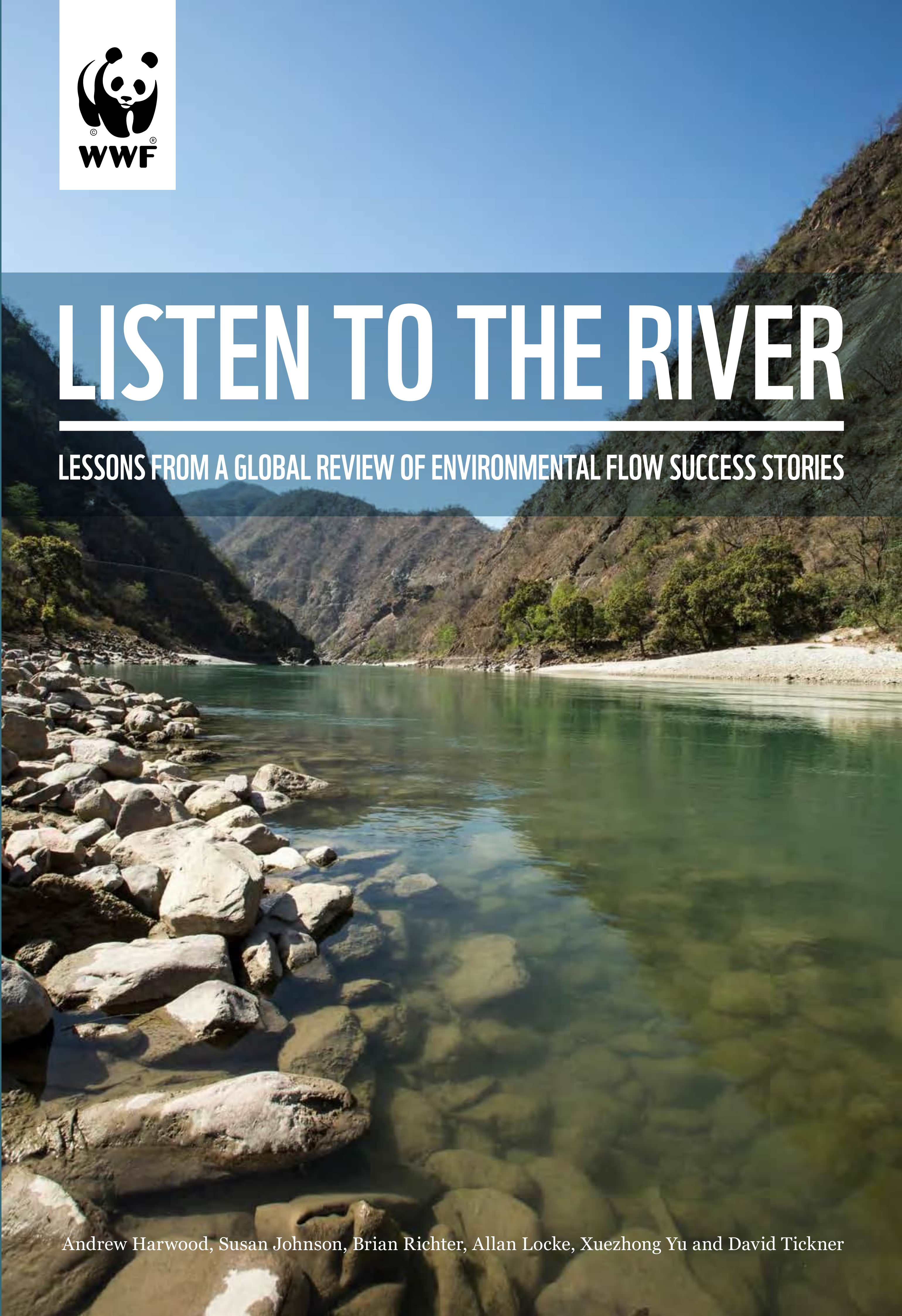

LISTEN TO THE RIVER

LESSONS FROM A GLOBAL REVIEW OF ENVIRONMENTAL FLOW SUCCESS STORIES

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ABOUT WWF

At WWF, we believe that a living planet – from the global climate to local environments – is vital not only for wildlife, but also as the source of our food, clean water, health and livelihoods. And as a source of inspiration, now and for future generations. So we're tackling critical environmental challenges and striving to build a world with a future where people and nature thrive.

To do this, we're educating, inspiring, influencing and engaging the public, policy-makers, business leaders and influencers. In particular, we're strengthening our voice at the heart of decision-making in the rapidly-growing economies of the global South and East. These are becoming ever more significant as they gain greater economic and political influence and use a larger proportion of the world's natural resources. And they're located in regions where much of the world's most important biodiversity is concentrated.

We're engaging the business community – especially in sectors we believe can make the greatest difference – to encourage global companies to become stewards of the natural world their activities depend on. And we're working to ensure that governments in the UK and EU are environmental champions – particularly when it comes to policies on climate and energy, marine issues and international development.

ABOUT ECOFISH

Ecofish are a specialist consultancy that provides a fully integrated, technical and scientifically robust service. Technical services include: environmental impact assessment (EIA), ecology, ornithology, hydrology & flood risk, river modelling & fish pass solutions, fish & fisheries monitoring, fish rescue, marine science & mitigation, underwater acoustics, environmental auditing & compliance and geographical information systems (GIS).

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CONTENTS

EXECUTIVE SUMMARY

Worldwide freshwater supplies are increasingly being exploited due to growing demands for water from a rising population and the needs of agriculture, industry, and towns and cities. It is estimated that one-third of the world's river basins are being heavily depleted, and water scarcity is now affecting one-half of the global population and three-quarters of all irrigated areas (Brauman *et al.* 2016). Furthermore, changes to river flow regimes are likely the single biggest factor in the 81% decline in freshwater species populations since 1970, as measured by the Freshwater Living Planet Index. This is double the decline observed in the world's marine and terrestrial species (WWF 2016). Globally, natural river flows have been altered by a proliferation of dams, changing land use and urbanisation, and over-abstraction of water. Poor water governance has enabled, and now compounds, these threats, which are also likely to be exacerbated by the effects of climate change.

The year 2017 marks the 10th anniversary of the Brisbane Declaration on Environmental Flows. This declaration was crafted at the 2007 Riversymposium and advocates for environmental flow (e-flow) protection and restoration. Since that time, governments and water management authorities across the globe have made significant progress towards developing policies and regulations, and taken myriad actions, to protect and restore e-flows. These efforts have faced significant challenges, including a lack of political will and stakeholder support, insufficient resources and capacity, competition for water among other sectors, and institutional barriers and conflicts of interest (Le Quesne et al. 2010). Despite these obstacles, many success stories in e-flow implementation have emerged.

The purpose of this report is to showcase several of these success stories where actions have led to e-flow implementation with benefits for society and ecosystems. The following case studies were chosen from a long list put forward by WWF colleagues and other water management experts to provide a range of geographical, cultural, economic and hydrological contexts:

THIS REPORT SHOWCASES SUCCESS STORIES IN E-FLOW IMPLEMENTATION

- The Sustainable Rivers Program, focusing on the Savannah River, USA
- Murray-Darling Basin, Australia
- Operations of the Three Gorges Dam on the Yangtze River, China
- River Kennet, England
- Crocodile River, South Africa
- San Pedro Mezquital River, Mexico
- Poonch River, Pakistan
- Ganga River, India

The focus of our case studies was on the political, economic and governance factors leading to the successful implementation of e-flows, and the specific roles played by key decision-makers and e-flow champions. We wanted to understand the human story of who advocated for e-flows, how sceptics were persuaded, and what motivated organisations to take action. For each case study we attempted to interview at least one stakeholder who advocated for e-flows, one who was sceptical and needed convincing, and one from the government ministry or water management authority charged with making decisions about water allocation and/or infrastructure operating regimes. By speaking to the stakeholders involved we gained an understanding of the barriers to e-flow implementation, the factors that enabled these barriers to be overcome, what triggered action, and what monitoring was undertaken to assess success.

Our case studies highlighted a number of enabling factors as important in successful e-flow implementation as set out in Table A.

Table A. Enabling factors that support successful e-flow implementation

ENABLING FACTOR	DESCRIPTION OF FACTOR	EXAMPLE OF IMPORTANCE
Legislation and regulation	Laws reflect the values of society, thus jurisdictions that have e-flows written into their laws and regulations have demonstrated a consideration and acknowledgment of the ecosystem services and values that rivers provide.	A critical enabling factor in most e-flow implementation success stories, legislation played a particularly important role in the Murray-Darling Basin, Crocodile River, San Pedro Mezquital River, and River Kennet case studies.
Collaboration and stakeholder engagement and understanding	It is critical for successful e-flow implementation that the competitors for the water, and the agencies that will implement the e-flow prescription, are part of the decision-making process in setting objectives and determining appropriate flows.	Collaboration and buy-in to the process of determining and implementing e-flows is so critical that it was an important factor in all of the case studies examined for this report. Those responsible for implementing e-flows, such as water management agencies, hydropower operators or irrigators, have to buy in to the process otherwise they will continually fight and try to undermine it. Structured Decision Making* is a valuable process for such collaboration and provides a forum for reviewing available information, setting objectives, addressing uncertainty, evaluating trade-offs between competing demands, and making decisions.
Driving force – a champion	A champion is needed to drive the process forward; there are many challenges to e-flow implementation and to overcome these there needs to be a person, or several persons, or an organisation pushing the process along and finding solutions.	One of the most prominent examples of champions in our case studies was Brian Jackson at the IUCMA in the Crocodile River case study. Other notable champions were the WWF teams in England and Mexico that campaigned for many years to secure e-flows in the River Kennet and San Pedro Mezquital River, respectively.
Technical knowledge, understanding and tools	E-flow implementation requires an understanding of the needs of the species or resource one is trying to protect or restore and how these needs relate to flow magnitude, timing, duration, frequency and rate of change. Tools are required to help managers make decisions on e-flows based on water availability and balancing the requirements of multiple water-users.	An example of the importance of this enabling factor is the work done by fish biologists and hydrologists in identifying the spawning locations of Chinese carp in the reaches downstream of the Three Gorges Dam, along with the important hydrologic indicators and their ranges for natural spawning that can be mimicked when designing e-flows. From a social perspective, the surveys carried out prior to Kumbh 2013 were important in determining appropriate flows for the spiritual rituals. The IUCMA uses decision-support and forecasting tools to manage e-flows in real time based on the available water in the Crocodile River. Similarly, the US Army Corps of Engineers uses real-time data collection and reservoir models to aid its releases of e-flow pulses from its dams.
Resources and capacity	Consistent funding for the technical studies and stakeholder engagement processes required to determine appropriate e-flows is a common barrier to e-flow implementation.	Given the funding requirements for e-flow assessments, stakeholder engagement, and e-flow management and monitoring, securing the necessary funding resources was a common challenge across case studies.
	Similarly, securing the necessary funding for e-flow implementation, monitoring and management is critical.	The resources to fund an e-flow implementation scheme were a critical factor in the River Kennet case study due to regulatory requirements that necessitated a change in legislation. Without legislative change, the Environment Agency would have had to compensate Thames Water directly for reducing its licensed water application. However, the levy on abstraction licences used to generate the compensation required would not have been sufficient to acquire the funds needed.
	Having the institutional capacity to understand the need for e-flows and how these are determined and monitored is an important factor in implementation.	The need for greater capacity was probably most pronounced in the Poonch River case study: here, the need for additional e-flow assessment was determined by an international funding agency (the Asian Development Bank), and the assessment was led by an international consulting firm from South Africa. However, building and maintaining capacity was a common requirement across case studies in developed and developing countries alike. Dedicated capacity within larger organisations can be deployed to implement e-flows on many rivers/sites, such as for the Sustainable Rivers Program supported by the US Army Corps of Engineers and The Nature Conservancy.
Standards and guidelines	Standards and guidelines on how to determine e-flows for ecological and socio-economic components, and what methods work best in different situations, are an important tool to streamline assessments and overcome barriers of capacity. Standards for monitoring the benefits of e-flow implementation are also important to facilitate the design of suitable monitoring programmes to enable adaptive management.	The publication of a national standard on e-flow assessment was a key enabling factor in the San Pedro Mezquital case study as it provided certainty over the approved approach. The importance of environmental standards set by international funding agencies was demonstrated in the Poonch River case study as adherence to these standards led to a more sustainable project design, which enabled the project to proceed.
Monitoring networks and adaptive management	Flow data are critical in determining natural flow levels and water availability. Physical, geomorphological, ecological, social and economic data are important in determining how the ecosystem and those who depend on it are responding to e-flow implementation, and to inform adaptive management.	The best example of adaptively managing e-flows based on data collected from a network of monitoring stations in our case studies is the Savannah River, where learnings over an 8 to 10-year period of test releases were used to refine e-flows. From a social perspective, monitoring of e-flow releases on the Ganga River during Kumbh 2013 demonstrated the success of that programme. Nonetheless, monitoring of ecological, social and economic benefits is an area that would benefit from further resources, analysis and reporting.
Reallocation and trading mechanisms	The ability to acquire water rights, through permanent sales or temporary leases, has enabled environmental organisations or governments to restore e-flows through purchases in some jurisdictions.	Having the ability to trade water rights has been immensely important in restoring e-flows in Australia and the western US. The Murray-Darling Basin has a well-established water-trading system allowing users flexibility to respond to variations in water availability. In the western US, the establishment of water banks has been an important mechanism in mitigating the effects of water abstraction through the purchase of senior water rights (Harwood *et al.* 2014).

* Structured decision-making was only specifically referred to as such in the Yangtze River case study. However, based on the meetings and collaborative efforts described for many of the case studies, this decision-making process is a valuable tool for e-flow implementation.

Our case study review of e-flow implementation demonstrates that there are a number of ways in which success can be achieved. These will be dependent on system- and jurisdiction-specific concerns and the legal, political, institutional, social, economic and ecological contexts. This supports the conclusion of Le Quesne et al (2010) that there is no single correct approach to the implementation of e-flows; instead, the approach must be carefully tailored to the context. Despite this finding, there are some common truths that emerge from this case study review that lead to the following recommended actions (Figure A):

1. Enact **clear and effective legislation and regulation**, and maintain the political will to implement and enforce;
2. **Engage meaningfully with stakeholders** to garner understanding and support;
3. Secure sufficient **resources and capacity** for e-flow design (including stakeholder engagement), implementation and monitoring;
4. Consider how e-flow implementation will affect not just **ecological, but also economic and social conditions** for different groups of people;
5. **Implement some level of protection as early as possible** since it is easier to restrict allocation than attempting to re-allocate water;
6. Keep e-flow prescriptions as scientific as possible according to the level of risk and intensity of water use, and within the available financial and human resource constraints – but balance this with the need to **keep science targeted and only as complex as the context allows**, and with the need for clear non-technical communication of the issues with stakeholders; and
7. **Monitor ecological, social and economic outcomes** of e-flow implementation and manage adaptively.

THERE ARE SOME COMMON TRUTHS TO EFFECTIVE E-FLOW IMPLEMENTATION

These lessons reinforce and complement the conclusions of earlier case study reviews of e-flow implementation (Hirji and Davis 2009, Le Quesne et al. 2010, Kendy et al. 2012). Based on our case studies and a review of the roles different organisations played in successful implementation, we provide guidance on what actions should be taken, and by whom, to promote further success in other jurisdictions and watersheds (Table B). This represents a call to action for decision-makers in governments, water management agencies, financial institutions, the private sector, NGOs and the science community to champion e-flow implementation. Our analysis shows that all these stakeholders have important roles to play in implementing e-flows. Moreover, it highlights the collective, collaborative effort required for successful implementation. Irrespective of social and economic standing, values and beliefs, we are all dependent on clean, freshwater and the goods and services provided by freshwater ecosystems. To protect this valuable resource requires understanding, openness, transparency and a collective will. This isn't theory – it has been demonstrated in practice. As our population grows, economies and lifestyles shift, and climate change takes hold, the world faces a watershed moment. If we want healthy rivers that support thriving economies, socially and culturally diverse communities, and a diversity of flora and fauna, now is the time to act.

Figure A: Recommended actions for e-flow implementation

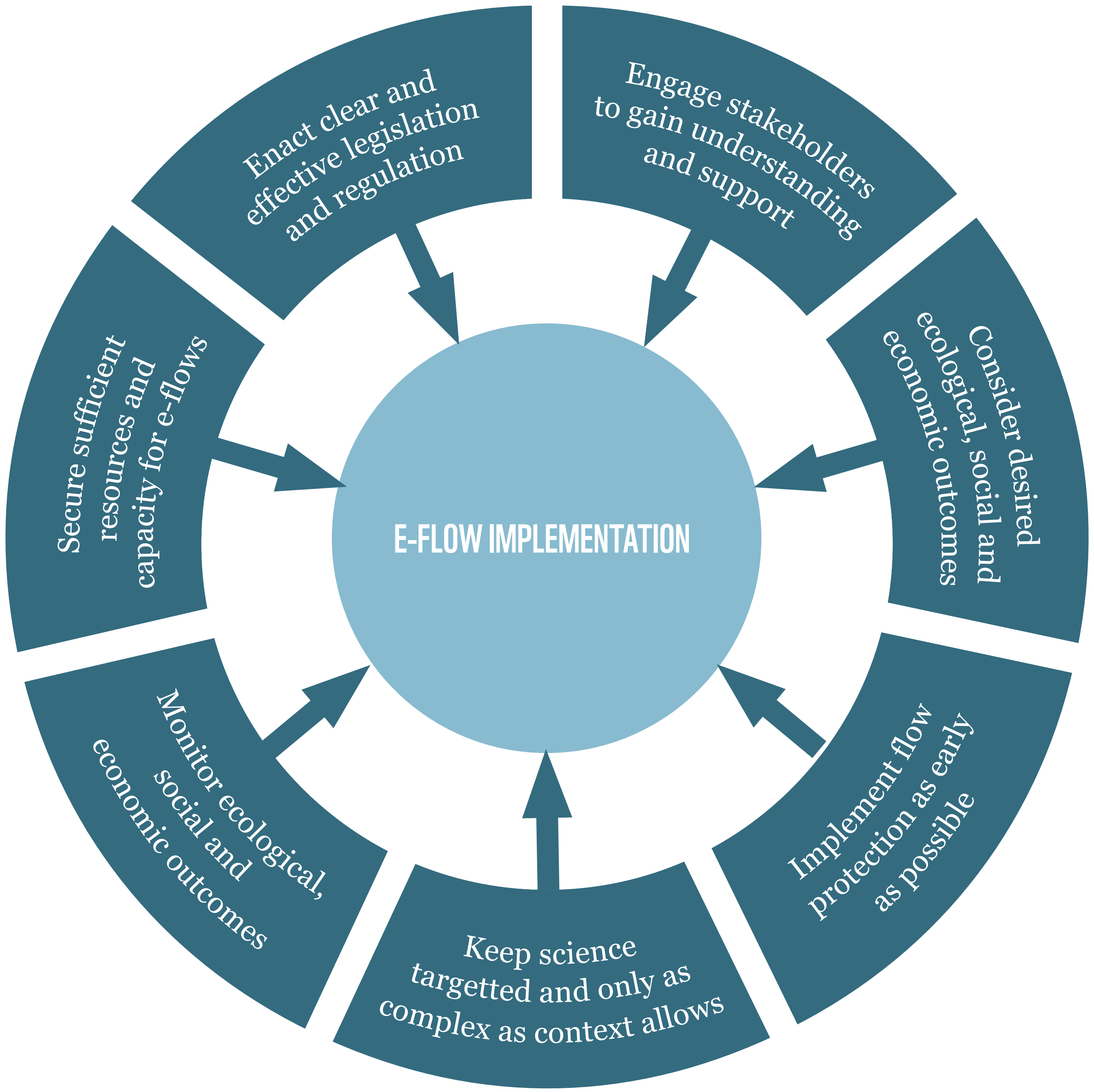


Table B. Actions required by different organisations to facilitate successful e-flow implementation

ROLE	ORGANISATION	ACTION
1. Enact clear and effective legislation and regulation, and maintain the political will to implement and enforce.		
Lead	Governments (federal, provincial/state, local)	Develop a clear legal basis for regulating water use, allocations, rights and licences, and put a water allocation system in place if one does not already exist. Recognise e-flows as a priority requirement to protect ecosystem services and a core component of water resource planning and management, ideally with legal standing at least equal to consumptive uses. Set a limit or cap on consumptive uses, or create an e-flow reserve, as a means to protect e-flows. Provide a framework for national and integrated basin water planning.
Support	Government water management agencies	Provide guidance on comprehensive or incremental reforms required based on existing water allocation system.
	Global NGOs	Push for action from state and federal governments to protect and restore e-flows. Provide guidance on legislative and regulatory requirements based on experience in other jurisdictions with similar legislative frameworks.
	Local NGOs, private sector actors	Push for reform in the management of water resources in the watershed if e-flows are absent or inadequate. Identify local specialists and encourage them to become involved in e-flow assessments and implementation. Communicate with the public on the issues and potential solutions that will serve local needs.
2. Engage meaningfully with stakeholders to garner understanding and support.		
Lead	Government water management agencies	Engage all water-users in the e-flow decision-making process for a watershed/basin to secure stakeholder buy-in. Ensure local/regional knowledge is accounted for in decision-making. Design and implement a clear, inclusive and detailed process for setting objectives for e-flows, which may be different for different rivers, and even for different sections of the same river.
Support	All users and stakeholders including farmers groups, dam operators, private sector actors	Enter into e-flow discussions, be willing to listen to diverse viewpoints, understand different values, and compromise on often firmly-held positions. Engage in the process of setting consensus environmental objectives for your river.
	Local NGOs	Educate and convene stakeholders, and help them to communicate their concerns regarding water availability and use.
	Large water-users	Be open and transparent about water use and estimated future requirements.
	Research community	Support e-flow assessments by clearly describing the predicted effects of e-flow implementation and the uncertainty associated with the predictions; ensure that social values are being addressed in e-flow recommendations. Build and apply tools to assess trade-offs between different water-using sectors under various flow management scenarios.
3. Secure sufficient resources and capacity for e-flow design, implementation and monitoring.		
Lead	Governments (federal, provincial/state, local)	Provide sufficient funding to allow effective management of the water resource.
Support	Government water management agencies	Push government for adequate funding to effectively implement, manage and monitor the water allocation system Build internal capacity and then promote continuity in institutional knowledge
	Global NGOs	Use experience gained in other countries to support e-flow determination and implementation. Fundraise. Connect people.
	Global and local NGOs	Push for funding from state and federal governments; help to fundraise from non-government sources such as foundations.
	International funding agencies	Evaluate opportunities to fund e-flow implementation programmes as a key part of water resource management and infrastructure schemes.
	Large water-users including farmers groups, dam operators, private sector actors	Be prepared to fund/conduct ecological and socio-economic studies to understand the impacts of flow withdrawal to inform appropriate e-flow assessments
	Scientific community	Use access to research grants to continue research on how physical, geomorphological, ecological, social and economic parameters respond to e-flow implementation; working in conjunction with other stakeholders to ensure that science is targeted and strategic.

ROLE	ORGANISATION	ACTION
4. Consider how e-flow implementation will affect not just ecological, but also economic and social conditions for different groups of people.		
Lead	Government water management agencies	Take a holistic approach to understanding how water allocation decisions will impact downstream water-users.
Support	Global NGOs	Gather data on the costs/benefits of e-flow implementation to inform e-flow assessments and demonstrate wide-ranging benefits.
	International funding agencies	Use leverage to ensure appropriate assessments are conducted to determine suitable e-flows that meet environmental and socio-economic goals.
	Scientific community	Continue to research how physical, geomorphological, ecological, social and economic parameters respond to e-flow implementation.
5. Implement some level of protection as early as possible since it is easier to restric allocation than attempt tore-allocate water.		
Lead	Government water management agencies	Implement in phases, ensuring that sufficient natural flows are protected as early as possible to avoid over-allocation.
Support	Global NGOs	Use experience gained in other countries to support schemes to protect e-flows.
6. Keep e-flow prescriptions as scientific as possible according to the level of risk and intensity of water use, and within the available financial and human resource constraints.		
Lead	Water management agencies	Use assessment tools appropriate for the context, and an open, transparent decision-making process to determine e-flow requirements, but keep the prescriptions as simple as possible to aid implementation and understanding.
Support	Large water-users and the scientific community	Continue to innovate to assist in the development of decision support and forecasting tools to improve real-time management.
7. Monitor ecological, social and economic outcomes of e-flow implementation and manage adaptively.		
Lead	Government water management agencies	Ensure that follow-up monitoring is conducted to determine the success and failures of e-flow implementation so that management practices can be adapted.
Support	Large water-users	Be prepared to fund/conduct ecological and socio-economic studies to monitor the impacts of flow withdrawal to inform adaptive management.
	Local NGOs	Advocate for adequate funding and implementation of monitoring networks to collect data on hydrological and ecological parameters to assist in e-flow determination and management.
	Scientific community	Provide input into design and implementation of monitoring networks, and assist with data collection and analysis as needed. Continue to innovate to improve techniques by which data can be collected, stored, managed and analysed to improve efficiency.

1. INTRODUCTION

Worldwide freshwater supplies are increasingly being exploited due to growing demands for water from a rising population and the needs of agriculture, industry, and towns and cities. It is estimated that one-third of the world's river basins are being heavily depleted, and water scarcity is now affecting one-half of the global population and three-quarters of all irrigated areas (Brauman et al. 2016). Furthermore, changes to river flow regimes are likely the single biggest factor in the 81% decline in freshwater species populations since 1970, as measured by the Freshwater Living Planet Index. This is double the decline observed in the world's marine and terrestrial species (WWF 2016). Globally, natural river flows have been altered by a proliferation of dams, changing land use and urbanisation, and over-abstraction of water. Poor water governance has enabled, and now compounds, these threats, which are also likely to be exacerbated by the effects of climate change.

The United Nations adopted 17 Sustainable Development Goals (SDGs) in 2015 with the aim of ending poverty, protecting the planet and ensuring prosperity for all. Each of the goals has specific targets to be achieved by 2030, and a few address issues related to biodiversity and freshwater management. For instance, SDG #15 aims to 'sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss'. In regard to freshwater, SDG #6 seeks to 'ensure availability and sustainable management of water and sanitation for all'. Targets for SDG #6 include:

- Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable water withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
- Target 6.5: By 2030, implement integrated water resource management at all levels, including through transboundary cooperation as appropriate.
- Target 6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

E-FLOWS ARE LINKED TO MANY SDG TARGETS

When the UN General Assembly adopted the 17 SDGs, it emphasised the importance of water as a crucial component of human development and ecosystem needs (Bhaduri *et al.* 2016). Therefore, environmental flows (hereafter, e-flows) may link to many other SDG targets beyond those described here. For instance, e-flows are likely to result in more sustainable fisheries and other freshwater foods and thus contribute to improvements in SDGs 1 (no poverty), 2 (zero hunger), 3 (good health and well-being), 8 (decent work and economic growth) and 11 (sustainable cities and communities). Healthy freshwater ecosystems also support other SDGs through the provision of building materials and other goods produced in freshwater ecosystems.

The year 2017 marks the 10th anniversary of the Brisbane Declaration on Environmental Flows[1]. This declaration was crafted at the 2007 Riversymposium and advocates for e-flow protection and restoration. Since that time, governments and water management authorities across the globe have made significant progress towards developing policies and regulations, and taken myriad actions, to protect and restore e-flows. E-flow implementation has nonetheless faced significant challenges, including a lack of political will and stakeholder support, insufficient resources and capacity, competition for water among other sectors, and institutional barriers and conflicts of interest (Le Quesne *et al.* 2010). Despite these obstacles, many success stories in e-flow implementation have emerged.

The purpose of this report is to showcase several of these success stories where actions have led to e-flow implementation with benefits for society and ecosystems. The case studies are drawn from a range of geographical, cultural, economic and hydrological contexts and focus on the political, economic and governance factors leading to the successful implementation of e-flows, and the specific roles that key decision-makers and e-flow champions have played.

[1] www.watercentre.org/news/declaration

We hope these stories will inspire decision-makers in government ministries and agencies (food, water, energy, economic planning), public and private sector financial institutions (including multilateral and bilateral donors), key economic sector actors (including farmers, dam operators, utilities), research institutions, and non-governmental organisations (NGOs) to commit to further action. We also hope that the lessons that have been learned from the case studies in this report will provide practical guidance to those who are facing similar challenges linked to e-flow implementation and water resource management.

Initially, this report provides a brief review of e-flows, their benefits, and implementation challenges (Section 2). Section 3 presents case study success stories where e-flows have been implemented or safeguarded in practice, not just in policy. Section 4 synthesises lessons from the past and prospects for the future, by focussing on the roles played by decision-makers and key stakeholders that led to successful e-flow implementation. We then develop a suite of recommended actions that key decision-makers in a variety of organisations should undertake to implement e-flows. Section 5 concludes by issuing a call to action to protect or restore the ecosystem goods and services that rivers provide through e-flow implementation.

2. E-FLOWS: A RECAP

2.1 WHAT DO WE MEAN WHEN WE TALK ABOUT E-FLOWS?

There is a growing concern over the environmental and socio-economic consequences resulting from the breakdown in the functions of freshwater ecosystems, and the increasing difficulty of managing water resources sustainably as the human population grows. For instance, anthropogenically reduced flows can result in inadequate fish biomass to feed communities that rely on this source of protein. Rivers where flow has been reduced may no longer provide recreational services, and consequently economic benefits, that they did in the past. Reduced flows also decrease sediment transport and flushing, which can affect river and estuary morphology and function, as well as the formation of coastal beaches. Additionally, rivers with reduced flow that also receive a lot of wastewater are potential centres for diseases such as malaria, cholera and dysentery (O'Keeffe and Le Quesne 2009).

Managing river systems involves complex trade-offs and opportunity costs (Parker and Oates 2016). For instance, the economic benefits provided by a river to some people through dams, diversions, agriculture and industry often come at a cost to benefits that others rely on such as recreation or fisheries. Conflicting demands for freshwater resources and the desire to maintain ecological functions have stimulated the science of e-flows to assess the consequences of altering flow regimes in aquatic ecosystems (O'Keeffe and Le Quesne 2009). An e-flow assessment can help stakeholders and decision-makers to understand trade-offs between instream and out-of-stream uses of water, and to design water or infrastructure management plans that can optimise among these uses. Resolution of conflicting demands for water resources and implementation of e-flows in practice normally depend on institutions (formal and informal) and infrastructure (grey and green), as they play a vital role in regulating access and entitlements by people to ecosystem services. It is important that institutions and infrastructure provide equitable access to ecosystem services through clear policies and planning that can balance instream and out-of-stream uses of water (Parker and Oates 2016, Tickner *et al.* 2017).

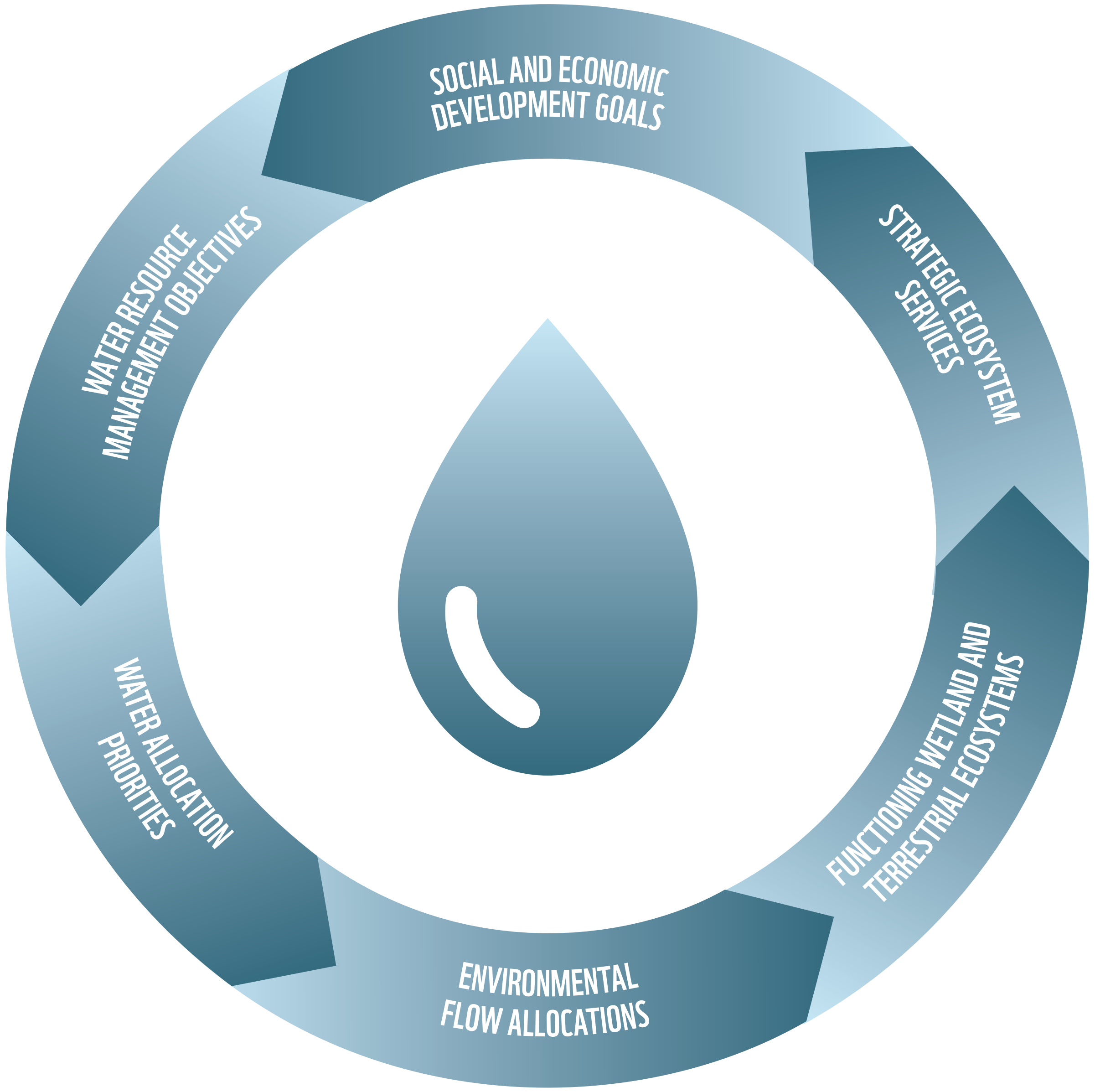
During the 10th International Riversymposium and International Environmental Flows Conference held in Brisbane, Australia in September 2007, a coalition of scientists and practitioners issued the Brisbane Declaration. The declaration presented a summary of findings and a global action agenda to address the urgent need to protect rivers globally. Environmental flows were defined in the Brisbane Declaration as:

> *'The quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.'*

This definition of e-flows emphasises not just the environmental importance of flow, but also clearly articulates the direct link to economic benefits and social values. Many other definitions of e-flows are used in jurisdictions across the globe (Box 1). Although these definitions vary and emphasise different values of importance based on the areas of the world from which they originate, they are all fundamentally similar to the definition of e-flows from the Brisbane Declaration and incorporate some measure of ecological, social, cultural and economic value.

