# Flow

The essentials of environmental flows

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Water & Nature Initiative

Edited by
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# Contents

# Key messages

## 1. Getting started

*Environmental flows generate benefits for people and nature*

An environmental flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated. Environmental flows provide critical contributions to river health, economic development and poverty alleviation. They ensure the continued availability of the many benefits that healthy river and groundwater systems bring to society.

*The price of not providing environmental flows should not be underestimated*

It is increasingly clear that, in the mid and long term, failure to meet environmental flow requirements has disastrous consequences for many river users. Addressing the water needs of aquatic ecosystems will often mean reducing the water use of one or more sectors. These are tough choices, but they have to be made to ensure the long-term health of the basin and the activities it encompasses.

*The river and drainage system should be considered in its context*

To start with environmental flows, one needs to consider all aspects of the river and drainage system in their context. This means looking at the basin from its headwaters to the estuarine and coastal environments and including its wetlands, floodplains and associated groundwater systems. It also means considering environmental, economic, social and cultural values in relation to the entire system. A wide range of outcomes, from environmental protection to serving the needs of industries and people, are to be considered for the setting of an environmental flow.

*Clear objectives and abstraction scenarios need to be defined*

To set an environmental flow, one needs to identify clear objectives as well as water abstraction and use scenarios. Objectives should have measurable indicators that can form the basis for water allocations. Objectives and scenarios can best be defined with multi-discipline expert teams and stakeholder representatives.

## 2. Defining water requirements

*Make an informed societal choice on water allocations*

There is no simple figure that can be given for the environmental flow requirements of rivers, wetlands and coastal areas. Much depends on stakeholders' decisions about the future character and health status of these ecosystems. Scientists and experts can help inform such decisions by providing information and knowledge on how a river, wetland or coastal ecosystem will evolve under various flow conditions.

*Carry out environmental flow assessments as part of river basin planning*
Environmental flow setting can best be done within the context of wider assessment frameworks that contribute to river basin planning. These frameworks are part of Integrated Water Resources Management and assess both the wider situation and river health objectives. They build on stakeholder participation to solve existing problems and include scenario-based evaluations of alternative flow regimes.

*There is no single best method, approach or framework to determine the environmental flow*
There are a number of existing methods for determining an environmental flow. Look-up tables and desk-top analysis for environmental flow assessment are used in scoping studies, national audits or river basin planning. Functional analysis and habitat modelling are the most widely applied approaches in impact assessment or restoration planning for single or multiple stretches of a river. These assessment methodologies can contribute to setting management rules and monitoring their impact on river health.

*Implementing environmental flows through active or restrictive flow management*
Implementing environmental flows requires either an active management of infrastructure such as dams, or a restrictive management, for example through reducing the abstractions for irrigation. When active flow management is applied, an entire flow regime can be generated, including low flows and floods. Restrictive flow management involves allocation policies that ensure that enough water is left in the river, particularly during dry periods, by controlling abstractions and diversions. Both types of interventions depend on people changing their behaviour, and should be based on an informed decision that has broad societal support.

## 3. Modifying water infrastructure

*Environmental flows can be realized with new and existing infrastructure*
Dams are often the most significant and direct modifiers of natural river flows. They are therefore an important starting point to implement environmental flows. Downstream releases from dams are determined by the design to pass water through, over or around the dam. The operating policies and rules determine the amount and timing of releases for environmental flows. The design and operations of other infrastructure such as distribution canals and weirs, can also contribute to establishing environmental flows.

*New dams provide opportunities to implement environmental flows*
During the planning phase it is important to ensure that dam and reservoir operating strategies conform to environmental flow requirements. Building in flexibility to not only meet current standards but also to accommodate future changes in regulation, use and climate is crucial. During the years of construction and reservoir filling, adequate provisions for environmental flows need to be made. Trial releases during the first years of operation will be required to test flow regimes and reduce the inherent uncertainties in predicting river response to environmental flows.

*Adjusting existing infrastructure can have immediate positive effects*
Many countries have a large stock of dams. The options for modifying releases from these dams depends on the type of dam, the provisions for releasing water and the state of the key water control outlets and structures. The periodic re-licensing of existing dams provides an opportunity to

establish environmental flows or update existing regimes. The greater focus on modernization and performance will help optimize the management of existing dams and implement environmental flows.

*Decommissioning can be an option to restore environmental flows*
The renewal or removal of physical infrastructure that has outlived its economic usefulness is a normal consideration and dams are no exception. Decommissioning a dam to restore environmental flows can involve permanently opening its gates, or even its partial or full removal. However, while these options are preferable in some cases, it is clear that it is not appropriate for all dams, and should not be undertaken without a full Environmental Impact Assessment (EIA).

## 4. Covering the costs

*Assessing financing and other resource needs*
An analysis of the cost and benefits – including who gains and who loses – is an important prerequisite for any decision on an environmental flow. It helps to identify the relevant stakeholders and leads to an understanding of the incentives for parties to participate, as well as defining how the poor can benefit from change. It also serves to establish the required money transfers, the potential sources of funding and the required financial mechanisms.

*Financing environmental flows hinges on the acceptance of changes in the status quo*
Investments in environmental flows will need to be justified by improvements in environmental, social or economic conditions within the wider society, rather than on the basis of the impacts felt by specific actors. Without societal benefits there will be little financial and economic rationale for undertaking and financing the required changes. High priority should be given to those situations where the direct benefits are clear, in particular for the poor, and where the applied methods are cost-effective and well-known.

*A modification of existing incentives will be needed to motivate actors to change*
Many existing incentives favour economic activities and thereby largely determine a system of water allocation. Understanding these is a critical step to establishing environmental flows. Slowly influencing the economic framework and creating the necessary social acceptance of environmental flows could be preferable to immediately changing the existing set-up for water allocations.

## 5. Creating a policy and legal framework

*Domestic legislation and administration is critical*
Only a limited number of countries have recognised the non-consumptive use of water and developed special domestic legislation to provide for it. A clear legal and administrative pathway to protect river flow is necessary before stakeholders will be willing to commit and agencies will be prepared to fund environmental flow projects. A serious attempt to manage for environmental flows will not occur unless clear policy decisions are taken at the appropriate level of government.

*International agreements form a basis for national laws and policies*
Environmental flows form part of an ecosystem approach to integrated water resources manage-

ment. Relevant international instruments include those directly dealing with water resources and those focused on the protection of nature and the environment. International agreements and obligations form an important basis from which national policies and laws on environmental flows can be developed.

*There is no ‘quick-fix’: domestic legislation needs to be tailored to realities*
Key principles or guidelines can assist the development of required policies and institutional and legal frameworks. However, engaging local communities and making use of the knowledge and experience of locally-elected officials is critical in tailoring laws and institutional arrangements to realities on the ground. Wherever possible, the best approach is to address environmental flows before water resources are over-allocated.

*Establish a clear and robust system to facilitate effective implementation, compliance and enforcement*
To develop domestic legislation it is important to determine the scale at which environmental flows are to be established. Dealing with issues at the lowest appropriate levels will be necessary to implement a successful regime. Rights over access to and use of water will need to be accommodated or adjusted. This is likely to involve the inevitable questions of whether, how and by whom compensation might be payable when water rights are varied, and will require decisions on who might ‘hold’ the environmental water ‘in trust’. An adaptive style of management is needed and liability issues should be addressed beforehand.

## 6. Generating political momentum

*It is inevitable and necessary to involve a range of actors*
Gaining the necessary momentum for establishing a regime for environmental flows will involve many different actors, from the highest levels of government right through to local communities and businesses. Under these conditions a successful strategy will involve working with as many actors and interest groups as possible and adapting tactics along the way.

*No ‘simple and single’ approach will work for every actor or interest group*
Different approaches will be required when engaging the various actors involved. Parliamentarians, civil servants in relevant ministries and policy advisors are likely to be interested in different arguments than farmers, environmentalists and tour-operators. Those ministries that are not directly responsible for the environment portfolio but are responsible for economic development and social agendas need to be involved. Understanding which interest groups have influence with the various government and private actors involved is critical.

*Communications and the media are vital elements for making progress*
Good communications starts with knowing what the issue is all about and understanding the background, interests and concerns of key constituencies. It is also essential to have a clear idea of what is asked for at different levels from different actors and to understand who gains and who loses. Articulating the right message will be critical, as there might be only a single opportunity to deliver it to a given constituency. However, it will take some time for actors to understand that an environmental flow is as much for people as for nature.

*A coalition for environmental flows for co-operation and balancing interests*

Fostering co-operation and balancing a range of competing interests is critical. It poses a major challenge and will require a good process for bringing people together in one or more coalitions. Securing support from local actors is vital. This could be based on the idea that well-established regimes for environmental flows will help long-term resource security for all water consumers. The best way to convince stakeholders of this idea is to keep the process relevant and to ensure that the implementation is optimal and realistic.

## 7. Building capacity for design and implementation

*Awareness is the first step towards increased capacities*

Environmental flows is a relatively new issue for the water sector. Generally, there is a lack of awareness throughout the sector and the general public of the concept and its application. Success in applying environmental flows depends greatly on the initial determination to 'get started'. In this regard, raising awareness about the river conditions and the best interests of the community is critical.

*Gaps in capacities need to be identified and addressed early on*

Capacities need to be built amongst various actors to design and implement environmental flows. The training of lawyers, technical staff, NGO members and policy-makers may therefore be necessary. It is also important to empower and educate politicians to better understand the societal costs of not establishing environmental flows. A failure to invest in capacity building will imply the continued mismanagement of water resources.

*Capacity building strategies are required to catalyse actions*

An effective capacity building strategy will incorporate several elements, including training courses, an assessment framework, the trial application of methods, visits to case study sites, and technical workshops. Once a minimal level of awareness and knowledge is established, further support will be needed in the form of technical back-stopping, research, a national database, networking and communications.

# Preface

'Environmental flows' is an easy concept. It means enough water is left in our rivers, which is managed to ensure downstream environmental, social and economic benefits. Yet, pioneering efforts in South Africa, Australia, and the United States have shown that the process to establish them, especially when part of an integrated management approach, poses great challenges.

Environmental flows requires the integration of a range of disciplines, including engineering, law, ecology, economy, hydrology, political science and communication. It also requires negotiations between stakeholders to bridge the different interests that compete for the use of water, especially in those basins where competition is already fierce.

The reward is an improved management regime that guarantees the longevity of the ecosystem and finds the optimal balance between the various uses. Given the worldwide overuse of water resources and the related degradation of ecosystems and their services, environmental flows is not a luxury, but an essential part of modern water management. It is an approach that deserves widespread implementation.

This guide, the second in the series of the Water & Nature Initiative, draws extensively on the experiences in these countries to offer hands-on advice for this emerging issue on the water resource agenda. It goes well beyond existing literature to offer practical guidance on technical issues, such as assessment methods and infrastructural adaptation, and the economic, legal and political dimensions of establishing environmental flows.

The guide does not stand alone. It is part of a process that also includes support to national and local initiatives to establish environmental flows, for example in Tanzania, Costa Rica, Vietnam and Thailand. There, the guidance provided in this guide will be tested in collaboration with national stakeholders, experts, policy-makers and elected officials.

This guide and those field experiences allow a much wider community to develop the most appropriate ways to implement environmental flows. IUCN stands ready to share its experience where needed and to help influence decision-making at national or international levels to allocate enough water to ecosystems and people.

Environmental flows in practice may not be easy. But it is a key component of any effort to deal with the destruction of our rivers and thereby the loss of their biodiversity and societal benefits. I hope this guide will be a source of support for policy-makers and practitioners in the long and sometimes difficult process to establish environmental flows.

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# Chapter 1

# Getting Started

## 1.1 Introduction

*A lush crop of cotton thrives on the irrigation waters derived from the nearby river. The owner of the cotton wonders why he should not maintain this profitable enterprise. After all, the river runs through his land, and his family's maxim has always been that "a drop that flows out to sea is a drop wasted".*

*But, downstream, disregard for the river's needs has caused serious deterioration in the river's condition. Native fish, once providing both food and commercial catch, are now on the brink of extinction. Inedible introduced species stir up the river bed and cause further deterioration of the water quality. Irrigated crops once growing strongly on the clean water supply, now face water shortages. The water is often too salty and yields drop when the salty water is used. Frequent algal blooms cause further havoc and once-healthy trees stand dying on the dry floodplain that used to be a seasonal wetland.*

*Downstream, fishers, farmers, environmental activists and recreational river users band together to take legal action against the government. They hold the authorities responsible for the allocation of the river's resources and demand from it the establishment of an environmental flow, the water needed to help restore the river they depend on.*

This scenario illustrates a growing reality. River and groundwater systems need water to maintain themselves and their functions, uses and benefits to people. The amount of water needed for this is named an 'environmental flow'. The consequences of neglecting this need are increasingly evident and costly. Downstream ecosystems, and the industries and communities that rely on these, are paying the price.