From an ecosystem perspective, the quantity, timing and quality of water are important because the flow in rivers naturally varies throughout a year and between years. The natural flow regime consists of periods of low flow, periods of high flow when rains return or snow melts, and occasional peak flows during flood events. Groundwater contributions to rivers also vary naturally throughout a year and between years in response to changes in recharge and discharge (Hirji and Davis 2009). Ideally e-flows, although different from the natural flow regime, will mimic this within- and between-year variation to support the aquatic, riparian and terrestrial organisms that have become adapted to such conditions, and deliver similar social and ecological functions.

Figure 1. The link between development goals, water resource management, e-flows and ecosystem services (source: Tickner and Acreman 2013)



There has been a progressive evolution in the determination of e-flows. In 1970s, the typical question asked was 'what minimum amount of water needs to be left instream for fish?' Today, more holistic approaches are available that factor in the full range of natural flow variability (magnitude, timing, duration, frequency, and rate of change for each flow component including low, high and peak flows: Richter *et al.* 1996; Locke *et al.* 2008) (Box 2). This evolution of e-flow assessment has coincided with a shift in water management concepts, such as the Integrated Water Resource Management (IWRM) concept, to account for environmental aspects as well as social and economic issues (Roy *et al.* 2011). In some instances, for example in South Africa, this has included a reframing of the outdated view that water for the environment is a rival use and/or a source of risk to social values. To the contrary, the value of ecosystem services provided by freshwater systems (both surface water and groundwater) to economies and societies is increasingly understood. Acknowledgement of the importance of flows for cultural purposes has also gained ground and in some instances has become as important as flows for environmental purposes, if not more so. For instance, flows and water levels for socio-cultural events such as Kumbh 2013 were the primary focus of e-flow initiatives for the Ganga River in India (WWF 2013). There has therefore been a convergence between e-flows and water resource management such that 21st century water management paradigms are steadily shifting to a genuinely integrated approach to sustainable development, as evidenced by the SDGs.

BOX 1: ENVIRONMENTAL FLOWS DEFINED

The concept of environmental flows has evolved over time from a single 'minimum instream flow' provided year-round, to a more inclusive concept that incorporates more elements of the natural flow regime (Richter et al. 1997, Poff et al. 1997, Locke et al. 2008). The definition and assessment of environmental flows have also expanded to emphasise the social and economic importance of flow.

The following examples illustrate the scope of definitions used for environmental flows in various jurisdictions and demonstrate that objectives encompass a variety of components, ranging from specific needs for fish or other wildlife, to wider ecological, social and cultural values.

» France: Minimal flow that must be left in a watercourse below hydraulic infrastructures to permanently guarantee the life, passage and spawning of fish species present (MEDDE 2014).

» Washington State (USA): Minimum instream flows to protect (or preserve water quality to protect) fish, game, birds or other wildlife resources or recreational and aesthetic values (DOE 2017).

» Florida State (USA): Minimum flows and levels are the limits at which further water withdrawals would be significantly harmful to the water resource or ecology of the area (Neubauer et al. 2008).

» European Water Framework Directive: The amount of water required for the aquatic ecosystem to continue to thrive and provide the services we rely upon (European Union 2015).

» South Africa: The South African National Water Act 1998 calls for a two-part 'reserve' of water, one to meet 'basic human needs' and the other as an 'ecological reserve'. The basic human needs reserve provides each South African with a minimum amount of water from the appropriate water resource with which to satisfy essential needs for drinking, food preparation, and personal hygiene (Salman and Bradlow 2006). The ecological reserve is defined as the water quality and quantity requirements that will ensure rivers sustain basic ecological functioning (Hughes and Hannart 2003).

» New Zealand: The flows and water levels required in a water body to provide for a given set of values which are established through a regional plan or other statutory process. Environmental flows and water levels may provide for ecological, tangata whenua (indigenous people), cultural, amenity, recreational, landscape, natural character and other values associated with water (New Zealand Ministry for the Environment 2008).

» Peru: The volume of water that has to be maintained in a river to conserve water ecosystems, landscape aesthetics and other aspects of scientific and cultural interest (MINAG 2009).

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BOX 2: BUSTING SOME OF THE MANY E-FLOW MYTHS

There are some common misconceptions or myths associated with e-flows that may impede action in certain regions or jurisdictions.

E-flows are just for the environment:

As is evident in Box 1, some definitions of e-flows are focused solely on the environment; however, more holistic definitions – including that of the Brisbane Declaration – acknowledge the economic and social benefits of flow and seek to root e-flows as a core aspect of water resource management. E-flows not only provide crucial contributions to the health of rivers but also underpin the ecosystem functions and services that can, with appropriate infrastructural operations and institutional management, lead to societal benefits. Such benefits can relate to social issues (e.g. household nutrition from fisheries), economic issues (e.g. maintenance of sediment flows to ensure low-lying delta settlements do not flood from rising seas), strategic issues (e.g. fulfilment of international treaty obligations), and spiritual/cultural issues (e.g. maintaining adequate flows and water quality for sacred bathing in the Ganga) (Le Quesne et al. 2007, Dyson et al. 2008).

E-flows only matter in arid areas:

The importance of e-flow provision is not limited to arid regions. Brauman et al (2016) found that rivers have been heavily depleted across all climate zones, and e-flows have been instituted in rivers flowing in a broad range of climates worldwide for the purpose of maintaining properly functioning ecosystems. This is evident in the case studies examined for this project where e-flows have been implemented in arid regions such as those in southern Australia and South Africa, but also in rivers in the Neotropical ecoregion in Mexico, and groundwater-fed chalk streams in southern England. While drought can be a significant factor leading to water scarcity, hydrological alteration from dams, diversions and canals and over-abstraction can also substantially alter the natural flow of rivers (Moore 2004).

E-flows are only for restoring depleted rivers:

E-flows are not just about restoring rivers that are degraded. Ideally, e-flows should be protected or reserved when first implementing a water allocation system, thereby protecting the function of rivers so that they do not become stressed from overuse and over-abstraction; e-flows should similarly be factored into water resource planning early in the process (O'Keeffe and Le Quesne 2009). In some instances, e-flow assessment might even demonstrate that more water can be abstracted from a river without endangering critical ecosystem functions and services (O'Keeffe 2012).

E-flows are the same as minimum flow:

Rivers are dependent on dynamic flows at different times of the year to inundate different channel and floodplain features and to enable completion of different plant and animal life cycles that are the foundation of aquatic ecosystems (Brown and King 2003, Postel and Richter 2003, Le Quesne et al. 2007). Cases in which river flows have been regulated to remove flow variability have resulted in a serious loss of biodiversity, even when the total flow volume has been increased (e.g. the Great Fish River in South Africa (O'Keeffe and de Moor 1988)). Higher flows scour fine sediments from substrate and bring in nutrient-laden materials. Flood flows are important to inundate riparian and floodplain habitat. Flows of a certain magnitude, frequency, and duration are required to maintain channel shape. Flow pulses of a specific timing and duration are also important in providing behavioural cues to aquatic species for migration and other life history events (O'Keeffe and Le Quesne 2009). The timing of flows can also maintain ecosystem services, e.g. to ensure freshwater flows during high tides to estuarine cities that rely on rivers for bulk water supplies (as is the case for Shanghai).

2.2 HOW DO WE DETERMINE E-FLOWS?

Science has a key role in guiding flow management for the conservation of biodiversity. However, the particular type of science – or other disciplinary expertise – needed depends entirely upon the outcomes to be protected or attained through e-flow management.

Much of the early e-flow science was focused on the conservation of one or a few targeted species, particularly commercially important fish species such as salmon and trout, requiring knowledge and data on the relationship between specific flow conditions and the life cycle requirements of those species. As the desired outcomes expanded to encompass entire aquatic communities, or to include ecological functions such as channel migration or nutrient or sediment transport, the array of necessary disciplinary expertise expanded greatly. When socially-based outcomes – such as restoration of fisheries or recreational benefits – began to be included as desired outcomes, the requisite expertise expanded again to include economics, human health and other social sciences.

Natural systems, and the communities dependent upon them, are complicated and variable, posing significant analytical challenges. Many key scientific knowledge gaps remain in our understanding of the relationships between flow and species or habitats of conservation or management concern, or between flow and ecological function (e.g. Bradford and Heinonen 2008, Bradford *et al.* 2011). This is particularly the case in developing countries where there is often a lack of hydrological and ecological data. Analytical challenges are compounded when trying to link flows to ecosystem services valued by human communities because the causative chain of linkages becomes more complicated. In many instances, the identification of desired outcomes is developed through engagement of local community members, but in other places those outcomes are defined by governmental policy.

Tharme (2003) identified approximately 250 distinct methods of assessing e-flows more than a decade ago, and new methods and tools continue to be developed. Methods are not only numerous, but the complexity of the methods is variable and ranges from simple to very complex (Acreman *et al.* 2014).

Overall, methods to define e-flow requirements can be split into four broad categories: (1) look-up tables; (2) desk top methods; (3) habitat modelling; and (4) holistic methods/functional analysis (Dyson *et al.* 2008, Linnansaari *et al.* 2013). An overview of these four categories is presented in Table 1, with further detail presented in Dyson *et al* (2008), Linnansaari *et al* (2013), Acreman *et al* (2014), and Acreman (2016).

The available methods all have their advantages and disadvantages, and range broadly in the degree that they are based on data or other scientific evidence or subjective professional judgement (Acreman *et al.* 2014). Additionally, results can vary greatly depending on the approach used to analyse the same data. Acreman *et al* (2014) note that the 'dilemma in method selection is whether to focus purely on quantitative relationships, which may restrict analysis to certain flow elements and species, or to take a more holistic approach that may require a mix of data and expert opinion to describe seasonal and annual flow variations needed to support diverse, dynamic ecosystems'. The choice of method should be determined according to the particular situation, as well as the available time, funding, and expertise.

Ultimately, it is very important to acknowledge that no first answer to the question of 'how much water is needed?' should be expected to be perfectly correct. Instead, any first answer should be viewed as a 'best first approximation' that will need to be further adjusted and refined over time through adaptive management (Richter *et al.* 2011) and which is largely dependent on the goods and services a society wants from the river. Furthermore, all e-flow assessment methodologies represent predictions of the flows required to achieve different ecological, social or economic objectives. Only when e-flows are monitored and implemented will it be possible to determine how accurate those predictions were. Therefore, the best e-flow management programmes are those that both allow for and enable adaptation over time.

Table 1. Overview of e-flow determination techniques (adapted from Linnansaari et al. 2013)

METHOD CATEGORY	GENERAL PURPOSE	SCALE	SCOPE	QUALITATIVE/ QUANTITATIVE	DURATION OF ASSESSMENT	RELATIVE COST	ADVANTAGES / DISADVANTAGES
Look-up tables/ Hydrological E.g., Tennant, Indicators of Hydrologic Alteration (IHA).	Use natural flow levels to determine "safe" thresholds for flow abstraction.	Whole rivers, applicable for regional assessments.	Low-risk situations, reconnaissance	Quantitative	Days to weeks	$	Application requires few resources once developed. Indices may not be transferable to different areas without calibration. No explicit consideration of biological, social, cultural, or economic values, although these are implicitly considered in some methods.
Desk-top methods E.g., Range of Variability Approach	Hydrologic methods explore flow regime of the entire river to maintain integrity, seasonality and natural variability of flows. Hydraulic methods examine change in a hydraulic variable (wetted width) as a function of discharge. The change in this variable is used as a proxy for general habitat quantity in a river. Ecological methods include biological response models that reflect the relationship between river hydrology and organism characteristics (i.e., depth and velocity and life history phase).	Whole river or applied at study site/ river reach, upscaled to whole river based on representative sites. River specific.	Medium	Quantitative	Days to months	$$	Can address both flow and ecology depending on the method used. May require a substantial amount of biological data that is not readily available. It is difficult to identify biotic indices that are only flow sensitive and not sensitive to other factors such as habitat or water quality. Ecological indices and flow time series may not be independent thus may violate assumptions. No explicit consideration of social, cultural, or economic values, although these are implicitly considered in some methods.
Habitat Modelling E.g., Physical Habitat Simulation (PHABSIM)	Examination or change in the amount of physical habitat for a set of target species as a function of discharge	Applied at study site/ river reach, upscaled to whole river based on representative sites. River specific.	Detailed	Quantitative	6 to 18 months	$$$	Clearly defined step by step procedures exist. May be more accurate than hydraulic and hydrological methods to determine flow threshold levels. The best application of the methods requires a team of experts and considerable field work. Poor application can result if used by practitioners with little experience. No social, cultural, or economic values are incorporated.
Holistic methods/ functional analysis E.g., Building Block Methodology (BBM)	Examination of flows in an expert opinion workshop leading to flow recommendations for all components of the river ecosystem including social, economic and recreational uses.	Whole rivers, applicable for regional or river specific scales	Flexible	Quantitative and qualitative	12 to 36 months	$ to $$$	Aims to retain the natural hydrological regime and addresses relevant river ecosystem components and societal needs.Relies on considerable professional judgement and opinion. Can be time consuming depending on depth of evaluation, field work needs, and extent of consultation. Data requirements may not be easily specified with a range in expert opinions.

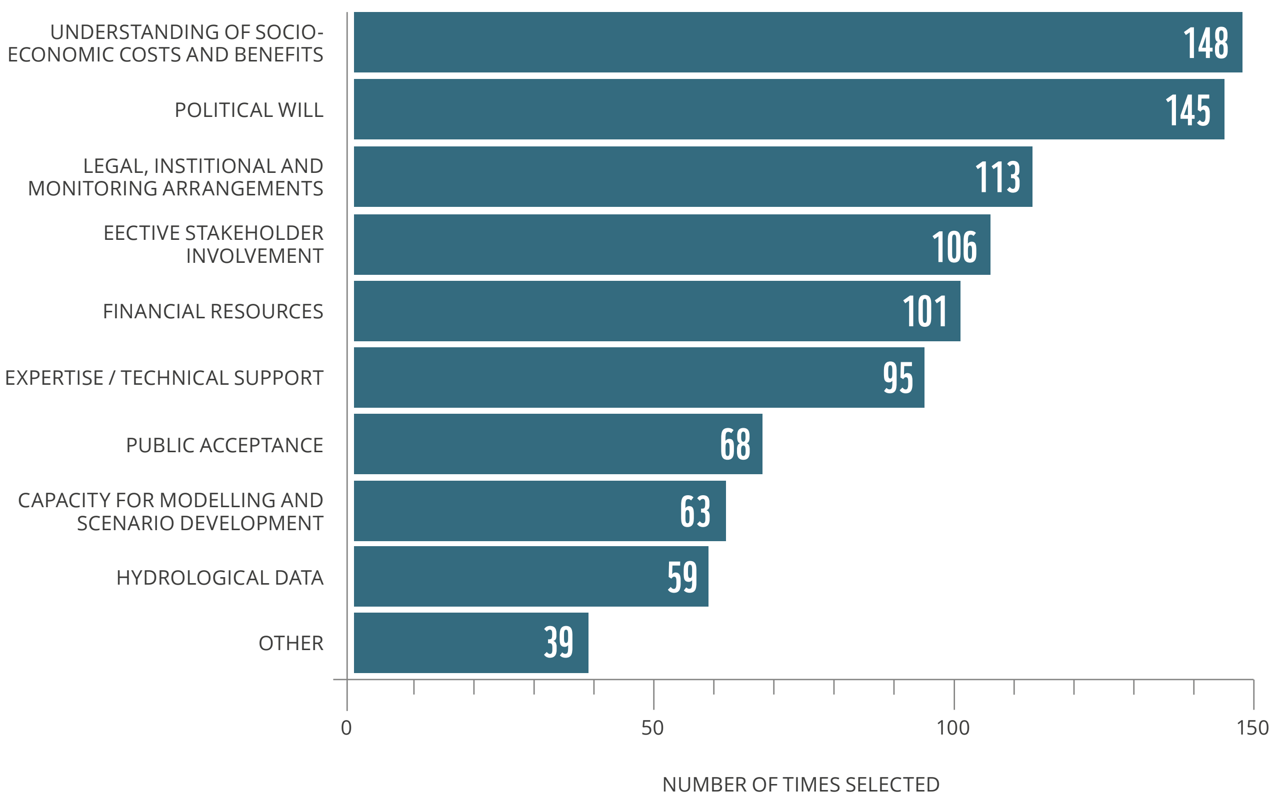
2.3 THE IMPLEMENTATION CHALLENGE

Through the Brisbane Declaration, the delegates to the 10th International Riversymposium and Environmental Flows Conference in 2007 called upon 'all governments, development banks, donors, river basin organisations, water and energy associations, multilateral and bilateral institutions, community-based organisations, research institutions, and the private sector across the globe' to commit to a set of actions for restoring and maintaining e-flows. The Global Action Agenda included:

- Estimating e-flow needs everywhere immediately;
- Integrating e-flow management into every aspect of land and water management;
- Establishing institutional frameworks;
- Integrating water quality management;
- Actively engaging all stakeholders;
- Implementing and enforcing e-flow standards;
- Identifying and conserving a global network of free-flowing rivers;
- Building capacity; and
- Learning by doing.

Despite the fact that most countries now have some form of policy or legal recognition of e-flows, implementation has been limited in many places (Hirji and Davis 2009). A number of international reviews (Moore 2004, Hirji and Davis 2009, Le Quesne *et al.* 2010) have assessed e-flow implementation challenges, identifying three principal, related obstacles (Figure 2): (1) a lack of political will and stakeholder support; (2) insufficient resources and capacity; and (3) institutional barriers and conflicts of interest (Le Quesne *et al.* 2010).

Figure 2: Difficulties and obstacles to understanding and implementing environmental flows (from Moore, 2004)



Evidence from many countries has shown that a change in policy does not automatically result in implementation (Hirji and Davis 2009). Hence, although legislation and policy are key factors that enable implementation, ongoing political and public support is essential for setting strategic direction, safeguarding planning resources, supporting environmental requirements with stakeholders, and enforcing implementation of e-flows. Competing social and economic interests that may be impacted by changes to water use (e.g. agriculture, hydropower, industry) may resist attempts to reform water management, and must therefore be included in discussions of e-flow management.

CHANGES IN POLICY DO NOT NECESSARILY LEAD TO E-FLOW IMPLEMENTATION

In many cases, there is a trigger or specific event that motivates different stakeholders to implement e-flows. For example, a period of drought can cause local stakeholders to take notice that a river is not functioning as it once did, and motivate them to make change. A change in legislation may also allow for an opportunity to implement e-flows where there was once a political or economic barrier. These triggers can be categorised into ecological factors, economic production and asset protection, water security, and social and cultural factors (Speed *et al.* 2016). The categories are not exclusive and can have some overlap in both motivation and outcomes. Triggers and objectives for implementing e-flows should be distinguished from each other although they are often closely linked. A trigger is something that demands a response that results in an action, and objectives are usually defined in broader terms as the results that people want to achieve (Speed *et al.* 2016).

E-flow implementation also cannot occur without capable institutions, and it cannot succeed over the long term without support from affected stakeholders. A comprehensive framework for implementing e-flows requires that 'relevant laws, policies, regulations, procedures, and institutions be in place across a wide range of water resource management functions' (Le Quesne *et al.* 2010). Implementing effective policies for e-flows requires both an effective water management and allocation policy and an institutional framework that includes active stakeholder engagement, with e-flow requirements recognised within this framework.

E-FLOW IMPLEMENTATION MUST REFLECT POLITICAL, ECONOMIC, SOCIAL, CULTURAL AND HYDROLOGICAL CONTEXTS

The interdisciplinary and inter-sectoral nature of e-flows sets up the possibility for institutional barriers and conflicts of interest. A variety of interests that operate under different legal authorities all play key roles in managing e-flows. Institutional barriers between different government agencies are further impaired by a lack of understanding of the connection between various downstream water needs (e.g. estuarine, near-shore, and aquifer) (Hirji and Davis 2009). Furthermore, it may be a challenge to develop the scientific and decision support tools necessary to set and manage e-flow targets in countries where political and academic institutions do not work together cooperatively, or within implementing agencies where there are competing incentives (Le Quesne *et al.* 2010). Reform of water policy may necessitate the change of administration institutions, which can significantly slow the process. The challenges of adjusting to major new water policies include, among others, establishing new regulatory, monitoring and enforcement institutions. These changes can become compounded when transboundary or interstate agreements are the vehicle for e-flow recognition, especially where a lack of overarching political authority often exists (Le Quesne *et al.* 2010).

A key message from the various challenges to e-flow policy is that there is no single correct approach to implementing e-flows. Efforts must reflect political, economic, social, cultural and hydrological contexts. Consequently, e-flow implementation – like all aspects of water management – can be complex. Nevertheless, success is possible. The following section highlights success stories in e-flow implementation from a wide range of geographical, cultural, economic, hydrological and institutional contexts. These case studies can provide guidance and inspiration for other stakeholders that desire to enact e-flow policy and successfully protect or restore e-flows.

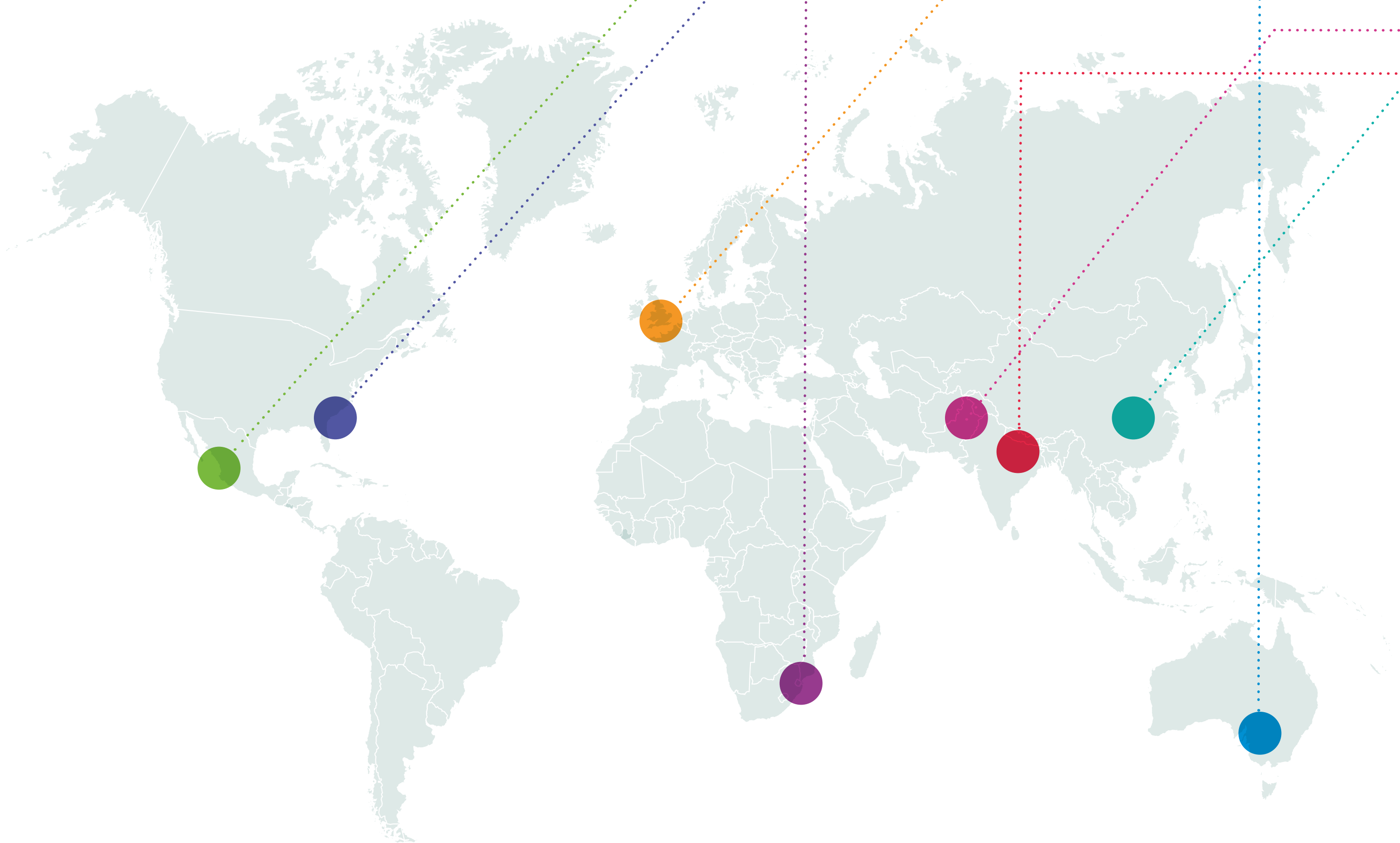
3. CASE STUDIES OF SUCCESS

3.1 RESEARCH APPROACH

Our goal through the case study review is to highlight key factors that have led to the successful protection or restoration of e-flows, thereby informing and inspiring stakeholders and decision-makers to take further action in securing e-flows in other jurisdictions or systems and providing a roadmap as to how this can be done.

The case studies were chosen from a list of suggestions put forward in response to a call we issued to the global WWF network, to the External Advisory Group we brought together for the project, and to members of the research team. We specifically asked for examples of rivers in which e-flows had actually been implemented to some degree, not just jurisdictions where legislative and policy instruments have been put in place. The complete long list of suggested case studies is set out in Table 2. It is worth emphasising that this is probably only a sample of places around the world where e-flows are beginning to be implemented in practice. The fact that so many examples were put forward – more than we expected – is in itself a cause for optimism.

Figure 3



THAT SO MANY E-FLOW IMPLEMENTATION EXAMPLES WERE PUT FORWARD IS A CAUSE FOR OPTIMISM

From the longlist we had to choose a smaller number of case studies to feature in this report. With our goal in mind, there were several criteria by which we made our selection. Firstly, we wanted to be able to review how e-flows came to be implemented through real-life politics and policy interventions. We have therefore purposefully not focused on the technical process by which e-flows were determined, but rather the human story of who advocated for e-flows, how sceptics were persuaded, and what motivated decision-makers to take action. To understand these perspectives, for each case study we had to be able to speak to a range of stakeholders – ideally including at least one stakeholder who advocated for e-flows, one who was sceptical and needed convincing, and one from the government ministry or water management authority charged with making decisions about water allocation and/or infrastructure operating regimes. We also wanted to include case studies where impacts of e-flows – in ecological, economic, or social terms – could be demonstrated through monitoring and comparison of 'before' and 'after' conditions. Finally, we wanted the case studies to provide a range of examples from across the globe and encompass different political, developmental, institutional, social, climatological and ecological contexts.

The eight case studies we chose were (Figure 3):

- The Sustainable Rivers Program, focusing on the Savannah River, US
- Murray-Darling Basin, Australia
- Yangtze River, China
- River Kennet, England
- Crocodile River, South Africa
- San Pedro Mezquital River, Mexico
- Poonch River, Pakistan
- Ganga River, India

Each of these case studies could in itself be the focus of extensive research. Indeed, many of them have been the subjects of long reports and PhD theses addressing the complex and dynamic processes by which e-flows, water allocations or broader arrangements for water governance have come to pass. Similarly, for each case study it would be possible to find dozens, if not hundreds, of stakeholders with varying perspectives on such processes who could provide helpful insights. With the resources at our disposal, we chose not to duplicate such research or to undertake additional academic analysis of one or two cases. Given that our aim was to provide a global review of factors that can lead to e-flow implementation, we focused on a practical approach that would help us to generate a synthesis of perspectives from a representative set of stakeholders in a wide range of international contexts.

DEFINITIVE TRUTHS ABOUT WATER GOVERNANCE AND MANAGEMENT ARE RARE

We acknowledge that "success" in e-flow implementation is a subjective term; that every stakeholder will tell a different story; and that definitive truths about water governance and management processes are rare. We encourage users of this report to read other analyses, including in depth academic or policy studies of specific river management contexts where necessary.

While our case studies focus on the protection or restoration of flows in rivers, several also refer to the importance of flood flows in sustaining and supporting healthy floodplain wetlands. Although not addressed explicitly in this report, we view the provision of e-flows as important not just for rivers but also for interconnected lakes, wetlands and aquifers.

Table 2. List of candidate case studies

CONTINENT	CANDIDATE CASE STUDY	FURTHER INFORMATION AVAILABLE FROM:
Europe	River Kennet (England)	Section 3.5
	River Pang (England)	Acreman (2000, 2001)
	Redgrave and Lopham Fen (England)	Howard Humphreys and Partners Ltd. (1994)
Asia	Lake Chilika (India)	Hirji and Davis (2009a)
	Ganga and Ramganga rivers (India)	Section 3.9
	Yangtze River (China)	Section 3.4
	Yellow River (China)	Gippel *et al* (2012)
	Poonch River (Pakistan)	Section 3.8
	Kishenganga and Neelum rivers (Pakistan)	King *et al* (2013)
Oceania	Murray-Darling Basin (Australia)	Section 3.3
Africa	Mara River (Kenya, Tanzania)	WWF and Lake Victoria Basin Commission (2010)
	Kilombero and Rufiji rivers (Tanzania)	CDM Smith (2016)
	Highlands Water Project (Lesotho)	Hirji and Davis (2009a)
	Crocodile River, Kruger National Park (South Africa, Mozambique)	Section 3.6
	Kafue River (Zambia)	Kalumba and Nyirenda (2017)
	Pongolo River (South Africa)	DWS (2014)
	Senegal River(Mali, Mauritania, Senegal, Guinea)	Hirji and Davis (2009a)
South America	Rio São Francisco (Brazil)	Brambilla *et al* (2017)
	Paraná River (Brazil)	Souza *et al* (2008), Agostinho *et al* (2008)
North America	Colorado River (US, Mexico)	CWCB (2012)
	Deschutes River (US)	Golden and Aylward (2006)
	Columbia River (US, Canada)	Dyson *et al* (2008), BC Hydro (2017)
	San Pedro Mezquital River (Mexico)	Section 3.7
	Athabasca River (Canada)	WWF (2011)
	Sustainable Rivers Program (US)	Section 3.2
	Peace River (US)	Locke *et al* (2008)

3.2 SUSTAINABLE RIVERS PROGRAM, UNITED STATES

THE RIVER

The Savannah River flows from the Blue Ridge Mountains of northern Georgia and divides the states of South Carolina and Georgia as it flows more than 500 km before emptying into the Atlantic Ocean.

THE ISSUE

A series of droughts in the late 1990s and 2000s drew attention to the river and highlighted that water is a finite resource. Impacts to water quality (low dissolved oxygen in the Savannah River harbour), fish species (e.g. endangered sturgeon species), recreation, and property values focused the attention of various stakeholder groups.

THE RESPONSE

In 2002, the US Army Corps of Engineers (USACE) and The Nature Conservancy (TNC) began a national collaboration, the Sustainable Rivers Program, to improve water management in rivers across the United States (US) by implementing e-flows through adaptive reservoir operations. The Savannah River was one of eight initial demonstration sites for the programme.

In May 2002, an orientation meeting for the Savannah River project took place with about 90 individuals representing state, federal and local agencies, academic institutions and NGOs. This was followed by an e-flow recommendations workshop in April 2003. This workshop developed initial e-flows that focused on spring flood pulses. E-flow implementation began in 2004 and has been adaptively managed since that time. E-flows were updated in 2014, based on research and learning since 2004.

INTERVIEWEES

Andy Warner – CDM Smith-consulting firm, Institute of Water Resources fellow (USACE), formerly National Initiative Director of the Sustainable Rivers Program for The Nature Conservancy

Eric Krueger – Director of Science and Stewardship, South Carolina Chapter, The Nature Conservancy

Stan Simpson – Operations Manager for Hydrology & Hydraulics Branch, United States Army Corps of Engineers (USACE) Savannah District Water Management

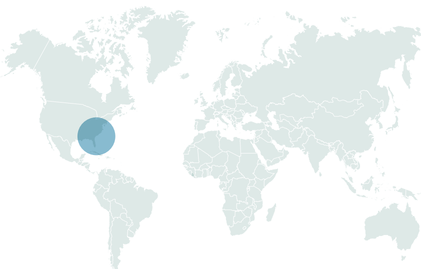
Harry Shelley – Chairman of the Savannah River Basin Advisory Council. The Council advises senior staff in the South Carolina Department of Natural Resources (DNR) and the Department of Health and Environmental Control (DHEC)

KEY FINDINGS

This case study highlights the collaboration between a federal agency, an international NGO, and state and local stakeholders to develop e-flow recommendations and implement them using an adaptive management approach based on the best available science.