However, an appreciation of the water needs of river and groundwater systems, and the costs of neglecting those needs, is not yet widespread. While there are a growing number of people who recognise the benefits of environmental flows, the issue is only just being introduced in formal training of scientists and engineers. In many cases, providing water for downstream ecosystems and uses still is not on the agenda of politicians and policy-makers. Yet, it is crucial to sustainable development and the long-term prosperity of communities. Environmental flows are not just a luxury to maintain nature, nor are they merely an interesting research topic. They are at the centre of the debate on sustainable water management.

*"RIVER AND GROUNDWATER SYSTEMS NEED WATER TO MAINTAIN THEMSELVES AND THEIR FUNCTIONS"*

Historically, water has been managed from a supply perspective with an emphasis on maximizing short-term economic growth from the use of water. Little thought has been given to the health of the resource itself and there is poor understanding of the implications of overuse or declining river health. Water resource managers are now trying to come to terms with the need to take a more holistic view of the river system using the Integrated Water Resource Management (IWRM) paradigm. They increasingly understand that there is a need to take care of aquatic ecosystems and the resources they provide for long-term economic viability.

Environmental flows must be seen within the context of applying IWRM in catchments and river basins. Environmental flows will only ensure a healthy river if they are part of a broader package of measures, such as soil protection, pollution prevention, and protection and restoration of habitats.

Taking steps to manage for environmental flows brings into focus the struggle over access to and ownership of water and water rights. In systems where water is already over-allocated, the challenge of environmental flows may include reallocating or conserving water from existing private users and returning it to the river. Before starting to work on environmental flows, one therefore needs to realize that a wide range of stakeholders will have to be involved.

*"Flow – The Essentials of Environmental Flows"* has been written for all those who will need to take action to provide environmental flows. These people include politicians, policy-makers, planners, economists, environmentalist, consumptive water-use lobby groups and other non-governmental organizations, river communities, engineers, hydrologists and lawyers.

This guide sets out what must be done to define and implement environmental flows. A 'hands-on' approach is used to explain the 'what', 'when', 'where' and 'how' of environmental flows. It clearly sets out the theory and practicalities of dealing with environmental flows. Examples from countries where environmental flow programmes are already in train, such as Australia, South Africa and the United States, are used throughout the text to illustrate the points made. Practical questions are answered: how to find funding, how to train people in the necessary skill areas, and how to raise understanding within and gain commitment from the community and political leaders? References to other publications with more detailed information help the reader further.

Each of the seven chapters deals with a different aspect of environmental flows. The guide moves from the definition of environmental flows and why they are important to clear technical, policy and practical advice on how to assess and deliver an environmental flow.

After introducing the concept of environmental flows and broadly outlining the framework for achieving adequate flows in Chapter 1, the guide discusses the scientific and technical aspects of the assessments required for environmental flows in Chapter 2. Chapter 3 then details the technical requirements and options for construction of new infrastructure and modification of existing infrastructure to provide environmental flow releases. In Chapter 4, the economic costs and benefits of environmental flows and methods available for financing what might be required to improve flows are further discussed.

Chapter 5 continues to deal with the policy, institutional and regulatory frameworks necessary for establishing environmental flows. The guide further provides information on how to create political and community momentum for change and commitment and how to build the necessary coalition of partners in Chapter 6. Finally, Chapter 7 addresses the capacity building requirements.

## 1.2 The definition

*In the Murray-Darling Basin in Australia, a 1-in-5 year flood event in the Barmah-Millewa Forest is enhanced through releases from a major storage in the Basin. Following the enhanced releases, the great egret bred for the first time since 1979, nine species of frog bred, as did native fish.*

*The Mowamba Aqueduct in the Snowy Mountains Hydro-Electric Scheme in Australia has been closed after a hundred years, doubling flows in the river from 3% of natural flows to 6%, and marking the beginning of a long commitment to raise flows in the Snowy River to 28% of natural flows.*

*In South Africa, irrigators' entitlements may be reduced to provide water to the 'Reserve', which is held and managed on behalf of the public to sustain basic human and ecological requirements.*

*In the mountains of Lesotho, the Mohale Dam is designed to release flows of variable quantity and quality, to provide, amongst others, occasional flooding downstream.*

All of these are actions taken to provide environmental flows. This guide defines an environmental flow as the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated.

A distinction may be made between the amount of water needed to maintain an ecosystem in close-to-pristine condition, and that which might eventually be allocated to it, following a process of environmental, social and economic assessment. The latter is referred to as the 'environmental flow', and it will be a flow that maintains the ecosystem in a less than pristine condition. Intuitively, it might seem that all of the natural flow, in its natural pattern of high and low flows, would be needed to maintain a near-pristine ecosystem. Many ecologists believe, however, that some small portion of flow could be removed without measurable degradation of the ecosystem. How much could be removed in this way is more difficult to assess, with estimates ranging between about 65% and 95% of natural flow having to remain, with the natural patter of flow also retained. Once flow manipulations move past this, then river ecologists can advise on patterns and volumes of flows that will result in a range of different river conditions. This information can then be used to choose a condition that allows an acceptable balance between a desired ecosystem condition and other social and economic needs for water. The flows allocated to achieve the chosen condition are the environmental flow.

Water resources need to be managed to provide environmental flows. Flow can be regulated by infrastructure, such as dams, or by diverting water from the system, for example pumping water away. There are thus different ways in which environmental flows can be provided, such as modification of infrastructure or changes in water allocation policies and entitlements.

## *1.3 The benefits*

Aquatic ecosystems, such as rivers, wetlands, estuaries and near-coast marine ecosystems, provide a great variety of benefits to people. These include 'goods' such as clean drinking water, fish and fibre, and 'services' such as water purification, flood mitigation and recreational opportunities. Healthy rivers and associated ecosystems also have an intrinsic value to people that may be expressed in terms of cultural significance, particularly for indigenous cultures. This intrinsic value is often overlooked as it is difficult to identify and quantify.

> *"THE ABSENCE OF ENVIRONMENTAL FLOWS PUTS AT RISK THE VERY EXISTENCE OF ECOSYSTEMS, PEOPLE AND ECONOMIES."*

Rivers and other aquatic ecosystems need water and other inputs like debris and sediment to stay healthy and provide benefits to people. Environmental flows are a critical contributor to the health of these ecosystems. Depriving a river or a groundwater system of these flows not only damages the entire aquatic ecosystem, it also threatens the people and communities who depend on it. At its most extreme, the long-term absence of environmental flows puts at risk the very existence of dependent ecosystems, and therefore the lives, livelihood and security of downstream communities and industries. The question is thus not whether environmental flows can be afforded, but whether and for how long a society can afford not to provide environmental flows.

The impacts of long-term regulation on aquatic ecosystems are becoming increasingly evident.[1] There is growing concern over these impacts, with corresponding increases in both political awareness and action. This guide contains many examples of countries and regions that have made progress towards providing environmental flows. Communities are often a driving force. For instance, in the case of the management of Mono Lake (California, USA) where a series of actions from fishing

Photo 1.1 Residents carry empty canisters as they walk on a dry river bed in search of water near Hyderabad, some 160 km from Karachi.

lobby groups and a court decision forced the government to make environmental flow releases. Community agitation and action played a pivotal role to allow for these changes.

Calls for action are not only being heard at the local level. International instruments and statements on water resources have, with increasing frequency, recognised that water management needs to provide for environmental requirements. For example, the Report of the World Commission on Dams[2] identified sustaining rivers and livelihoods and recognising entitlements and sharing benefits as priorities. This requires dams to provide for releases for environmental flows and to be designed, modified and operated accordingly. Likewise, the Vision for Water and Nature[3] calls for "leaving water in the system to provide environmental services such as flood mitigation and water cleansing". This contributes to a six-part framework for action to protect and manage water resources including "caring for and managing freshwater resources in river or drainage basins".

Environmental flows are a relevant consideration at every stage in the history of a river or drainage basin, albeit during the first allocations of water for consumptive uses, or during Environmental Impact Assessments for the re-licensing of water storage infrastructure. Starting to address environmental flows is also opportune when water allocation plans or river rehabilitation programmes are being developed. Best is to address environmental flows as early as possible, though the lack of political attention and relevant information might impede progress. However, if environmental flows are left until later, the problems are often more severe and solutions will carry higher economic and social costs.

## 1.4 The reality

The goal of environmental flows is to provide a flow regime that is adequate in terms of quantity, quality and timing for sustaining the health of the rivers and other aquatic ecosystems. The degree of 'good health' at which the river will be sustained is, however, a societal judgement that will vary from country to country and region to region. What the appropriate environmental flow is for a particular river will thus depend on the values for which the river system is to be managed. Those values will determine the decisions about how to balance environmental, economic and social aspirations and the uses of the river's waters.

This means that ecological gains will not necessarily be the only or even the primary outcome of an environmental flow programme. Such a programme will need to strike a balance between water allocations to satisfy the ecological water requirement and other water use needs like those of hydropower generation, irrigation, drinking water or recreation. Developing an environmental flow programme therefore means articulating the core values on which to base decisions, determining what outcomes are sought and defining what trade-offs those will entail. A number of considerations need to be taken into account when starting with environmental flows.

*"CONSIDER THE RIVER AND DRAINAGE SYSTEM IN ITS CONTEXT."*

First of all, river and drainage systems need to be considered in their context. In a physical sense, this means considering the system from its headwaters to the estuarine and coastal environments and including its wetlands, floodplains and associated groundwater systems. In terms of values, this means considering environmental, economic, social and cultural values in relation to the entire system. A wide range of outcomes, from protection to serving the needs of industries and people are to be considered for possible inclusion in an environmental flow programme.

In a river system where water has been over-allocated to consumptive use, environmental flows might be provided simply to have ecosystems that function sufficiently to provide a sustainable base for present and future consumptive and in-stream uses. Where a system is seriously over-committed and values do not allow a sufficient reallocation of resources to restore 'the entire system', certain river stretches or wetland sites may be targeted for protection and specific water allocations. For rivers with high biodiversity values, for example, an environmental flow might be provided to preserve the natural state of the river system. In such case, consumptive water use may be limited to a minimum amount, which might imply that water diversions may occur only during times of very high flow and reservoir storage is banned.

*"CLEAR STREAM OBJECTIVES AND ABSTRACTION SCENARIOS ARE TO BE DEFINED."*

To set an environmental flow, one needs to identify clear stream objectives and water abstraction and use scenarios. Objectives should have measurable indicators that can form the basis for water allocations. Useful objectives can be, for example, "maintaining the brown trout at 1995 levels", "preserving at least 75% of downstream mangrove forests", or "maintaining river nitrate levels below a particular standard".

Social and political objectives might, at first sight, seem less useful as environmental flow objectives. However, "keeping at least 85% of the farmers happy" or "ensuring the leading nature campaigners remain quiet" might prove to be extremely practical and useful as objectives. As establishing environmental flows is a question of values, so the setting of river objectives is largely a socio-political process. A successful process therefore needs to include representatives of different interest groups as well as scientists and experts. All involved need to have a basic understanding of what environmental flow setting and management entails.

The various competing uses of river resources are all enjoyed at a cost to other users and to the downstream aquatic ecosystems. Reconciling water needs of aquatic ecosystems with other water uses will therefore often mean deciding upon which users will need to give way to the needs of these ecosystems. The costs associated with these choices will be borne both by the downstream aquatic ecosystems and by water users. The environment may not receive all of its 'ecological water requirements' and water users might need to make costly changes to their practices, e.g. to improve water efficiency.

*Box 1.1 "Healthy working rivers"*

The stated goal for environmental flows for the River Murray in Australia is "a healthy, working river – one that assures us of continued prosperity, clean water and a flourishing environment". The term 'working' has been used to recognise the fact that the River will not be restored to its pre-European settlement, pre-regulation, pristine condition. For more information, visit 'The Living Murray', Murray-Darling Basin Ministerial Council, July 2002, at www.mdbc.gov.au/naturalresources/e-flows/thelivingmurray.html.

However, the price of not providing environmental flows cannot be underestimated. It is increasingly clear that, in the middle and longer term, failure to meet environmental flow requirements may have disastrous consequences for many river users.

Besides costs, it is important to realize there are major uncertainties associated with environmental flows. There will be uncertainties over the science, for example about how much water is needed, when and how. But the area of uncertainty that will be most acutely felt is that of social and economic impacts. The costs and benefits are often subject to the most scrutiny. Uncertainty regarding the impacts represents a danger to many members of the community, and is often used as an excuse for inaction. It is therefore critical to bring out the uncertainties that are intrinsic to achieving environmental flows into the open and ensure that the stakeholders start accepting these uncertainties.

*"IT IS CRUCIAL TO RECOGNISE THE COSTS UP-FRONT, INCLUDING THOSE OF NOT PROVIDING FLOWS"*

## 1.5 The trade-offs

The provision of environmental flows is not intended to mimic a pristine river. A regulated system, by definition, cannot reproduce all aspects of natural flow while also providing for competing uses. For example, a river that is naturally subject to droughts cannot provide a pool level that is suitable for navigation at all times.

Part of the challenge of providing environmental flows will be to determine which elements of the natural flow regime are critical to achieving the identified flow objectives. For example, it might be discovered that floodplains need to be inundated for a certain minimum period to stimulate fish breeding. This knowledge can be used to ensure that available water is used to prolong a natural flood past that critical period, rather than to increase the peak of the flood.

Depending on the climate in which the system is situated, average river discharge may be one of the least essential elements of natural flow. Variability in flow quantity, quality, timing, and duration are often critical to maintain river ecosystems. Flows for flooding to maintain fish spawning areas, specific flows for fish migration, or flushing to wash down debris, sediment or salt, are examples of the need for variability. This is particularly the case for countries with drier climates that typically see seasonal flooding, followed by periods of drought. Minimum or average flow allocations would not be useful in such circumstances.

*"ENVIRONMENTAL FLOWS ARE LIKELY TO BE DIFFERENT FROM NATURAL FLOWS AND SELDOM TO BE 'MINIMUM' OR 'AVERAGE 'FLOWS'."*

Identifying and making trade-offs are at the heart of setting and implementing environmental flows. When the regulated flow is manipulated to provide environmental flows, there will inevitably be costs to other users or uses. Competing interests will emerge between various consumptive users, and between up-stream and down-stream environmental and user benefits. Competition will also arise between parts of the river environment that require different natural flow regimes. For example, while a floodplain may require irregular inundation, estuaries may rely on frequent high flows to have freshwater inputs.

Photo 1.2 Solitary elephant seeks an unusual source of drinking water in Kruger National Park during the 1992 drought, when Sabie River stopped flowing for the first time on record.

Does the provision of an environmental flow lead to winners and losers? There are complex and competing interests that must be assessed and determined in addressing the question what environmental flows are required, and how they can be provided. One thing is certain – everyone loses if we do not manage for environmental flows.

Adequate environmental flows are not the only characteristic of a healthy river system. There are other requirements for river health such as reduction of pollution and control of in-stream activities like fishing and recreation. Focusing on environmental flows out of context is unlikely to yield a good result and may even alienate communities. Environmental flows should therefore be considered as an integral part of the modern management of a river basin.

*"ENVIRONMENTAL FLOWS ARE AN INTEGRAL PART OF THE MODERN MANAGEMENT OF A RIVER BASIN."*

Ideally, the provision for environmental flows should be supported by a comprehensive package of basin-wide management practices and regulations, for example related to land-use, water rights and in-stream uses. Provision of an environmental flow alone to a significantly degraded river may be useless or even detrimental. For example, river banks that have been destabilized due to the removal of riparian vegetation can be severely eroded by the provision of variable flows. Likewise the inundation of severely degraded and polluted wetlands and floodplains can cause or exacerbate infestation of weeds and cause pollutants to spread throughout the basin. Carrying out environmental flows in perfect isolation is therefore not a preferred option.

As new information will become available regularly and river conditions will change, scientists and water managers will need to periodically adapt their environmental flow practices to the new conditions. Therefore the adequacy of an environmental flow should be assessed on a regular basis using the best available information. As responses of plants, animals, resources and people to the flows are monitored and evaluated, environmental flows may need to be amended. This process is known as adaptive management, and forms an essential part of dealing with the trade-offs environmental flow setting and management entail.

*Chapter 2*

# Defining Water Requirements

## 2.1 Introduction

There is no simple figure that can be given for the environmental flow requirements of rivers and associated wetlands. Much depends on the desired future character of the river ecosystem under consideration. All elements of a flow regime will influence the ecology of a river in some way, so that if a totally natural ecosystem is desired, the flow regime will need to be natural. However, most river ecosystems are managed to a lesser or greater extent and it is accepted that removal of water from the river for human uses, such as public supply, irrigation and industrial processing, is necessary for human survival and development. The environmental flow allocated to a river is thus primarily a matter of social choice, with science providing technical support in terms of what the river ecosystem will be like under various flow regimes. The desired condition of the river may be set by legislation, or may be a negotiated trade-off between water users.

In some cases, water is returned to the river after use, i.e. in the case of hydropower generation[4] or cooling of an industrial plant. However, the timing of the river flow downstream of the point where water is returned is likely to be altered. In the bypassed river section, the flows will be lower than natural. In other cases, i.e. when abstracting water for irrigation, the water may be returned in such small quantities or so far away from the abstraction point that, effectively, it is consumed. It is also important to recognise that flow is not the only factor affecting river health. Water quality, over-fishing and physical barriers to migration of species all influence aquatic ecosystems.

*"THERE IS NO SINGLE BEST METHOD, APPROACH OR FRAMEWORK TO DETERMINE AN ENVIRONMENTAL FLOW."*

During the past 20 years, a range of methods, approaches and frameworks have been developed to help set environmental flows. 'Methods' typically deal with specific assessments of the ecological requirement. 'Approaches' are ways of working to derive the assessments, e.g. through experts teams. 'Frameworks' for flow management provide a broader strategy for environmental flow assessment. They will typically make use of one or more specific methods and apply a certain approach. The various methods, approaches and frameworks all have advantages and disadvantages.

There is no single best way for environmental flow assessment. Each method, approach or framework will thus be suitable only for a set of particular circumstances. Criteria for selecting a specific method, approach or framework include the type of issue (i.e. abstraction, dam, run-of-river scheme), expertise, time and money available, as well as the legislative framework within which the flows must be set. During recent years, the distinction between methods, focusing on ecological requirements, and frameworks, focusing on environmental flows, has become diffuse. Many of these are now more and more holistic and use multi-stakeholder groups and multi-discipline expert teams to define the amount of water to leave in the river. For sake of clarity this guide presents these two as separate categories.

## 2.2 Defining objectives or negotiating scenarios

For some river systems, specific objectives have been set, for ecological, economic or social reasons. In such cases, environmental flows need to be defined to meet those objectives. The objective for the central valley of the Senegal River basin was to maintain an area of 50,000 hectares for flood recession agriculture. As approximately half the flooded area is cultivated, this equates to the inundation of 100,000 hectares of the floodplain, which requires around 7500 million $m^3$ of water to be released from Manatali Dam in the head waters.

The Water Framework Directive of the European Union requires member states to achieve 'Good Status' (GS) in all surface and groundwater.[5] Good Status is a combination of Good Chemical Status and Good Ecological Status (GES). GES is defined qualitatively and includes populations and communities of fish, macro-invertebrates, macrophytes, phytobenthos and phytoplankton. It also includes supporting elements that will affect the biological elements, such as channel form, water depth and river flow. Setting environmental flows is a key step in achieving 'Good Status'. In South Africa, a similar classification is used; however, rather than aiming for good status in all cases, the Department of Water Affairs and Forestry sets objectives, according to different ecological management targets. There are four target classes, A-D (see Table 2.1). Two additional classes, E and F may describe present ecological status but not a target. Water resources currently in category E or F must have a target class of D or above.

*Table 2.1 Ecological management classes*[6]

| Class | Description |
|---|---|
| A | Negligible modification from natural conditions. Negligible risk to sensitive species. |
| B | Slight modification from natural conditions. Slight risk to intolerant biota. |
| C | Moderate modification from natural conditions. Especially intolerant biota may be reduced in number and extent. |
| D | High degree of modification from natural conditions. Intolerant biota unlikely to be present. |

The application of the objective-based approach necessitates first that the desired status of the river has been set. It then should be possible to define threshold flows above or below which a change in status will be evident. It has been suggested[7] that in Australia the probability of having a healthy river falls from high to moderate when the hydrological regime is less than two-thirds of the natural flow regime. Whilst this seems a reasonable figure, there is little scientific evidence to support it. Indeed from a theoretical point of view it may not be possible to define the flow regime that will maintain a desired river condition.[8] From a practical standpoint, the assessment of an environmental flow remains a practical river management tool. However it should be noted that, as long as knowledge of the aquatic environment remains limited, setting threshold environmental flows will inevitably retain an element of expert or political judgement.

*"FOR MOST OF THE WORLD'S RIVER SYSTEMS, NO SPECIFIC ECOLOGICAL OBJECTIVES HAVE BEEN SET."*

For most of the world's river systems, no specific ecological objectives have been set. Furthermore, many regulatory authorities have to balance the needs of water users with environmental concerns.

In such cases, an alternative to the objective-based approach is to examine various water allocation options or scenarios. For example, in the River Wylye Catchment in the UK there are four major pumped groundwater sources. Setting acceptable abstraction levels by the Environment Agency of England and Wales has involved consideration of a suite of abstraction scenarios ranging from no abstraction to full abstraction from all sources, with various combinations of different pumping rates in between.[9] For each scenario, the impact on habitat for target fish species and the implications for water supply to the public and industry were determined. Relationships between habitat and flow were examined and the effects of flow variation on different parts of the river were compared, taking into account the variations in channel form and size. These scenarios provided the basis for discussions with stakeholders, such as fishers and representatives of water companies, of acceptable abstraction strategies.

Similarly, as part of the Lesotho Highlands Water Project, various scenarios of environmental flow releases from dams were considered. For each scenario, the impacts on downstream river ecosystems and dependent livelihoods were determined, as were the economic implications of water available for sale to South Africa. These scenarios permitted the Lesotho Government to assess the trade-offs presented by different environmental flow options.

*Table 2.2 Examples of objectives*

| | Overall management objective | Flow/level objective | Approach used |
|---|---|---|---|
| River Babingley | Maintain a wild brown trout population | Ecologically acceptable flow duration curve | Physical habitat modelling (PHABSIM) and naturalized flow duration curve from rainfall-run-off model |
| River Kennet | Maintain a wild brown trout population | Flow should not fall below that which results in a reduction in physical habitat for brown trout of more than 10% | Physical habitat modelling (PHABSIM) |
| River Avon | Protect salmon migration | Minimum flows at critical times of the year | Radio tracking of salmon |
| Pevensey Levels Wetland | Restore and maintain ecology at 1970 levels | Maintain ditch water levels not more than 300 mm below ground level Mar-Sept not more than 600 mm below ground level Oct-Feb | Expert research opinion on water requirements of ecology of wetland species |
| Somerset Moors & Levels | Restore numbers of breeding waders to 1970 level | Raise water levels in Winter to produce splash-flooding and maintain water levels within 200 mm of ground surface in Spring | Expert opinion on ecology of wading birds |
| Chippenham, Wicken, Fulbourn Fens | Protection of vegetation communities | Target flows identified in the River Granta and Lodes | Lodes-Granta groundwater model, test pumping, hydrological studies |

## 2.3 Methods for defining flow requirements

A range of methods has been developed in various countries that can be employed to define ecological flow requirements.[10] In broad terms, these can be classified into four categories:

1. *Look-up tables*
2. *Desk top analysis*
3. *Functional analysis*
4. *Habitat modelling*

Each of these methods may involve more or less input from experts and may address all or just parts of the river system. Consequently, the use of experts and the degree to which methods holistically embrace all parts of the system are considered as characteristics of the various methods. Other classifications of methods have been undertaken[11] which include more sub-divisions. The intention here is to produce a simple classification readily accessible to non-specialists.