It is helpful to initially implement e-flows based on available information, and then refine the targets based on monitoring results and adaptive management. This method gets the process moving forward without delays due to data gaps. Monitoring and adaptive management are critical.

A working river still needs to be a healthy river; otherwise it will not function and provide the ecosystem goods and services upon which people rely.



3.2.1 Background

The Sustainable Rivers Program (SRP) is a national collaboration in the US between the US Army Corps of Engineers (USACE) and The Nature Conservancy (TNC). It began in 2002 with the goal of improving water management in rivers across the country by implementing e-flows through adaptive reservoir operations (Richter et al. 2006, Warner et al. 2014, Warner, pers. comm. 2017). The USACE is given authority through the US Congress to build dams for flood management, recreation, water supply storage, hydropower, and environmental and ecosystem protection and restoration. Although more recent than their other authorities, the USACE has an environmental mandate, so advancing e-flows is within their responsibility to balance social and environmental needs (Warner, pers. comm. 2017). The SRP was created to develop and test advances in methods, tools and practices used for environmentally-sustainable water management (Warner et al. 2014). The SRP started out as a project of eight demonstration sites located throughout the continental US, including the Connecticut River, Roanoke River, Savannah River, Green River, White River, Big Cypress Bayou, Bill Williams River and the Willamette River, which collectively contain 36 USACE dams.

The SRP sites vary significantly in their size, demands on water, and ecological, social, political and economic characteristics (Warner et al. 2014). Although flood management is a common purpose, factors such as water supply, hydropower generation, recreational uses, navigation and environmental quality influence dam operations differently across SRP sites. Work in each of the SRP watersheds involves a collaborative and coordinated effort of state and federal agencies, academic institutions, NGOs and the private sector. In some instances, coordination and collaboration also extend across SRP sites (Warner et al. 2014). At each site, the partners sought to develop environmental flow prescriptions using a science-based, stakeholder-driven process based on collaborative effort and then, to the extent possible, pursue implementation (Richter et al. 2006, Warner et al. 2014). The SRP process of developing e-flows can be summarised in four general phases: (1) initiating the process and engaging key stakeholders; (2) defining holistic environmental flows in explicit and quantified terms; (3) implementing the environmental flows; and (4) monitoring and adaptive management (Warner et al. 2014). The SRP continues to expand, and currently includes 14 sites and 60 USACE dams across the US (Warner, pers. comm. 2017).

THE SUSTAINABLE RIVERS PROGRAM CURRENTLY INCLUDES 14 SITES AND 60 DAMS ACROSS THE US

Our case study examines the development and implementation of e-flows on the Savannah River. The Savannah River flows from the Blue Ridge Mountains of northern Georgia and traverses more than 500km before emptying into the Atlantic Ocean. The river divides the states of South Carolina and Georgia and crosses three different ecoregions: the Blue Ridge, the Piedmont and the Atlantic Coastal Plain (Richter et al. 2006). The river basin is approximately 27,000 sq km and is comprised of aquatic shoals, bottomland hardwood forests, tidal wetlands, longleaf pine forests, Carolina bays, granite outcrops and bluff forests (Richter et al. 2006). The USACE operates three large dams on the river upstream of Augusta, Georgia – the Hartwell, Russell and Thurmond Dams – as well as the New Savannah Bluff Lock and Dam. The latter serves to re-regulate hydropower peak releases from Thurmond Dam, and maintains a recreational pool through the City of Augusta. Downstream of the lock and dam, the river is relatively pristine with no major infrastructure until the deepened harbour on the coast at Savannah, Georgia.

The Thurmond and Hartwell Dams were built in the 1950s and 1960s, respectively, with the Russell Dam constructed in the early 1980s (Shelley, pers. comm. 2017). The three dams are operated on the river in a coordinated manner as a single unit (Warner, pers. comm. 2017). The dams are multi-purpose and are authorised for hydropower generation, flood management, recreation, water supply, and fish and wildlife habitat (Richter et al. 2006). The reservoirs formed by the dams have a large vocal constituency surrounding them with well-organised homeowner associations that defend their interest in the lakes. These stakeholders have an interest in keeping the lake levels high and relatively stable as ecotourism is important to the economics of the upper lake area of the Savannah River (Shelley, pers. comm. 2017). The reservoir supports a popular and productive fishery for largemouth bass (*Micropterus salmonids*) and striped bass (*Morone saxatilis*) that generates considerable revenue (Krueger, pers. comm. 2017a). Below the dams, the Savannah River flows through relatively flat lands and is laden with sediment from the Piedmont ecoregion. The economic drivers associated with water in the middle of the Savannah River basin are tourism and water supply for the city of Augusta. In the lower Savannah River, shipping and industry are important economically, but persistent low dissolved oxygen levels in the harbour have raised regulatory compliance concerns.

The Savannah River is home to ~100 different fish species, including two that are federally endangered (shortnose sturgeon, *Acipenser brevirostrum*, and Atlantic sturgeon, *Acipenser oxyrhynchus oxyrhinchus*), and a candidate species[2] (robust redhorse, *Moxostoma robustum*). Additionally, there are relatively rare freshwater mussels in the river, with some populations doing well while others are imperilled (Krueger, pers. comm. 2017a).

At the same time the SRP was being launched, the USACE Savannah District was in the initial phase of a new Comprehensive Plan for the Savannah River Basin. The purpose of the plan was to assess the existing authorised uses of the river and reservoirs associated with the dams, and evaluate whether water management practices were adequately addressing the needs of all stakeholders. As part of this process, the Savannah River was enrolled in the SRP, and TNC was invited to help facilitate the development of e-flow recommendations.

[2] The robust redhorse has a Candidate Conservation Agreement with Assurances (CCAA), which is a means by which partnerships between public and private sectors and government agencies can conserve imperiled species and their habitat under the Endangered Species Act.

3.2.2 Implementation of e-flows on the Savannah River

The process of developing e-flow recommendations for the Savannah River used an inter-disciplinary, collaborative and adaptive approach. In May 2002, an orientation meeting for the Savannah River project took place with about 90 individuals representing state, federal and local agencies, academic institutions, and NGOs (Richter *et al.* 2006). The participants reviewed and commented on a scientific approach, and identified key science contributors and sources of relevant information for developing e-flow recommendations for the Savannah River. After a summary report and literature review of relevant information was prepared by the University of Georgia's River Basin Science and Policy Centre, a flow recommendations workshop took place in April 2003 with 47 scientists and technical experts participating.

Quantitative flow recommendations were developed during the workshop with a goal of sustaining the river, floodplain and estuarine ecosystems based on information gathered from the literature review and professional judgement, with different recommendations for climatically dry, average, and wet years. As part of this process, knowledge gaps, scientific uncertainty and known information were identified in a physical way (e.g. charts).

E-flows were initially developed to provide carefully-managed seasonal (spring) floods in a manner that facilitated anadromous fish spawning (especially shortnose sturgeon). The process of developing e-flows on the Savannah River was termed the 'Savannah Process' and specific recommendations were integrated into management practices immediately where USACE knew there to be no conflicts with flood management and water supply storage (Warner, pers. comm. 2017). The recommended e-flows developed by the working group were used as an initial approximation to be refined over time through an adaptive management process. In this manner, a lack of data did not inhibit initial e-flow determination and implementation.

THE IMPORTANCE OF MONITORING AND ADAPTIVE MANAGEMENT IS DEMONSTRATED IN THIS CASE

The importance of monitoring and adaptive management is demonstrated in this case because tagging studies used to monitor the initial flood pulse releases showed that instead of encouraging upstream migration by shortnose sturgeon, the flood pulses resulted in sturgeon migrating downstream back to the ocean (Simpson, pers. comm. 2017a). The reason for this was unsuitable water temperatures resulting from a cold front and deep reservoir releases of cold water. Further research has demonstrated that sturgeon spawning migrations are temperature-driven, rather than flow-driven. Hence, although spring flood pulses continue to be released, these are directed at improving floodplain values and fish passage at the lock and dam, rather than to stimulate or improve sturgeon migration (Krueger, pers. comm. 2017b). In addition to illustrating the importance of research and adaptive management, this example also emphasises the importance of water quality as well as water quantity when developing and implementing e-flows.

Initial e-flow implementation on the Savannah River focused on spring flood pulses but other issues have since emerged that may be more important, such as the provision of minimum flows to the shoals. The shoals are located approximately 22km downstream of Thurmond Dam, and provide important habitat for numerous species.

The phased approach to e-flow implementation has allowed for further changes to be made to the operating regime to provide improved e-flows to the shoals. Flow fluctuations from peak hydropower releases also cause immersion of fish nests downstream of New Savannah Bluff, particularly robust redhorse, whose spawning period overlaps with peak energy use. This issue has proven intractable thus far. Other issues such as flows to maintain connectivity and oxygen for side-channel habitat have also been examined (Krueger, pers. comm. 2017a).

Initially, e-flows were developed for average, dry and wet years (three climatic types), with a monitoring programme also initiated to assess how physical and biological conditions were affected by implementation of the flow recommendations (Richter *et al.* 2006). The research undertaken, along with the monitoring of a series of test releases between 2004 and 2014, created a substantial new body of information that has informed development of a revised e-flow prescription for the Savannah River (Krueger *et al.* 2015).

In addition to incorporating the learning on a wide range of ecosystem values, services and processes within the Savannah River and the refinement of e-flows for average, dry and wet years, the revised e-flow prescription also covers periods of drought, which the original 2003 prescription did not address. The revised prescription was developed collaboratively with university scientists, agencies and stakeholders over the year 2014. Fifty-one individuals representing 21 organisations participated in its development. The revised prescription includes recommendations for releases of water from the three major reservoirs associated with dams in the upper river during times of drought (Shelley, pers. comm. 2017), and is currently undergoing review under the National Environmental Policy Act (NEPA) (Simpson, pers. comm. 2017b).

Barriers to implementation

E-FLOW TARGETS ARE REFINED THROUGH AN ONGOING PROCESS

There were a number of barriers to implementation of e-flows for the SRP at both the site level and the national level. Scientific uncertainty was one such challenge. In the Savannah River – as at the other SRP sites – uncertainty was managed by defining and implementing initial e-flows based on existing knowledge, so that there would not be a delay in implementation while additional field studies were conducted. The plan was that e-flow targets would be refined later through additional field work, monitoring and adaptive management. This is an ongoing process, with refinements to e-flows evaluated as the results of new studies become available (Simpson, pers. comm. 2017a).

Additionally, at the start of the process of implementing e-flows, different interests around the reservoirs (e.g. flood management, hydropower generation, in-reservoir recreation) were concerned that there would be an adverse impact from e-flow implementation on their particular interest, and many individuals and groups resisted these changes (Warner, pers. comm. 2017, Krueger, pers. comm. 2017a). This barrier was overcome by holding workshops and public hearings. This allowed people to voice their concerns and learn about other perspectives, leading to reduced tensions (Krueger, pers. comm. 2017a). Collaborative workshops also enabled the reservoir operators and engineers to participate in the development of e-flows and share their knowledge on how the river responds to reservoir operations.

Another barrier related to trade-offs between multiple uses is not having an adequate grasp of the economic value of ecosystem health and the products and services that a healthy ecosystem provides (Simpson, pers. comm. 2017a). This makes evaluating trade-offs with values that are more readily converted to a monetary value (e.g. hydropower generation, recreation, industry) challenging.

Finally, institutional relationships can present a challenge at the local level. During the creation of the e-flow prescription for the Savannah River there were two major barriers. The first was getting the states to recognise the importance of the issue to secure the necessary funding. The second was to get the federal and state agencies to work together on the plan. The agencies had to be publicly forced by the stakeholders to join in the comprehensive study to provide the public with a better understanding of the impacts associated with the implementation of e-flows, as well as other proposed changes to reservoir releases. TNC volunteered to work on the plan, which helped push the studies forward (Shelley, pers. comm. 2017). At the local level, understanding of the value of e-flows can differ substantially depending on the location in the country. If there is not an understanding of what e-flows are, or an understanding of the process for developing and implementing e-flows, it takes a lot of patience and time to build trust and support. In the US, environmental goals are often implemented through litigation using established legislation (e.g. Endangered Species Act, Clean Water Act), which can lead to suspicion and wariness about e-flows processes. The SRP sought to promote collaborative problem-solving between agencies and stakeholders to define shared environmental goals, and implement e-flows collaboratively rather than through litigation (Warner, pers. comm. 2017).

The national-level challenges are similar to challenges at the site level, especially in regard to institutional relationships. There is turnover in personnel in different institutions. For instance, the leadership of the USACE at national and district levels is military, usually with two-to-four-year terms, thus new leaders cycle through frequently. The policies and personnel surrounding the implementation of e-flows need to be reintroduced with each staffing change (Warner, pers. comm. 2017).

Enabling factors

THE MAIN DRIVER OF THE SRP WAS TO IMPROVE CONDITIONS DOWNSTREAM OF DAMS

The main driver for the SRP as a whole was to improve environmental conditions downstream of USACE dams, along with the restoration of ecosystem services that rivers provide. Two key enabling factors for the national development of the SRP and development of e-flows were a willingness by USACE to re-evaluate the manner in which their dams were being operated, and persistent engagement and encouragement by TNC to keep the process moving forward. There has been an attempt to get Congress to pass legislation to increase the authority and provide funding for the SRP but thus far it has been unsuccessful. The partnership between TNC and the USACE has built trust over time and allowed the process to succeed in spite of funding challenges (Warner, pers. comm. 2017).

In the Savannah River, there was pressure from other groups besides TNC and USACE to move the process along (e.g. lake-front groups, state regulators) (Krueger, pers. comm. 2017a). Congressmen were pressured by constituents and became interested in the issues surrounding flows in the river. Political pressure helped secure funding for revising the e-flow prescription (Shelley, pers. comm. 2017). TNC funding to study the flow requirements of various species within the Savannah River was also an important enabling factor (Simpson, pers. comm. 2017a).

Another key enabling factor was the phased approach to implementation. There is often an unwillingness to implement change in the face of uncertainty; however, the development of the Savannah Process meant that knowledge gaps did not impede initial e-flow implementation. Once underway and some progress is demonstrated, additional interest is generated and further steps to improve the process are more readily taken (Warner, pers. comm. 2017).

Triggers for action

PERSISTENT WATER QUALITY PROBLEMS WERE THE TRIGGER FOR E-FLOWS

The institutional trigger for developing e-flows through the SRP was the signing of a memorandum of understanding between the USACE and TNC at their highest levels to seek improved environmental management at Corps dams, and was inspired by early collaborative success in changing the operations of USACE's Green River Dam in Kentucky. The Savannah River was one of eight original places identified where the USACE could start the process. The timing of this national agreement coincided with the Savannah District of the USACE recognising that they needed to update comprehensive studies of the river to meet new demands going forward (Krueger, pers. comm. 2017a).

The dissolved oxygen issue in the harbour at the downstream end of the Savannah River provided a regulatory trigger to the implementation of e-flows in the river. Persistent low dissolved oxygen levels in the harbour meant that water quality standards set by the EPA were not being met and this resulted in state agencies and the EPA pushing for e-flows in the river to increase dissolved oxygen concentrations in the harbour (Krueger, pers. comm. 2017a,b).

Another trigger for continued attention to e-flows in the Savannah River was a series of droughts (Shelley, pers. comm. 2017). There was a severe drought from 1998 to 2002, followed by additional drought years in 2007, 2008 and 2012. The drought periods brought to light the reality that the water in the river is a finite resource, whereas it was believed that there were no issues with water quantity in the south-eastern US (Shelley, pers. comm. 2017). This issue generated a lot of interest in the river and motivated stakeholders to learn about how flows could be improved. In 2011, TNC, the Departments of Natural Resources in Georgia and South Carolina, and USACE signed a project agreement to develop drought flows for the Savannah River. A comprehensive study was conducted focused on updating the existing operating manual for drought. The new protocol will result in quicker recovery from drought that will benefit a number of ecological resources (e.g. mussel populations in side channel habitats, fall-spawning Atlantic sturgeon, estuary population of striped bass, increased minimum flows in the shoals) (Krueger, pers. comm. 2017a).

Monitoring and assessing success

VERIFICATION OF THE RELATIONSHIP BETWEEN FLOWS AND HABITAT CONDITIONS WAS A BIG SUCCESS

Monitoring programmes are in place in the Savannah River; however, not all results from monitoring are conclusively linked to e-flows. There is monitoring of the imperilled species (i.e. shortnose and Atlantic sturgeon, robust redhorse, and a variety of mussels) in the Savannah River, so flow effects on these are more closely examined. However, due to funding limitations, some of the field team has been reduced so there is difficulty in directly monitoring some lower profile impacts. Indirect monitoring can take place because specific relationships have been developed between habitat and flow. Monitoring of the annual hydrograph can indirectly show how often and how well targets have been achieved using these relationships. This process gives an indirect but excellent framework for monitoring on a regular basis (Krueger, pers. comm. 2017a). There are USGS buoys in the lakes and river to monitor certain water quality parameters, and flows and water levels in real time, but this is limited in scope.

There are e-flow implementation successes within the SRP at both the site and national level. At the site scale, there was success in organising individuals and institutions to define and implement e-flows within an adaptive management context through monitoring and adjustments to the e-flow regime. Success has been seen in improvements to the ecosystem in sites where e-flows have been instituted without compromising social goals (e.g. water supply, recreation, flood management) (Warner, pers. comm. 2017). For the Savannah River, a big success was the verification of the relationships between flows and different habitat conditions. At the beginning of the process there was a lot of uncertainty in what the relationships were. E-flows were developed to a level of refinement that makes them actionable (Krueger, pers. comm. 2017a). The revised e-flow prescription was built on data from the last 20 years when there have been considerable periods of drought. This allows for better capture of what extreme low flows look like and thus will result in improved management. The revised e-flow prescription was also successful for bringing together the state and federal agencies to formulate a cohesive and actionable plan. Through the joint drought study, South Carolina and Georgia decided to form a water caucus. This will allow the states to settle water issues without litigation. South Carolina is also hoping to improve water planning for rivers and groundwater as part of this process. Funding will still need to be secured from federal sources and Georgia for the plan (Shelley, pers. comm. 2017).

At the institutional level, success has been seen through continued advances in work at individual sites and seeing the SRP as a whole grow. Additional sites have been added to the original eight sites, bringing the current total to 14 sites involving 60 dams. The USACE has embraced the SRP and has now made the project into an official programme within the agency. There has also been success in joint training provided by TNC. Over the last 14 years, 700 to 800 USACE staff have been trained in e-flow development and implementation. The process of implementing e-flows through adaptive reservoir operations has also been promoted internationally by the USACE through its involvement in international venues (e.g. World Water Forum) and in some of the 36 countries where the agency works around the world (Warner, pers. comm. 2017). Tools and models for supporting water management are also available free of charge through USACE's Hydrologic Engineering Center (HEC; www.hec.usace.army.mil/software), including a number directly applicable to e-flow efforts such as the Regime Prescription Tool (HEC-RPT), Reservoir System Simulation (HEC-ResSim), and Ecosystem Functions Model (HEC-EFM).

LESSONS

1. Collaboration between federal, state and local governments, NGOs, scientists, academics and local stakeholders is critical to the process of developing and implementing e-flows in a wide variety of rivers.

2. Define e-flows in quantitative and specific terms (magnitude, seasonality, frequency and duration of events). Specificity allows for a more rigorous and open assessment of e-flow implications among stakeholders and facilitates implementation. When an e-flow prescription is constructed of different components (e.g. extreme low flows, low flows, high-flow pulses, floods), the implementing entities may be able to move some components into implementation immediately, even though the entirety of the prescription cannot be implemented right away.

3. When starting the process of developing e-flows, it is beneficial to capture knowledge gaps, scientific uncertainty and known information in a tangible way (e.g. charts, reports). Separate the known information from the knowledge gaps so they can be clearly identified. A lack of complete data and information should not inhibit e-flow implementation. Some e-flow components can be implemented based on existing knowledge and then refined through additional studies, monitoring and adaptive management.

4. It is critical to have reservoir operators and engineers involved in the process of developing e-flows. This provides a foundation for engineers to understand that they have an important role in implementing e-flows, and they can work collaboratively with scientists to fill in knowledge gaps and help scientists to better understand implementation feasibility.

5. It is important to have transparency in the construction and resolution of tools for developing e-flows. Interactions with the public are good to show what can and cannot be done to solve problems.

3.3 MURRAY-DARLING BASIN, AUSTRALIA

THE RIVER

The Murray-Darling Basin is a large region (>1 million sq km) of south-eastern Australia spanning four states (Queensland, New South Wales, Victoria and South Australia) and the Australian Capital Territory with thousands of interconnected creeks and rivers, more than 30,000 wetlands, and an extensive network of groundwater aquifers beneath the land surface.

THE ISSUE

The Murray-Darling Basin is home to more than two million residents and supports a further one million outside the Basin, including Aboriginal people and migrants from all over the world whose livelihoods and culture are tied to water in the Basin. The challenge for governments and residents of the Basin is to share the water so that the interests of residents and agriculture are maintained, while at the same time respecting traditional cultures and protecting and restoring the natural environment. Over-allocation of water for consumptive uses in the Basin, combined with the effects of drought, brought issues to a head in the early- to mid-2000s, with severe impacts on agriculture, municipal water supply and the environment.

THE RESPONSE

The Commonwealth Government of Australia, under the leadership of John Howard, enacted the Water Act 2007 that led to water reform. The Water Act 2007 established the Commonwealth Environmental Water Office and required the development of a Murray-Darling Basin Plan, which was enacted in November 2012. The Basin Plan provides a framework for governments, regional authorities and communities to sustainably manage and use the water of the Basin, and sets Sustainable Diversion Limits for water extraction. The Water Act 2007 also established the Murray-Darling Basin Authority (MDBA), a Basin-wide institution responsible for preparing and implementing an integrated plan for the sustainable use of the Basin's water resources, efficiently delivering water to users on behalf of partner governments, and monitoring the quality and quantity of the Basin's water resources. The responsibilities of the MDBA replace and augment those of the former Murray-Darling Basin Commission.

INTERVIEWEES

Hilton Taylor – Acting First Assistant Secretary, Commonwealth Environmental Water Office; responsible for the southern half of the Murray-Darling Basin.

John Foster – Director, Environmental Water Policy, Commonwealth Environmental Water Office; leads a team responsible for operational policy for the Commonwealth Environmental Water Holder.

Andrew Beal – Director of River Murray Operations, Department of Environment, Water and Natural Resources in South Australia.

Ian Atkinson – Former CEO of the Nature Foundation South Australia.

Tom Rooney – Founder and President of Waterfind Australia and Founder of Healthy Rivers Australia.

In addition to the above interviewees, we reviewed a presentation by David Papps, the Commonwealth Environmental Water Holder, on water management within the Murray-Darling Basin.

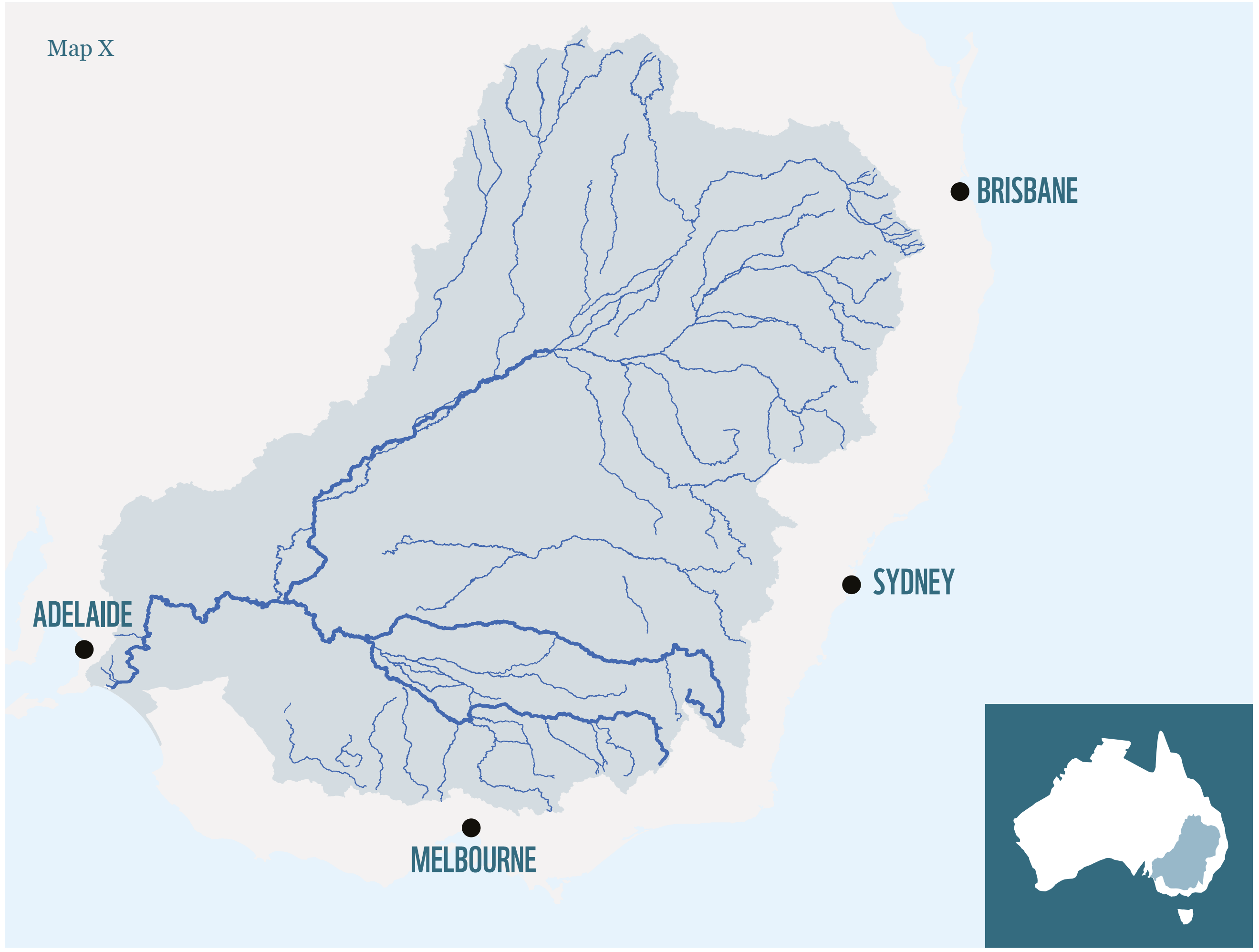
KEY FINDINGS

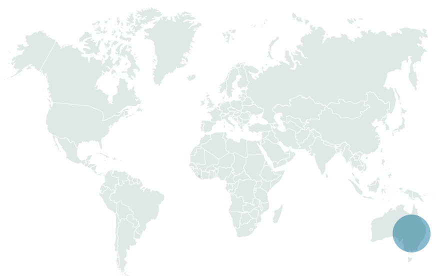
Reforms that separated land and water rights were a critical legislative change that enabled action in this case. This reform began at a state level in the 1980s and was formalised nationally through the National Water Initiative in 2004.

It is important to place a cap on water allocations; preferably before over-allocation becomes an issue.

Reforms that separated land and water rights were a critical legislative change that enabled action in this case. This reform began at a state level in the 1980s and was formalised nationally through the National Water Initiative in 2004.

It is important to place a cap on water allocations; preferably before over-allocation becomes an issue.





3.3.1 Background

The Murray-Darling Basin is a large region (>1 million sq km) of south-eastern Australia spanning four states (Queensland, New South Wales, Victoria and South Australia) and the Australian Capital Territory, with thousands of interconnected creeks and rivers running through it (MDBA 2017a). There are more than 30,000 wetlands in the Basin, many of which are of international importance for migratory water birds (i.e. Ramsar[3]-listed). There is also an extensive network of groundwater aquifers within the Basin. Most of the waterways of the Basin connect in some way to the River Murray. Flow into the River Murray from tributaries, and out to the Southern Ocean, is extremely variable.

The Murray-Darling Basin is home to more than two million residents and supports a further one million outside the Basin, including Aboriginal people and migrants from all over the world (MDBA 2017a). The Basin is a working basin with nearly 90% of the water used for non-environmental uses (Garrick, pers. comm. 2017). The livelihoods of people living within it are supported by various industries tied to water including agriculture, food processing, manufacturing and tourism. The water of the Basin sustains rivers, floodplain forests and wetlands, and an estuary; it is an essential resource for households and communities; and it is culturally significant to Aboriginal people. The challenge for residents and governments in the Murray-Darling Basin is to share the water so that the interests of residents and industry are maintained, while at the same time respecting traditional cultures, and protecting and restoring the natural environment (MDBA 2017a).

[3] The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

3.3.2 Implementation of e-flows in the Murray-Darling Basin

The Millennium Drought occurred in Australia between 2001 and 2009[4]. The drought brought issues surrounding water management and over-allocation in the Murray-Darling Basin to the forefront of political and community attention. In response, the Commonwealth Government enacted the Water Act 2007, which established the Commonwealth Environmental Water Holder (CEWH) to protect or restore the environmental assets (rivers, wetlands and floodplains) of the Murray-Darling Basin (Papps 2017). The CEWH works closely with the Basin states while engaging the community to provide environmental outcomes. The establishment of the MDBA and development of the Murray-Darling Basin Plan were other components of the Water Act 2007. The Basin Plan was legislatively adopted in 2012. Although it will not be fully implemented until 2019, the Basin Plan provides a framework for governments, regional authorities and communities to sustainably manage and use the water of the Basin.

Outcomes of the Basin Plan cover three broad objectives: (1) protection and restoration of water-dependent ecosystems; (2) protection and restoration of ecosystem services; and (3) improvement of resilience of water-dependent ecosystems to risk, including climate change. Under these broad objectives there are specific targets that apply to particular portions of the Basin. The Basin Plan sets Sustainable Diversion Limits (SDLs), which are the maximum amounts of water that can be taken for consumptive use so that there is sufficient water for the environment. The Plan also includes a mechanism by which SDLs can be adjusted if environmental outcomes can be achieved using less water.

The Basin-wide environmental watering[5] strategy builds on the environmental objectives in the Basin Plan. The strategy outlines the MDBA's best assessment of how four important components (river flows and connectivity, native vegetation, water birds and native fish) are expected to respond over the next decade given the management of available water (MDBA 2014). The strategy outlines approaches for the planning and management of environmental water at the Basin scale and over the long term to meet environmental objectives.

[4] Published drought assessments used different criteria to determine the start and end of the drought and hence report different periods; here we use the duration documented by van Dijk et al (2013) although some water managers consider the drought as early as 1997 (Garrick, pers. comm. 2017).

[5] E-flows are commonly referred to as environmental water within the Murray-Darling Basin; hence we have adopted this terminology for this case study.

To meet these objectives, the Basin Plan called for the dedication of at least 2,750 GL/yr of water entitlements[6] to the environment (a later agreement set a more ambitious 3,200 GL/yr target). The CEWH and state governments have therefore been purchasing water entitlements through direct buybacks from willing sellers as well as seeking to improve water availability by investing in improved irrigation infrastructure. Water for achieving the outcomes of the Basin Plan therefore comes from three sources: (1) natural floods, (2) planned environmental water, and (3) held environmental water (Papps 2017). Planned environmental water represents water that Basin governments are securing to achieve environmental outcomes at a regional scale through long-term watering plans that complement the Basin-wide environmental watering strategy (MDBA 2014). Held environmental water consists of the Commonwealth environmental water portfolio acquired from across the Basin.

THE BASIN PLAN CALLED FOR AT LEAST 2,750 GL/YR OF WATER ENTITLEMENTS FOR THE ENVIRONMENT

Water plans are made each year with mandated outcomes as per the Basin Plan and Basin-wide environmental strategy. Once yearly plans are made, water is delivered into rivers, floodplains and wetlands using an adaptive management strategy. In any given year, water is allocated to users based on permanent entitlements (rights) issued by state governments; water allocations vary each year in response to changes in variables such as amount of rainfall and reservoir storage (MDBA 2015). The first of July marks the start of each water year, when each Basin state makes water allocation announcements based on seasonal availability. Where river systems are regulated by dams and reservoirs, allocations are reviewed and adjusted throughout the year based on availability. For instance, allocations can be increased if the available water has not been fully allotted, or if there is an improvement in storage levels. In unregulated river systems, seasonal flows are the foundation for allocation such that once predetermined flow conditions are met, water can be extracted. Extraction is limited by a maximum daily extraction amount and the time of year of the extractions (MDBA 2015). This method of allocation allows users assurance of the water they will receive and allows the states to manage for climatic variability. A long-term environmental monitoring programme undertaken by scientists and evaluated by the MDBA, CEWH and state agencies is used to make adjustments to water delivery.

In addition to the work done by the Commonwealth and state governments to purchase and distribute environmental water, various NGOs have also been involved. For example, Healthy Rivers Australia developed a trading mechanism (Box 3) by which farmers could rent water to the environment for a season as a donation and hence receive a tax break (Rooney, pers. comm. 2017). Nature Foundation South Australia (NFSA) is another NGO that was granted access to up to 10 GL/year for five years by the CEWO to conduct environmental watering projects in South Australia (Atkinson, pers. comm. 2017a). NFSA focused on returning environmental water to floodplain habitats where the natural flood cycle had been altered by the construction of dams and weirs.

The Nature Conservancy (TNC), in collaboration with a local NGO (Murray Darling Wetlands Working Group) and an asset management firm (Kilter Rural), has adopted a different model whereby instead of obtaining water from the CEWH for environmental watering purposes, they have established a Water Sharing Investment Partnership (WSIP) that attracts investors to invest in water as a valuable asset (Richter 2016). The WSIP is comprised of two entities: an Environmental Water Trust (the Trust) and the Murray-Darling Basin Balanced Water Fund (the Fund). The Fund acquires a portfolio of permanent water entitlements from farmers, the majority of which are then sold or leased back into the agricultural community with the remainder donated to the Trust. The Trust carries out an annual environmental water programme, which applies water to areas of high ecological and Aboriginal cultural significance.