### 2.3.1 Look-up tables

Worldwide the most commonly applied methods to define target river flows are rules of thumb based on simple indices given in look-up tables. The most widely employed indices are purely hydrological, but some methods employing ecological data were developed in the 1970s.

Water managers use hydrological indices to define water management rules and to set compensation flows below reservoirs and weirs. Examples are percentages of the mean flow or certain percentiles from a flow duration curve.[12] This method has been adopted for environmental flow setting to determine simple operating rules for dams or off-take structures where few or no local ecological data are available. Such indices may be set using various techniques or assumptions including those that are purely hydrological, those that are from generalized observations on hydro-ecological relationships, or those that stem from more formal analysis of hydrological and ecological data.

Implicit in these indices is that they are based on statistical properties of the natural flow regime. A hydrological index is for example used in France. The French Freshwater Fishing Law of 1984 requires that flows remaining in the river in bypassed sections of rivers must be a minimum of 1/40 of the mean flow for existing schemes and 1/10 of the mean flow for new schemes.[13] In dams used for public water supply, water may be returned to the river after use, presumably via a sewage treatment plant. However this may be some distance from the intake or even in another catchment. For hydropower dams, where releases are made for power generation, the annual flow downstream of the dam may not be significantly less than the natural flow, but the timing of flow will depend on electricity demand that is likely to be served during peak hours.

In regulating abstractions in the UK, an index of natural low flow has been employed to define the environmental flow. Often used is the Q95 Index: the flow that is equalled or exceeded for 95% of the time. In other cases, indices of less frequent drought events have been used such as the mean annual minimum flow. The Q95 Index was chosen purely on hydrological grounds. However, the implementation of this method often requires the use of ecological information.[14]

*"LOOK-UP TABLES ARE PARTICULARY USEFUL FOR LOW-CONTROVERSY SITUATIONS."*

The Tennant Method[15], is another index method used. It was developed using calibration data from hundreds of rivers in the mid-Western states of the USA to specify minimum flows to protect a healthy river environment. Percentages of the mean annual flow are specified that provide different quality habitat for fish e.g. 10% for poor quality (survival), 30% for moderate habitat (satisfactory) and 60% for excellent habitat. This method can be used elsewhere, but the exact indices would need to be re-calculated for each region. In the mid-Western USA, the indices have been widely used in planning at the river basin level. However, they are not recommended for specific studies and where negotiation is required.

Some authors have concluded that methods based on proportions of mean flow were not suitable for the flow regimes of Texan rivers, as they often resulted in an unrealistically high flow.[16] Instead, they devised a method that used variable percentages of the monthly median flow. The percentages were based on fish inventories, fish life-history requirements, flow frequency distributions, and water needs for special periods such as breeding and migration.

The advantage of all look-up methods is that once the general procedure has been developed, application requires relatively few resources. Unfortunately, there is no evidence that simple hydrological indices are transferable between regions and so they only become 'rapid' when re-calibrated for a new region. Even then they do not take account of site-specific conditions. The indices based only on hydrological data are more readily re-calibrated for any region, but have no ecological validity and so the uncertainty to achieve good results is very high. Those indices based on ecological data clearly have more ecological validity, but the ecological data may be costly and time-consuming to collect. In general, look-up tables are thus particularly appropriate for low controversy situations. They also tend to be precautionary.

### *2.3.2 Desk top analysis*

Methods in this section focus on analysis of data. Desk-top analysis methods use existing data such as river flows from gauging stations and/or fish data from regular surveys. If needed some data may be collected at a particular site or sites on a river to supplement existing information. Desk-top analysis methods can be sub-divided into those based purely on hydrological data, those that use hydraulic information (such as channel form) and those that employ ecological data.

Hydrological desk-top analysis methods examine the whole river flow regime rather than pre-derived statistics. A fundamental principle is to maintain integrity, natural seasonality and variability of flows, including floods and low flows. For example, emphasis is put on defining the hydrological conditions for drying-out where rivers are ephemeral or flushing sediment where floods are important in maintaining the physical structure of the river channel.[17]

*"AS A RULE OF THUMB, SHALLOW, WIDE RIVERS TEND TO SHOW MORE SENSITIVITY."*

An example of a hydrological desk-top analysis method is the Richter method.[18] The method-defines benchmark flows for rivers where the primary objective is the protection of the natural ecosystem. The method identifies the components of a natural flow regime, indexed by magnitude (of both high and low flows), timing (indexed by monthly statistics), frequency (number of events) and duration (indexed by moving average minima and maxima). It uses gauged or modelled daily flows and a set of 32 indices. Each index is calculated on an annual basis for each year in the hydrological record, thus concentrating on inter-annual variability in the indices. An acceptable range of variation of the indices is then set, for example + or - 1 standard deviation from the mean or between the 25th and 75th percentiles. This method is intended to define interim standards, which can be monitored and revised. However, so far, there has not been enough research to relate the flow statistics to specific elements of the ecosystem.

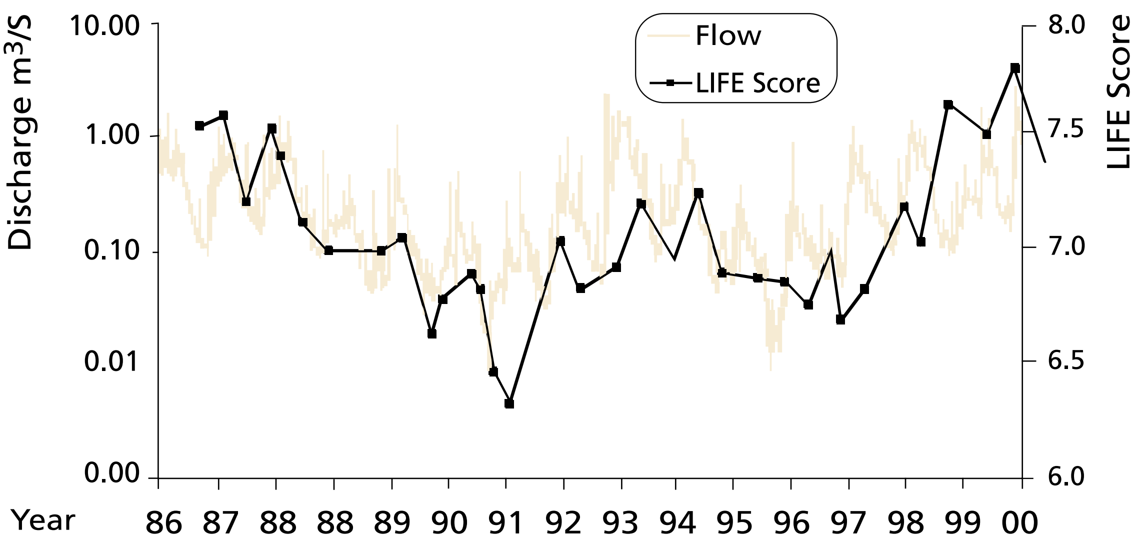
Hydraulic rating methods[19] form another important group of desk-top analysis techniques. They use changes in hydraulic variables, such as those in the 'wetted perimeter', the area of river-bed submerged, to define environmental flows. These provide simple indices of available habitat in a river at a given discharge.[20] As a rule of thumb, shallow, wide rivers tend to show more sensitivity of their wetted perimeter to changes in flow than do narrow deep rivers. In some cases limited field surveys are undertaken while in others the existing stage-discharge curves from river gauging stations are used. This method has been used in the United States[21] and Australia[22] considerably and some researchers[23] have highlighted the problems of trying to identify threshold discharges below which wetted perimeter declines rapidly. Given this limitation, the method is more appropriate to support scenario-based decision-making and water allocation negotiations than to determine an ecological threshold.

Desk-top analysis methods that use ecological data tend to be based on statistical techniques that relate independent variables, such as flow, to biotic dependent variables, such as population numbers or indices of community structure calculated from species lists. The advantage of this type of method is that it directly addresses the two areas of concern (flow and ecology), and directly takes into account the nature of the river in question. However there are some disadvantages:

(a) It is difficult or even impossible to derive biotic indices that are only sensitive to flow and not to other factors such as habitat structure and water quality. At the very least, biotic indices designed for water-quality monitoring should be used with extreme caution.[24]
(b) Lack of both hydrological and biological data is often a limiting factor, and sometimes routinely collected data may have been gathered for other purposes and not be suitable.
(c) Time series of flows and ecological indices may well not be independent, which can violate assumptions of classical statistical techniques and require special care.

A recently developed method in the UK in this category is the Lotic Invertebrate Index for Flow Evaluation (LIFE).[25] It is designed to be based on routine macro-invertebrate monitoring data. An index of perceived sensitivity to water velocity was developed by giving all recorded UK taxa a score

*Figure 2.1 Example river flow (logarithmic scale) and LIFE Score time series*



between 1 and 6. For a sample, the score for each observed taxon is modified based on its abundance, and an aggregate score calculated. The system works with either species or family level data. For monitoring sites close to flow gauging stations, the relationship between LIFE score and preceding river flow may be analysed. Moving averages of preceding flow have shown good correlation with LIFE scores over a range of sites (see Figure 1.1). Procedures for using this information in the management of river flows are still under development. Nevertheless, the principle is believed to be sound and LIFE has the major advantage of utilizing the data collected by existing bio-monitoring programmes.

### *2.3.3 Functional analysis*

The third group of methods includes those that build an understanding of the functional links between all aspects of the hydrology and ecology of the river system. These methods take a broad view and cover many aspects of the river ecosystem, using hydrological analysis, hydraulic rating information and biological data. They also make significant use of experts. Perhaps the best known is the Building Block Methodology (BBM), developed in South Africa.[26] The basic premise of the BBM is that riverine species are reliant on basic elements (building blocks) of the flow regime, including low flows and floods that maintain the sediment dynamics and geomorphological structure of the river. An acceptable flow regime for ecosystem maintenance can thus be constructed by combining these building blocks.

The BBM revolves around a team of experts that normally includes physical scientists, such as a hydrologist, hydro-geologist and geomorphologist, as well as biological scientists, such as an aquatic entomologist, a botanist and a fish biologist. They follow a series of steps, assess available data, use model outputs and apply their combined professional experience to come to a consensus on the building blocks of the flow regime. The BBM has a detailed manual for implementation,[27] which is now routinely used in South Africa to comply with the 1998 Water Act. It has also been applied in Australia[28] and is being tried in the United States.

In Australia, several functional analysis methods have been developed,[29] including the Expert Panel Assessment Method,[30] the Scientific Panel Approach[31] and the Benchmarking Methodology.[32] As with the BBM, all aspects of the hydrological regime and ecological system are studied by an expert group of physical and biological scientists. They make judgements about the ecological consequences of various quantities and timings of flow in the river, using a mix of available and newly acquired data. In the Murray-Darling Basin[33] where river flow is controlled by dams, the expert panel has viewed the river directly at different flows corresponding to various releases. In other cases, field visits are accompanied by an analysis of hydrological data. This integrated method also involves public meetings with key stakeholders in the catchment.

### *2.3.4 Habitat modelling*

As discussed above, difficulties exist in relating changes in the flow regime directly to the response of species and communities. Hence methods have been developed that use data on habitat for target species to determine ecological flow requirements. Within the environmental conditions required by a specific freshwater species, it is the physical aspects that are most heavily impacted by changes to the flow regime. The relationship between flow, habitat and species can be described by linking the physical properties of river stretches, e.g. depth and flow velocity, at different measured or modelled flows, with the physical conditions that key animal or plant species require. Once functional relationships between physical habitat and flow have been defined, they can be linked to scenarios of river flow.

Photo 2.1 Introduction of the Instream Flow Incremental Methodology to South Africa by Dr Bob Milhous (2nd right at rear) in the Kruger National Park Board Room, 1992.

Photo 2.2 Water level monitoring is an essential element of environmental flow management.

The first step in formulating this method for rivers was published in 1976.[34] This quickly led to the more formal description of a computer model called PHABSIM (Physical Habitat Simulation) by the US Fish and Wildlife Service.[35] Over the years, this has led to other models that follow basically the same method.[36] As implemented in a number of software packages, the traditional PHABSIM method uses one-dimensional hydraulic models, adapted to handle low flow conditions and to model cross-sectional velocities. These are coupled with representations of habitat suitability or preference to define how habitat changes with flow. The extent of the change will be specific to the species under consideration, and is frequently different for different developmental stages of individual species.