[6] Similar to water rights, but volumes change annually, depending on water availability.

Barriers to implementation

There are various barriers to e-flow implementation across the large, multi-jurisdictional Murray-Darling Basin. One of the critical initial barriers to water reform in the Basin was that land and water entitlements were bound together, i.e. each water entitlement could only be used for a specific area of land. The separation of land and water rights allowed landowners to sell the rights to their water without selling their land. This reform began at a state level in the 1980s and was formalised nationally through the National Water Initiative in 2004. This paved the way for the CEWH to be established by the Water Act 2007 and for the Commonwealth government to acquire water for environmental benefits (Taylor and Foster, pers. comm. 2017). The reform also allowed water markets to develop.

Despite this key reform there are still several political, cultural and operational barriers to e-flow implementation in the Basin. The complexity of the regulatory framework is one such barrier as the Commonwealth and state policies and regulations that govern water management are sometimes in conflict. Moreover, each water entitlement has its own rules with respect to how it can be traded, the regions it can be traded to, and how an associated water allocation can be carried over into the following year. The CEWH manages a water portfolio worth AU$3 billion with 75 different entitlement types over 10 water resource planning areas in the four state jurisdictions. The management of this water portfolio is therefore very complex and is made more challenging by the cultural and social aspects of water use and distribution at the regional and state levels.

BOX 3: WATER TRADING AS A TOOL TO ENABLE E-FLOW IMPLEMENTATION

Water trading is an important tool for many irrigators in the Basin, allowing them the flexibility to respond to variation in water availability (MDBA 2017b). The development of the Murray-Darling Basin's water market is not only driven by variable inflows in the Basin but also by variable demand for water from agriculture (MDBA 2015). Water markets in the basin are based upon a 'cap and trade' system, where the cap determines the total pool of water available for consumptive use. The available water is distributed to users by Basin states through water entitlements and allocations. Two types of water-use rights can be traded in the Basin: (1) water access entitlements, which are permanent rights to a continuing share of the available water in a system; and (2) water allocations, which are the actual amount of water available in a season issued to each water access entitlement (MDBA 2017b).

A user can choose to buy or sell water at almost any time (within the limitations of the specific type of right). The price of water is a reflection of supply and demand; thus price differs across time, space and type of water rights. A permanent water trade is the trade of water entitlements and is known as entitlement trade, while temporary trade is the trade of water allocations and is known as an allocation trade. Interstate water trading is also allowed though a collective agreement between state governments and the MDBA. Interstate trading has allowed irrigators to buy water from a broader range of users and allowed for different water management options to be developed throughout the Basin (MDBA 2015). There are a number of rules regulating water trading in the Basin including: (1) Basin Plan water trading rules, (2) the Australian Competition and Consumer Commission (ACCC) water market and charge rules, (3) Basin State trade rules, and (4) Irrigation infrastructure operator (IIO) rules. The rules are operated jointly to guarantee the continued operation and development of the water market (MDBA 2017b). The MDBA is responsible for enforcing the Basin Plan water trading rules (MDBA 2015).

THIS CASE HIGHLIGHTS THE IMPORTANCE OF INVOLVING LOCAL COMMUNITIES IN DECISION-MAKING

Environmental water is not forcibly acquired by the CEWH. There are examples of how the separation of costs, benefits and rewards in the Basin's water management system can exacerbate social and cultural differences between upstream and downstream states, and between regions within states. For instance, the benefit to the environment established through e-flows may be located thousands of miles away from the location where the water is purchased. This has in some instances led to environmental water being maligned because of water being moved from one region to another. However, this movement of water between regions is not restricted to environmental water, with the water market resulting in the movement of water between regions for consumptive uses as well. Such social issues highlight the importance of involving local communities in decision-making around environmental watering programmes.

There are also operational and infrastructure barriers to implementation. There are many dams and weirs on the River Murray but these were developed for a certain purpose (e.g. navigation and irrigation), and a shift in water use (e.g. for environmental purposes) may require changes to operational rules, structural upgrades, or new structures to be built. Providing e-flows has also required a cultural shift, as the River Murray was for a long time managed by dampening floods and maintaining water levels behind weirs (in the lower Murray within a narrow band of ±30 cm) (Atkinson, pers. comm. 2017a). This resulted in ecological changes on the floodplain as wetlands that were periodically flooded became either permanently wetted or permanently dry. In South Australia sections of the River Murray, the river flows through an incised canyon and the distribution of environmental water to the many stranded wetlands on the floodplain requires water to be pumped. This acted as a barrier to NFSA's environmental watering programme as the cost of the pumps and funds to run the pumps is significant. The NFSA applied for philanthropic grants to purchase pumps and asked the Commonwealth to contribute to purchasing fuel for the pumps, while relying on volunteers to run the pumps.

Enabling factors

The issues surrounding water management in the Murray-Darling Basin have been debated between the different states for 100 years or more, and there have been several periods of reform often triggered by drought (Atkinson, pers. comm. 2017a). The most recent reforms were enabled by the National Water Initiative in 2004, which separated land and water rights, and the Water Act 2007. These changes were critical in allowing the trade of water rights and enabling water to be transferred more freely across regions and water resource planning areas to provide environmental benefits. This legislation has provided a mechanism for managing water for the environment across the Basin and has also resulted in economic benefits (Taylor and Foster, pers. comm. 2017).

Following on from the separation of land and water rights, the development of a trading mechanism and market for water rights has been a key enabling factor for the purchase and reallocation of water rights. At present, approximately 1,950 GL of water per year is held by the CEWH in the Basin for environmental watering purposes, which represents approximately 25% of the total diversion limit in the Basin (10,000 to 12,000 GL/year). The presence of a market enables the price of water to rise or fall according to its availability and value to farmers and other water users (including environmental interests), and this monetised value promotes efficiency in its use. The market also allows users flexibility in their decision-making with respect to what crops to grow, whether or not to grow crops in a particular year, and whether to sell a portion or all of their water allocation for a given year. It is hoped that over the long term the value placed on water through a market mechanism, and the flexibility it affords, will result in more sustainable decisions regarding land and water use.

Another key enabling factor for e-flow implementation in the Basin is the people's appreciation for and reliance on the river. In addition to providing the means for agricultural production, the river is also very important for public water supply, recreation, tourism, and cultural reasons. This meant there was community support and political will for action when water management issues came to a head during the Millennium Drought. The political will and community support for action has waxed and waned since the drought broke, which highlights how important natural climate variability can be in driving change.

The involvement of several NGOs (NFSA, Healthy Rivers Australia, Murray Wetlands Working Group, The Nature Conservancy) in developing environmental watering programmes was also an important enabling factor that acted as a catalyst for more government involvement (Atkinson, pers. comm. 2017a, Rooney pers. comm. 2017). The willingness of landowners to participate in environmental watering programmes on their properties was critical to their success.

Triggers for action

DROUGHT WAS THE MAJOR TRIGGER FOR WATER REFORM

There was consensus among those interviewed for this case study that the trigger for recent water reform in the Murray-Darling Basin was the Millennium Drought. However, this was just the latest in a series of droughts that have catalysed reform over the last century, with previous reforms triggered by droughts occurring at the start of the 20th century and towards the end of World War II (Atkinson, pers. comm. 2017a). By the mid-1980s there was also an acceptance that water in the Basin had been over-allocated, and there has been a rapid progression in understanding of the issue since that time (Beal, pers. comm. 2017). Salinity and the effects that it had on agricultural productivity in the lower part of the Basin has also been a factor in water management reform in the Basin, along with the 1,000km-long blue-green algae blooms on the Darling River in 1991, in part caused by depleted river flows (Atkinson, pers. comm. 2017a, Taylor and Foster, pers. comm. 2017).

The Millennium Drought stimulated action; although there were reforms underway before the drought, the issues became more urgent when the River Murray essentially stopped flowing. The drought resulted in significant impacts to agriculture in the Basin due to low flows that were affecting the economy and imperilling the long-term viability of many farms. Additionally, water in the Basin was over-allocated for consumptive use and over-regulated with weirs, dams and regulating structures, which became a very apparent problem during the height of the drought. The Prime Minister declared that water reform was necessary, and legislation began with the National Water Initiative in 2004 and the Water Act in 2007 (Taylor and Foster, pers. comm. 2017).

In South Australia, at the downstream end of the Basin, the Millennium Drought resulted in severe restrictions for all consumptive and environmental uses, high salinities (particularly in Lake Albert) and the risk of acidification in the entire 900 sq km Lower Lakes. This in turn posed serious risks to the water supplies of Adelaide and other metropolitan areas. This resulted in the (then) South Australian Ministers for Water Security (Karleen Maywald) and the Environment (Jay Weatherill, now the Premier of South Australia) bringing the issue to the attention of the Commonwealth government in Canberra and pushing for water reform. The Millennium Drought was therefore a key trigger[7] for recent reform but the reforms are an ongoing, dynamic process with constant evolution of water management and periods of peak intensity driven by climatic conditions, political will and community support (Taylor and Foster, pers. comm. 2017).

[7] Garrick (pers. comm. 2017) indicated that other triggers for action in the Murray-Darling Basin were a push for irrigation modernization, electoral politics and the availability of financing (i.e. a budget surplus).

Monitoring and assessing success

ECOLOGICAL RESTORATION EXPECTATIONS MUST BE REALISTIC

There has been an AU$30 million investment by the CEWH for long-term monitoring over a five-year period to measure the impacts of environmental water in the Murray-Darling Basin. However, the problems with flows in the Basin have accrued over decades and it is expected that it will take time to see Basin-scale improvements (Taylor and Foster, pers. comm. 2017, MDBA 2014). Initial success will be arresting the rate of decline of the environment. This is a hard message to sell both politically and to communities if conditions are still worsening, even if it is at a slower rate (Taylor and Foster, pers. comm. 2017). Two indicators of success in the Basin are (1) improvements in fish populations that are without a doubt attributable to intentional environmental water manipulation; and (2) major bird breeding events are being triggered by natural flows and sustained by environmental water. Without stored e-flows that were released as the flood water receded, breeding success would have been poor. There have also been substantial improvements in the water quality of the northern Coorong estuary (Beal, pers. comm. 2017).

These results do not yet equate to an overall improvement in Basin-scale ecosystem health, but they are indicators that environmental water can contribute to some improvements in Basin health. Documenting overall benefits to Basin health is challenging, due to the inherent natural variability induced by droughts and floods, so teasing out the positive effects attributable to e-flows is difficult. However, this challenge is common across jurisdictions and naturally variable systems. Success will be the ability to apply a range of environmental actions that will lead to a healthy working Basin over a long period of time and tracking improving trends in ecological, social and economic indicators over time.

There is no intention to return the Basin to a pristine condition, however, so ecological restoration expectations must be realistic and managed in the context of a working Basin (Taylor and Foster, pers. comm. 2017).

Based on the interviews conducted for this case study, the success of the environmental watering programme is not being monitored directly in economic and social terms. There is a general acceptance that water security has improved (Beal, pers. comm. 2017); however, some scepticism persists in some members of the irrigation community and the communities around the Lower Lakes in South Australia that were particularly hard hit during the Millennium Drought (Beal, pers. comm. 2017), and some groups in the northern parts of the system who perhaps didn't see a need for reform (Atkinson, pers. comm. 2017b).

In South Australia, NFSA has been successful in obtaining limited funding grants to monitor the ecological outcomes of their environmental watering programme. Ecological success has been seen through improvements in the condition of the woodlands and wetlands where the NFSA has been delivering water. The success of the programme from a social perspective is not measured directly, but there is continued support for the programme throughout the local community and the organisation continues to attract the funds necessary to pump water (Atkinson, pers. comm. 2017a). Nevertheless, the energy costs of moving water are a large concern for the long-term viability of the programme.

LESSONS

1. Reform to separate land and water rights was a critical legislative change that enabled water markets – i.e. the ability to buy and sell water, including purchasing water entitlements for environmental purposes. This reform also allowed development of a mechanism by which farmers could rent water to the environment for a season as a donation and hence receive a tax break. This reform began at a state level in the 1980s and was formalised nationally through the National Water Initiative in 2004.
2. It is important to place a cap on the total volume of water entitlements issued; preferably before over-allocation becomes an issue. Water markets will not function without a cap on water allocations.
3. It is important to set clear goals and objectives for an e-flow programme, as this will dictate the most appropriate management tools.
4. Environmental water management incorporates a mix of science and local knowledge to get the best results. Local knowledge can bring a lot to the table, so it is important to involve indigenous people and the local community and draw on their experience.
5. The local community must be involved in the process and needs to understand and accept the physical, policy, and cultural constraints to managing water for the environment. The local communities along the river may or may not support changes, based on their needs at the time. Nevertheless, the community needs to be brought along on the journey as community support for the programme is necessary for success.
6. It is important to monitor the results of e-flow implementation and be prepared for unexpected results and the need to adapt. This is the foundation of adaptive management.
7. Crisis can be an opportunity. Drought was a driver of reform in the Murray-Darling Basin but it is important to be prepared prior to the impetus. It is important to have the tools, mechanism and legislation at the ready before they are needed.
8. A working river still needs to be a healthy river otherwise it will not function and provide the ecosystem goods and services upon which people rely.

3.4 THREE GORGES DAM, YANGTZE RIVER, CHINA

THE RIVER

The Yangtze River is the longest river in Asia and the third longest river in the world, with a length of 6,300km. The Yangtze River basin supports 36% of all freshwater fish species in China, including as many as 177 endemic fish species. It has substantial potential for the generation of hydropower. The Three Gorges Dam (TGD) is located in the upper reaches of the Yangtze River and has the world's largest installed capacity (22,500MW). It is the last dam on the mainstem of the Yangtze River that has regulation storage.

THE ISSUE

More than 30 large dams have been constructed on the upper reaches of the Yangtze River and its tributaries. The operation of these dams and the TGD affect the natural flow and thermal regime downstream of TGD. The flow and temperature requirements for four species of Chinese carp have been impacted, affecting the reproduction of the carp. As a result, annual harvest of these commercial fish below the dam from 2003 to 2005 was 50 to 70% below the pre-dam baseline in 2002, and even more dramatic declines were observed on larvae and egg numbers downstream.

THE RESPONSE

The resource agencies and the hydropower operator collaborated to implement e-flows at the TGD to mimic the Yangtze River's natural flood pulse and promote carp spawning. In particular, the Ministry of Agriculture (MOA) and Ministry of Water Resources (MWR) were key in promoting and approving e-flow operations. WWF-China also played a critical implementation role through the coordination of stakeholders, and by identifying the MOA as a key ally in the promotion of e-flows given the agency's concern with fisheries resources.

INTERVIEWEES

Jin Chen – Vice President of the Changjiang River Scientific Research Institute of Changjiang Water Resources Commission. Jin and his team provided advice on the e-flows and evaluated the effectiveness of the operational improvement.

Office of Fisheries Law Enforcement for the Yangtze River Basin, Ministry of Agriculture (written reply) – The Yangtze Office is in charge of aquatic resources conservation in the Yangtze River basin and promoted e-flows for Chinese carp production downstream of TGD.

Hai Wang – Deputy Director of the Operations Department of Construction and Operation Management Bureau, China Three Gorges Corporation (CTGC). Hai participated in the decision-making and implementation of e-flows at TGD.

In addition to the above interviewees, we would like to acknowledge Lin Cheng of WWF-China for assistance in arranging and conducting the interviews.

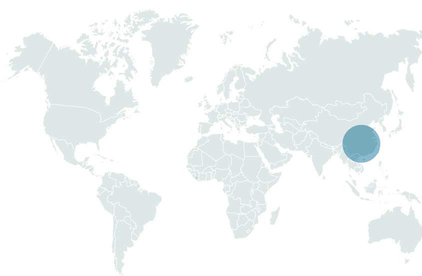
KEY FINDINGS

Political will is critical in successful implementation of e-flows. Government attention and public concern have played the most important role in advancing and implementing e-flows in China.

Collaborative engagement and structured management of the implementing entities is extremely important in e-flows implementation at TGD.

Institutional resources and capacity are necessary for e-flows implementation. Regulatory, technical, and conservation institutions played their roles in e-flows implementation based on their resources and capacities.

Scientific and socio-economic studies directed at understanding the impacts of dam operations and the potential benefits of e-flow releases are necessary to guide effective e-flow implementation.



3.4.1 Background

The Yangtze River (or Changjiang in Chinese, literally, the 'long river') is the longest river in Asia and the third longest river in the world, with a length of 6,300 km. Its basin, extending for some 3,200km from west to east and for more than 1,000km from north to south, drains an area of 1.8 million sq km. From its source on the Tibetan Plateau to its mouth at the East China Sea, the river traverses or borders 11 provinces, autonomous regions and municipalities. The annual runoff of the Yangtze River is 961.6km^3, making the Yangtze the sixth largest river in the world by volume.

More than three-quarters of the river's course runs through mountains and thus the Yangtze River is rich in hydroelectric generating potential. The Three Gorges Dam (TGD), one of the largest dams in the world, is located in the upper reaches of the Yangtze River. It has a length of 2,309m and a height of 185m, and is the world's largest power station in terms of installed capacity (22,500MW). Its reservoir has a total storage capacity of 45 billion m^3, approximately 10% of the annual runoff at the dam site. The construction of the TGD began in 1994, and the reservoir began to be impounded in 2003.

The Yangtze River basin contains 36% of all freshwater fish species in China, including as many as 177 endemic fish species (Yue and Chen 1998; Xie 2003). The operation of multiple dams, including the TGD, in the upper reaches of the Yangtze River has affected the natural flow and thermal regime downstream: impacts on fisheries is one of the critical consequences of TGD. The flow and temperature requirements for four species of Chinese carp (silver carp, *Mylopharyngodon piceus*; bighead carp, *Ctenopharyngodon idellus*; grass carp, *Hypophthalmichthys molitrix*; and black carp, *Aristichthys mobilis*) have been impacted, affecting the reproduction of the carp. As a result, the annual harvest of these commercial fish below the dam from 2003 to 2005 was 50 to 70% below the pre-dam baseline in 2002, and even more dramatic declines were observed in larvae and eggs below the dam (Xie *et al.* 2007). To address this critical issue, the operator of TGD has collaborated with governmental agencies, research institutions and conservation organisations since 2006 to study the natural flow and temperature requirements for carp spawning and explore the ways in which operations could be modified to improve spawning conditions (Chen and Li 2015).

In addition to exploring operational improvements for carp, the TGD operator examined ways in which more water could be released from the reservoir to meet the downstream water demands for economic production (e.g. industry and agriculture), human needs (e.g. drinking water), navigation and the environment (e.g. water quality) during the dry season.

THE YANGTZE BASIN CONTAINS AN ESTIMATED 177 ENDEMIC FISH SPECIES

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3.4.2 Implementation of E-flows from Three Gorges Dam

Dam operation was first modified in 2011 to mimic the Yangtze's natural flood pulse and promote carp spawning. As of May 2017, the e-flow operation has been implemented for seven consecutive years. Similarly, releases from the TGD reservoir to improve downstream conditions for human livelihoods in the dry season were implemented in 2011. The e-flows operation of TGD usually occurs in the early flood (late May to early June for flood pulse) or drought season (January to April for extra water release). The high pulse flows during the carp spawning season last for 3 to 10 days with the release of between 600 and 3,000m^3/s per day. In the dry season from January to April the reservoir releases 6,000m^3/s, which is 1,500m^3/s (25%) higher than the inflow discharge.

Barriers to implementation

E-FLOWS MUST NOT LIMIT THE ABILITY TO MANAGE FLOODS

The coordination of relevant stakeholders was the primary barrier to implementing e-flows at TGD. TGD is a multi-purpose project that has major functions of flood management, electricity production, navigation and drought alleviation. The implementation of e-flows needs to be integrated into the operational requirements to accommodate multiple uses, and this requires the engagement of all stakeholders. Flow alteration to provide e-flows must not limit the dam's ability to manage floods and should not adversely affect navigation and bank stability. Coordination with the electricity grid is also important because electricity production may decrease or become unstable when the dam releases more water for environmental purposes. The collaboration of the parties involved – including the hydropower operator, water resources commission, environmental agency, agriculture department and power grid – allowed this barrier to be overcome through consultation and conducting the necessary studies. For example, the relationship between e-flows operation for Chinese carp and operational requirements for flood management was carefully studied to assess the feasibility of e-flows implementation. WWF-China played a critical implementation role through the coordination of stakeholders, and by identifying the MOA as a key ally in the promotion of e-flows given the agency's concern with fisheries resources. WWF-China leveraged their partnership developed over the previous decade with the MOA's Office of Fisheries Law Enforcement for the Yangtze River Basin to aid with e-flow implementation, while also helping build capacity in other resource agencies (e.g. the MWR).

The connection between TGD operations and ecological impacts was another barrier to implementing e-flows. Appropriate e-flow implementation for Chinese carp required the identification of suitable eco-hydrological indicators, and the thresholds that allow successful natural spawning of Chinese carp. Based on the assessment of TGD's impacts on these indicators, the improved operational scheme had to be developed to restore natural eco-hydrological processes during the carp spawning period. To overcome this barrier, the CTGC funded the necessary studies (field survey, analysis of hydrologic and fish biology data, numerical modelling) to identify hydrologic indicators and thresholds, assess impacts on natural spawning of Chinese carp, and make recommendations for operational changes to improve conditions for Chinese carp. These studies are ongoing to monitor the effects of e-flows operation and analyse further potential improvements to operations.

Enabling factors

The government's determination to conserve ecological health has played the most important role in advancing and implementing e-flows operation in China. For more than a decade, the Chinese government has continuously strengthened environmental protection to address environmental problems after three decades of spectacular economic growth. The central government requires governments at all levels to address the root cause of deterioration of the ecological environment so as to reverse this trend. The instream flow requirement of the rivers affected by hydropower projects is one of the critical issues for the environmental assessment and management of hydropower. In 2005, China's State Environmental Protection Administration (now the Ministry of Environmental Protection) required that hydropower projects should release e-flows according to economic production, human needs, environmental and landscape requirements for coordinating economic, social and environmental benefits. This requirement was repeated and detailed in a series of subsequent policies by government agencies including the MWR, MOA, Ministry of Environmental Protection (MEP), and National Energy Administration (NEA) (Chen *et al.* 2016). The operation guidelines – including the Optimised Operation Scheme of TGD issued by The State Council and the Operation Guideline of TGD and Gezhouba approved by the MWR – required that the operation of the reservoir should 'maintain river health' by controlling certain flows and water levels in the reservoir and below the dam. In addition to the attention from government, the steep decline of fisheries following construction of TGD also generated strong concerns among the public. This helped the dam operator and government agencies to understand the importance of mitigating adverse impacts on the downstream fish community, and they began studying the eco-hydrological requirements of the fish community and implementing e-flows operation to help Chinese carp propagation.

The operational scheme in flood and drought seasons is determined by the Yangtze River Flood Control and Drought Relief Headquarters (YFDH). The operational plan is drafted based on a structured decision-making (SDM) process involving relevant agencies, which is then submitted to the YFDH for approval. The agencies consulted include government departments of water resources, agriculture, environmental protection, land and resources, electricity grid, and navigation. The operational department of the CTGC implements the operational plan after YFDH's approval. The operational guidelines for TGD clearly indicate that only flood management takes priority over water resources operation (water released for downstream economic production, human needs and environmental needs), and reservoir operation for water resources has higher priority than electricity production and navigation. Stakeholders discuss the e-flows implementation plan, and potential conflicts of interest can be resolved based on the operational guidelines. For example, in order to cope with salt-water intrusion in the Yangtze River estuary in 2014, the reservoir released more water (1.73 billion m^3) and lost electrical generation of 160 MWh. The SDM process used is effective and efficient for balancing trade-offs when implementing e-flows through the evaluation of a variety of scenarios and their impacts on different water uses.

INTERNATIONAL ENVIRONMENTAL ORGANISATIONS HAVE ADVANCED TGD E-FLOWS PRACTICES

Institutional resources and capacity also play an important role in the e-flows implementation of TGD, and relevant institutions are adaptively managing the e-flows programme. Firstly, government institutions lead e-flow implementation at TGD. The YFDH and Changjiang Water Resources Commission (CWRC) coordinate and manage the comprehensive operation of TGD including the e-flows operation, whereas the Office of Fisheries Law Enforcement for the Yangtze River Basin and the MOA actively advance the e-flows implementation for Chinese carp. Secondly, a multi-institutional interdisciplinary team funded by the CTGC effectively facilitates the development of the e-flows operational scheme. Fish biologists and hydrologists collaborated to identify the locations of the spawning grounds of four species of Chinese carp. They also identified the critical hydrologic indicators (water temperature, discharge before the flow rise, daily rate of flow rise, and duration of flow rise) and their ranges for natural carp spawning. The research institutions have been monitoring e-flow implementation to support the adaptive management of the e-flows programme. Thirdly, international environmental organisations advance the e-flows practices of TGD. In 2008, WWF collaborated with relevant institutions to establish the Expert Working Group of E-flows in China for promoting e-flows research and practice. This Working Group collaborates closely with CTGC and other stakeholders in the TGD e-flows programme and other initiatives, including the reconnection of river and lakes, measures to aid carp breeding, and ecological operational guidelines.

Triggers for action

Government and public concern over the environmental consequences of TGD was the key trigger that led to regulators and the hydropower developer improving dam operations. Since the beginning of construction more than two decades ago the project has remained highly controversial, mainly due to the environmental consequences of the giant dam. The dramatic declines in Chinese carp larvae and eggs below the dam were reported in the public media, and thus attracted widespread concerns in China and internationally. This put pressure on regulators and the developer to seek solutions to avoid biological impoverishment of the Yangtze River. Meanwhile, regulators and the developer want to demonstrate that TGD can play an important role in improving environmental conditions and meeting water demands during the dry season. They hope this can offset the controversy surrounding the TGD.

Monitoring and assessing success

AVERAGE DENSITY OF FISH EGGS AND LARVAE MORE THAN DOUBLE THAT BEFORE E-FLOW OPERATION

Flows and carp spawning are monitored during the period of e-flow operation. Monitoring results to date indicate that the release of high pulse flows promotes Chinese carp propagation. The average number of carp eggs and larvae sampled at Jianli station was about 140 million in 2006-2009 before e-flow operation, and increased to around 350 million in 2011-2014 after e-flow implementation (Chinese Sturgeon Research Institute 2015). From 4 to 6 June 2014, the average density of eggs and larvae in the reach from Yichang to Yidu was three times higher than before e-flow operation, and the density on the third day of operation was seven times higher than before e-flow operation (Chen and Li 2015). The effectiveness of e-flows implementation for Chinese carp is also helpful in conserving the biodiversity of China's freshwater fishes. Chinese carp are also prominent among the fish species that contribute to the economy, so e-flows implementation also has socio-economic benefits through its contribution to freshwater aquaculture. The Yangtze is China's biggest freshwater fishery, accounting for 56% of all freshwater catches; and the river is believed to produce the best quality Chinese carp, which is a particularly popular food in China (CHINCOLD 2017).

In terms of water release for human livelihoods in the dry season, TGD released an extra 199.7 billion m^3 in 1,601 days from 2003 to 2016. The benefits of this extra flow release were most important in February 2014, when sharply decreased precipitation and flow in the middle and downstream portions of the Yangtze River caused unprecedented salt-water intrusion in the Yangtze River estuary. This adversely affected the urban water supply of around two million people in Shanghai (Eastday 2014). TGD increased outflow discharge by 1,020m^3/s and released an extra 1.73 billion m^3. In this instance, the operation of the reservoir effectively alleviated the water source crisis in the Yangtze River estuary: in doing so it saved money and maintained social stability (CHINCOLD 2017).

Despite these success stories, more work is required. Although e-flow implementation has increased the production of eggs and juvenile carp, the number of eggs and larvae is still far below the baseline values from before the construction of TGD (Lu *et al.* 2016). In addition, the hydrologic requirements of other critical fish species (e.g. Chinese sturgeon) and aquatic ecosystems (e.g. wetlands) need further study to be considered in the implementation of e-flows. Currently, e-flows implementation at TGD is still at the trial stage and stakeholders are making efforts to improve its operation. Meanwhile they are also actively studying and advancing the e-flows operation of cascade dams, including TGD and upstream dams on the lower Jinsha River, a tributary to the Yangtze.

LESSONS

1. Political will is critical in successful implementation of e-flows. In this case, government attention and support were fundamental. With the requirements set by government, and governmental support in achieving them, relevant stakeholders were coordinated and potential conflicts of interest were addressed to facilitate successful e-flow implementation.
2. Concern over the environmental consequences of the dam from a number of government departments (MWR, MEP, MOA, NEA), along with the concerns of the public and NGOs, triggered action to implement e-flows. This demonstrates that governmental and public concern over environmental degradation can drive change, and that it can be accommodated while also meeting a nation's objectives for economic growth.
3. Collaborative engagement and structured management of the implementing entities is extremely important at TGD. TGD is a mega-dam with multiple functions, so operational changes for environmental purposes have to involve many different parties. The structured decision-making mechanism used is effective and efficient, given the trade-offs required between multiple uses.
4. Adequate institutional resources and capacity are necessary for successful e-flows implementation. In this case study, regulatory, technical and conservation institutions played their roles in e-flows implementation based on their resources and capacities in management, science and technology, and communication.
5. Scientific and socio-economic studies and monitoring directed at understanding the impacts of dam operations and the potential and actual benefits of e-flow releases are necessary to guide effective e-flow implementation. Such studies provide confidence that desirable outcomes can be realised, and facilitate an understanding of the costs and benefits of e-flow implementation.

3.5 RIVER KENNET, ENGLAND

THE RIVER

The River Kennet springs from chalk aquifers in the Marlborough Downs in southwest England and flows east through an Area of Outstanding Natural Beauty for some 64km before connecting with the River Thames. It is one of only approximately 200 chalk streams in the world.

THE ISSUE

Groundwater is abstracted from the chalk aquifer beneath the River Kennet, at Axford, and is used as a local water supply as well as supplying water to south Swindon, which is another catchment. A portion of the treated wastewater is therefore not returned to the River Kennet and is lost to the river basin. Under drought conditions, abstraction of groundwater reduces River Kennet surface flows by up to 35%.

THE RESPONSE

Studies conducted by the Environment Agency (EA) and Thames Water provided evidence that groundwater abstraction caused reduced flows in the River Kennet. The EA and Thames Water then worked together to find a solution to the public water supply issue that would arise from reducing abstraction from the River Kennet aquifer. The solution was to build a pipeline to supply south Swindon with water from a nearby reservoir when a low flow threshold on the River Kennet is reached. However, the regulatory framework governing the process by which funding could be secured for the project acted as a significant barrier to implementation. WWF and a local NGO (Action for the River Kennet) campaigned for many years for a change in legislation that would allow Thames Water to fund the project and recover costs directly through charges to customers. Once this change in legislation took place, Thames Water secured the necessary funding and work on the pipeline was completed in spring 2017.

INTERVIEWEES

Richard Aylard – 15 years as a Director at Thames Water. Richard studied applied biology at university and has a good understanding of the River Kennet through his background and time spent by the river as a fisherman and bird watcher.

Graham Scholey – Ecologist working for the Environment Agency (EA). Graham and his team provide advice on the ecological implications of permits related to abstractions, discharges and physical works within rivers.

Charlotte Hitchmough – Director of Action for the River Kennet (ARK), she has been involved with the charity for 12 years. Charlotte has a background in geography and has lived near, and has a keen interest in, the River Kennet.

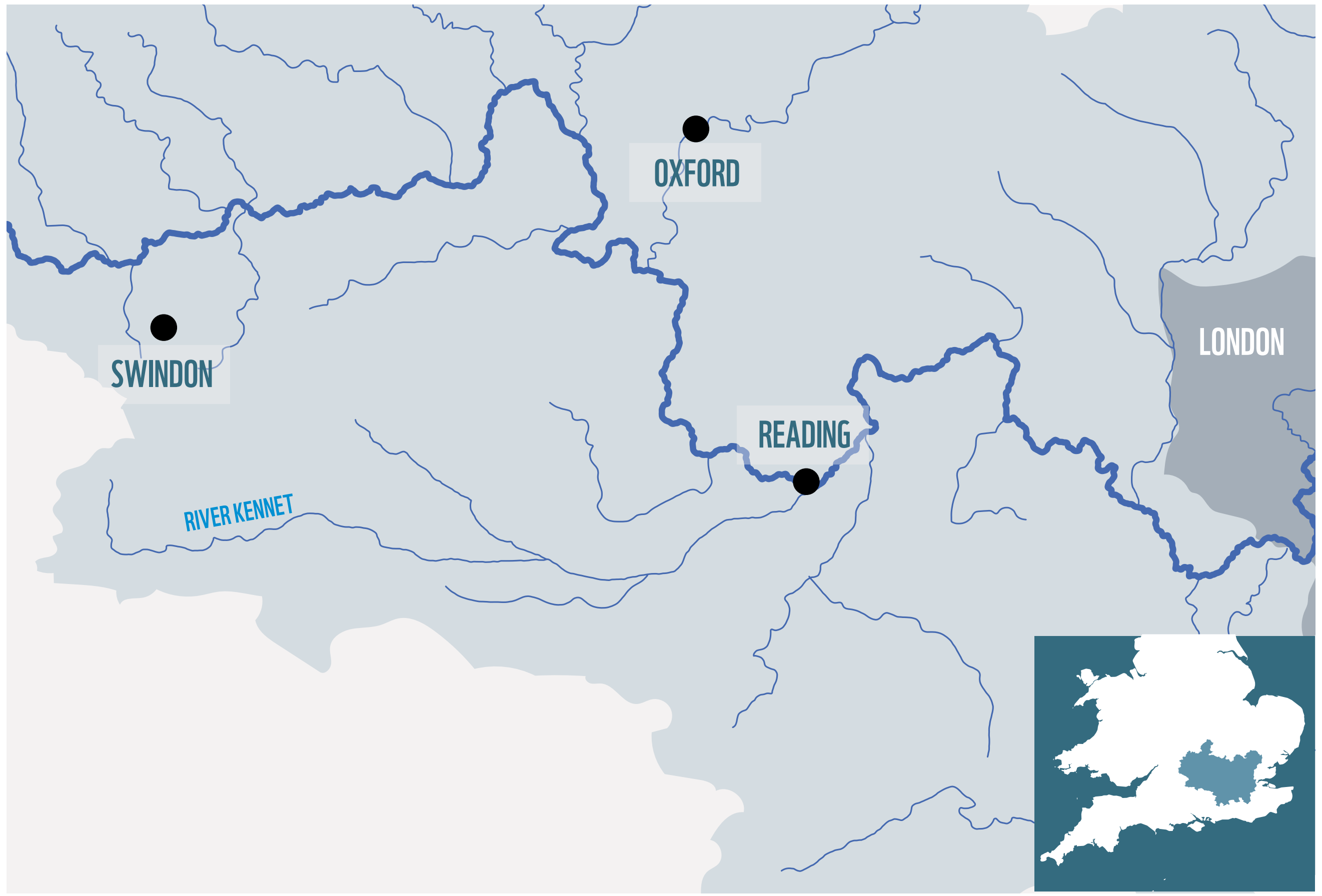
Rose O'Neill – Water Policy and Programme Manager at WWF-UK for over 8 years. Rose visited the River Kennet and started work there on her second day of work at WWF.