The physical habitat modelling method has now been adapted for use in many countries including France,[37] Norway,[38] and New Zealand,[39] while other countries have independently developed similar methods.[40]

*"PHYSICAL HABITAT MODELLING HAS NOW BEEN ADAPTED FOR USE IN MANY COUNTRIES."*

Physical habitat modelling has been used to estimate the effects, in terms of usable physical habitat, of historical or future anticipated changes in flow caused by abstraction or dam construction. The method has evolved from steady-state analysis of flows for given levels of habitat to time-series analysis for the entire flow regime in the river. In turn, the techniques of analysis have developed from looking at simple flow and habitat duration curves, to more in-depth analysis of habitat reductions under various scenarios. This considers a range of scenarios against a baseline, commonly of natural flows, and allows scenarios to be compared quantitatively.

The simplicity of these methods, both hydraulic and habitat modelling, was criticised in the 1980s. In particular, the biological representation concentrates on empirical descriptions of preferred habitat and does not model the complexity of processes occurring in a river ecosystem.[41] Since then, numerous specific modelling applications have been described which show some kind of improvement. Greater hydraulic process representation have been achieved using 2D and 3D computational fluid dynamics models[42] and new methods to quantifying hydraulic habitat have been published.[43] Likewise, new habitat models have included additional variables and have been expanded to the community level.[44] Yet other methods have moved away from empirical models to include a greater degree of process representation.[45] All these efforts have, however, not yet given rise to the development of a single package that is the logical replacement of PHABSIM. All of the model improvements currently come at a cost of increased complexity. It is hoped, however, that the new models could lead to new general rules for improved look-up methods and would define the impacts of river flow regulation on populations rather than habitats.[46]

One advantage of habitat modelling methods is that clear manuals exist that define step-by-step procedures. This allows for replication of results by different researchers, be they individuals or teams. The disadvantage of this method is that it has led to some poor applications by practitioners with little experience. Best results are obtained where teams, including hydraulic engineers, hydrologists and ecologists, work together, using habitat modelling as a basis for their river-specific studies.

## 2.4 Holistic approaches and using experts

Many early applications of environmental flow setting were focused on single species or single issues. For example, much of the demand for environmental flows in North America and northern Europe was from recreational fishermen concerned about the decline in trout and salmon numbers due to abstractions and dam operations. As a result, environmental flows were set to maintain critical levels of habitat for these species, including sediment discharge, flow velocity, and river depth. Part of the justification was that these species are very sensitive to flow, and if the flow is appropriate for them and their habitat it will be suitable for other parts of the ecosystem. In some ways, even purely hydrological methods can be said to be holistic. The concept that all elements of the ecosystem will be supported if the flow regime is natural is implicitly holistic, if not explicitly.

More and more methods now take a holistic approach that explicitly includes assessment of the whole ecosystem, such as associated wetlands, groundwater and estuaries. These also account for all species that are sensitive to flow, such as invertebrates, plants and animals, and address all aspects of the hydrological regime including e.g. floods, droughts, and water quality. A fundamental principle is to maintain natural variability of flows. The functional analysis methods described above are good examples of a more holistic approach. However, habitat modelling studies can also include assessment of a range of species, flow dynamics and stakeholder participation.[47] Overall a more holistic approach is increasingly found in all environmental flow methods.

*"MORE AND MORE METHODS NOW TAKE A HOLISTIC APPROACH."*

Generally, holistic approaches make use of teams of experts and may involve participation of stakeholders, so that the procedure is holistic in terms of interested parties as well as scientific issues. Where methods have the characteristic of being holistic they clearly have the advantage of covering the whole hydrological-ecological-stakeholder system. The disadvantage is that it is expensive to collect the relevant data.

Environmental flow assessment is a specialized subject and thus necessarily involves experts. There are rarely sufficient data available to fully apply an integrated, objective method in any specific situation by a non-expert. In the early days and in the development of look-up tables, single experts were often used to give their opinion, particularly where data were scarce. For example, an expert may have classified a river into a specific category within a look-up table to set the environmental flow. Use of expert opinion in this way has been criticised in some countries, such as the UK, as being subjective, inconsistent, non-transparent and biased.

An alternative is to form a multi-disciplinary team of experts, who can establish a consensus of opinion. This approach is thought to be more robust and can be more acceptable to interested parties. The team approach is also more consistent with the recognition that environmental flow assessment is a multi-disciplinary subject, requiring input from a wide range of specialist areas.

The Australian functional analysis methods[48] and the South African Building Block Methodology all make extensive use of a team of experts. The team usually includes a hydrologist, hydro-geologist, aquatic entomologist and botanist, geomorphologist, and a fish biologist. The team makes judgements about the ecological consequences of various quantities and timings of flow in the river. Where the river is controlled by upstream impoundments, the experts may view the river directly at different flows corresponding to various releases. Otherwise, field visits will be accompanied by analysis of hydrological data. Many habitat modelling studies have made use of expert opinion, for example, to describe habitat suitability indices for fish in the absence of specific field data. However, the use of round-table discussions has often not been productive, and other methods[49] have been developed.

The advantage of the 'expert team approach' is its flexibility and consensus building amongst experts who come to the best solution based on the data and model results available. The disadvantage is that it is not necessarily replicable and another group of experts might come to different conclusions. In addition, not only do the biological experts need to have a good understanding of their field and the functioning of the river under examination, they also need to have a basic understanding of hydrology. Furthermore, all the experts need training in how to follow the process.

In recent years a trend for increasing the involvement of stakeholders in the analysis has emerged. These may include both experts, e.g. on river functioning from conservation organizations or water companies, and non-experts, e.g. from industry or the general public. If stakeholders are to be included in determining an environmental flow, it is vital that the methods employed are acceptable to them. Although some stakeholders will be limited by their background knowledge in understanding environmental flow methods, often their knowledge of the river can be extremely valuable. Some stakeholders may have had training in relevant related subjects such as water supply, agriculture and industrial processes and can play an influential role in the debate.

## 2.5 Frameworks for flow assessment

The methods and approaches described above are normally incorporated into a wider assessment framework that identifies the problem, uses the best technical method and presents results to decision-makers. Below three of such frameworks that are most commonly used are discussed.

### 2.5.1 In-stream Flow Incremental Methodology (IFIM)

The In-stream Flow Incremental Methodology (IFIM) is a framework for addressing the impacts on river ecosystems of changing a river flow regime. The US Fish and Wildlife Service developed IFIM and its use has become a legal requirement in some states of the USA, especially for assessing the impacts of dams or abstractions. It has five phases to derive at inputs for environmental flow negotiations (see Box 2.1).

*Box 2.1 The five phases of the In-stream Flow Incremental Methodology (IFIM) include:*

*Phase 1. Identifying problems*
The problems are identified and broad issues and objectives are related to legal entitlement identification.

*Phase 2. Project planning and catchment characterization*
The technical part of the project is planned in terms of characterizing the broad-scale catchment processes, species present and their life history strategies, identifying likely limiting factors, collecting baseline hydrological, physical and biological data.

*Phase 3. Developing models*
Models of the river are constructed and calibrated. IFIM distinguishes between micro-habitat, commonly modelled using an approach such as PHABSIM, and macro-habitat, which includes water chemistry/quality and physico-chemical elements such as water temperature. A structure for specifying channel and floodplain maintenance flows is present, but there is little guidance on specific methods. Hydrological models of alternative scenarios, including a baseline of either naturalized or historical conditions, drive the habitat models. The models are integrated, using habitat as a common currency.

*Phase 4. Formulating and testing scenarios*
Alternative scenarios of dam releases or abstraction restrictions are formulated and tested using the models to determine the impact of different levels of flow alteration on individual species, communities or whole ecosystems.

*Phase 5. Providing inputs into negotiations*
The technical outputs are used in negotiations between different parties to resolve the issues set out in step one.

Advantages of IFIM include it being a comprehensive framework for considering both policy and technical issues and its problem-orientated structure. Its implicit quantitative nature integrating micro and macro-habitat is generally considered an advantage. Furthermore, its scenario-based approach is favoured for negotiations between water users, but may be less suitable in setting flow regimes to comply with ecological objectives.

Disadvantages of IFIM partly arise from its comprehensive nature. A full study takes a considerable time and because of the wide range of issues included, provides numerous avenues for criticism. Furthermore, it is important to understand the limitations of the models used, what they include, omit or simplify, and any further issues arising from the linkages of models. Quantification of uncertainty is an element that has been frequently overlooked. Many IFIM studies have been criticised, but these criticisms have often arisen because the framework was not applied in its entirety. Often, emphasis has been placed on Step 3 - Modelling, at the expense of the other critical steps. Paradoxically, IFIM studies have also been criticised for being too institutionalized, with the method being applied in an inflexible fashion. Finally, the fact that IFIM is an incremental procedure - it does not give "the answer" - has been viewed as both a disadvantage and an advantage.

### *2.5.2 Downstream Response to Imposed Flow Transformation (DRIFT)*

The Downstream Response to Imposed Flow Transformation (DRIFT) framework[50] was developed in South Africa, with its first major application being in Lesotho. Similar to the Building Block Methodology it forms a more holistic way of working as it addresses all aspects of the river ecosystem. It is a scenario-based framework, providing decision-makers with a number of options of future flow regimes for a river of concern, together with the consequences for the condition of the river. DRIFT has four modules to determine a number of scenarios and their ecological, social and economics implications (see Box 2.2). Probably its most important and innovative feature is a strong socio-economic module, which describes the predicted impacts of each scenario on subsistence users of the resources of a river.

*Box 2.2 The Downstream Response to Imposed Flow Transformation (DRIFT) framework uses four modules:*

*Module 1. Biophysical.* Within the constraints of the project, scientific studies are conducted of all aspects of the river ecosystem : hydrology, hydraulics, geomorphology, water quality, riparian trees and aquatic and fringing plants, aquatic invertebrates, fish, semi-aquatic mammals, herpetofauna, micro-biota. All studies are linked to flow, with the objective of being able to predict how any part of the ecosystem will change in response to specified flow changes.

*Module 2. Socio-economic.* Social studies are carried out of all river resources used by common-property users for subsistence, and the river-related health profiles of these people and their livestock. The resources used are costed. All studies are linked to flow, with the objective of being able to predict how the people will be affected by specified river changes (last module).

*Module 3. Scenario-building.* For any future flow regime the client would like to consider, the predicted change in condition of the river ecosystem is described using the database created in modules 1 and 2. The predicted impact of each scenario on the common-property subsistence users is also described.

*Module 4. Economics.* The compensation costs of each scenario for common-property users are calculated.

If there are no common-property subsistence users, modules 2 and 4 can be omitted. Although DRIFT is usually used to build scenarios, its database can equally be used to set flows for achieving specific objectives.

Two other activities outside DRIFT provide additional information to the decision-maker:

(a) a macro-economic assessment of each scenario, to describe its wider regional implications in terms of industrial and agricultural development, cost of water to urban areas and so on; and
(b) a public participation process, in which the wider body of stakeholders can voice its level of acceptability of each scenario.

DRIFT has also been applied to the Breede and Palmiet Rivers in South Africa and, in an abbreviated rapid form, in Zimbabwe. Implementation of the chosen scenarios is already underway in the Palmiet system and Lesotho. Because of its multidisciplinary nature, a comprehensive DRIFT application could cost US$1 million or more for a large river system. It is often an issue of trade-offs: the greater the investment in assessments and studies, the higher the confidence in the scenarios produced. It is important to put the costs into perspective. Most environmental flow assessments are carried out as part of the project planning for a new dam. A comprehensive DRIFT study will probably cost less than 1% of the total cost of many dams.

### *2.5.3 Catchment Abstraction Management Strategies (CAMS)*

The UK Environment Agency is responsible in England and Wales for ensuring that the needs of the abstractor are met whilst safeguarding the environment. To implement this responsibility in a consistent manner, the Agency has developed Catchment Abstraction Management Strategies (CAMS). The CAMS process includes participation of interested parties through catchment stakeholder groups and a Resource Assessment and Management (RAM) framework. RAM is intended as a default methodology in the absence of other more sophisticated techniques.

*Table 2.3 Fisheries Scoring Scheme as part of the Environmental Weighting within the Resources Assessment and Management Framework (RAM)*

| RAM score | Description |
|---|---|
| 5 | Salmonid fish – spawning/nursery areas |
| 4 | Adult salmonid residents (wild) and/or rheophile coarse fish – barbell, graling. |
| 3 | Salmonid fish passage (smolts and adults) and/or flowing water cyprinid fish - dace, chub, gudgeon, Bullhead, and/or shad spawning/rearing/passage |
| 2 | Slow/still water cyprinid fish - roach, bream, tench, carp |
| 1 | Minimal fish community e.g. eels and sticklebacks only, or no fish. |

The first step is to calculate the environmental weighting that determines a river's sensitivity to a reduction in flow. Four elements of the ecosystem are assessed: 1. Physical characterization; 2. Fisheries; 3. Macrophytes; 4. Macro-invertebrates. Each element is given a RAM score from 1 - 5 (1 being least sensitive to reductions in flow, 5 being most sensitive). In terms of physical characterization, rivers with steep gradients and/or wide shallow cross sections score 5, since small reductions in flow result in a relatively large reduction in wetted perimeter. At the other extreme, lowland river reaches that are narrow and deep are not so sensitive to flow reduction and score 1. Photographs of typical river reaches in each class are provided to aid the scoring of physical character. Scoring for fisheries is determined either by modelling using an approach such as PHABSIM, or by using expert opinion of Environment Agency fisheries staff to classify the river according to description of each of the RAM score classes. An example of the description and RAM score for each class is given in table 2.3.

*Table 2.4 Percentages of natural Q95 flow that can be abstracted for different environmental weighting bands*

| Environmental weighting band | % of Q95 that can be abstracted |
|---|---|
| A | 0 - 5% |
| B | 5 - 10% |
| C | 10 - 15% |
| D | 15 - 25% |
| E | 25 - 30% |
| Others | Special treatment |

Once a score for each of the four elements has been defined, the scores are combined to categorize the river into one of five Environmental Weighting Bands, where Band A (5) is the most sensitive (average score of 5) and E is the least sensitive (average score of 1). In a separate part of the RAM framework a flow duration curve for natural flows is produced. The RAM framework then specifies allowable abstractions at different points of the curve for each weighting band. Table 2.4 shows the percentage of natural Q95 flow that can be abstracted.

The percentages in this table are not well supported by hydro-ecological studies and are only intended as a default method. Where environmental flows need to be defined in more acurately, more detailed methods, such as habitat modelling, are recommended . The RAM framework focuses on producing an ecologically acceptable flow duration curve. The flow duration curve retains many characteristics of the flow regime, such as the basic magnitude of droughts, low flows and floods. However, it does not retain other characteristics, including temporal sequencing, duration or timing of flows, which may be important for the river ecosystem.[51] An ecologically acceptable flow duration curve is most appropriate where the river ecosystem is controlled by broad characteristics of dry season/wet season or winter/summer flows.

## *2.6 Choosing the right method*

There thus exist a wide range of methods, approaches and frameworks to determine the environmental flow. Now, what will be the most appropriate method for a specific case? What is the process for development of a set of methods in a country where no methods exist to date? Unfortunately there are no simple answers to these questions as there is no simple choice of which method is the best or most appropriate. Some of the advantages and disadvantages of the different methods are summarised in the Table 2.5.

*Table 2.5 Some advantages and disadvantages of different methods and characteristics of setting environmental flows*

| Method type | Sub-type | Advantages | Disadvantages |
|---|---|---|---|
| Look-up table | Hydrological<br>Ecological<br>Hydrological | Inexpensive, rapid to use once calculated | Not site-specific. Hydrological indices are not valid ecologically<br>Ecological indices need region-specific data to be calculated |
| Desk top | Hydraulic<br>Ecological | Site specific<br>Limited new data collection | Long time series required<br>No explicit use of ecological data<br>Ecological data time consuming to collect |
| Functional analysis | | Flexible, robust, more focused on whole ecosystem | Expensive to collect all relevant data and to employ wide range of experts. Consensus of experts may not be achieved. |
| Habitat modelling | | Replicable, predictive | Expensive to collect hydraulic and ecological data Replicable, predictive |

The choice of a particular method is mainly determined by the data available and the type of issue to be addressed. A number of categories can be defined. Table 2.6 at the end of this section gives a summary of this selection approach.

*Level 1. National level audit*

Scoping includes national assessments, to identify areas in which water allocation is potentially contentious, and national auditing, to determine the general level of river health. In those cases, where many river basins need to be assessed, a rapid method such as a look-up table would be most appropriate.

*Level 2. River basin planning*

Basin scale planning involves the assessment of environmental flows through an entire river basin. In this case, assessment may begin with use of look-up tables to help identify critical sites. A desk-top approach would then be most appropriate. Further, more detailed, investigation would probably come under the heading of impact assessment, and could include habitat-modelling studies.

*Level 3. Infrastructure impact assessment*

In many cases, environmental flow assessment involves impact assessment and mitigation of specific flow modifications such as dams or major abstractions. Where there is a single impacted site, a detailed modelling method is normally needed and the regulatory authority is more likely to be willing to fund the high costs. This will particularly be the case where water allocation is highly contentious and demanding a public inquiry. Where the impact is spread over several sites, it may be appropriate to make initial assessments of the impact throughout the basin using a desk-top method before detailed habitat modelling is undertaken as part of an holistic approach. Look-up approaches are not appropriate.

*Level 4. River restoration*
In the strictest sense, restoration is the re-establishment of the structure and function of an ecosystem[52] to a more or less natural condition. In practice, full restoration is not possible, due to major abstractions, dams or floodplain developments. As a result, restoration is often used to mean returning a river or river stretch to a recent pre-industrial state. It often involves reducing abstractions, releasing water from reservoirs and structural measures, and physical alterations, such as re-instatement of meanders. An holistic approach to restoration would allow the benefits of any activity to be assessed in terms of enhanced functioning of the entire or parts of the river ecosystem.

The level of expert input required again depends on how contentious decisions will be. In general, involving a group of experts will produce more credible results than using single experts. In addition, a highly structured use of experts, such as in the Building Block Methodology, produces far more robust results than ad hoc meetings.

*Table 2.6 Choice of methods*

| | | Look-up table | Desk top | Functional analysis | Habitat modelling |
|---|---|---|---|---|---|
| 1. Scoping study or national audit | | X | | | |
| 2. Basin-scale planning | | X → | X | | |
| 3. Impact assessment | level 1 | | X → | X | |
| | level 2 | | | X → | X |
| 4. River restoration | level 1 | | | X → | X |
| | level 2 | | | X → | X |

Each country has different experiences with assessing environmental flows. In some, such as South Africa Australia, the UK and the USA, specific methods have been developed, expert staff are available in universities, consultancies and government agencies, and national programmes of monitoring are in place. In many other countries there is no experience, little expertise and very few data. In these countries there may be a wish to establish a national environmental flow programme to develop the most appropriate methods, collect the right data and train appropriate personnel. A number of steps are suggested for such a programme:

*Step 1. Establish data collection*
Establish a national data-collection programme. This should include measurements of hydrology (river flows), hydraulics (water level and river cross-section) and ecology (species present, location found and links with flow) from a wide range of sites covering examples of the national situation.

*Step 2. Identify expertise*
Identify expertise within universities, consultant companies, government agencies and NGOs in relevant subject areas, including hydrology, hydraulics, water chemistry, botany, aquatic invertebrate and vertebrate zoology, geomorphology and engineering. Their expertise needs to be crystallized into concise knowledge about the hydro-ecology of the nation's rivers. They should be trained to work in multi-disciplinary teams and to understand each others' subject areas.

*Step 3. Create a data centre*
Establish a data centre and library, available to all, and publicise its existence.

*Step 4. Conduct training courses*
Run training courses to build local institutional structure to undertake assessment.

*Step 5. Develop and start implementing a research programme*
Establish a research programme to develop locally appropriate methods and knowledge. Methods need to be further applied and tested under specific conditions before definitive assessments can be made. An important consideration is to ensure that methods are compatible, so that results from any of them are consistent.

*Step 6. Conduct pilot studies*
Undertake pilot studies using local experts and a range of methods and available data to compare outcomes and test appropriateness.

## 2.7 Applying the methods and monitoring impacts

Environmental flow assessment involves defining an appropriate flow to meet a specific environmental objective or to achieve a balance between environmental, social and economic conditions. Deciding on the actual environmental flow that will be implemented may be a political judgement that involves compromises with other imperatives. For example, many laws have clauses to allow for particular conditions, such as "where there are overriding economic, social, health or safety considerations", where it would not be in the "national interest" or where it "compromises national security".

In applying environmental flow methods it is useful to distinguish between active flow management and restrictive flow management:

*Active flow management* occurs in the case where an action must be taken, such as opening a sluice gate, to implement an environmental flow downstream. In this situation, the dam operator may have complete control over the flow downstream, although, in times of flood, water may pass the dam via a spill-way. It is then possible to design and generate an entire flow regime, including low flows and floods. In such a case, a method such as the Building Block Methodology and a framework like DRIFT may be most appropriate, as they aim specifically to construct a flow regime. DRIFT can be used to construct different scenarios that have different ecological implications for the river.

If the environmental flow is prescribed in terms of some proportion of the natural flow that would have been in the river below the dam site, then some method of determining this natural flow is required. This is often achieved by monitoring the inflow to the reservoir or a nearby similar catchment that has a natural or semi-natural flow regime. In many cases water released from a reservoir will be of a different quality than would normally be in the river. It may be lower in oxygen or colder and, in the case of stratified reservoirs, may be chemically altered. In these situations, water may need to be released through different gates depending on the level of water in the reservoir. On occasions, the point at which a particular environmental flow is required may be at some distance from the dam itself, such as a floodplain or estuary. Flow releases may have to be altered according to lateral and tributary inflows below the dam.

*Restrictive flow management* occurs where abstractions or diversions are controlled in order to achieve an environmental flow. Such abstractions may be from the river itself or from groundwater within an aquifer supplying the river. The impact of the abstraction may vary depending on the river flow. While the impact may be very significant at low flows, it may be negligible at high flows. In such cases, scenarios are often dictated by potential abstraction profiles, i.e. the timing and amount of water taken.

Implementation of the environmental flows, under these conditions, may be achieved by reducing the amount of water that can be abstracted as the flow declines. There may be a threshold flow below which no abstraction is permitted. In the UK this flow is termed a 'hands-off' flow. In such cases monitoring the river flow is a key to implementing the management policy. Problems may arise where the process of control is bureaucratic. In the UK, the abstractor must be informed in writing when the flow falls to a critical level at which abstraction rates must be reduced. By the time the abstractor receives the letter and acts, the flow may have risen again. This may not be an issue where the flow regime has a pronounced seasonal pattern. Achieving environmental flows in groundwater-dominated catchments has particular problems. The relationships between abstractions, water-table level and river flow are often complex. The long lag-time in groundwater systems means that reducing abstraction when the river flow falls to a critical level may be too late, since the impact of the abstraction may continue for many months. Forecasting river flows based on aquifer conditions is often required to produce a more sensitive operational procedure for controlling abstractions.

As described above, methods of environmental flow assessment are at best indicative of the flow required to meet the environmental need. It is therefore essential to monitor three elements:

1. The river flow: to ensure that the implementation procedures are achieving the defined environmental flow. Flow should be assessed in relation to baseline conditions, both in the short term to assess whether day-to-day or seasonal variations in flow are achieved and in the long term to determine the year-to-year variability of flows;

2. The response of the ecosystem: to assess whether the ecological objectives are being achieved. This could require long term monitoring since the ecosystem may adapt slowly to any changes in flow. Although monitoring is often focused on key indicator species, it should cover as many elements of the ecosystem as possible to capture any unforeseen changes.

3. The social responses to ecosystem change: to identify where and to what degree communities rely for their livelihoods on fish or other river related resources.

Chapter 3

# Modifying Water Infrastructure

## 3.1 Infrastructure impacts and options

Until quite recently, water resource management was synonymous with building up a nation's stock of dams, diversion works and other physical infrastructure to store and regulate river flows. The aim was essentially to reduce natural hydrological variability. Similarly, "predict and provide" approaches dominated decisions about providing water services in different sectors. Frequently, no limit was set on how much water was abstracted from rivers, lakes, artificial reservoirs and ground-water aquifers. Likewise, limited attention was paid to the efficient management and use of water, once the resource left the supply pipe or canal.