KEY FINDINGS

Robust data and evidence were required to define and understand the problem, and develop an appropriate solution.

The case study demonstrates that regulators can work with water utilities to successfully implement e-flows, but there must be an institutional commitment because the process can take many years.

Persistent pressure from local- and national-level NGOs was critical in securing e-flows.



3.5.1 Background

The River Kennet is one of the largest tributaries of the River Thames in southern England. The River Kennet springs from groundwater in the Marlborough Downs and flows eastwards through an Area of Outstanding Natural Beauty (designated originally under the National Parks and Access to the Countryside Act 1949, and now under the Countryside and Rights of Way Act (CRoW 2000)) for approximately 64km before entering the River Thames at Reading. The river is one of 224 chalk streams in England, with few such rivers found elsewhere in the world (WWF 2014). The upper Kennet was designated a Site of Special Scientific Interest (SSSI) in 1995 in recognition of its outstanding and diverse plant and animal communities, including priority species such as the water vole (*Arvicola amphibius*), water crowfoot (Ranunculus aquatilis), river lamprey (*Lampetra fluviatilis*) and brown trout (*Salmo trutta*) (WWF 2010).

The river is prized for fly fishing, including opportunities to fish on private estates that employ full time river keepers to manage the fisheries (Scholey, pers. comm. 2017a). The spring water that flows into the River Kennet is of exceptional quality, contributing to its rich ecology and its value as a public drinking water source that requires very little treatment (Aylard, pers. comm. 2017). Groundwater discharge to the River Kennet from the chalk aquifer supports a unique and ecologically rich river system by providing a reliable base flow with stable temperatures. The surface to groundwater connection is therefore very important to the river and its ecology. The groundwater-dominated flow in the Kennet relies on winter rainfall to recharge the groundwater aquifer. In wet years, the aquifer contains sufficient water to supply all water licenses and maintain adequate e-flows year-round. However, in dry years there is insufficient groundwater discharge to support both water abstractions and adequate summer flows.

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COLLABORATIVE STUDIES WERE UNDERTAKEN TO UNDERSTAND THE IMPACTS OF ABSTRACTION

Thames Water held licences issued by the national Environment Agency (EA) to extract up to 35 million litres of water per day from the upper Kennet for public water supply (WWF 2010). In addition to supplying water to local communities that subsequently return treated wastewater to the River Kennet, the Axford licence (one of the licences held by Thames Water) on the river also provides water for the town of Swindon, across the Wiltshire Downs. The water abstracted for the Swindon supply is returned to the River Ray in a different catchment, and is thus lost to the River Kennet.

In the late 1980s and early 1990s there was a dry period that caused an upsurge in local concern about flows in the River Kennet. Public perception and some evidence suggested that the upper Kennet was adversely affected by over-abstraction. In 1990, a local community group, Action for the River Kennet (ARK), was established to champion efforts to improve the health of the river. The mounting concerns culminated in a public inquiry into the Axford abstraction licence on the Kennet in 1996, when the National Rivers Authority (NRA, predecessor to the EA) sought to constrain the licence held by Thames Water (Scholey, pers. comm. 2017a,b).

Initial assessments of ecological impact focused on water crowfoot, a plant species that requires swift-flowing water over clean gravel and which is a critical element of the freshwater ecosystem, and brown trout. It was suggested that there may be a benefit to water crowfoot growth by reducing abstraction at times of low flow (WWF 2010). However, due to the complex nature of the groundwater-fed system and the synergistic impacts of poor habitat and water quality stress, it was difficult to demonstrate specific evidence of a direct causal link between the low flows caused by abstraction and effects on the environment.

The public inquiry, continued pressure from ARK, and a lack of definitive evidence that groundwater abstraction depleted surface water prompted the EA and Thames Water to collaboratively undertake detailed studies to understand the hydrological and ecological impacts of abstraction. Subsequent investigations conducted between 2000 and 2005 concluded that abstraction of groundwater depleted river flow downstream, with summer flows reduced by 10-14% on average and by greater percentages during low flow or drought periods (e.g. 35-40% estimated during the early 1990s drought) (WWF 2010). As a result, the EA and Thames Water agreed that the Axford abstraction licence in the River Kennet should be reduced.

3.5.2 Implementation of e-flows on the River Kennet

The EA and Thames Water worked together from 2005 to 2010 to find a public water supply to substitute for abstractions from the River Kennet aquifer. After carefully investigating a range of proposals, the best solution was to supply south Swindon with water from the nearby Farmoor reservoir (supplied by the River Thames) during times of low River Kennet flows. This alternative water supply was to be delivered via a new pipeline from the Farmoor reservoir.

Barriers to implementation

The initial barrier to implementing e-flows on the River Kennet was generating conclusive proof of a causal connection between abstraction, groundwater and river flow levels, and ecological impacts. In order to justify the infrastructure construction and additional water treatment costs associated with the alternative water supply, the EA and Thames Water needed robust proof for the project to be approved within the economic and regulatory framework. The collaboration of the parties involved (EA, Thames Water and ARK) allowed this barrier to be overcome by securing funding and conducting the necessary studies. Although this initial barrier required lengthy and complex studies and persistence to resolve, the largest barrier to implementing e-flows in the River Kennet in a timely manner stemmed from the regulatory framework governing the process by which funding for the pipeline infrastructure could be secured.

ROBUST PROOF WAS NEEDED TO JUSTIFY THE PROJECT WITHIN THE ECONOMIC REGULATORY FRAMEWORK

Government legislation and policy at the time required that if the pipeline project were to proceed, the EA would have to compensate Thames Water directly for reducing their licensed water allocation. The initial mechanism by which the pipeline would be funded entailed the collection of a levy on abstraction charges imposed over time, which would generate a national compensation fund. Despite the River Kennet project being earmarked as a national priority for such funding, generating sufficient funding in this manner would have required many years because the levy was far too small. This represented a significant hurdle, slowing the process of building the necessary infrastructure. In 2008 WWF became involved in the flow issues on the River Kennet, and thoroughly investigated potential solutions to the issue. After some back-and-forth discussion with the EA about options, WWF suggested to the EA that the best solution would be to end the requirement to pay compensation and revert to the pre-existing arrangement that would allow water companies to instead make good any reductions in water supply via the regulatory price review mechanism (i.e. the same mechanism that regulates all other water company investment in infrastructure). In 2014, a new Water Act was passed, which included an amendment removing the requirement for funding to be acquired through the EA compensation scheme. This amendment was not in the original draft of the Act but was included following pressure from WWF, and ultimately enabled Thames Water to raise funds for the Swindon pipeline via the price review process. This mechanism allowed Thames Water to invest in the pipeline (~£10 million) and recover costs directly through charges to customers. Once this change in legislation took place, funding was secured and work on the pipeline was completed in spring 2017. Concurrently, changes to the Axford water licence were made such that water will be drawn from Farmoor reservoir when flows in the River Kennet reach a low flow threshold.

Enabling factors

Implementation of e-flows on the River Kennet was enabled by several different factors. A variety of institutional frameworks was already in place supporting the process. For instance, the Water Framework Directive (WFD) adopted by all countries within the European Union requires that all rivers meet 'good ecological status', as defined by a number of characteristics of any river that is moderately affected by human activity. Monitoring of these characteristics (e.g. fish populations, invertebrate populations, plant diversity and river chemistry) is conducted by the EA as the regulatory body that administers the WFD throughout each river catchment in England. Although the monitoring is not as extensive as the EA would like, the WFD provides a legislative basis for protecting the environment and support for monitoring processes that can detect ecological and hydrological changes in rivers. Additionally, the designation of the River Kennet as a Site of Special Scientific Interest (SSSI) by Natural England (sponsored by the government Department for Environment, Food and Rural Affairs, DEFRA) necessitated the development of flow targets that provide fairly strict safeguards to protect the natural flow regime.

MAJOR LEGISLATIVE CHANGE WAS FUNDAMENTALLY IMPORTANT FOR E-FLOW IMPLEMENTATION

Another enabling factor for e-flow implementation was that the EA is responsible for issuing abstraction licences but also acts as the main environmental regulator in England. It is the goal of the EA to apply best-practice principles to minimise adverse impacts and build a sustainable approach to managing water for the environment. The EA has a mandate to protect or enhance the environment and thus has a desire to work with other interest groups and water companies to address stresses and environmental pressures (Scholey, pers. comm. 2017a). This regulator focus on the environment provides the EA with a foundation for protecting e-flows on rivers where they license abstractions – although presently change in abstraction, or e-flow implementation, is a slow process with changes to the River Kennet licence taking 20 years to implement. As described above, the major legislative change in 2014 (Water Act 2014) was of fundamental importance to e-flow implementation. Without the legislative change the cost of the pipeline would always have been prohibitive and thus no change in the River Kennet water licence would have been made for some considerable time.

The positive, collaborative working relationship between the key parties involved in the process (EA, Thames Water, WWF and ARK) also acted as an enabling factor. After the public inquiry into the Axford water licence in 1996 it became clear that the EA and Thames Water must work together to find a reasonable solution to protect flows in the river and still provide water to Thames Water customers (Scholey, pers. comm. 2017a). This joint institutional commitment proved to be essential, given the resulting length of the process and the need for change to the Axford abstraction licence. Additionally, ARK was involved in various steps of the process, representing local interests and applying pressure to keep the process moving forward.

Triggers for action

PUBLIC PERCEPTION OF DETERIORATING RIVER HEALTH WAS A TRIGGER FOR E-FLOW IMPLEMENTATION

Various triggers for the implementation of e-flows on the River Kennet were identified as important. Public perception of the deteriorating health of the river during dry periods (during the late 1980s and early 1990s and again in 2011 and 2012) put pressure on regulators (EA) and Thames Water to make a change to abstraction from the river. Instrumental to this was a media campaign WWF launched at the time that heightened the political awareness of the issue (O'Neill, pers. comm. 2017a). The public inquiry into the Axford licence in 1996 prompted the EA and the water company to pursue robust evidence for determining whether abstraction was the problem (Scholey, pers. comm. 2017a). However, it took an additional 15 years after the investigations concluded before there was a change to the licence (O'Neill, pers. comm. 2017a).

More recently, recognition of the problem of low flows in the River Kennet was widely publicised on national television, and was referenced in Parliament by the local Member while acting as Water Minister, i.e. the Minister responsible for the EA and the Water Act 2014 (Hitchmough, pers. comm. 2017). The concern of legislators and regulators ultimately resulted in the EA mandating a reduction in abstraction from the River Kennet (Aylard, pers. comm. 2017), which triggered Thames Water to design and implement a solution. WWF played a key role by focusing ministerial, regulator and media attention on the issue over a long time period (O'Neill, pers. comm. 2017a).

MONITORING HAS SHOWN SOME ECOLOGICAL IMPROVEMENTS AS A RESULT OF CHANGES IN ABSTRACTION

Monitoring and assessing success

Monitoring on the River Kennet has been in place at a number of sites according to the provisions of the WFD, which provides statutory ecological status requirements for catchments across the European Union. According to the WFD, every river (except waterbodies designated as 'heavily modified') has to meet 'good ecological status' as measured by a number of characteristics of the river (Acreman *et al.* 2008). Flow regimes are set according to best available knowledge based on deviations from natural flows and informed by hydrological gauging stations in the catchment. WFD monitoring provides background information that over time can show general improvements in rivers. The River Kennet currently meets most of the parameters for 'good' status in many reaches of the river system; and because of the change in abstraction, improved flows are expected to support good ecological status in locations where the river previously did not (Scholey, pers. comm. 2017a). Ecological monitoring will continue to be conducted by the EA and ARK to help measure the impact of the abstraction reduction.

Monitoring the health of the river has shown some ecological improvements as a result of changes in abstraction made prior to the installation of the pipeline, and as a result of other initiatives such as physical habitat restoration. Now that the pipeline replacement is complete, success can be measured when the flow constraint is reached and abstraction during low flows is reduced. Nevertheless, it is understood that it will be difficult to attribute ecological change in the river specifically to changes in abstraction due to annual environmental variability and other pressures on the system. The ultimate goal of the process for implementing e-flows on the River Kennet will be achieved when the statutory conservation requirements show that the river is in favourable condition for the first time since being designated a SSSI. It is currently moving in the right direction.

LESSONS

1. Detailed technical studies were required to prove a causal link between groundwater abstraction, low river flows and ecological effects. Robust data and evidence were required to define and understand the problem. This need for detailed studies will likely exist whenever existing uses of a river will be directly impacted by e-flow provision, as they provide confidence that desirable outcomes can be realised by the imposed changes in water use.

2. Establishing a positive relationship between the regulators, water company and stakeholders was crucial to moving the process forward, understanding the issue, and identifying solutions. Being open and honest was critical in overcoming institutional barriers. The active, collaborative engagement of the implementing entity (in this case Thames Water) is extremely important in any e-flow restoration project.

3. Institutional commitments to finding a solution are required – the process can be long and arduous. The success of e-flow restoration projects will almost always rely upon durable and sincere commitments by the affected or interested parties. In this case, the commitment of the EA and Thames Water was solidified by the actions of organised and committed public interest groups (ARK and WWF) that applied pressure and brought national attention to the issue to push the process along.

4. In the case of the River Kennet, a change to the regulatory mechanism was necessary to secure funding. Without a realistic funding mechanism, change would have taken considerably more time. WWF was instrumental in assisting legislators in writing the amendment to the Water Act that allowed change to occur.

5. It is important that when the governmental organisation responsible for water allocation – in this case the EA – also has a mandate to protect the environment there are adequate checks on the potential conflict of interest between the two roles. In this case, the internal conflict between the two roles is viewed by some case study interviewees as being an important factor in the length of time that it took to change the River Kennet abstraction licence, and the continuing backlog of other streams within England that suffer from unsustainable abstraction.

3.6 CROCODILE RIVER, SOUTH AFRICA

THE RIVER

The Crocodile River is the most utilised tributary of the transboundary Incomati River basin shared between Swaziland, South Africa and Mozambique. It falls within the South African Inkomati Water Management Area. The Crocodile River also forms the southern boundary of Kruger National Park (KNP) prior to joining the Komati River and flowing into Mozambique.

THE ISSUE

The Crocodile River flows through a diverse landscape ranging from highland grassveld at its source, through a mountainous transition zone where most of the rain falls heavily planted with commercial forestry, into a semi-arid lowland bushveld region where water resource infrastructure is extensively developed to support irrigated agriculture and large urban and semi-urban areas. The catchment is water-stressed from large existing demands and anticipated future demands, causing concerns over meeting the needs of irrigators, municipalities, and the KNP, along with transboundary water-sharing commitments to Mozambique.

THE RESPONSE

E-flows have successfully been implemented in the Crocodile River through the establishment of the Inkomati-Usuthu Catchment Management Agency (IUCMA), which was given the responsibility of implementing e-flows developed by the National Department of Water Affairs under the National Water Act of 1998. The IUCMA has extensively engaged local stakeholders in South Africa through the establishment of an operations committee, and is using real-time decision support tools and strategic adaptive management to better manage the available water.

INTERVIEWEES

Brian Jackson – Formerly the Water Resources Planning and Operations Manager at the Inkomati Usuthu Catchment Management Agency (IUCMA) – responsible for integrated adaptive management for the Catchment Management Strategy.

Eddie Riddell – Manager for Water Resources and Aquatic Biodiversity Management, Kruger National Park.

Dawie van Rooy – Chairman of the Crocodile River Irrigation Board. Manages local distribution of water to irrigators in the South African portion of the watershed (~28,000 ha total irrigated land).

Jackie King – University of Cape Town researcher in 1990s collaborating with the national Department of Water Affairs and KNP to establish the legislation requiring e-flows.

In addition to the above interviewees, we would like to acknowledge Dr Freek Venter for providing background information for the case study.

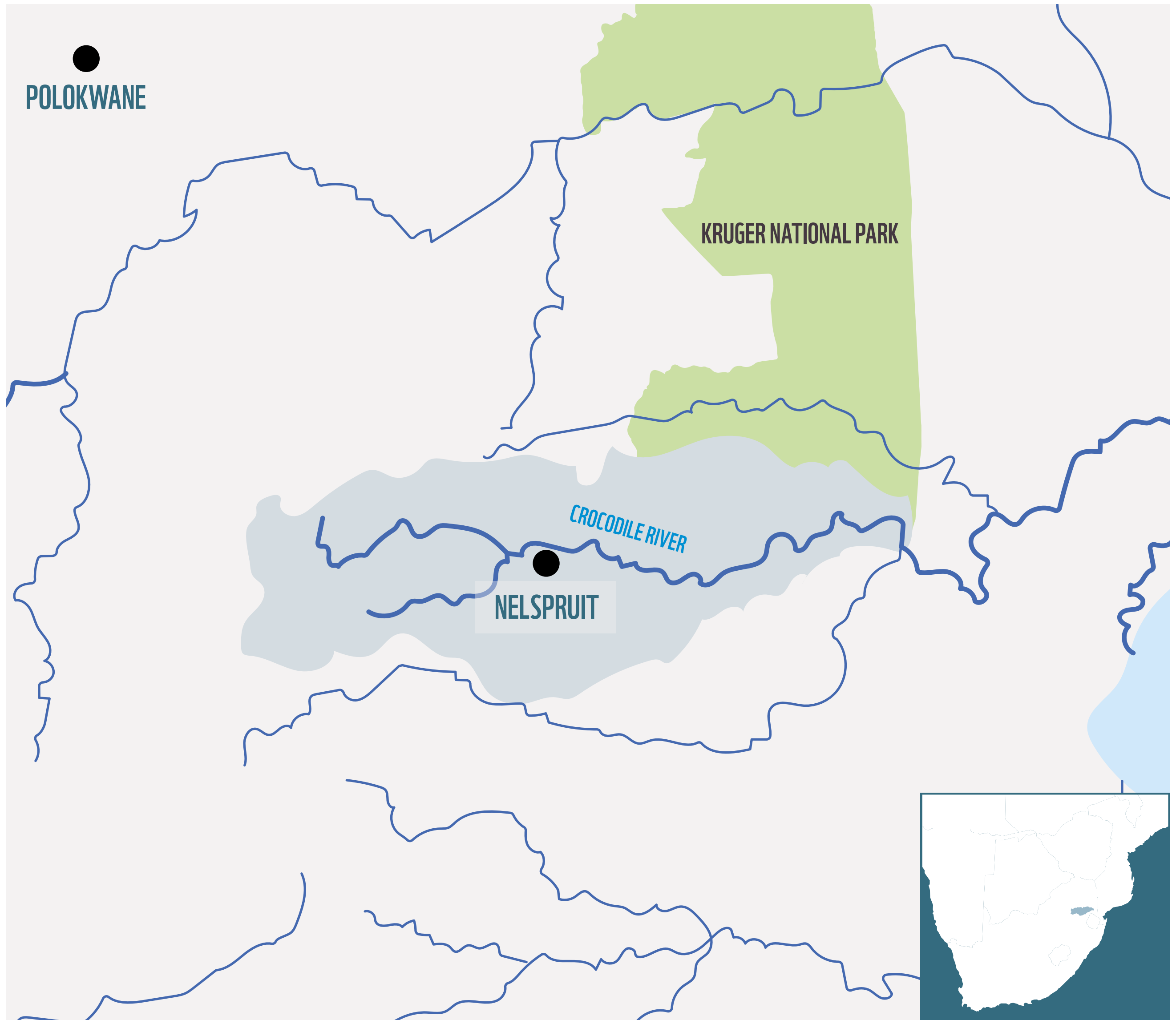
KEY FINDINGS

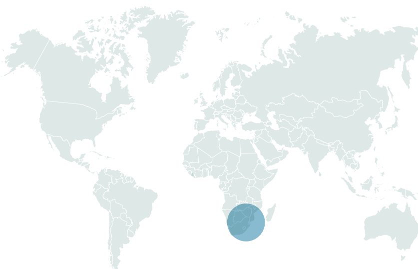
New legislation allowed for a more localised system of managing water and e-flows and led to the involvement of all stakeholders.

Involving all stakeholders led to a transparent process, with all parties gaining a better understanding of the need for improved water management and supporting e-flow implementation.

Action research[3] is an effective methodology for developing and implementing a strategic adaptive management approach in a stressed, complex system such as the Crocodile River catchment.

Action research is an interactive inquiry process that balances problem-solving actions implemented in a collaborative context with data-driven collaborative analysis or research to understand underlying causes enabling future predictions about personal and organizational





3.6.1 Background

The two million hectare Kruger National Park (KNP) is located in north-eastern South Africa and is one of the largest national parks in the world (Biggs et al. 2017). The eastern boundary of the park is shared with Mozambique. Several historically perennial rivers run through the park, the largest of which is the Olifants River. The Limpopo River acts as the northern boundary of the park and the Crocodile River forms the southern boundary. Other rivers flowing within the KNP are the Sabie, Letaba and Luvuvhu rivers. The climate within the park is subtropical with a rainy season from October until April.

The river catchments upstream of KNP are under administrative influence from national government departments and the provincial governments of Limpopo, Mpumalanga and Gauteng, along with multiple district and local municipalities (Biggs et al. 2017). The rivers within KNP experienced dramatic flow reductions starting in the 1970s due to increased domestic water use associated with population growth, the expansion of irrigation, and industrialisation in the upper basin. Conservation efforts to reduce pollution and drying-up of the perennial rivers in the park have been active for decades, along with institutional arrangements regarding river flows between South Africa and Mozambique (van der Walt 2012).

Recognising that rivers were degrading across the country, the national Department of Water Affairs collaborated with scientists, water engineers et al in the 1980s to improve water management (King, pers. comm. 2017). This resulted in the National Water Act of 1998, which inter alia mandated that water of a certain quantity and quality must be made available by law as an 'ecological reserve' to sustain aquatic ecosystems. The National Water Act prompted the Department of Water Affairs to create a new Directorate of Resource Directed Measures tasked with addressing these new aspects of water management. Around the same time, conservation and water resource managers were instituting the principles of integrated water resource management (Biggs et al. 2017).

A decision was made to determine e-flows for every major river in the country starting with those where there was conflict over water, those with high conservation status, or those where dams were proposed (King, pers. comm. 2017). Initially, the Building Block Methodology (King and Louw 1998) was developed to assess e-flows (in the Luvuvhu, Sabie, Olifants and Letaba rivers), but eventually other methods such as DRIFT and the Habitat Flow-Stressor-Response evolved. Enhanced cross-sectoral water resource management has led to improvement in drought flows in the rivers of KNP. The park managers have direct communication with upstream water management agencies, including the Catchment Management Agency or Provincial Operations offices of the Department of Water and Sanitation, Irrigation Boards or Water User Associations (for agricultural irrigation), and Water Boards that supply bulk water. Regular meetings with the operations committees allow decisions to be made on water allocations from dams and restrictions on water-users that enable transparent and accountable water management (WW 2016).

THE CROCODILE RIVER IS THE MOST UTILISED TRIBUTARY OF THE TRANSBOUNDARY INKOMATI RIVER BASIN

Our case study examines the development and implementation of e-flows within the Crocodile River basin, set against this backdrop of changes to the management of South Africa's water resources. The Crocodile River is the most utilised tributary of the transboundary Incomati River basin shared between Mozambique, South Africa and Swaziland and falls in the South African Inkomati Water Management Area. The river is some 320km long and drains an area of approximately 10,400 sq km. The Crocodile River is topographically diverse with a western upper plateau (highveld) that experiences moderate rainfall, a middle mountainous region (middleveld) with high rainfall, and an eastern sub-tropical region (lowveld) with low yearly rainfall (Riddell et al. 2014). Land use in the river catchment includes agriculture and grazing in the highveld region, pine and eucalyptus plantations in the central region, and irrigated agriculture in the lowveld region (Riddell et al. 2014). The eastern catchment of the Crocodile River is formed by the KNP conservation area to the north and mixed irrigated land and savanna to the south. Water resource infrastructure is extensively developed in the catchment due to the presence of large urban and semi-urban areas (Riddell et al. 2014). The catchment is water-stressed from large existing demands of agriculture and anticipated future demands, causing concerns for maintaining the environmental water reserve. The Kwena Dam in the upper catchment is the only large dam on the Crocodile River. It is critical for regulating water supply to downstream farmers and providing sufficient water for environmental flow and basic human needs (IUCMA 2010). However, the dam only captures approximately 10% of the surface water within the watershed and is unable to manage most of the rainwater, which falls further downstream in the basin (Jackson, pers. comm. 2017a). Management of the Crocodile River must also consider the provision of cross-border flow into Mozambique downstream of KNP (Riddell *et al.* 2014).

3.6.2 Implementation of e-flows on the Crocodile River

THE STAKEHOLDER ENGAGEMENT PROCESS WAS A MAJOR SUCCESS FACTOR IN E-FLOW IMPLEMENTATION

The Crocodile River is the most water-stressed river in the Inkomati region – and although the river has occasionally dried up naturally under drought conditions (Riddell, pers. comm., 2017), drying began occurring fairly frequently as water use increased in the upper basin prior to e-flow implementation (Jackson, pers. comm. 2017a). As a result, there was conflict between a variety of stakeholders (e.g. irrigators, KNP, local residents and downstream users in Mozambique). The new National Water Act in 1998 called for the establishment of Catchment Management Agencies (CMAs) in South Africa, with the Inkomati-Usuthu Catchment Management Agency (IUCMA) being the first to be created in 2006. The national Department of Water Affairs delegated some of its water management responsibilities to the CMAs, although most water licensing is still undertaken by the Department of Water Affairs[8] based on CMA recommendations. The IUCMA saw the need for a water management framework in the Crocodile River when developing its Catchment Management Strategy in 2009. The strategy identified three major needs for the river including (1) integrated adaptive management of the water resource, (2) improving water quality and water quality monitoring, and (3) redressing past social imbalances and including stakeholders (e.g. emerging farmers) in discussions on water use.

To advance the integrated adaptive management of the water resource, the Crocodile River Operations Committee (CROCOC; hereafter Operations Committee) was established by the IUCMA with representatives from most of the major water use sectors along the Crocodile River (the exception being the agroforestry industry[9]). This Operations Committee reviewed the e-flow requirements recommended by the Department of Water Affairs, revised them through hydrological modelling and stakeholder engagement, and subsequently developed operating rules to balance water use in a sustainable way. A re-evaluation of the e-flows determined for the Crocodile River by the Department of Water Affairs was necessary because the e-flows were significantly higher than actual recorded flows during certain seasons, and there was thus no buy-in from the primary water-users in the watershed (i.e. irrigators). The stakeholder engagement process that was undertaken to review and revise the e-flow recommendations was a major factor in the success of e-flow implementation in the Crocodile River, as it meant that the major water-users (i.e. irrigators, KNP and municipalities) gained an understanding of water management in the watershed and the needs of other users. This engagement process is ongoing through the real-time management of the water resource by the Operations Committee. E-flow targets are published a week in advance and sent out to the Operations Committee, with flow monitoring along the river used to evaluate whether targets are reached (Jackson, pers. comm. 2017a).

[8] Now the Department of Water and Sanitation

[9] When the Operations Committee was constituted its focus was on the management of Kwena Dam operations on the mainstem of the Crocodile River, and the major irrigators downstream; whereas agroforestry is most dominant on an upstream tributary, the Eland River.

70%

AGRICULTURE, PRIMARILY SUGARCANE, IS THE MAIN ECONOMIC DRIVER IN THE CATCHMENT AND IRRIGATION IS THE MAIN WATER USE

Barriers to implementation

An early barrier to implementation of e-flows in the Crocodile River was the conflict between two government agencies – the Department of Water Affairs and the IUCMA – and the lack of clarity on roles and responsibilities (Jackson, pers. comm. 2017a). Being the first CMA established in South Africa, there was a learning process required as to how rules developed at the national level would be implemented. Although the Department of Water Affairs was developing e-flow rules, it had no regional capacity for implementation; it was therefore agreed that the IUCMA would implement the rules. The conflict between the two government agencies was also evident in the process of setting e-flow targets. The initial e-flow targets set by the Department of Water Affairs were developed in isolation from the stakeholders, who believed they were unrealistic in certain seasons based on the amount of water available. They were therefore not accepted by the stakeholders who would be responsible for implementation. The IUCMA understood the need to involve stakeholders in discussions on new e-flow targets and the Operations Committee was therefore established. The e-flow targets established by the Operations Committee are not too dissimilar from those originally proposed in terms of total annual volume, but they are more realistic within different seasons. Importantly, the process also increased the understanding of water management in the system and showed the stakeholders that each sector or interest was willing to compromise; thereby ensuring buy-in from all parties. Institutional barriers to e-flow implementation were also resolved once the environmental water reserve (EWR) for the Crocodile River had been set and there were clear rules established as to how the river would be managed to meet the EWR (Riddell, pers. comm. 2017).

Prior to the establishment of the Operations Committee, there was additional conflict between KNP and irrigators in the area. Agriculture, primarily sugarcane, is the main economic driver in the catchment and irrigation is the main water use (approximately 70%). The irrigators needed to extract water for farming, but KNP needed water in the river for the environment, so common ground needed to be established. These conflicts were underscored by a lack of knowledge and understanding in other sectors (e.g. municipalities) on how the system was managed. As noted above, the formation of the Operations Committee improved relationships between the various stakeholders and increased understanding of the needs of other sectors (van Rooy, pers. comm. 2017).

Another hindrance to e-flow implementation was poor gauging and weather monitoring systems for real-time monitoring and management. Additionally, a forecasting tool and decision support system had to be developed due to the seven-day lag time between the dam releases and water arriving in the lower reaches (Jackson, pers. comm. 2017a). The development of better e-flow targets by the CMA helped to overcome these barriers.

THE NEW CATCHMENT MANAGEMENT AGENCY NEEDED TO DEMONSTRATE ITS WORTH

Enabling factors

The formation of CMAs through the new Water Act was a key enabling factor in the implementation of e-flows in the Crocodile River. The new organisation needed to demonstrate its worth and prove that it could address pressing issues in order to establish itself over the long term. Through innovation and engaging stakeholders the IUCMA was able to implement the Catchment Management Strategy, and it has successfully determined and implemented e-flows and a real-time management system. The process pioneered in the Crocodile River has been adopted in other catchments (Jackson, pers. comm. 2017a); however, the importance of the CMA in this process is demonstrated by the fact that e-flow implementation in other regions of South Africa where CMAs are yet to be established is much further behind. In addition to an appropriate institutional arrangement, successful e-flow implementation requires funding and a champion within that organisation to drive the process. In this case, Brian Jackson was the champion within IUCMA that was able to secure the funding to implement the modelling required to enable real-time management of water resources.

Along with the establishment of the IUCMA, the formation of the Operations Committee was integral to success by creating an environment where a variety of interested stakeholders were engaged to develop an understanding of the scientific basis behind the process, determine appropriate e-flows and set rules that would govern water management through action research. This led to more widespread support for implementing e-flows.

KNP also played an important role in advancing e-flow implementation in the watershed by applying consistent pressure since the 1980s and arguing that e-flows were essential to the park, and that these should be implemented in a progressive and adaptive process (Riddell, pers. comm., 2017). The multi-disciplinary KNP River Research Programme was also important to increase understanding of the need for e-flows and for benchmarking the biophysical environment so that the effect of e-flows can be monitored.

Continued pressure from the Mozambique government to meet an international agreement on flows was also an important driver. However, the international agreement between South Africa and Mozambique also provides a cautionary note regarding legislated requirements, as the agreed minimum flows were a static target that did not take into account seasonal variation (e.g. drought or wet season). As a result, there is no flexibility or ability to adapt to new information or the development of new management techniques.

LEGISLATION AND THE ESTABLISHMENT OF CMAS WERE TRIGGERS FOR CHANGE

Triggers for action

There was not one particular trigger that led to action on e-flow implementation in South Africa or the Crocodile River watershed specifically. On the national scale, scientists at the University of Natal realised in the 1970s that the nation's freshwater resources were badly degrading. This was first brought to the attention of public officials by a 1982 report entitled *Man and the Pongolo Floodplain* (Heeg and Breen 1982) that documented adverse ecological impacts on one of the last remaining fully natural areas in South Africa (King, pers. comm., 2017). The first national meetings on saving the country's rivers were held in the 1980s and culminated in the publication of *Ecological Flow Requirements for South Africa Rivers* (Farrar, 1989). This discourse, and the election of the first democratic government in 1994, ultimately resulted in the enactment of a new National Water Act in 1998.