*"NEW THINKING IS NEEDED TO MANAGE WATER RESOURCES SUSTAINABLY AND EQUITABLY."*

It is now widely accepted that new thinking on water infrastructure, set within a broader framework of integrated water resource management, is needed to manage water resources sustainably and equitably. Many countries are now somewhere along the road to adapting integrated water resources management approaches to their particular circumstances. Agenda 21[53] and the Dublin Principles[54] were important milestones that offer guidance to this work. Broadly, integrated water resources management considers land-water-environment interactions throughout the entire river basin, in conjunction with surface and groundwater flows, in a more systematic manner.[55] More emphasis is placed on co-ordinating actions across jurisdictions and sectors to improve overall surface and ground-water availability and water quality. Equally significant is that water service provisions are placed in a demand-supply management context. Also water users and service providers are jointly responsible for the most efficient and equitable use of water within their sector.

In basins facing water scarcity, greater emphasis on the reduction of water demand will relieve pressure on limited supplies and "free up" water for higher value uses. Increasingly this will create flexibility and support negotiations for difficult water allocations. Ultimately, this helps societies to better manage risks and uncertainty. It avoids the more painful economic and environmental dislocations when changes in water availability and quality are forced upon them.

### 3.1.1 Impacts of infrastructure on environmental flows

Table 3.1 on the next page shows various types of 'soft' and 'hard' infrastructure used in water management, together with the associated strategies and measures that serve to improve environmental flows. The physical ability to modify releases from existing dams depends on the type of dam, the provisions for releasing water through the dam, and the state of repair of the key water control outlets and structures.

Some measures could be implemented relatively quickly and achieve immediate results in terms of environmental flows. For example, a dam operator could open a sluice gate to increase downstream

*Table 3.1 Representative 'soft' and 'hard' infrastructure development and management strategies to improve environmental flows*

| Water Management | | Representative Strategies and Measures (To improve environmental flows) | |
|---|---|---|---|
| Function | Infrastructure/activity | Strategy/objective | Possible measures |
| River water storage, abstraction and flow regulation | **Dams, weirs, and river diversions of all scales** | • Improve the quantity, timing and quality of downstream releases<br>• Reduce the quantity of abstractions/ diversion flows (via demand management) | • Change design standards for new facilities<br>• Modify existing reservoir operating strategies<br>*Where feasible:*<br>• Retrofit outlet works of existing dams<br>• Decommission dams to restore flows |
| Groundwater abstraction and recharge | **Tubewells, groundwater recharge systems, retention/recharge basins, community-scale rainwater harvesting, etc.** | • Reduce unsustainable abstractions lowering groundwater tables<br>• Improve flows (availability) to groundwater-dependent ecosystems<br>• Improve infiltration of storm and flood water to groundwater sources<br>• Improve groundwater quality | • Modify abstraction rates (through pricing, fees and demand-side measures)<br>• Introduce infrastructure for storm and flood water retention/ groundwater recharge at different scales<br>• Introduce sustainable groundwater/aquifer management<br>• Introduce/modify infrastructure for conjunctive water use |
| Transport, bulk delivery and distribution to consumptive off-stream uses | **Canals, aqueducts, primary and tertiary distribution canals, pipelines, etc.** | • Reduce unnecessary losses in distribution systems to take pressure off supply<br>• Improve the efficiency of delivery systems | • Repair leaks in municipal water distribution systems and infrastructure<br>• Line irrigation canals |
| End-use demand management | **Water-efficient end-use devices, water conservation and water management** | • Reduce abstractions from surface and groundwater abstractions<br>• Recycle and reuse water where feasible | • Utilize water-efficient end-use devices<br>• Increase water metering and control (piped and groundwater)<br>• Implement policy measures promoting conservation (e.g. progressive tariffs)<br>• Employ technologies and systems for water reuse |
| Water quality management | **Water treatment facilities, drainage systems, land use systems, agrochemical systems** | • Improve water treatment<br>• Control/reduce urban, agricultural and industrial pollutants entering the watercourses<br>• Restore wetlands, environmental flows for natural purification | • Expand and rehabilitate water treatment infrastructure and facilities<br>• Design water treatment facilities for new water quality standards<br>• Eliminate/modify infrastructure (e.g. holding or settling ponds) and practices that contaminate groundwater |
| Catchment and Watershed Management | **Land management systems and farming practices, erosion control, forest and vegetation cover management, etc.** | • Improve water retention capacities of catchments and reduce uncontrolled run-off<br>• Reduce erosion and sediment flow into rivers<br>• Improve soil stability | • Implement/reinforce catchment management measures where feasible, e.g. adapting:<br>• forest and vegetation cover management;<br>• agriculture land use practices; and local water harvesting technologies |
| Non-Conventional Supply | **Recycling, desalination of brackish water and sea-water, conjunctive water management, traditional water harvesting systems, etc.** | • Add non-conventional supply to centralize water system and networks<br>• Add local supply options<br>• Improve integrated management of water sources | • Introduce / reinforce infrastructure where feasible, e.g. introduce:<br>• desalination;<br>• conjunctive surface-groundwater management; and<br>• local rural/urban use of rain water harvesting |

releases. Other measures need more time to take effect, such as those requiring retrofit or those to promote long-term structural changes in water demand that reduce pressure on surface and groundwater abstraction.

All infrastructure options and measures should be seen as context-specific, complementary and effective over different timeframes. The integrated water resources management framework and participatory decision-making approaches enable societies to identify the most practical, first steps in a coherent, co-ordinated approach.

### *3.1.2 Options to modify releases from dams and reservoirs*

Environmental flows are not about dams specifically. However, dams are often the most significant and direct modifiers of natural river flows and a starting point for improving environmental flows. Downstream releases from dams are broadly determined by the physical provisions to pass water through, over, or around the dam, and the operating policies for releasing water stored in reservoirs behind the dam.

Physically modifying flows through a dam depends on a combination of factors, such as the dam's type and size, and the design and state of repair of its outlet works. The outlet works include the means to pass water through the dam, such as the gates, spillways and pipes. If a dam has a reservoir behind it, the operating policies of the reservoir determine the daily and seasonal water release patterns. These normally reflect water inflows to the reservoir, storage policies, demand schedules for the dominant services, e.g. irrigation or hydropower production, or environmental flows. Table 3.2 shows typical provisions for passing river flows through various types of dams. Potential physical limits in modifying the quantity, timing and quality of the downstream releases are also shown in the table.

*Table 3.2 General provisions for modifying flow releases from different categories of dams*

| General Categories of Dams | Flow Provisions and Possible Physical Limitations |
|---|---|
| **Simple run-of-river dams, barrages, and diversion run-of-river dams.**<br><br>About 40 percent of the 45,000 large dams globally are less than 20 metres high.<br><br>Most of these would have vertical-type gates.<br><br>Alterations in environmental flows, and periodic flushing releases, would be readily accommodated with operation changes, without major investments or retrofit. | Structures whose primary purpose is to raise the water level in the river behind the dam, usually up to several metres, to divert some portion of the flow to intakes, such as feeding irrigation canals or power turbines. Large gates incorporated in the main structure of the dam are lifted out of the river to pass high flows and floods. Low flow seasons are most critical (for environmental flows), particularly if a run-of-river hydropower dam 'ponds' water to generate power at peak times during the day, or where diversion run-of-river dams "dewater" sections of the river, even if it is returned some distance downstream.<br><br>*Generally, there are no physical limitations to increasing flows through such dams and their associated structures. Water can easily be passed either:*<br><br>• under sluice gates (which can be partially lifted at any time);<br>• down fish passage structures (e.g. fish ladders); and<br>• through other low pressure outlets, pipes and valves when gates are closed.<br><br>Water quality is not generally affected due to the low pressures and short retention times, and because gates are open during flood flows. |

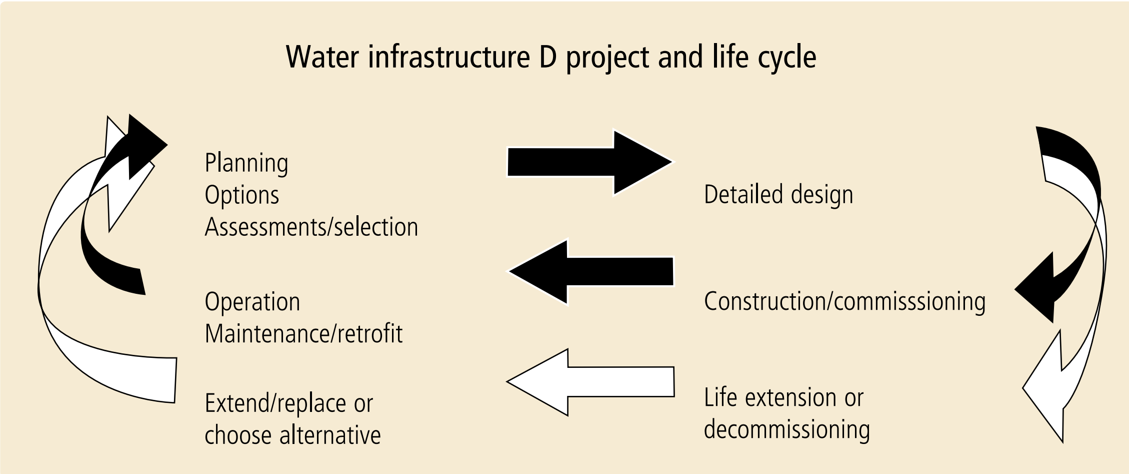
| General Categories of Dams | Flow Provisions and Possible Physical Limitations |
|---|---|
| **Storage dams (20m up to 60m high)**<br><br>About 50 percent of the world's 45,000 large dams are between 20-60 metres.<br><br>Many dams can modify environmental flows with operations; in other cases, retrofit or restoration of outlet works may be required. | Mostly storage dams 20-60 metres in height that incorporate a combination of spillways and gated lower pressure outlet works. Some will have vertical-type lift gates similar to run-of-river dams. Most often, these are embankment dams (earth or rock fill) for irrigation and water supply.<br><br>*Physical provisions for passing water through such dams include:*<br>• bottom flow outlets (gated) generally located in dam abutments, or less frequently under the dam;<br>• power tunnels and turbines (in dams with hydropower units);<br>• diversion tunnels (primarily used during construction);<br>• fish passage structures (e.g. fish ladders);<br>• under vertical-type lift gates (if incorporated); and<br>• in flood conditions – overflow spillways located on the dam, or separately.<br><br>*Possible physical limitations when modifying environmental flows:*<br>• bottom flow outlets or low level valves may be too small to release higher flow volumes, or inoperable due to age, lack of maintenance or sediment blockage;<br>• increasing minimum flows may be possible but full flood simulations may be more difficult; and<br>• diversion tunnels may not be operable, or not designed for regular use (e.g. unlined tunnels). |
| **High dams and major dams**<br><br>About 10 percent of large dams globally are above 60 metres high.<br><br>Generally they have high pressure outlets.<br><br>Provisions for modifying environmental flows would be assessed on a case-by-case basis. | Generally, these are higher dams from 60m to upwards of 300m or more. They incorporate spillways to pass major floods and high-pressure outlets at various heights and locations in the dam. Some have large, deep reservoirs where the water quality of releases from the dam may be a concern (e.g. due to thermal stratification, or low levels of dissolved oxygen in deep water in the reservoir).<br><br>*Physical provisions for passing water through such dams include:*<br>• high pressure outlets and valves;<br>• power tunnels and turbines (normally incorporated);<br>• bottom flow outlets (gated), located in dam abutments, or under the dam;<br>• diversion tunnels located in dam abutments, or away from the dam; and<br>• in flood conditions – overflow spillways either located on the dam, or separate to the dam itself.<br><br>*Possible physical limitations for modifying environmental flows:*<br>• bottom flow outlets may be too small to release higher flows, or blocked with sediment, or inoperable;<br>• high pressure outlet valves may be blocked, or inoperable; and<br>• water intakes may be at a fixed level in the reservoir. |

Re-regulation weirs are sometimes constructed downstream of a dam when there are large fluctuations in daily releases from the peaking operation of hydropower units. These weirs can range from a few hundred metres to a few kilometres downstream. They are generally designed to pool water during peak discharge periods to prevent large surges, and release it more regularly.