From one perspective it could be argued that this legislation was the trigger for change in the Crocodile River, although the stakeholders interviewed for this case study focused on the establishment of different entities (the CMA and Operations Committee). The establishment of the CMA can be traced back to the Water Act, and it is clear from the status of e-flow implementation elsewhere in South Africa that having a CMA with regional capacity was critical to success in this case (Jackson, pers. comm. 2017a, Riddell, pers. comm. 2017). However, the establishment of the Operations Committee and the process of stakeholder engagement was also fundamental (van Rooy, pers. comm., 2017). Given the importance of the Water Act, the IUCMA and the Operations Committee, and the various factors that influenced these, it can be concluded that there were multiple triggers for action in this case.

Monitoring and assessing success

The IUCMA has appointed KNP to monitor biological parameters within the park, with the IUCMA responsible outside the park, as well as for monitoring flow within and outside the park. Maintenance of the EWR is measured at six sites along the Crocodile River, of which two are in the park. Monitoring of these sites allows an evaluation of whether the IUCMA is meeting its e-flow targets. There are flow management logbooks kept by the IUCMA and KNP that document when warning levels are reached and alerts that require intervention are triggered. When an alert is triggered KNP contacts the IUCMA which then takes action; these alerts and mitigative actions are tracked in the logbooks. These checks and balances allow for consensus among the groups and ease management (Jackson, pers. comm. 2017a). The Crocodile River Irrigation Board provides on-the-ground management of water use by making sure that water is reaching individual farmers, and also measures abstraction of water by irrigators (van Rooy, pers. comm., 2017).

RESULTS FROM MONITORING PROGRAMMES HAVE SHOWN A 20-35% IMPROVEMENT IN MEETING TARGETS

Results from various monitoring programmes are showing some improvements to the Crocodile River. The monitoring of actual observed flow is used to determine whether river flows are meeting daily and monthly targets, along with the percentage of time that flow is in different alert levels on a monthly basis. From 2010 to 2014 there was a 20% improvement in meeting targets compared to 2000 to 2010, and a 35% improvement compared to 1983 to 2000 (Jackson, pers. comm. 2017b). Additionally, when targets have not been met, there has been a reduction in the magnitude by which they are missed (Jackson, pers. comm. 2017a). Although the first five of the last 10 years were wet years, the Crocodile River was kept flowing from 2014 to 2016, which was perhaps the most extreme drought on record (Riddell, pers. comm., 2017). The economic viability of the sugarcane industry was also maintained throughout this drought, which represents a major success story.

In addition to monitoring flow, there is a river health monitoring programme conducted every three years that examines fish, invertebrate and riparian communities. This biomonitoring has shown that many parameters are stable. A lack of marked improvement in biological indices may be explained by a deterioration in water quality despite the improvements in meeting water quantity targets. Social aspects of e-flow implementation are also being monitored through questionnaires sent to the Operations Committee members (Jackson, pers. comm. 2017a).

Not all successes attributable to e-flows on the Crocodile River have been quantified, but a few successes are being seen from different perspectives. From the viewpoint of irrigators, better water management has improved their sector and allowed more crops to be produced, resulting in more jobs for the community. The current water management system contributes to the irrigators receiving their full annual allocation of water more often. Restriction in water allocations has a direct impact on the irrigated agriculture sector (crop yields), and due to the rural nature of the area a massive impact on the local economy and jobs available (van Rooy, pers. comm. 2017). At the municipal level, Mbombela has adapted bylaws to restrict water use in times of drought using a progressive tariff system. All sectors involved in the process of implementing e-flows have adapted to drought situations and have realised benefits of improved water management, although tangible economic benefits in response to e-flow implementation have not yet been quantified. Overall water management in the basin would benefit from participation of the agroforestry industry on the Operations Committee, along with improvements to monitoring and adaptive management (Riddell, pers. comm., 2017).

LESSONS

1. Successful e-flow implementation requires a champion within the organisation charged with implementation to drive the process forward.
2. It is critical that water management agencies have clearly defined roles and responsibilities.
3. Engagement of stakeholders and the technical steps in determining e-flow targets should take place in tandem as both are necessary for successful implementation. Users/ stakeholders possess valuable knowledge that needs to be understood and integrated into the knowledge of technical experts, whether from government, industry or academia. Determining e-flows and then informing users will not result in successful implementation. The overlapping processes may take longer to conduct but they are critical for long-term success.
4. It is important to maintain relationships among stakeholders by meeting frequently. If the frequency of interactions is reduced, engagement recedes and challenges become more frequent. The frequency of meetings should increase during times of crisis (e.g. drought).
5. Monitoring is necessary to understand the ability to meet e-flow targets, but also to draw attention to areas that still require improvement to meet larger objectives of ecosystem protection or restoration. In the case of the Crocodile River, improvements in water quantity have been offset by deterioration in water quality that must be addressed to meet long-term environmental objectives.
6. Monitoring relies on properly functioning infrastructure, such as streamflow and rainfall gauging networks, that needs to be maintained. Data collected in this manner should be managed in an accessible information management system that provides transparency around the real-time management of flows.
7. Adaptive management should be implemented to ensure that lessons are learned from monitoring results, stakeholder engagement processes and changing climatic conditions.
8. Action Research is an effective methodology for developing and implementing a strategic adaptive management approach in a stressed, complex system such as the Crocodile River catchment.
9. E-flows will come under pressure in the future as a result of an increase in primary water users and the impacts of climate change. Long-term strategies need to be developed jointly to ensure a sustainable management system and a suitable e-flow regime over the long term.

3.7 SAN PEDRO MEZQUITAL RIVER, MEXICO

THE RIVER

The San Pedro Mezquital River is a largely free-flowing river that flows 540km through the western Sierra Madre Mountains in Mexico before emptying into the Pacific Ocean.

THE ISSUE

The San Pedro Mezquital River feeds a mangrove forest that is the largest of its kind in Mexico and an internationally important Ramsar site, the Marismas Nacionales Biosphere Reserve. Local indigenous peoples are also closely tied to the river through ancestral customs and ceremonies. Although not water-stressed in the mid-basin and lowlands, there were concerns about future pressures on the system and impacts on the ecological integrity of the protected area.

THE RESPONSE

E-flows have been successfully implemented in the San Pedro Mezquital River. This has worked through a joint initiative by government agencies and WWF to establish an Environmental Water Reserve through a presidential decree, fixing an annual volume of water to remain in the environment that cannot be allocated through water permits. The river was Mexico's first designated Environmental Water Reserve, with approximately 80% of its mean annual runoff allocated to ensure water and nutrient supply to the Marismas Nacionales. The social and economic benefits of e-flows were also considered through a cost-benefit analysis that showed that water for the environment would improve the socio-economic position of the people living near the river. The San Pedro Mezquital River was one of six pilot studies in the National Water Reserves Programme, and serves as a model for e-flow implementation in watersheds across Mexico.

INTERVIEWEES

Mario López Pérez – Hydrology Coordinator of the Mexican Institute of Water Technology. Formerly worked for the National Water Commission in charge of the National Water Reserves Programme (CONAGUA).

Víctor Hugo Vázquez Morán – Director of Marismas Nacionales Biosphere Reserve and Ramsar site from the National Protected Areas Commission (CONANP).

Eugenio Barrios – Director of Public Policy, Corporate and Social Engagement, WWF-Mexico; and Sergio Salinas-Rodríguez – Freshwater Practice Leader, WWF-Mexico

In addition to the above interviewees, we would like to acknowledge Ignacio Daniel González Mora and Sergio Salinas-Rodríguez for their assistance with translation.

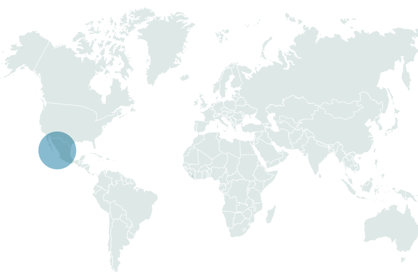
KEY FINDINGS

The case study highlights an example of proactive reservation of flows for the environment.

National e-flow guidelines were established through collaboration between a variety of stakeholders (i.e. WWF, the National Water Commission, the National Commission of Natural Protected Areas and other national, regional and local stakeholders and academic institutions). The development and publication of a national standard for determining e-flows overcame an implementation barrier related to the selection of an appropriate e-flow assessment method.

E-flows have been successfully established to protect rivers from over-allocation, including those in arid environments, disproving the myth that there is not enough water for the environment and other users in such climates.

It is necessary to engage the water use sector in the determination and implementation of e-flows from the beginning of the process. The users must understand the process and the benefits to be invested and supportive.



3.7.1 Background

The National Water Reserves Programme (NWRP) is a joint initiative of the National Water Commission (CONAGUA), the National Commission of Natural Protected Areas (CONANP), and the WWF-Gonzalo Río Arronte Foundation Alliance. The NWRP is funded by the Interamerican Development Bank (IDB) and began in 2012 to establish an integrated national system of water reserves for the environment (Moir *et al.* 2016, WWF 2017). An Environmental Water Reserve (EWR) is a presidential decree to allocate an annual volume of water to remain in the environment that cannot be allocated through water permits. The goals of the NWRP are (1) to establish a national system of water reserves; (2) to demonstrate that water reserves ensure a healthy functioning of the water cycle, as well as the environmental services they provide; and (3) to build capacity in the implementation of e-flows backed by official national guidelines throughout the country.

A VOLUNTARY NORM TO DETERMINE ENVIRONMENTAL FLOWS WAS FIRST PUBLISHED IN 2012

In 2007, CONAGUA collaborated with WWF to lead an expert working group with an aim of establishing procedures and technical methods for determining the e-flow requirements for rivers and guide the study of mean annual water availability, the issuing of water permits, and future infrastructure projects. The concepts of the Natural River Flow Paradigm and the Biological Condition Gradient, among others, were adopted by the group for the foundation of e-flow determination. The result of the working group was a *Voluntary Norm to Determine Environmental Flows* published in November 2012 that provided a range of hydrological, hydro-biological and holistic methodologies that can be used to guide environmental flow determination. This voluntary standard allows flexibility in the method used depending on the socio-economic and environmental conditions of the basin. A complete analysis of experiences can then be used to determine the best approach to move from a voluntary standard to a required standard (Moir *et al.* 2016).

In 2011, WWF-Mexico and CONAGUA identified 189 basins where water reserves could be established for ensuring e-flows as stated under the National Water Law. These reserves were defined as watersheds with high biological richness, high conservation values, availability of water, and low water use pressure. In 2016, CONAGUA identified 167 additional suitable potential water reserves that are hydrologically and administratively connected to the initial 189 basins, bringing the total number of basins that are currently part of the NWRP to 356 (WWF 2017). Pilot studies in six of the reserve zones were conducted to determine e-flows using the Voluntary Norm. On 15 September 2014 the first EWR decree was signed by the president: it included 11 river basins in the San Pedro Mezquital hydrologic sub-region, including the San Pedro Mezquital River (WWF 2017). The EWR decree outlines three types of reserves: one for domestic water use, another for hydropower generation, and the third for environmental water. The EWR decree regulates any proposed infrastructure projects related to water, which must prove that they will not exceed the EWR and negatively affect flow. Additionally, development must comply with parameters for sediment and the protection of social resources related to indigenous people's rights and lands (Moir *et al.* 2016). The EWR decree links for the first time the issuance of water rights and environmental protection (López Pérez, pers. comm. 2017). Decrees for the remaining basins are expected to be completed by the end of 2018 (Moir *et al.* 2016, WWF 2017). In addition to ensuring e-flows, decrees provide a framework for conditions authorising environmental, social and economic water uses, and aim to provide water security for the next 50 years (Moir *et al.* 2016).

THE SAN PEDRO MEZQUITAL RIVER IS FREE-FLOWING WITHOUT ANY SIGNIFICANT INFRASTRUCTURE

The San Pedro Mezquital River is unique. It is one of the few rivers that cross the western Sierra Madre, and the river is free-flowing without any significant infrastructure from the headwaters to the mouth (Moir *et al.* 2016). The headwaters of the San Pedro Mezquital River support small agricultural activities of three main indigenous populations. The mid-basin area supports large agricultural activities and cattle rearing and is where the largest impacts of the river are seen (Vázquez, pers. comm. 2017). At the downstream end of the San Pedro Mezquital River is the biggest wetland in Mexico, Marismas Nacionales Biosphere Reserve (hereafter Marismas Nacionales), which has been recognised as a wetland of international significance under the Ramsar Convention. The wetland is highly productive and is comprised primarily of a 200,000 hectare mangrove forest in a natural region of more than 480,000 hectares of hydro-geomorphological linkages (Blanco *et al.* 2011). A state-owned hydropower company, Comisión Federal de Electricidad (CFE), constructed three large dams on the Santiago River (in the neighbouring basin) that affected the southern end of the wetlands. The San Pedro Mezquital River provides nearly one-fifth of the flow to the entire wetlands natural region. However, it represents 44% of the remaining free-flowing freshwater discharge, thus provision of flow and sediment from the San Pedro Mezquital is crucial for the health of the wetlands and the freshwater shrimp, fish and bird species that live in them. The river and the livelihoods of those living alongside it are heavily reliant on rains during the wet season (June to October). During high flows, the river supplies water and nutrients to the Marismas Nacionales, and deposits nutrient-rich sediment across its floodplain, supporting agriculture and fisheries for the surrounding local communities (Moir *et al.* 2016). The San Pedro Mezquital River is also very important to local indigenous people, as it provides the focal point for many of their ancestral customs and ceremonies.

3.7.2 Implementation of e-flows on the San Pedro Mezquital River

A proposed dam on the San Pedro Mezquital River, Las Cruces, prompted concern from multiple groups including CONAGUA and WWF over the effect of the development on the wetlands and people that rely on the river. The decision was made to establish an EWR decree for the San Pedro Mezquital River that dictated the amount of water needed to maintain a suitable hydrological regime (Salinas-Rodríguez and Barrios, pers. comm. 2017). The decree for e-flow in the San Pedro Mezquital River was the first for the seven rivers that feed into the Marismas Nacionales. The 2010 management plan includes the goal of establishing water reserves in the other six rivers (Vázquez, pers. comm. 2017). As described above, the San Pedro Mezquital River was one of six pilot studies undertaken to prove the concept of EWR decrees in Mexico (Salinas-Rodríguez and Barrios, pers. comm. 2017). For the six pilot studies, WWF and CONAGUA worked together with local water-users to develop e-flows through an interdisciplinary effort (Vázquez pers. comm. 2017). E-flows were initially determined using both hydrological and holistic methods to evaluate their performance and assist in the development of an e-flow standard (the Mexican norm). The goal in the case of the San Pedro Mezquital River was to preserve the greatest amount of water possible for the wetland.

In addition to the e-flow assessment, an analysis was completed to evaluate the costs and benefits of reserving water for the environment to prove its effectiveness as a regulatory instrument. The cost-benefit analysis showed that water for the environment would improve the socio-economic position of the people living there, as for every US$1 of cost there are approximately US$3,500 of ecosystem services, such as benefits to agriculture and fisheries (Salinas-Rodríguez and Barrios, pers. comm. 2017, Salinas-Rodríguez, pers. comm. 2017). The resulting decree includes reserved water for the environment as well as water supply for villages, towns and cities (López Pérez, pers. comm. 2017). The proposed Las Cruces hydropower dam along the San Pedro Mezquital River has been put on hold because it could not fulfil the e-flow requirements set out in the decree and 17 other conditions listed in the environmental impact assessment resolution (Salinas-Rodríguez and Barrios, pers. comm. 2017).

Barriers to implementation

IT WAS A CHALLENGE TO DEMONSTRATE THAT ALLOCATION OF WATER FOR THE ENVIRONMENTAL WAS NOT A COMPETITOR TO OTHER WATER USES

Initially there was an issue with institutional capacity for water management. Historically, the government implemented a system of water rights where CONAGUA issued water permits to all water-users in Mexico, with a poor understanding of e-flows, a lack of data, and an insufficient number of administrative officers. It was also a challenge to demonstrate that allocation of water for the environment was not a competitor to other water uses. Senior decision-makers (often engineers) needed to be convinced that letting water flow is not a waste for society because it provides ecosystem services. There remain detractors today; however, there is now a national movement to develop EWRs for the whole country (Salinas-Rodríguez and Barrios, pers. comm. 2017).

In conjunction with the lack of institutional capacity, there were other institutional barriers that hindered the development of e-flows. In the past, CONAGUA (the agency responsible for water allocations) and CONANP (the agency responsible for protected areas) did not communicate effectively. With the support of WWF and other stakeholders the two organisations worked together to develop e-flows (Vázquez, pers. comm. 2017). Another institutional barrier occurs when there is a change in the people who make decisions. As new people are elected to government or people change jobs there is a need to educate them on the procedures and reasoning behind implementing e-flows (Salinas-Rodríguez and Barrios, pers. comm. 2017).

Presently, the largest barrier to the implementation of e-flows in Mexico is financing for the NWRP. Although the process is established in national programmes, there are still problems in securing budget allocations to finance the studies to support the issuance of the EWR decrees and the follow-up monitoring studies (López Pérez, pers. comm. 2017).

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Enabling factors

One of the key enabling factors in the implementation of e-flows in Mexico was the enactment of the National Water Law in 1992. This law recognised the environment as a legitimate user of water; however, many years passed between the enactment of the legislation and the reserving of water for the environment that began in earnest in 2010. The main cause of the hiatus was the lack of an official regulatory instrument to determine e-flows. The development and publication of a national standard for determining e-flows was therefore an essential step in allowing implementation to move forward in different regions. Prior to this there was a lot of discussion about which methods to use, but that hindered the process from moving forward (Salinas-Rodríguez and Barrios, pers. comm. 2017).

WWF-Mexico was instrumental in leading the process to develop the e-flow standard, but it involved many groups including CONAGUA, CONANP, regional and local governments, the basin councils, and other NGOs. This broad, collaborative approach led to wide support for the environmental standard and subsequently for the NWRP to establish environmental water reserves (López Pérez and Vázquez, pers. comm. 2017).

WWF-Mexico was instrumental in developing the conceptual framework for the cost-benefit analysis, advancing the national standard for determining e-flows and helping to secure funding for the EWR programme. It has therefore acted as a champion for the e-flow movement in Mexico since 2004.

Triggers for action

There was not one particular trigger that led to action on e-flow implementation in Mexico or the San Pedro Mezquital River specifically: the stakeholders interviewed for this case study pointed to various events that led to change. From the perspective of the agency responsible for water allocation, CONAGUA, a meeting between CONAGUA, WWF and international funding agencies at World Water Week in Stockholm in September 2010 inspired the development of the NWRP and the process by which EWR decrees would be issued to secure water for the environment. Other factors that triggered action by CONAGUA were an audit of the organisation that examined areas that could be improved where no action was yet being taken; and discussions over how water availability would be affected by climate change at the Conference of the Parties 16 (COP 16) of the UN Framework Convention on Climate Change in Cancun, Mexico in December 2010. These discussions led the director of CONAGUA to push the NWRP process forward, to understand where water availability was being affected, and to develop climate change adaptation measures (López Pérez, pers. comm. 2017).

From the WWF perspective, the two key triggers for change were the success of the pilot studies in demonstrating that securing e-flows was possible, and the cost-benefit analysis that showed that the benefits of leaving water in the river outweighed the costs. By demonstrating that e-flows could be secured even in arid areas, the programme was able to dispel the myth that Mexico does not have enough water to be able to allocate any for the environment (Salinas-Rodríguez and Barrios, pers. comm. 2017).

Another trigger that prompted action in the San Pedro Mezquital River watershed was the proposal for a hydropower dam, Las Cruces, on the river. This proposal brought various stakeholders together to evaluate the likely impacts of the dam (Vázquez, pers. comm. 2017).

Monitoring and assessing success

WITHOUT THE ENVIRONMENTAL WATER RESERVE DECREE, THE WATER WOULD NOT BE RESERVED FOR ECOLOGICAL PROTECTION

The implementation of the NWRP in the San Pedro Mezquital River is being monitored by CONANP. Hydro-morphological indices, biological indices and physio-chemical indices are being integrated into monitoring of the EWR and the Protected Areas Management Plan. There is a hydrological station 30km upstream of the mouth of the San Pedro Mezquital River to monitor flow, with changes in salinity and sediment transport and deposition also being monitored. Biological monitoring is focused on the mangroves (Salinas-Rodríguez and Barrios, pers. comm. 2017). Monitoring of social indicators is also conducted by a local NGO (Nuiwari A.C.), which reports that indigenous groups are still holding cultural events and ceremonies associated with the river.

Despite Mexico being in the early stages of implementation, many EWR decree successes could be reported. The issuance of the decree for the San Pedro Mezquital River can itself be viewed as a success. Without the document the water would not be reserved for ecological protection – and the fact that the decree extends for 50 years means there will be protection of water for the environment, but also for public water supply and hydropower, for a long period of time (Vázquez, pers. comm. 2017; Salinas-Rodríguez and Barrios, pers. comm. 2017).

Another major success was proving that implementing e-flows was feasible to those who thought the process would not be worthwhile. Now that the groundwork has been laid in the San Pedro Mezquital River and other pilot studies, the implementation in other watersheds will be a more streamlined process. The initial goal of the NWRP was to issue at least 189 decrees to preserve water for the environment, but analysis now suggests that more than 300 basins will have e-flows decreed in the next couple of years (López Pérez, pers. comm. 2017). Thus far, eight pilot zone e-flow assessments have been conducted in different areas of Mexico for 54 river basins covering 111,000 sq km of surface area with a combined environmental water reserve of more than 51,000 million m^3 per year (~10% of Mexico's total mean run-off), 40 aquifers, 20 natural protected areas, and 16 Ramsar sites.

There have been 136 flow-dependent species directly considered in the e-flow assessments, with 605 endangered species (not all flow-dependent) expected to benefit. The NWRP was successful in involving a wide variety of people in the process of developing and implementing e-flows, with the participation of 92 institutions and 183 experts in a variety of fields (Salinas-Rodríguez and Barrios, pers. comm. 2017). The goals of the NWRP have also been integrated into other programmes such as the National Development Plan and the National Climate Change Plan (López Pérez pers. comm. 2017).

Finally, WWF has presented the Mexican NWRP as an example to South American countries (Bolivia, Colombia, Ecuador, Guatemala, Perú and more) seeking to develop similar environmental water reserve programmes.

LESSONS

1. E-flows can protect rivers that are not water-stressed. These rivers present an opportunity to set sustainable levels of water extraction before over-allocation becomes an issue.

2. It is important not to get too invested in a discussion about the suite of methodologies that could be used until the principles and purpose of implementing e-flows (e.g. protecting a natural area, protecting an endangered species, restoring flows, protecting an economic generator such as power generation or agricultural production) have been determined. The purpose of implementing e-flows in a particular watershed, and current conditions in the watershed, are important factors in determining the appropriate methodology.

3. There are challenges to the process of determining and implementing e-flows but these challenges can be overcome, even in arid or water-stressed basins. A demonstration of this can be used to spur action in other rivers and regions.

4. The development of guidance on e-flow assessment methods can provide certainty in approved approach and thus overcome a barrier to implementation.

5. It is advantageous when the agency responsible for water allocation has a legal mandate or motivation to protect the environment. In this case many years elapsed from the enactment of the Water Law in 1992 before CONAGUA and CONANP collaborated to protect environmental flows in protected areas. When the agency responsible for water allocation has a mandate or motivation to protect e-flows, e-flow protection can readily be integrated into allocation decisions. A corollary to this is the importance of having a champion within the water allocation agency to drive the process of e-flow implementation forward.

6. It is necessary to engage water users – in this case indigenous and agricultural communities – in implementation of e-flows from the beginning of the process. The users must understand the process and the benefits to be invested and supportive. Without this support, implementation success will not be achieved.

7. It is important for each stakeholder to understand the role that they play in e-flow assessment and implementation. In Mexico, the federal agencies allow the academic sector and NGOs to conduct e-flow assessments based on science, then the regulators use the results to implement e-flows or integrate them into the allocation system. The National Commission for Protected Areas integrates e-flow regimes into the National Protected Area Management Plans. WWF, other NGOs and the academic sector have promoted and developed a network of e-flow experts to share assessment outcomes in scientific congresses in Mexico and internationally.

8. Funding for the EWR programme was secured from the IDB, WWF, and Alliances of WWF-Gonzalo Río Arronte Foundation and WWF-Carlos Slim Foundation through the collaborative efforts of WWF and CONAGUA. The involvement of CONAGUA was a significant factor in acquiring the level of funding required for the development and implementation of the programme. Collaborative efforts are therefore important in acquiring the necessary resources, as well as facilitating successful implementation through stakeholder buy-in.

3.8 POONCH RIVER, PAKISTAN

THE RIVER

The Poonch River originates in the western foothills of the Pir Panajal mountain range before running through the Poonch River Mahaseer National Park.

THE ISSUE

The Gulpur Hydropower Project (HPP) is being developed 50km upstream of the Mangla Dam within the Poonch River Mahaseer National Park, mainly to supply energy to people residing in nearby towns. The planning, initial environmental and social impact assessment (ESIA) and project approval occurred in the absence of an e-flow assessment and without the involvement of international funding agencies.

THE RESPONSE

The international funding agencies, the Asian Development Bank (ADB) and the international finance corporation (IFC) for the Gulpur HPP have very strict environmental regulations and required an e-flow assessment due to the presence of two globally-threatened fish species in the National Park. The project developer (Mira Power Ltd.) contracted consulting firms to conduct the e-flow assessment using a holistic approach (DRIFT method). The assessment was reviewed by the Environmental Protection Agency (EPA) for Azad Jammu & Kashmir, the Department of Fisheries and Wildlife, the Himalayan Wildlife Foundation (HWF), and WWF-Pakistan. Through extensive stakeholder engagement, review and alterations to the project design, and the development of a biodiversity action plan, the project was approved and allowed to move forward. The Gulpur HPP is considered an ecologically sustainable hydropower project in the region, and the process of its development has set the stage for future hydropower developments in the area.

INTERVIEWEES

Jahanzeb Murad – Environmental and Social Manager with Mira Power (a subsidiary of Korea South East Power)

Mark Kunzer – Director, Private Sector Operations Department, ADB (international funder of the Gulpur HPP)

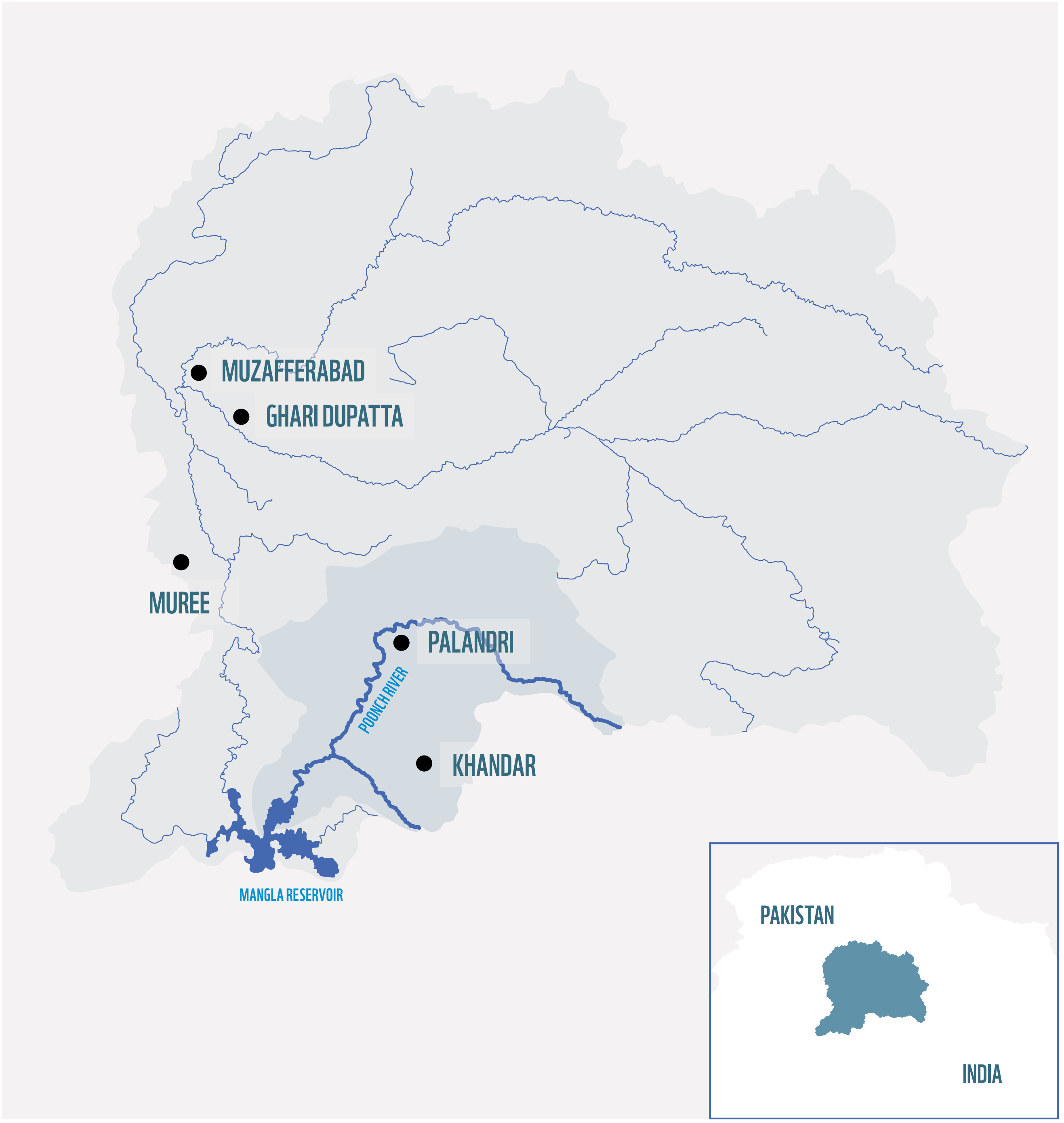
Muhammad Razzaq – Director General of Environmental Protection Agency for Azad Jammu and Kashmir

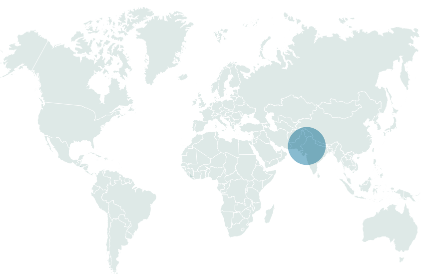
In addition to the above interviewees, we would like to acknowledge Jackie King and Vaqar Zakaria for their recommendations on suitable participants and their assistance in providing contact details.

KEY FINDINGS

International funding agencies can play a critical role in sustainable resource development in developing countries through application of strict environmental standards. A strong legal framework is also necessary to uphold the environmental conditions set on projects.

A solid technical justification based on sound science is crucial to support proposed development. A comprehensive, holistic approach for determining e-flows allowed for an evaluation of a number of different developmental scenarios and their impact on the environment, while also allowing the assessment of social, cultural and economic factors.





3.8.1 Background

The Poonch River originates in the western foothills of the Pir Panajal mountain range. It is a major tributary of the Jhelum River, which it joins at the Mangla Dam reservoir. The reservoir is one of the major fish-producing water bodies in Pakistan. Flows in the Poonch River are highest during summer and are driven by snowmelt followed by monsoon rains (HBP 2014). The ~100km stretch of the Poonch River that runs within Pakistan-administered Kashmir is located in the Poonch River Mahaseer National Park. The park was designated in 2010 and is recognised for its scenic beauty and high fish diversity relative to other rivers in the region.

The Poonch River is important for supporting fish of both conservation and economic importance: the endangered mahaseer (*Tor putitora*) and the critically endangered Kashmir catfish (*Glyptothorax kashimirensis*). The mahaseer has suffered a dramatic decline in population size and is listed as an endangered fish species (IUCN Red List 2013.) The largest stable population of the mahaseer is found in the Poonch River, which provides breeding grounds for the species. Pressures on the river within the poorly-funded National Park include sediment mining in the river, damaging non-selective fishing practices, removal of riparian vegetation, and nutrient enrichment from effluents (Brown *et al.*, submitted to *Journal of River Basin Management*).

FUNDING AGENCIES (IFC AND ADB) REQUIRED A SECOND ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

The Gulpur Hydropower Project (HPP) is being developed 50km upstream of the Mangla Dam within the Poonch River Mahaseer National Park, mainly to supply energy to approximately 113,000 people residing in nearby towns. The planning, initial Environmental and Social Impact Assessment (ESIA), and project approval occurred in the absence of an e-flow assessment and without the involvement of international funding agencies. When the developer, Mira Power Limited, approached the funding agencies (ADB and IFC) critical habitat thresholds were triggered due to the presence of the two globally-threatened fish species in the National Park (IFC 2012). A second ESIA was completed to satisfy the funders' compliance criteria: this included an e-flow assessment, extensive stakeholder engagement, review of the project design, and development of a biodiversity action plan (HBP 2014, HBP 2015).

3.8.2 Implementation of e-flows on the Poonch River

The DRIFT e-flows assessment method was used as a holistic approach to evaluate more than 20 different scenarios with different minimum flow releases; three levels of future management aimed at reducing the non-flow-related pressures on the system; peaking versus base flow operation; options for reducing the length of the diversion reach between the weir and tailrace; and options for turbine selection (King *et al.* 2003, Brown *et al.*, submitted to *Journal of River Basin Management*). The full range of scenarios was presented to stakeholders including local community members, government officials, Mira Power, the Pakistan Power Authority and representatives from the funding organisations. The stakeholders used the findings of the DRIFT assessment, along with an economic analysis of power generation, to come to an agreement on a change in the turbine design and operating rules for the Gulpur HPP. The e-flows assessment was reviewed by the Environmental Protection Agency (EPA) for Azad Jammu & Kashmir, the Department of Fisheries and Wildlife, the Himalayan Wildlife Foundation (HWF) and WWF-Pakistan, and the international funding agencies, and approved on the condition that the Biodiversity Action Plan would ensure a net gain in key fish species through the establishment of a fish hatchery to stock the river reach downstream of the project (Brown *et al.*, submitted to *Journal of River Basin Management*). The Biodiversity Action Plan requires commitments from the government to implement conservation measures, participation of environmental groups and communities in implementing independent monitoring, and designation of the financial commitments made by Mira Power (Brown *et al.*, submitted to *Journal of River Basin Management*). The measures incorporated into the Biodiversity Action Plan resulted in the approval of project financing by the ADB and IFC. The Gulpur HPP is considered an ecologically sustainable hydropower project in the region and the process of its development has set the stage for future hydropower developments in the area.

The results of the DRIFT e-flow study were critical to making informed decisions on the design and operation of the Gulpur HPP, and pointed to management actions required to achieve a net gain in key biodiversity values that triggered Critical Habitat requirements of the international lenders. The project design was modified to reduce environmental and social impacts by (1) relocating the weir closer to the powerhouse, which reduced the diversion reach from approximately 6km to less than 1km; and (2) changing turbine selection to Kaplan turbines that would allow greater operating flexibility under low-flow conditions (King, pers. comm. 2017). Additionally, key project operating rules were agreed upon by the stakeholders, such as (1) operating the Gulpur HPP for baseload power generation (i.e. no peaking power as originally planned); and (2) releasing a minimum flow of $4m^3/s$ for the shortened diversion reach between the weir and the tailrace. There was also an agreement for improved management interventions, with associated financial arrangements, to achieve high levels of ecosystem protection in the National Park. The management programme included funding in perpetuity for wildlife protection services staff to implement the Biodiversity Action Plan through the sale of electricity generated by the project. The Biodiversity Action Plan also called for the construction and operation of a fish hatchery to stock the river reach downstream of the Gulpur HPP tailrace with mahaseer, to allow for sustainable artisanal and recreational fishing.

Barriers to implementation

THE ENERGY CRISIS IN PAKISTAN RESULTS IN PRESSURE TO MAXIMISE POWER GENERATION

One barrier to e-flow implementation on the Poonch River is the energy crisis in Pakistan, which puts a lot of pressure on power regulators and purchasers not to compromise power generation (Murad, pers. comm. 2017). As a result, there is a conflict for developers between maximising power generation, and hence economic gain, and meeting environmental standards through the implementation of e-flows. In this case, the strict environmental safeguards imposed by the international funding agencies based on potential impacts to critical habitat for endangered species meant that the project could not have proceeded under the original design. Once projects are approved and constructed, it is also important that there is a strong legal framework in place that allows developers to be charged and brought before the tribunal if all environmental conditions imposed by the EPA of Azad Jammu & Kashmir are not met (Razzaq, pers. comm. 2017).

By using the DRIFT assessment method, all parties came to an agreement, and the holistic approach demonstrated that there would not only be environmental benefit, but also social benefit (e.g. resettlement of families would no longer be required, reduced noise and dust pollution from tunnelling). This detailed technical and holistic assessment was fundamental in getting the project approved: the assessment needed to demonstrate a net environmental benefit to the ecosystem to secure funding from the international funding agencies.

Another barrier to e-flow implementation in Pakistan in general is the lack of institutional capacity in government and power developers, and the general lack of pressure from the public or NGOs for environmental protection. The use of a holistic approach to reassess project design and determine suitable e-flows educated regulators, the developer and lenders as it was the first time that this process had been implemented at a project level in Pakistan (Murad, pers. comm. 2017). This has increased institutional capacity and streamlined the approval of subsequent projects; however, there is a concern that the lack of continuity in personnel in different institutions (EPA of Azad Jammu & Kashmir and the Department of Fish and Wildlife) will result in a loss of this capacity, which may slow future approval processes. Furthermore, there are a variety of power developers in Pakistan, not all of which have environmental teams, so protection of the environment is not always treated consistently. Additionally, there are very few organisations in Pakistan (except the IUCN and WWF) that take environmental issues seriously (Murad, pers. comm. 2017). The general public also tends to have little interest in environmental protection, with the focus being on social and economic conditions. Convincing the public that the environment is important is therefore a challenge (Razzaq, pers. comm. 2017). In this case, the experience of WWF and IUCN in other countries facilitated the development of a more sustainable project and helped increase the capacity of the other organisations involved.

Enabling factors

The influence of the international funding agencies (IFC and ADB) was an enabling factor for the Gulpur HPP moving forward in a sustainable manner. They required that stringent environmental performance standards be met by the project; these standards were the main driver behind the reassessment of the initial project design and a change to a more environmentally sustainable design (Kuzner, pers. comm. 2017). The requirement for international funding, along with a commitment by Mira Power to develop a sustainable project that took account of the valued ecological resources at the site, was critical for the project advancing beyond the design phase (Kuzner, pers. comm. 2017). Once Mira Power retained environmental consultants (Hagler Bailly and Southern Waters) to conduct the DRIFT assessment and identify potential solutions, the project was able to proceed (Murad, pers. comm. 2017). Also critical to the project's success was the collaborative, consultative process between the developer, funding agencies and consultants to make the project more sustainable through the evaluation of alternative design and management scenarios (Kuzner, pers. comm. 2017).

Triggers for action

The primary trigger for e-flows being implemented on the Poonch River was the National Park designation and the presence of endangered fish (especially the mahaseer and Kashmir catfish) and critical habitat (Murad, pers. comm. 2017). The ecological value of the site limited project development because lenders would not support construction without proper environmental protection. This necessitated finding a solution that would allow the Gulpur HPP to move forward, while having a net positive effect on the environment (Razzaq, pers. comm. 2017).

Monitoring and assessing success

MOVING THE WEIR AS A RESULT OF THE E-FLOW ASSESSMENT REDUCED SOCIAL IMPACTS INCLUDING RESETTLEMENT

Monitoring initiated as a result of the Gulpur HPP in the Poonch River includes environmental, social and economic parameters. The first-year results from environmental monitoring of six indicator fish species in the Poonch River demonstrated increases in all six in the time since protective measures have been implemented. Fish species richness has also increased (Murad, pers. comm. 2017). These positive results may to some extent be explained by warm winter temperatures and high survival rates of fry; however, the river wardens have also reported a dramatic decrease in the number of illegal fish activities observed (Kuzner, pers. comm. 2017). Long-term success will be measured through the ability of the Biodiversity Action Plan to improve habitat quality in the National Park and continued improvement in fish populations in the river (Kuzner, pers. comm. 2017).

Social and economic monitoring has also shown various successes that benefit the river and surrounding communities. One of the key successes of the holistic DRIFT assessment was to identify the option of moving the weir, which reduced the length of the diversion reach but also avoided the need to resettle a large number of people from the flooded area behind the weir. A reduction in the length of the tunnel required also reduced social impacts from noise and vibration during the construction phase (Murad, pers. comm. 2017). Social mobilisers also interacted with the local people during the construction phase to identify concerns and ensure they were swiftly addressed through corrective action. As part of its mandate, ADB regularly checks in on the performance of Mira Power in responding to local concerns (Kuzner, pers. comm. 2017). Social mobilisers will continue to interact with the local community as part of the Biodiversity Action Plan, helping people understand why the National Park was developed and should be protected. Social monitoring through the use of questionnaires shows that this is succeeding as there is an increased public awareness of protective measures for the river. Meanwhile, angler associations in the area have been pushing for the reduction of non-selective fishing methods and encouraging the issuance of recreational licences, which will bring additional income to the local community. Recreational fishing will be monitored by the Fish and Wildlife Department.

Monitoring has also shown that the availability of sand and gravel for the local community has increased and dust in the air has decreased due to the reduction in commercial gravel removal. Commercial mining licences are not being renewed in the Poonch River upon expiration, and no additional licences will be issued (Murad, pers. comm. 2017). Local artisanal mining operations will be maintained through the Biodiversity Action Plan but in a more sustainable way to maintain local livelihoods (Kuzner, pers. comm. 2017).

LESSONS

1. A solid technical justification based on sound science is crucial to support a proposed development. A comprehensive, holistic approach for determining e-flows allowed for an evaluation of a number of different developmental scenarios and their impact on the environment, while also allowing the assessment of social, cultural and economic factors. Holistic methods for setting e-flows are considered best practice for ensuring sustainable projects.

2. The strict environmental safeguards and standards of the international funding agencies were critical in moving this project forward to a more sustainable outcome. This highlights the leading role that international funding agencies can play in sustainable resource development in developing countries. A strong legal framework is also necessary to uphold the environmental conditions set on projects. Without this, there is no accountability.

3. It is important to take the time to develop the best project design at the planning stage. Accounting for environmental, social and economic factors in the early stages will ensure the most benefit and will reduce the number of issues that need to be addressed later. This can be achieved through collaborative efforts between developers, regulators, funding agencies, stakeholders and consultants.

4. Institutional capacity was a barrier to e-flow implementation: efforts must be made to share knowledge and expertise gained in other jurisdictions to improve decision-making, while factoring in local knowledge and concerns. Efforts must also be made to retain institutional capacity once acquired, to streamline future decision-making.

3.9 GANGA RIVER, INDIA

THE RIVER

The Ganga River is over 2,500km long, originating at the Gangotri Glacier in the Indian state of Uttarakhand in the central Himalayan mountains. The river drains into the Bay of Bengal via a large delta in the Sunderbans. The Ganga River and its tributaries drain a large, fertile basin of approximately one million sq km and support one of the world's most dense populations (WWF 2017a).

THE ISSUE

The central and state governments require adequate water levels and flows in the sacred rivers during socio-cultural events such as the Kumbh[4] in 2013.

THE RESPONSE

The state government of Uttar Pradesh made the decision to implement e-flows during Kumbh 2013 at Allahabad to ensure "desired flows and adequate water levels" for a successful cultural event. Various entities such as Uttar Pradesh Irrigation and Water Resource Department (UPI&WRD), Tehri Hydro Electric Corporation, scientists leading the development of the Ganga River Basin Management Plan (GRBMP) and conservation organizations, including WWF, worked with central and state governments to implement e-flows in the Ganga River in 2013. Water levels and flows were closely monitored throughout the three month event by UPI&WRD with daily reports to the Chief Secretary of the Government of Uttar Pradesh.

INTERVIEWEES

Vinod Tare- Professor at the Indian Institute of Technology Kanpur, Lead at the Centre for Ganga River Basin Management Studies, and Coordinator of the Ganga River Basin Management Plan.

A.K. Ojha- Former Engineer in Chief, Uttar Pradesh Irrigation and Water Resource Department (2012-2014).

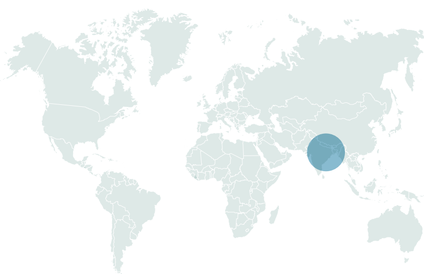
Niraj Agarwal- DGM-Designs, Tehri Hydro Electric Corporation, Rishikesh.

In addition to the above interviewees, we would like to acknowledge Nitin Kaushal and Suresh Babu of WWF-India for conducting the interviews for this case study.

KEY FINDINGS

This case study highlights how an important socio-cultural event can inspire different stakeholders (government, NGO, irrigators, hydro projects) to implement e-flows successfully for at least a short period of time. Kumbh 2013 provided an opportunity for the Government of Uttar Pradesh to demonstrate to the world how e-flows could be restored in the Ganga River for the benefit of people and nature. Political will for a successful cultural and spiritual event ensured its achievement. WWF-India and other stakeholders initiated a rapid assessment of e-flows for the Ganga River (during Kumbh at Triveni Samganga Allahabad), the recommendations were presented to the top-level departmental bureaucrats of the Government of Uttar Pradesh for implementation.

The challenge lies in gaining political will and stakeholder buy-in for long-term e-flows implementation.



3.9.1 Background

The Ganga River is over 2,500 km long originating at the Gangotri Glacier in the Indian State of Uttarakhand in the central Himalayan Mountains. The river drains into the Bay of Bengal via a large delta in the Sunderbans. The Ganga River and its tributaries drain a large, fertile basin of approximately one million square kilometres and support one of the world's highest density populations (WWF 2017a). The basin covers parts of Nepal, India, China and Bangladesh (WWF 2017b). The Ganga River is a trans-boundary river system and all the countries through which the mainstem passes are bound by an international treaty to ensure desired flow to the border of the next state (Ojha, pers. comm. 2017).The Ganga River basin has fertile soil and is important to agriculture in India and Bangladesh. The main agricultural crops grown in the area include rice, sugarcane, lentils, oil seeds, potatoes and wheat (WWF 2017a). Abstraction of water for irrigation has resulted in low flows in some of the upper reaches of the Ganga River (LeQuesne et. al. 2007).The Ganga River is home to over 140 fish species, 90 amphibian species and five areas that support bird species that are not found anywhere else in the world (WWF 2017b). The middle 475 km stretch of the Ganga River (including Allahabad) is biologically very productive due to high concentrations of nutrients, warm water, and the meandering nature of the river with low velocities and floodplains. The important species in the river stretch include: Rohu (*Labeorohita*), Catla (*Catlacatla*), Mrigal (*Cirrhinusmrigala*), Calbasu (*Labeocalbasu*), Gharyal (*Gavialisgangeticus*), the endangered Gangetic River Dolphin (*Platanista gangetica gangetica*), soft shelled turtles (*Aspideretesgangeticus*), and hard shelled turtles (*Kachugasp.*) (WWF 2013). The Ganga River has immense socio-cultural significance and is particularly sacred in Hinduism (WWF 2017b). Decisions made on the management of water in the river are often governed by the emotions of the masses (Agarwal, pers. comm. 2017); however, while the Ganga is revered by millions of people as a "holy river", this is not always translated into protective measures and the state of the Ganga River has degraded over the last few decades. On the other hand, the river supports the livelihoods and economic activities of many and the current political leadership is showing intentions of improving river health (Tare, pers. comm. 2017).

THE GANGA RIVER HAS IMMENSE SOCIO-CULTURAL AND ECOLOGICAL IMPORTANCE

3.9.2 Implementation of e-flows on the Ganga River

The mandate of the Uttar Pradesh Irrigation and Water Resource Department (UPI&WRD) is to regulate the river systems within the state of Uttar Pradesh to sustain irrigation systems dependent on the river. In addition, the UPI&WRD is also responsible for ensuring adequate flows in the Ganga River during socio-cultural activities throughout the year and those that come every year in January (Maagh-Mela) after every 6 years (Aardh-Kumbh) and after every 12 years (Kumbh) (Ojha, pers. comm. 2017). During these events, people gather to perform cultural rituals including bathing and worshipping, including Aachman (taking a few millimetres of Ganga River water into the mouth).Unless there is sufficient flow and adequate water levels in the Ganga River, the cultural rituals cannot be suitably performed and there would be widespread dissatisfaction from the public on the administration and local government.

UNLESS THERE IS SUFFICIENT FLOW IN THE GANGA RIVER, CULTURAL RITUALS CANNOT BE PERFORMED

Our case study examines the development and implementation of e-flows on the Ganga River in preparation for the Kumbh in 2013. The Kumbh attracted over 80 million people in 2013. The state government of Uttar Pradesh took action to ensure e-flows during Kumbh 2013 (January through March) to provide a satisfactory experience for residents and visitors, improve public well-being, and strengthen people's perception of the government (Ojha, pers. comm. 2017, Tare, pers. comm. 2017). The state government was motivated to do so because of pressure from various sectors of society, including religious leaders, local activists and lawyers, and conservation organizations such as WWF. In preparation for Kumbh 2013, an e-flows assessment for the Ganga River was conducted by a multidisciplinary working group including WWF-India, IIT – Kanpur, IIT BHU Varanasi, CIFRI Allahabad, PSI Dehradun, independent experts, and other technical institutions and NGOs. The assessment was conducted between December 2012 using the Building Block Methodology (BBM).

The Uttar Pradesh Irrigation & Water Resources Department (UPI&WRD) conducted another study in mid 2012 to assess the desired flow requirements which would provide adequate water levels for cultural rituals, including bathing (Ojha pers. comm. 2017).

The philosophy driving the e-flows assessment in this case was that e-flows studies should be a multidisciplinary social and scientific process, with social choices being the central issue (WWF 2013). Baseline socio-cultural surveys were conducted in 2012 for cities along the Ganga River by the People's Science Institute, Dehradun. These surveys sought to understand the social importance of the Ganga River in general terms, as well as specific desired water levels for Kumbh events to allow sufficient depth for spiritual bathing. The surveys focused on Allahabad, but spiritual leaders from other towns such as Haridwar, Rishikesh and Varanasi were also interviewed. The e-flows recommended based on these surveys were 225 m3/s for the entire duration of Kumbh, which corresponded to a depth of 1.2 m (close to the bank of the river) in Allahabad, and 310 m3/s on special bathing days (snan), which corresponded to a depth of 1.5 m (close to the bank of the river) in Allahabad (Kaushal 2015). Since hydrology data were not available, river cross-section surveys at 7 locations in and around Triveni Sangam area were conducted to establish water levels and understand the flows in the Ganga around Triveni Sangam, Allahabad (WWF 2013). Based on these data and information collected from surveys and secondary literature, the flows recommended to meet social requirements were also judged to be suitable from a geomorphological and biological perspective. The flows would maintain longitudinal connectivity and ensure that some bars remained submerged, while providing a mid-channel depth of approximately 4 m, which would be suitable for the important carp, turtle and river dolphin species for that time period. These species are present in Ganga in and around Triveni Sangam area in Allahabad. Once the assessment was completed, e-flows were recommended for the single dry season in which Kumbh 2013 took place and the results were presented to the top decision makers in the state of Uttar Pradesh (Tare, pers. comm. 2017).

The Tehri Project, managed by the Tehri Hydro Electric Corporation (THDC), is a multipurpose project for hydropower generation, domestic water, irrigation, and flood protection that provides water to the UPI&WRD from a reservoir to meet downstream water commitments. The Tehri Project is one of the key mechanisms by which flows can be enhanced in the Ganga River to meet downstream requirements, including irrigation and socio-cultural festivities (Agarwal, pers. comm. 2017). The key impediment to e-flows for the duration of Kumbh was competition for the water to provide irrigation for agricultural production (Ojha, pers. comm. 2017). In addition to the e-flow assessment led by WWF, UPI&WRD, the THDC also conducted an internal study prior to Kumbh 2013 to assess how desired water levels could be achieved for the duration of the event via different flow releases from the reservoir. Ultimately, it was realized that water levels could be maintained simply by modifying the operation of the irrigation canals, and reservoir releases by THDC were not necessary (Agarwal, pers. comm. 2017). The diverted water from Ganga for irrigation canals was carefully used such that adequate flows could be maintained in the river. For this to happen, the UPI&WRD informed the command farmers about this activity and the farmers were accordingly prepared.

Barriers to implementation

THE TEHRI HYDRO DEVELOPMENT CORPORATION WAS WILLING TO COMPROMISE POWER GENERATION TO RELEASE WATER TO THE GANGA IF NEEDED

It is increasingly acknowledged by the public and Government in India that e-flows during major socio-cultural festivities are critical,and short term e-flows requirements are therefore something that governments are willing to address. The critical barrier to implementing e-flows over the longer-term is a lack of political will, which is mainly due to the apprehension that reduced irrigation deliveries may lead to dissatisfaction amongst water users, mainly farmers (Tare, pers. comm. 2017). The first step that is required for long-term e-flows implementation is to facilitate improved irrigation water use efficiency, provide incentives for individuals or groups that demonstrate water saving techniques, and upgrade and remodel irrigation infrastructure to allow similar or even better levels of agricultural production with less water (Ojha, pers. comm. 2017). Farmers also need to be educated on the long-term benefits of providing e-flows to improve the health of the Ganga River. State and central governments would need to support longer-term e-flows implementation through policy changes, given the over-allocated status of the Ganga, but the political will, for this to be realised, is critical.

Enabling factors

The state government of Uttar Pradesh made the decision to implement e-flows during Kumbh2013 at Allahabad to ensure "desired flows and adequate water levels" for a successful cultural event (Tare, pers. comm. 2017). The central government extended extra funding and personnel to ensure a successful event (Ojha, pers. comm. 2017). The importance of the occasion prompted e-flows assessments by WWF and partners, as well as separate assessments by the UPI&WRD and THDC. E-flows recommendations from the WWF and UPI&WRD assessments were similar, and were agreeable to the state government (Tare pers. comm. 2017). The UPI&WRD implemented the government decision by improving the operation and regulation of irrigation systems associated with the Ganga River to ensure adequate flows during the entire period of Kumbh at Allahabad in 2013 (Ojha, pers. comm. 2017). Additionally, THDC was willing to compromise power generation to release water to the Ganga River, if needed to maintain flows for Kumbh; however, this was deemed unnecessary during the event.

Triggers for action

The key trigger for action for implementing e-flows in the Ganga River was the magnitude and importance of the socio-cultural festivity of Kumbh taking place on the banks of the Ganga at Triveni Sangam – Allahabad in 2013 (Agarwal, pers. comm. 2017). Organizing such events puts respective state government's reputation at stake, as scores of visitors and residents visit the banks of the rivers at identified sacred locations and perform cultural rituals. The desired water levels, adequate flows, and acceptable water quality in the river are a prerequisite for satisfactory performance of such rituals and if unsuitable would cause visitors to have a negative perception of local authorities. State authorities feel that it's their moral responsibility to ensure that the visitors and residents satisfactorily perform their rituals (Ojha, pers. comm. 2017). Courts were also applying pressure to ensure clean and adequate flows in the Ganga at Allahabad during Kumbh 2013 (Agarwal 2013).

There was also a growing understanding of the issue of flows in the Ganga River by conservation organizations and technical institutions that played a role in triggering the debate around e-flows for Kumbh 2013. Furthermore, there was a growing debate about Ganga rejuvenation that attracted media attention (Tare, pers. comm. 2017).

Monitoring and assessing success

E-FLOW REQUIREMENTS WERE MET FOR OVER 90% OF THE DURATION OF KUMBH 2013

Political leadership was very serious about providing a successful socio-cultural experience for visitors to the Ganga River during Kumbh 2013. Flow and water level was monitored on a daily basis by the UPI&WRD, who directly reported to the Chief Secretary of the Government of Uttar Pradesh. This close monitoring was a key to the success of maintaining e-flows through operational modifications to the irrigation canal system and marginal adjustments and curtailment of withdrawals for irrigation (Ojha, pers. comm. 2017). A perception survey was conducted during the entire duration of Kumbh 2013 to gauge visitor's satisfaction with their experience during the event, with the annual Maagh fair in 2014 surveyed in a similar manner (Kaushal 2015).

E-flows requirements were met for over 90% of the duration of Kumbh 2013 through the successful regulation of irrigation, without the need to augment flows with water from other sources (i.e., THDC reservoir releases, Ramganga flows, or Sharda Sahayak Canal flows; Ojha, pers. comm. 2017). Media reports of Kumbh 2013 were positive and the performance of cultural rituals by visitors on the banks of the Ganga River was generally satisfactorily performed for the duration of the festivities (Kaushal 2015). There were also no major complaints from farmers regarding reduced water delivery for irrigation, although rains during part of the event reduced irrigation demand (Tare, pers. comm. 2017). However, water quality in the Ganga remained a concern during Kumbh 2013 and solving this issue requires a long-term commitment by the authorities to address waste water treatment and the release of untreated waste water into the Ganga River.

In contrast to concern over low flows, there was an unprecedented rainfall in the upper Ganga catchment during Kumbh 2013 that threatened to flood temporary camps on the banks of the river where many visitors were staying. Water was successfully diverted by UPI&WRD into irrigation canals in the upstream Ganga to avert massive flooding. This flood water was run through the irrigation canals (wherever feasible) for a few days prior to being released into tributaries of the Ganga. Flow releases into Ganga River tributaries were also managed to avoid immediate enhancement of the water levels in the Ganga River at Allahabad (Ojha, pers. comm. 2017). This was seen as a great success in water management by avoiding impacts to visitors inhabiting the banks of the river for the event.

The successful implementation of e-flows during Kumbh2013 is a milestone in a larger journey towards sustainable management of the Ganga River Basin through long-term e-flows implementation (Tare, pers. comm. 2017).

LESSONS

1. E-flows can be implemented on a short-term basis to meet requirements for special cultural events.
2. Strong political will is required to implement e-flows and address water quality concerns over the long-term.
3. An assessment of the trade-offs associated with e-flows implementation should be conducted to get a clear picture of the implications for other existing water users and determine mechanisms by which effects can be mitigated. In this case, good planning and efficient use of irrigation canals meant that adequate flows were provided for Kumbh without adversely affecting farmers.
4. Be proactive, plan in advance, implement the plan and monitor ongoing activity to allow for adaptive management as required. In this case, heavy rains helped to address low flow concerns during Kumbh 2013 but having a plan in place, supported by monitoring data, allowed excess flows to be managed within the irrigation canal system such that flows within the Ganga River in Allahabad met e-flows targets. Reporting on the monitoring results is also important so that lessons can be learned for future e-flows implementation.
5. It is important to be adaptive and open to external ideas. For instance, the UPI&WRD and WWF and affiliates completed separate e-flows assessments but input was shared and the flows provided by UPI&WRD also met the e-flows recommendations of WWF.

4. LESSONS FROM THE PAST, PROSPECTS FOR THE FUTURE

The case studies undertaken for this project demonstrate that e-flow implementation is possible despite multiple challenges. In this section, we review the factors that have enabled successful implementation in our case studies, and the key triggers that stimulated action. We then delve deeper into the specific factors that enabled implementation challenges such as those identified by Le Quesne *et al* (2010) to be overcome, and place these factors in the context of wider water resource policy, planning and management frameworks. The importance of monitoring and adaptive management of e-flows is then discussed before we summarise the lessons learned from the case study review.

4.1 ENABLING FACTORS AND TRIGGERS

Throughout our case studies, we examined the factors that enabled implementation to occur. Table 3 describes the types of enabling factors identified as being important, along with examples demonstrating their importance.

The fundamental enabling factor that underpins most, if not all, cases of successful e-flow implementation is the existence of conducive legislation and regulation. The type of legislation and corollary regulation behind the implementation of e-flows varies greatly; however, the long-term protection or restoration of flows for the environment is dependent on there being a legislated framework within which to act. In broad terms, laws reflect the values of society, thus jurisdictions that have e-flows written into their laws and regulations have demonstrated a consideration and acknowledgment of the ecosystem services and values that rivers provide. We identify three principal types of legislation that have facilitated the implementation of e-flows:

1. **Water management legislation**
   If the governing entity responsible for water management (whether at national or state level) has set a standard or regulation that mandates e-flows, it can create a lot of momentum for both protection and restoration. In South Africa, for example, it was the National Water Act of 1998 calling for an ecological reserve of water; whereas in Mexico the National Water Law of 1992 recognised the environment as a legitimate user of water. Another legislative mechanism for protecting e-flows is to set a 'cap' or to 'close' a basin to any further or new uses, thereby implicitly reserving the remaining water for environmental purposes. A cap was set for the Murray-Darling Basin overall, followed by Sustainable Diversion Limits for individual sub-basins that have the effect of protecting all water remaining in the system once the limits are reached. In Europe, the Water Framework Directive provides a legislative basis for protecting the environment and support for monitoring that can detect ecological and hydrological changes in rivers.

2. **Endangered species or other environmental legislation**
   In the US, the Endangered Species Act has been the single most powerful lever for protecting and restoring e-flows. In Australia, commitments to both the Convention on Biological Diversity and the Ramsar Convention were used as the basis for the Commonwealth (federal) government to assume leadership for water decision-making in the Murray-Darling Basin, including the preparation of a basin plan that limits how much water can be extracted from any sub-basin.

3. **Regulations on dam operations**
   In the US, the licensing (and re-licensing) requirements set by the Federal Energy Regulatory Commission (FERC) have opened the door for e-flow advocates to set operating conditions that create desirable e-flow conditions. Other countries have similar regulatory or licensing frameworks. For example, regulations in China governing the operations of the Three Gorges Dam have been adjusted to provide e-flows for ecological, social and economic benefits.

ANOTHER ENABLING CONDITION IS THE EMERGENCE OF ONE OR MORE CHAMPIONS FOR E-FLOW IMPLEMENTATION

Although legislation is a fundamental factor behind e-flow implementation, in and of itself legislation is rarely sufficient. This is evident in the time elapsed between the enactment of legislation and the implementation of e-flows in some of the case studies examined for this report, and no doubt in many more cases across the world. For example, in South Africa the National Water Act was enacted in 1998, calling for the formation of catchment management agencies, but it was 2006 before the Inkomati-Usuthu Catchment Management Agency was formed (the country's first) and another five years before e-flows were implemented.

Therefore, another enabling condition is the emergence of one or more champions. A champion within a regulatory authority responsible for water allocation can be a powerful force, often spurring rapid action in response to initial triggers; however, the emergence of e-flow champions in other organisations such as NGOs can also greatly influence implementation. In the case of Mexico's environmental water reserves programme, a champion within WWF was successful in persuading the director of CONAGUA, the water allocation authority, of the value of protecting e-flows. The director of CONAGUA in turn spurred e-flow assessments in almost double the original target number of watersheds. Political champions for the e-flow cause can also help smooth the road to e-flow implementation. This is evident in the River Kennet case study where a ministerial ally to the local and national NGOs helped pass a Water Bill through parliament that was necessary for the e-flow restoration project to secure adequate funding. Champions in international funding agencies can also facilitate action through adherence to standards and the provision of funds, two of the other key enabling factors for successful e-flow implementation (Table 3).

Despite the importance of having an e-flow champion, successful e-flow implementation is by no means a solo effort. Collaboration is an essential ingredient for success, and many individuals and organisations have a role to play; however, each must enter into discussions willing to listen to diverse viewpoints, understand different values, and compromise often firmly-held positions. The roles that can be played by different organisations in successful e-flow implementation are explored more thoroughly in Section 4.4. Collaboration ensures that stakeholders understand the need for e-flows and how trade-offs are assessed. Without this understanding, the probability of successful implementation declines. This requirement often means that capacity-building is a necessary early component of e-flow assessment and determination processes, regardless of jurisdiction. For example, through the Sustainable River Program, The Nature Conservancy has trained ~800 engineers from the US Army Corps of Engineers on e-flow management at Corps dams across the US. Maintaining capacity and ensuring that institutional memory is retained then becomes an ongoing need for successful implementation.

COLLABORATION IS AN ESSENTIAL INGREDIENT FOR SUCCESS

In many examples of successful e-flow implementation the legal, institutional, resource and technical factors that enable successful implementation may be in place, but there is a specific event that triggers action. Often the trigger is a crisis, such as a drought, that highlights the critical nature of water availability and spurs action from individuals and organisations. In other cases, there is not one specific trigger, but a number of events that act together to result in change. The triggers that prompted change in the case studies evaluated can be classified into two types: responsive and proactive. Table 4 provides examples of these two types of trigger from the case studies explored in this report. Not surprisingly, many of the triggers for action on e-flows are the same as the triggers identified by Speed et al (2016) for action on river restoration.

In a general sense, responsive triggers can also be viewed as restorative (i.e. restoring flows to a river) and proactive triggers can be viewed as protective (i.e. protecting flows to avoid over-allocation). However, this may not hold true in all cases as a severe drought may spur action to protect flows in a relatively natural system to mitigate potential effects of future droughts.

Table 3. Enabling factors that support successful e-flow implementation

ENABLING FACTOR	DESCRIPTION OF FACTOR	EXAMPLE OF IMPORTANCE
Legislation and regulation	Laws reflect the values of society, thus jurisdictions that have e-flows written into their laws and regulations have demonstrated a consideration and acknowledgment of the ecosystem services and values that rivers provide.	A critical enabling factor in most e-flow implementation success stories, legislation played a particularly important role in the Murray-Darling Basin, Crocodile River, San Pedro Mezquital River, and River Kennet case studies.
Collaboration and stakeholder engagement and understanding	It is critical for successful e-flow implementation that the competitors for the water, and the agencies that will implement the e-flow prescription, are part of the decision-making process in setting objectives and determining appropriate flows.	Collaboration and buy-in to the process of determining and implementing e-flows is so critical that it was an important factor in all of the case studies examined for this report. Those responsible for implementing e-flows, such as water management agencies, hydropower operators or irrigators, have to buy in to the process otherwise they will continually fight and try to undermine it. Structured Decision Making[5] is a valuable process for such collaboration and provides a forum for reviewing available information, setting objectives, addressing uncertainty, evaluating trade-offs between competing demands, and making decisions.
Driving force – a champion	A champion is needed to drive the process forward; there are many challenges to e-flow implementation and to overcome these there need to be a person, or several persons, or an organisation pushing the process along and finding solutions.	One of the most prominent examples of champions in our case studies was Brian Jackson at the IUCMA in the Crocodile River case study. Other notable champions were the WWF teams in England and Mexico that campaigned for many years to secure e-flows in the River Kennet and San Pedro Mezquital River, respectively.
Technical knowledge, understanding and tools	E-flow implementation requires an understanding of the needs of the species or resource one is trying to protect or restore and how these needs relate to flow magnitude, timing, duration, frequency and rate of change. Tools are required to help managers make decisions on e-flows based on water availability and balancing the requirements of multiple water-users.	An example of the importance of this enabling factor is the work done by fish biologists and hydrologists in identifying the spawning locations of Chinese carp in the reaches downstream of the Three Gorges Dam, along with the important hydrologic indicators and their ranges for natural spawning that can be mimicked when designing e-flows. From a social perspective, the surveys carried out prior to Kumbh 2013 were important in determining appropriate flows for the spiritual rituals. The IUCMA uses decision-support and forecasting tools to manage e-flows in real time based on the available water in the Crocodile River. Similarly, the US Army Corps of Engineers uses real-time data collection and reservoir models to aid its releases of e-flow pulses from its dams.
Resources and capacity	Consistent funding for the technical studies and stakeholder engagement processes required to determine appropriate e-flows is a common barrier to e-flow implementation.	Given the funding requirements for e-flow assessments, stakeholder engagement, and e-flow management and monitoring, securing the necessary funding resources was a common challenge across case studies.
	Similarly, securing the necessary funding for e-flow implementation, monitoring and management is critical.	The resources to fund an e-flow implementation scheme were a critical factor in the River Kennet case study due to regulatory requirements that necessitated a change in legislation. Without legislative change, the Environment Agency would have had to compensate Thames Water directly for reducing its licensed water application. However, the levy on abstraction licences used to generate the compensation required would not have been sufficient to acquire the funds needed.
	Having the institutional capacity to understand the need for e-flows and how these are determined and monitored is an important factor in implementation.	The need for greater capacity was probably most pronounced in the Poonch River case study: here, the need for additional e-flow assessment was determined by an international funding agency (the Asian Development Bank), and the assessment was led by an international consulting firm from South Africa. However, building and maintaining capacity was a common requirement across case studies in developed and developing countries alike. Dedicated capacity within larger organisations can be deployed to implement e-flows on many rivers/sites, such as for the Sustainable Rivers Program supported by the US Army Corps of Engineers and The Nature Conservancy.
Standards and guidelines	Standards and guidelines on how to determine e-flows for ecological and socio-economic components, and what methods work best in different situations, are an important tool to streamline assessments and overcome barriers of capacity. Standards for monitoring the benefits of e-flow implementation are also important to facilitate the design of suitable monitoring programmes to enable adaptive management.	The publication of a national standard on e-flow assessment was a key enabling factor in the San Pedro Mezquital case study as it provided certainty over the approved approach. The importance of environmental standards set by international funding agencies was demonstrated in the Poonch River case study as adherence to these standards led to a more sustainable project design, which enabled the project to proceed.
Monitoring networks and adaptive management	Flow data are critical in determining natural flow levels and water availability. Physical, geomorphological, ecological, social and economic data are important in determining how the ecosystem and those who depend on it are responding to e-flow implementation, and to inform adaptive management.	The best example of adaptively managing e-flows based on data collected from a network of monitoring stations in our case studies is the Savannah River, where learnings over an 8 to 10-year period of test releases were used to refine e-flows. From a social perspective, monitoring of e-flow releases on the Ganga River during Kumbh 2013 demonstrated the success of that programme. Nonetheless, monitoring of ecological, social and economic benefits is an area that would benefit from further resources, analysis and reporting.
Reallocation and trading mechanisms	The ability to acquire water rights, through permanent sales or temporary leases, has enabled environmental organisations or governments to restore e-flows through purchases in some jurisdictions.	Having the ability to trade water rights has been immensely important in restoring e-flows in Australia and the western US. The Murray-Darling Basin has a well-established water-trading system allowing users flexibility to respond to variations in water availability. In the western US, the establishment of water banks has been an important mechanism in mitigating the effects of water abstraction through the purchase of senior water rights (Harwood *et al*. 2014).

Table 4. Typology of triggers for action.

TRIGGER TYPE*	TRIGGER	EXAMPLE
Responsive	Drought	Drought, or a series of droughts, was a key trigger that highlighted water availability issues in a number of our case studies: Murray-Darling Basin, River Kennet, Crocodile River, and Savannah River.
	Water supply shortage	Water supply shortages that were impacting economic production from irrigated agriculture acted as a contributing factor to water management reform in the Murray-Darling Basin and the Crocodile River.
	Environmental damage	Ecological impacts were a trigger for action in the Yangtze River, Murray-Darling Basin, and River Kennet.
	Impacts on human health	Salt intrusion into the urban water supply of a portion of the city of Shanghai helped to trigger e-flow releases from the Three Gorges Dam on the Yangtze River. Blue-green algae blooms were also a trigger in the Murray-Darling Basin, resulting in the setting of a cap on issuance of water entitlements and the eventual Sustainable Diversion Limits that protect flows.
	Political or institutional motivation	Politics, or institutional pressures, can also trigger action. In the Crocodile River case study, the need for the IUCMA to prove itself as a new institution capable of successfully managing water was a highly motivating factor for innovation. Similarly, an audit of the Mexican water management authority, CONAGUA, also inspired action on the Environmental Water Reserves programme.
Proactive	Response to anticipated pressures	E-flow assessment and implementation were triggered in the San Pedro Mezquital River and Poonch River, in whole or in part, due to proposed hydropower developments.
	Significant cultural/social events	An e-flow assessment was undertaken for the Ganga River to ensure that desired flows and adequate water levels were present during Kumbh 2013 at Allahabad. Any high-profile event involving a river (e.g. paddling races, fishing competitions) can be used to demonstrate and promote e-flows.
	Climate change	Concerns over the effects of climate change on water availability were a trigger for action on the San Pedro Mezquital River and the broader Environmental Water Reserves programme in Mexico.

*The emergence of a champion for e-flows can drive change in either a responsive or proactive manner.

4.2 OVERCOMING IMPLEMENTATION CHALLENGES

As noted in the introduction (Section 2.4), a number of international reviews have assessed e-flow implementation challenges (Moore 2004, Hirji and Davis 2009, Le Quesne *et al.* 2010). Le Quesne *et al* identified three principal, related obstacles:

- A lack of political will and stakeholder support;
- Insufficient resources and capacity; and
- Institutional barriers and conflicts of interest.

In the following sections, we draw on this project's case studies to provide examples of how each of these challenges can be overcome. In doing so we focus where possible on the roles played by key stakeholders and decision-makers in making implementation happen. We note that these examples are not intended to provide guidance on how to solve similar challenges in all contexts; successful implementation will depend on system- and jurisdiction-specific attributes. Nevertheless, the following provides some examples of what has worked in the past, and will be used in conjunction with the preceding discussion to discern several common truths about successful e-flow implementation in Section 4.4.

4.2.1 Political will and stakeholder support

As noted in Section 4.1, legislation and regulation are critical enabling factors in e-flow implementation, thus the political will to introduce or enforce regulations that protect or restore e-flows, and to provide sufficient resources to management agencies, is a key element to success. As evidenced by several of our case studies, and noted by Le Quesne *et al* (2010), the passing of ambitious laws does not necessarily result in the implementation of e-flows, as on-the-ground actions typically face many politically challenging realities and conflicts between water uses. It is for this reason that stakeholder support is so essential to success, and why it is critical that all interests for the water, and the agencies that will implement the e-flow prescription, are engaged and part of the decision-making process. Otherwise, the implementation process will either be undermined by water-users unsupportive of e-flows, or not enforced by the agencies responsible for oversight. A critical early step in the implementation of e-flows where stakeholders can make an important contribution is the setting of environmental objectives. The process of reaching agreement on realistic, achievable, flow-related objectives that most people can support is a pre-requisite for successful e-flow implementation. Objectives are likely to be different for different rivers, or even parts of the same river, and will depend on the political, social, economic and ecological context (O'Keeffe, pers. comm. 2017).

A CRITICAL EARLY STEP FOR STAKEHOLDER ENGAGEMENT IS IN THE SETTING OF E-FLOW OBJECTIVES

One tool used to generate political will and stakeholder support within our case studies was the cost-benefit analysis performed by WWF in Mexico as part of the pilot case studies for the Environmental Water Reserves programme. This analysis demonstrated that in the case of the San Pedro Mezquital River, the overall benefits of protecting ecosystem services through the implementation of e-flows greatly outweighed the costs. This analysis became a persuasive tool when generating support for the programme within the water management agency, CONAGUA, where many felt that letting water flow within the river would be a waste to society. The analysis was also valuable in generating stakeholder support by demonstrating the socio-economic benefits of e-flows to the poor inhabitants of the watershed. Such analyses which account for all interests can also assist in securing resources from international funding agencies by illustrating the potential benefits of such a programme.

An example of when a lack of stakeholder support can derail efforts to implement e-flows is in the Crocodile River case study. In this case, target e-flows developed by the national Department of Water Affairs were significantly higher than recent actual flows during the low flow periods, leading irrigation stakeholders to refuse to implement them. This led to the IUCMA, specifically the Water Resources Planning and Operations Manager, Brian Jackson, starting a dialogue with the irrigation sector and the KNP to discuss appropriate objectives for the river and develop a new unofficial e-flow regime that better mimicked current flows. This unofficial e-flow regime was agreed to by the stakeholders and then by the Department of Water Affairs. The collaborative process used to engage stakeholders and the decision support tools used to facilitate water management resulted in an improvement in e-flow targets being reached, even during a recent drought. An inclusive, open and transparent process for determining e-flows is necessary to understand how infrastructure such as dams or diversions may impact downstream ecosystems or other water-users – either directly or indirectly – through impacts to ecosystem services (Parker and Oates 2016).

As a result of the numerous challenges in reallocating water from existing rights-holders, it is best if e-flows are protected as a reserve or a cap on allocations whenever possible, and to implement such a cap or reserve well before the water becomes over-allocated. This will be far more politically expedient and cheaper to administer than the reallocation or reduction of existing rights, or the enforcement of regulations against multiple users. The San Pedro Mezquital River case study is an excellent example of protecting e-flows before they are over-allocated. The presidential decree in this case includes conditions that provide a clear framework for authorising future water abstraction. In contrast, the case studies on the River Kennet, Murray-Darling Basin and Crocodile River demonstrate some of the challenges that can be faced when attempting to reallocate or reduce existing rights.

4.2.2 Resources and capacity

A lack of resources and/or capacity was a common barrier across many of this report's case studies, as it was in the 20+ case studies examined by Le Quesne *et al* (2010). The fact is that e-flow determination, implementation and management requires the assembly of data, individuals trained in a number of different fields, the coordination of stakeholders and experts, the use of decision support tools, and government managers to license and enforce standards. In complex situations with multiple users of water or the necessity to reallocate water, experienced facilitators are also required to balance conflicting needs and facilitate the generation of solutions that stakeholders can all support. These tasks require sustainable funding over many years and the ability to retain those that have developed the capacity to determine, implement, enforce and manage e-flows. A common trend across our case studies, both in developed and developing countries, was the learning and understanding that was gained by those involved and the disappointment that such knowledge often had to be re-taught as a result of turnover, particularly in government agencies.

INTERNATIONAL EXPERIENCE CAN HELP ADDRESS LACK OF CAPACITY IN E-FLOW ASSESSMENT AND IMPLEMENTATION

One remedy to the lack of capacity in determining e-flows is to harness the capacity of international organisations that have experience in conducting e-flow assessments in a diverse array of scenarios and climates. This approach was taken in the Poonch River case study as Mira Power hired both a local consultant, Hagler Bailly, and a consulting team from South Africa, Southern Waters, that was experienced in conducting the DRIFT e-flow assessment. The DRIFT e-flow assessment was critical in engaging stakeholders and reviewing a number of operational and management scenarios that allowed an optimal design for the Gulpur Hydroelectric Project to be identified and approved. The combination of outside expertise to manage the e-flow assessment process and local expertise to distil knowledge on the basin and its resources is a collaboration that is expected to prove valuable in many similar scenarios. WWF staff were also involved and supportive of the e-flow assessment process for the Gulpur project; NGOs with a global reach such as WWF or The Nature Conservancy can also be an excellent resource to provide technical analysis, facilitation and other valuable forms of support.

The Savannah River case study also illustrates the value in building capacity within large implementing organisations, such as the US Army Corps of Engineers' engagement in the multi-basin Sustainable Rivers Program with The Nature Conservancy. Many dam engineers and reservoir operators have been trained in workshops on the importance of e-flow releases from dams, and strategies for 're-operating' reservoirs to provide e-flow releases.

Another important note with respect to capacity is that the e-flow prescriptions must be understandable to managers and stakeholders. The more scientific, detailed and holistic e-flow assessments become, the less non-specialists understand the scientific underpinning of how flow recommendations are generated and trade-off analyses are conducted, and thus the prescriptions become less likely to be supported and implemented (O'Keeffe, pers. comm. 2017). Moreover, in some situations the simpler the e-flow prescriptions, the more likely they are to be implemented. Nonetheless, there are situations where more extensive data, more complex decision-support tools, and more involved decision-making processes will be required. In such cases, all stakeholders must agree to the process by which the more complex issues will be resolved and the funds required, and understand the tools and analysis that will be used to evaluate the trade-offs between different scenarios.

Another effective strategy to build capacity and improve implementation is to involve the eventual e-flow implementers in the e-flow design process from the beginning. In the Savannah River case study, the engineers responsible for managing dam releases participated in a number of workshops in which scientists and other technical experts discussed and debated the e-flow prescription for the river.

With respect to resourcing e-flow determination and management, there is no doubt that effort and innovation are required to secure sustainable financing. Many jurisdictions have specified e-flow needs, or mandated their provision, but they never get implemented because there is not a clear and agreed-upon pathway to implementation. It is therefore very important that a clear pathway exists from e-flow specification to implementation and that any costs associated with proper implementation are explicitly addressed, otherwise e-flows become an 'unfunded mandate'.

E-FLOW RECOMMENDATIONS MUST BE UNDERSTANDABLE TO MANAGERS AND STAKEHOLDERS

As noted in Section 4.1, the emergence of an e-flow champion can act as a trigger for action and can also be an important factor in obtaining sufficient resources to initiate and sustain the programme. Our case studies demonstrate there are a variety of approaches that have been adopted to supplement government funding:

1. **International funding agencies and NGO foundations:** The Inter-American Development Bank, WWF, and alliances of WWF-Gonzalo Río Arronte Foundation and WWF-Carlos Slim Foundation supported the establishment of the Mexican environmental water reserves programme. Similarly, The Nature Conservancy contributed to the funding of the Phase II Drought Study on the Savannah River along with the federal government and the state governments of Georgia and South Carolina.

2. **Market-based mechanisms:** The use of market-based mechanisms for the reallocation of water rights has been effective in the Murray-Darling Basin and the western US. However, there are several critical considerations that must be taken into account to avoid adverse economic and other social impacts, such as impacts on local agricultural economies and communities resulting from large transfers of water from irrigated agriculture to the environment (Garrick et al. 2009 quoted in Le Quesne et al. 2010).

3. **Developer-led funding initiatives**: In the Poonch River, the developer Mira Power funded the e-flow assessment and will provide funds from electricity generation to administer catchment management and river conservation plans that include monitoring. Similarly, Thames Water funded the installation of additional infrastructure to reduce the flow withdrawal required from the River Kennet during natural low flow periods.

4. **Collaboration with universities:** Many aspects of e-flow assessment, monitoring and adaptive management can also be supported by partnering with universities. The academic sector was involved in e-flow assessment or monitoring in a number of case studies: Crocodile River, San Pedro Mezquital River, Savannah River, Ganga River, and Yangtze River.

4.2.3 Institutional barriers and conflicts of interest

E-flow management must fit within a sound water management framework – this poses a challenge because agencies that manage natural resources such as water are typically separate from those that plan and manage hydropower, agriculture, land use, and urban and industrial development (Le Quesne *et al.* 2010). Poor cross-sectoral coordination and a lack of integrated planning, often driven by political expedience, can result in sub-optimal outcomes (Parker and Oates 2016). An institutional barrier was evident in our River Kennet case study where the water utility regulator (Ofwat) would not allow the utility, Thames Water, to fund the e-flow implementation scheme through demand-management schemes or a price review of the costs charged to water customers. This was despite the Environment Agency's (water allocation regulator) recommendation that water abstraction from the River Kennet be reduced. A legislative change was therefore required and ultimately achieved as a result of political pressure applied over a number of years by WWF and a local NGO (Action for the River Kennet). Our case studies also provide excellent examples of different regulatory authorities working together, such as:

- The collaboration between the National Water Commission (CONAGUA) and the National Protected Areas Commission (CONANP) in designing and gazetting the environmental water reserve for the San Pedro Mezquital River in Mexico.
- The collaboration between the Ministry of Water Resources, Ministry of Environmental Protection, Ministry of Agriculture, and National Energy Administration in determining e-flows that balance economic, social and environmental benefits in the Yangtze River, China.

OUR CASE STUDIES PROVIDE EXAMPLES OF DIFFERENT REGULATORY AUTHORITIES WORKING TOGETHER

Such collaborative efforts can yield solutions that on occasion result in improved conditions for multiple water-users. For example, in the Crocodile River case study, the decision by the IUCMA to develop an e-flow regime by setting up an Operations Committee that included most of the major water-users enabled them to garner support for an e-flow regime and a real-time management process. Consequently, water resource management in the basin has become stronger and more effective such that conditions have improved for both the major abstractor (irrigators) and the predominant organisation pushing for better e-flow management (Kruger National Park). In this case, all stakeholders were willing to compromise on their requirements through a democratic, open and transparent decision-making process. Although not the norm, examples also exist that demonstrate that such decision-making processes can result in an e-flow regime that benefits all users (e.g. Campbell River Water Use Plan, Locke *et al.* 2008). Case study examples of where collaborative, open and transparent decision-making processes have alleviated conflict and resulted in better flow management can be used to spur action in other problem basins.

The River Kennet case study also demonstrates how conflicts of interest can hinder action. In this case, the agency responsible for issuing water licences, the Environment Agency, also has a mandate to protect the environment. The internal conflict between the two roles is viewed as being an important factor in the length of time that it took to change the River Kennet abstraction licence, and contributes to the backlog of other streams within England that suffer from unsustainable abstraction (O'Neill, pers. comm. 2017b). The counterargument to this internal conflict is the barriers that agencies responsible for environmental management often face in protecting e-flows. For example, instream flow programme managers at state departments of fish and wildlife in the US are often frustrated by the lack of political support for e-flows outside of their departments, as they lack the authority to manage water abstractions or water quality issues that are handled by other state and federal agencies (Annear *et al.* 2009). The message from these alternative standpoints reinforces the point that the political will to implement e-flows is critical, irrespective of a country's institutional management framework (Section 4.2.1).

4.3 IMPORTANCE OF MONITORING AND ADAPTIVE MANAGEMENT

Despite marked advances in e-flow science, there remains uncertainty in the understanding of flow-ecology relationships (e.g. Bradford and Heinonen 2008, Poff *et al.* 2010, Bradford *et al.* 2011). The ecological component of most e-flow regimes is developed and accepted based on predictive models using habitat for specific species of concern as a surrogate for the entire (abiotic and biotic) aquatic ecosystem. However, the uncertainty in flow-ecology relationships means it is important to implement a monitoring and adaptive management system to ensure that the e-flows implemented are having the desired outcome. The importance of this was emphasised in the US and Canada's Instream Flow Council Monitoring Policy Statement (Annear *et al.* 2004):

> *Monitoring riverine resource responses to instream flow[10] prescriptions is a fundamental component of effective instream flow programs. Monitoring studies should be based on long-term ecosystem processes as opposed to short-term responses of individual species.*

The implementation of an adequate ecological monitoring programme presents its own challenges given the complexity of aquatic ecosystems, natural variability in the response variables of interest (e.g. fish abundance and diversity), the multitude of confounding environmental variables (e.g. temperature, changes in land use, fishing pressure), and the often substantial financial cost of sustaining it.

This makes it essential to identify suitable ecological indicators, goals and objectives for the monitoring programme (Locke *et al.* 2008) in a similar manner to programmes aimed at river restoration more specifically (Speed *et al.* 2016). The value of monitoring is demonstrated by the learning and adaptive management that was feasible in the Savannah River case study, and the improvements shown in carp egg and larvae numbers in the Yangtze River case study. In addition to the monitoring of e-flow implementation, it has been demonstrated that large-scale flow experiments also provide value in aiding with future decisions regarding water policy and management (Konrad *et al.* 2011 and references therein). Based on their review such experiments, Konrad *et al* (2011) developed a set of principles for conducting effective large-scale flow experiments that have both scientific and social value.

MONITORING SOCIAL AND ECONOMIC OUTCOMES OF E-FLOWS IS CRITICAL

The monitoring of social and economic outcomes resulting from provision of an e-flow regime is also critical to understanding the costs and benefits of e-flows (Dyson *et al.* 2008). This monitoring should aim to verify predictions of cost-benefit analyses, such as those conducted for the San Pedro Mezquital River, to improve the prediction and management of socio-economic conditions. Surveys of people's perception of change can also be useful (Speed *et al.* 2016), and within our case studies have already demonstrated an increase in the public awareness of the protective measures implemented for the management of the Poonch River Mahaseer National Park, and highlighted the effective management of flows within the Ganga River to enable a successful Kumbh 2013.

Parker and Oates (2016) note that to ensure the equitable distribution of river-related benefits, decisions regarding trade-offs between conflicting needs must be transparent, inclusive and based on the best available evidence. Only through proper monitoring will the ecological, social and economic consequences of e-flow decisions be validated and available to help inform adaptive management and future decisions.

[10] Instream flow is the term more commonly used for environmental flows, or e-flows, in North America.

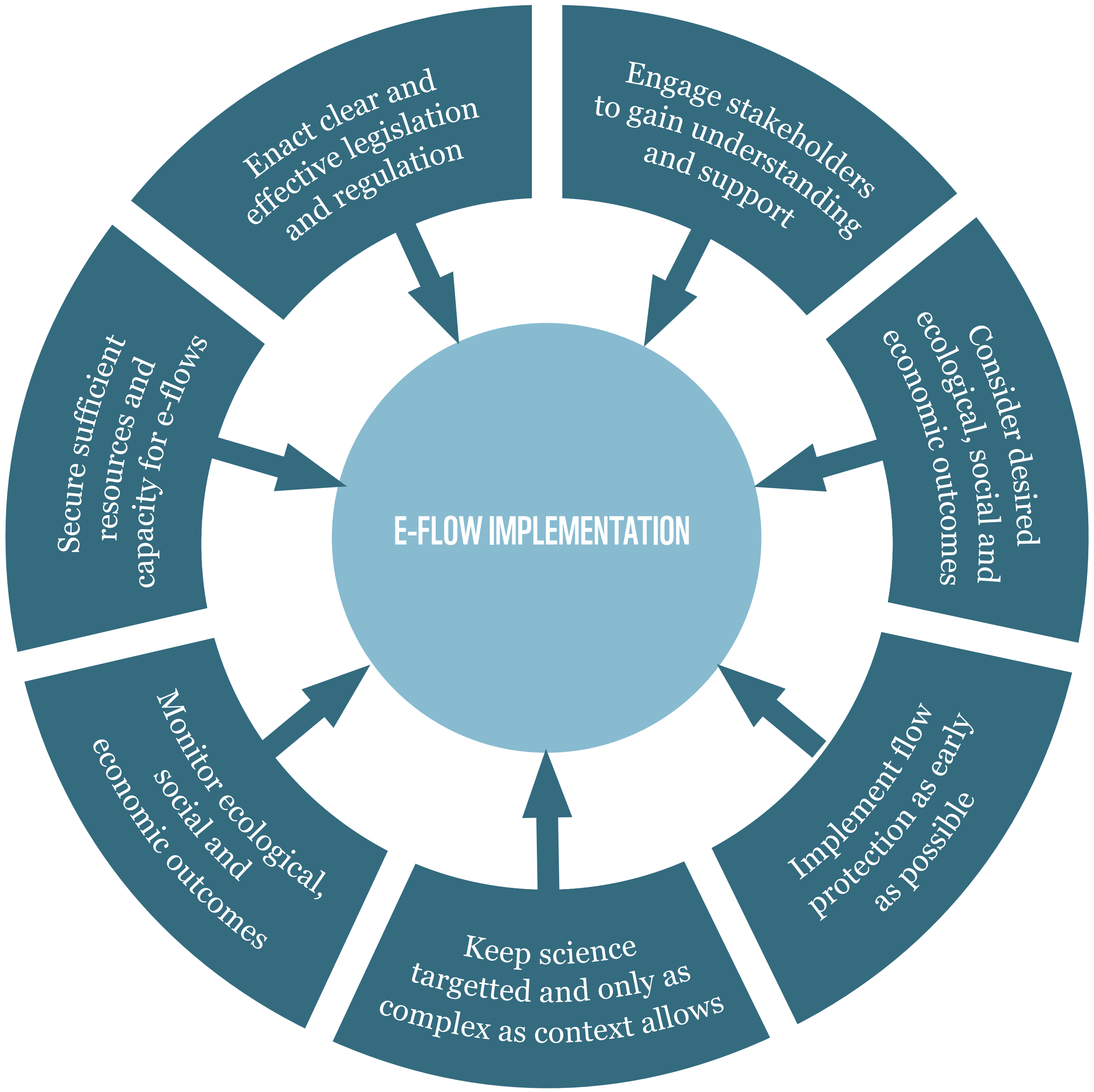
4.4 LESSONS LEARNED

Our review of case studies of e-flow implementation has demonstrated that there are a number of ways in which success can be achieved. These will be dependent on system- and jurisdiction-specific concerns and the legal, political, institutional, social, economic and ecological contexts. This supports the conclusion of Le Quesne *et al* (2010) that there is no single correct approach to the implementation of e-flows; instead, the approach must be carefully tailored to the context. Despite this finding, there are some common truths that emerge from this case study review that lead to the following recommended actions (Figure 4):

1. Enact **clear and effective legislation and regulation,** and maintain the political will to implement and enforce;
2. **Engage meaningfully with stakeholders** to garner understanding and support;
3. Secure sufficient **resources and capacity** for e-flow design (including stakeholder engagement), implementation and monitoring;
4. Consider how e-flow implementation will affect not just **ecological, but also economic and social conditions** for different groups of people;
5. **Implement some level of protection as early as possible** since it is easier to restrict allocation than to reallocate water;
6. Keep e-flow prescriptions as scientific as possible according to the level of risk and intensity of water use, and within the available financial and human resource constraints – but balance this with the need to **keep science targeted and only as complex as the context allows,** and with the need for clear non-technical communication of the issues with stakeholders; and
7. **Monitor ecological, social and economic outcomes** of e-flow implementation and manage adaptively.

These lessons reinforce and complement the conclusions of earlier case study reviews of e-flow implementation (Hirji and Davis 2009, Le Quesne *et al.* 2010). Based on our case studies and a review of what roles different organisations played in successful implementation, Table 5 provides guidance on what actions should be taken, and by whom, to promote further success in other jurisdictions and watersheds.

Figure 4: Recommended actions for e-flow implementation



ROLE	ORGANISATION	ACTION
Enact clear and effective legislation and regulation, and maintain the political will to implement and enforce.		
Lead	Governments (federal, provincial/ state, local)	Develop a clear legal basis for regulating water use, allocations, rights and licences, and put a water allocation system in place if one does not already exist. Recognise e-flows as a priority requirement to protect ecosystem services and a core component of water resource planning and management, ideally with legal standing at least equal to consumptive uses. Set a limit or cap on consumptive uses, or create an e-flow reserve, as a means to protect e-flows. Provide a framework for national and integrated basin water planning.
Support	Government water management agencies	Provide guidance on comprehensive or incremental reforms required based on existing water allocation system.
	Global NGOs	Push for action from state and federal governments to protect and restore e-flows. Provide guidance on legislative and regulatory requirements based on experience in other jurisdictions with similar legislative frameworks.
	Local NGOs, private sector actors	Push for reform in the management of water resources in the watershed if e-flows are absent or inadequate. Identify local specialists and encourage them to become involved in e-flow assessments and implementation.
		Communicate with the public on the issues and potential solutions that will serve local needs.
Engage meaningfully with stakeholders to garner understanding and support.		
Lead	Government water management agencies	Engage all water-users in the e-flow decision-making process for a watershed/basin to secure stakeholder buy-in. Ensure local/regional knowledge is accounted for in decision-making. Design and implement a clear, inclusive and detailed process for setting objectives for e-flows, which may be different for different rivers, and even for different sections of the same river.
Support	All users and stakeholders including farmers groups, dam operators, private sector actors	Enter into e-flow discussions, be willing to listen to diverse viewpoints, understand different values, and compromise on often firmly-held positions. Engage in the process of setting consensus environmental objectives for your river.
	Local NGOs	Educate and convene stakeholders, and help them to communicate their concerns regarding water availability and use.
	Large water-users	Be open and transparent about water use and estimated future requirements.
	Research community	Support e-flow assessments by clearly describing the predicted effects of e-flow implementation and the uncertainty associated with the predictions; ensure that social values are being addressed in e-flow recommendations. Build and apply tools to assess trade-offs between different water-using sectors under various flow management scenarios.

ROLE	ORGANISATION	ACTION
Secure sufficient resources and capacity for e-flow design, implementation and monitoring.		
Lead	Governments (federal, provincial/ state, local)	Provide sufficient funding to allow effective management of the water resource.
Support	Government water management agencies	Push government for adequate funding to effectively implement, manage and monitor the water allocation system Build internal capacity and then promote continuity in institutional knowledge
	Global NGOs	Use experience gained in other countries to support e-flow determination and implementation. Fundraise. Connect people.
	Global and local NGOs	Push for funding from state and federal governments; help to fundraise from non-government sources such as foundations.
	International funding agencies	Evaluate opportunities to fund e-flow implementation programmes as a key part of water resource management and infrastructure schemes.
	Large water-users including farmers groups, dam operators, private sector actors	Be prepared to fund/conduct ecological and socio-economic studies to understand the impacts of flow withdrawal to inform appropriate e-flow assessments
	Scientific community	Use access to research grants to continue research on how physical, geomorphological, ecological, social and economic parameters respond to e-flow implementation; working in conjunction with other stakeholders to ensure that science is targeted and strategic.
Consider how e-flow implementation will affect not just ecological,but also economic and social conditions for different groups of people.		
Lead	Government water management agencies	Take a holistic approach to understanding how water allocation decisions will impact downstream water-users.
Support	Global NGOs	Gather data on the costs/benefits of e-flow implementation to inform e-flow assessments and demonstrate wide-ranging benefits.
	International funding agencies	Use leverage to ensure appropriate assessments are conducted to determine suitable e-flows that meet environmental and socio-economic goals.
	Scientific community	Continue to research how physical, geomorphological, ecological, social and economic parameters respond to e-flow implementation.
Implement some level of protection as early as possible since it is easier to restrict allocation than attempt to re-allocate water.		
Lead	Government water management agencies	Implement in phases, ensuring that sufficient natural flows are protected as early as possible to avoid over-allocation.
Support	Global NGOs	Use experience gained in other countries to support schemes to protect e-flows.
Keep e-flow prescriptions as scientific as possible according to the level of risk and intensity of water use, and within the available financial and human resource constraints.		
Lead	Water management agencies	Use assessment tools appropriate for the context, and an open, transparent decision-making process to determine e-flow requirements, but keep the prescriptions as simple as possible to aid implementation and understanding.
Support	Large water-users and the scientific community	Continue to innovate to assist in the development of decision support and forecasting tools to improve real-time management.
Monitor ecological, social and economic outcomes of e-flow implementation and manage adaptively.		
Lead	Government water management agencies	Ensure that follow-up monitoring is conducted to determine the success and failures of e-flow implementation so that management practices can be adapted.
Support	Large water-users	Be prepared to fund/conduct ecological and socio-economic studies to monitor the impacts of flow withdrawal to inform adaptive management.
	Local NGOs	Advocate for adequate funding and implementation of monitoring networks to collect data on hydrological and ecological parameters to assist in e-flow determination and management.
	Scientific community	Provide input into design and implementation of monitoring networks, and assist with data collection and analysis as needed. Continue to innovate to improve techniques by which data can be collected, stored, managed and analysed to improve efficiency.

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5. CONCLUSIONS

This report set out to showcase a number of e-flow implementation stories where actions have led to benefits for society and ecosystems despite the various challenges to implementation. In telling these stories we have highlighted both the need for e-flow implementation and charted a path forward under various political, legislative, economic, social, cultural and hydrological contexts. It is clear from our case studies that e-flows are required to protect not only aquatic ecosystems, but also the social, economic and cultural benefits that humans draw from rivers and interconnected lakes, wetlands and aquifers, and to enhance water security. With the rise of water scarcity across the globe and the pressures on water resources increasing from factors such as population growth, economic transition and climate change, the number of 'working rivers' that serve multiple functions is growing. Yet rivers that provide ecological, social, economic and cultural value must be healthy; otherwise they will cease to deliver these benefits. As this becomes progressively better understood, legislative and policy regimes are being updated and e-flows are increasingly playing a central role in water allocation regimes, infrastructure design and operation, and water resource management more broadly. Implementation and adaptive management of e-flows are therefore part of sustainable water management.

The technical aspect of e-flow assessment was not the major theme of this report, but it is clear that there are a host of scientific methodologies available that can be tailored to the specific context to facilitate the development of an appropriate e-flow regime. This does not, however, negate the need for monitoring and adaptive management of e-flows to ensure that objectives are met. There is still much to learn about the complex relationships between flow and how habitats and species react, the delivery of ecosystem services, and the socio-economic effects on those reliant on the river. Uncertainty in these relationships should not impede action, and a number of our case studies highlighted a willingness to act and adapt. These examples serve as a blueprint for other jurisdictions and basins seeking to act to protect or restore ecosystem goods and services through the implementation of e-flows. As articulated in the Brisbane Declaration in 2007, e-flow protection should be instated for all rivers; precautionary reserves of water can be adopted until more detailed scientific study and stakeholder engagement can be conducted.

Our case study analysis shows clearly the range of roles that different stakeholders can play in implementing e-flows. Moreover, it highlights the collective, collaborative effort required for successful implementation. Irrespective of social and economic standing, values and beliefs, we are all dependent on clean, fresh water and the goods and services provided by freshwater ecosystems. To protect this valuable resource requires understanding, openness, transparency and a collective will. This isn't theory – it has been demonstrated in practice.

This report presents a clear call to action for decision-makers in governments, water management agencies, international funding agencies, the private sector, NGOs and the research community. The world faces a watershed moment. If we want healthy rivers that support thriving economies, socially and culturally diverse communities, and a diversity of flora and fauna, now is the time to act.

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