Improving downstream releases can be a simple matter of lifting a sluice gate, turning a valve to open bottom outlets, or increasing flows through power turbines. New dams can be designed with physical provisions for adjusting releases and accommodating future changes in values for managing the river at limited costs. When it is not physically feasible to adjust releases from older existing dams, retrofit is required.

### *3.1.3 The project cycle – introducing and improving environmental flows*

*Figure 3.1 Project and life cycle*[56]




The project cycle is one way to consider when and how to introduce environmental flows considerations in the selection, development and management of water infrastructure. The figure above provides a generic representation of the project cycle as it relates to water infrastructure.

The project cycle is also related to the concept of life-cycle management of physical assets. Most long-life structures will undergo many changes over their planned life as they age. Dams, which typically have a design life of 50 -100 years, may go through several cycles of renovation and upgrading, expansion, and possibly decommissioning. This will depend on how the physical, economic and social circumstances in the river basin change over time.

## *3.2 Enhancing environmental flows with new water infrastructure*

### *3.2.1 Criteria influencing planning and selection of new infrastructure*

In the development phase of the project cycle, strategic decisions are made concerning what new water infrastructure to develop, structural or non-structural. When a dam is selected this is followed by detailed design, construction and commissioning trials. Before selection, however, it is important to assess the various options.

The principles of integrated water resources management advance criteria to identify and assess all options. Building on this, the World Commission on Dams[57] identified the need for a comprehensive options assessment early in the project cycle so as to ensure that environmental and social factors could be incorporated into the decision-making. Consistent with these approaches, stakeholders involved in a policy dialogue and planning exercise would typically pose the following questions:

- Are all demand-supply options for water management and water service provision on the table to be evaluated?
- Are a sufficiently diverse set of options at different scales (e.g. large and small scale), and are those options emerging from 'top-down' and 'bottom-up' processes, included in the options inventory?

- Have opportunities to more efficiently manage existing supplies and water infrastructure been fully exploited before new sources are tapped?
- Are the options considered in a river basin context, and are the criteria for the evaluation and selection of options balanced, made explicit, and applied in a transparent way?
- Are the criteria for meeting and improving environmental flows explicit in the comparison and strategic selection of options?

If a new dam is proposed, the preliminary designs and operating strategies for the proposed dam must be sufficiently well defined to permit proper comparison with the other alternatives. The following checks should be made to assess the adequacy of treatment of environmental flows in these dam-related preparation studies:

- Have environmental, social and health impact studies of the proposed changes in flow regimes been sufficiently comprehensive?
- Do the preliminary designs incorporate provisions to meet a full range of environmental flows? For example, minimum releases on a seasonal basis, periodic flushing releases, multi-year flood simulations, and specific structural and operational measures to improve the water quality of downstream releases?
- Are the environmental flow provisions accounted for in calculations of project benefits? For example, in the overall benefit-cost evaluations?
- Have sensitivity tests been performed against economic and financial evaluation criteria, and for different scenarios? For instance, in relation to hydrological conditions, scenarios for potential influences of climate change on runoff in the catchment, and different environmental flow release regimes?
- Is a monitoring program in place to gather information on baseline conditions?

### *3.2.2 Required studies when proceeding with a dam*

It is important to ensure that the design of the dam and proposed reservoir operating strategies conform to environmental flow regulations. Because these structures are long-life, the aim should not only be to meet current standards, but to build-in flexibility to accommodate future changes in regulations, and to provide room for adaptive management more generally. This would include for example the ability to adjust to the influences of projected climate change.

*Stage 1: Detailed design*
Studies of environmental flow requirements would be undertaken using one of the assessment frameworks discussed in Chapter 2 (e.g. IFIM, DRIFT or CAMS). During this stage the parameters for environmental flows must be clearly set out as explicit design criteria. These studies, together with other environment mitigation and management studies, need to be well integrated with engineering optimization and design work.

*"DESIGN IS NOT AN EXACT SCIENCE – ENSURE STAKEHOLDERS ARE INVOLVED."*

Typically studies that were undertaken earlier during the project preparation stage leading up to the selection of the dam, such as feasibility and EIA studies, would be supplemented with more detailed monitoring and field assessments. These might include reservoir simulation studies to assess possible water quality effects. For example, thermal stratification, pollutant dispersion, sediment

Photo 3.1 Waterfall in Bosnia-Herzegovina

deposition, and the effect of drawing water at different levels from the reservoir. They could also include sedimentation and morphology studies to identify how changes in reservoir inflows and outflows impact on river morphology and erosion processes. Water balance studies could also be conducted to evaluate downstream interaction of surface and groundwater flows, water table levels, and issues such as salt intrusion in estuaries.

In addition, computer simulations and hydraulic model tests may be required to finalize the design of additional structures and operating strategies required for releases through the dam. Additional structures could include fish passages and variable level intakes. Computer simulations and tests would also assist in the choice of turbines and ancillary equipment for dams with hydropower units. These could include new rotor designs for power turbines that reduce mortality of fish, and air injection systems to increase the amount of dissolved oxygen released through the turbines. Finally, the studies must also define the environmental mitigation and monitoring programmes, including those related to meeting environmental flow requirements for construction and commissioning periods. However, keep in mind that designing environmental flows and working towards implementation is not an exact science – thus, keep stakeholders involved!

*"IT TAKES YEARS TO BUILD A DAM."*

*Stage 2: Construction*

The construction of dams can take several years. It is thus important that adequate provisions are made for environmental flows over the entire construction period. For instance, temporary cofferdams and diversion tunnels are normally constructed and will function while the main dam is built across the river. These temporary regulation structures should be capable of accommodating environmental flow releases. To achieve this, environmental flow considerations may need to be reflected in the scheduling of construction activities. The issues are case-specific and should be addressed in the environmental management studies during detailed design. Monitoring during the construction phase would look both at flows and water quality issues, such as the release of chemicals and wastes into the watercourse.

*Stage 3: Commissioning a trial period*
All the planning and design assumptions are tested at this time. Because of inherent uncertainties in predicting the behaviour of complex hydrological and biophysical systems it is desirable that the trial period is long enough and the environmental flows can be adjusted during this period. This is particularly important when environmental flow regulations are not specific. Ideally, flow adjustments would be made in the first year of operation, or over a longer commissioning trial period of 2-3 years, especially when reservoir filling takes a number of years.

*"ENSURE THE TRIAL PERIOD IS LONG ENOUGH TO MAKE THE NECESSARY ADJUSTMENTS."*

Longer trial periods are likely to be resisted where licences do not provide such flexibility. To avoid unnecessary confusion and conflict, it is important to set out the specific characteristics of trial environmental flow releases, the criteria to be used to decide adjustments, and who will decide. This should be done at the commencement of the detailed design stage, or preferably when the project is initially selected. The regulations on environmental flows and the dam operating licence will nonetheless have a large influence on the approach in specific circumstances.

### *3.2.3 Examples of environmental flows and new infrastructure*

There are many examples of incorporating provision for environmental flows in soft and hard infrastructure. At one end of the spectrum is South Africa's award winning Working for Water (WfW) Programme, launched in 1995, that brings environmental flows goals into catchment management. The problem was growing water scarcity in minor river catchments due to adverse, multiple impacts of water-intensive, exotic species of plants and trees. Left unchecked, a 38% reduction in in-stream flows was forecast in 10-20 years, rising to a 74% reduction in river flows in 30-40 years. The WfW solved the hydrology problem in a way that created employment and development opportunities for poor and marginalized stakeholders in the catchment. Initial studies undertaken on the effectiveness of the programme indicate that clearing invasive species results in average stream-flow increases of 8,000 to 12,000 litres/hectare per day in the wetter winter season, and up to 34,000 litres/hectare per day in the dryer summer period.[58]

At the other end of the scale are, the Lesotho Highlands Development Authority's procedures to introduce environmental flows provisions for new dams. The new environmental flow policy is being developed based on studies conducted by a multi-disciplinary team in 1997 using DRIFT (see Chapter 2). The approach was groundbreaking in that it involved stakeholder communities downstream of the dam affected by the change in flow regime. The original 1987 treaty between Lesotho and South Africa had provided releases of 0.5 and 0.3 cubic meters per second (cms) from the Katse and Mohale Dams, respectively. Based on the results of DRIFT, the design of the Mohale Dam was modified to include a multiple-level intake structure capable of passing 3 to 4 cms. With this measure the water quality, in particular water temperature and dissolved oxygen levels, of releases to downstream ecosystems could be improved. The diameter of lower level outlet structures was also increased to allow water to pass from the reservoir at 57 cms, thus providing the capacity for releasing occasionally flows that would simulate a flood.[59]

## 3.3 Implementing environmental flows using existing water infra-structure

### 3.3.1 Required studies and stakeholder involvement

Existing dams are often the first place to start implementing new environmental flow policies. Many countries have a large stock of existing dams, weirs and barrages where the beneficial effects can be immediate. If new environmental flow regulations prescribe what is required at each dam, then the necessary studies could focus on how to implement these best, if retrofit is required, how monitoring should be conducted or compliance can be ensured.

More substantive studies are needed where the environmental flow regime calls for periodic, case-specific adjustments in flow releases based on environmental quality indicators, such as in the Lesotho Highlands case. Environmental quality indicators nevertheless need to be translated to physical parameters that dam operators can act upon. These could include maximum and minimum flow releases per hour, chemical and thermal properties of water released, and, discharge of periodic releases for flushing, or volumes and timing of seasonal flood simulation flows.

In situations where both environmental flow regulations are open ended and major retrofit is required, the investigations may include an interrelated set of studies on:

- environmental flow requirements and environmental quality indicators;
- alternative means of providing services reduced by increasing the allocation to environmental flows;
- engineering optimization concerned with the selection of retrofit measures;
- operating strategies to optimize the impacts of environmental flows on existing services; and
- commissioning/re-operation trials and monitoring, to establish if the new releases provide the expected environmental qualities, and decisions to adjust flows accordingly.

Operating licences, and more recently water-use-plans for dams, are among the mechanisms available to engage stakeholders in decision-making on environmental flows. Environmental flows are just one of many regulations concerning the operation of dams, in addition to those relating to issues such as dam safety, flood management and water level control. Rather than taking a piece-meal approach, water-use-plans help integrate the various aspects and involve the local community in decisions.

What process is required depends on regulations in each country and how they are interpreted in practice. On this issue, the World Commission on Dams[60] called for all countries to formally licence all existing dams with clear provisions to involve stakeholders appropriately in decisions on the management of dams that affect them. This includes developing operating strategies and establishing environmental flows. The Commission further recommended adopting provisions for the publication of annual monitoring reports, and for the periodic, comprehensive review – at 5 -10 year intervals - of the management of dams, with full community and stakeholder involvement.

## *3.3.2 Limits to modifying existing dams*

A key limiting factor in improving environmental flows for existing dams is the cost and the issue of who should pay. There are broadly two main costs to consider. The first is the up-front cost of retrofitting needed to modify releases from the dam. If it is simply a matter of opening a gate in a run-of-river dam, this cost will be minimal. However, if a major retrofit is required on a high storage dam, then costs could be considerable.

*"ENVIRONMENTAL FLOWS ARE JUST ONE OF MANY REGULATIONS FOR THE OPERATION OF A DAM."*

The second cost is the ongoing cost of replacing the water services lost by releasing additional environmental flows. Such losses might include reduced power generation, or a drop-off in the delivery of water to an irrigation system. In economic terms, this cost should factor in the added value of environmental services that are maintained or restored. Overall, the general notion is that the social value of maintaining or restoring ecosystem services would be higher than the value of those services that are given up, even though the market might be unable to calculate some of these costs. Chapter 4 explores this issue more fully, together with the vital question of who should pay for environmental flows and the potential loss in some other water-related services.

Photo 3.2 Fish ladder enables fish to migrate beyond irrigation dam (Burkina Faso). Fish ladders are an important infrastructure improvement that can accompany environmental flow releases.

From the point of view of a private owner or even a public corporation, it might not be feasible to continue to operate a dam if implementing an environmental flow reduces the profitability of other services. Where an exemption from meeting the new standards is not given, some owners may decide that decommissioning is the only alternative. In this instance, the matter of who should pay for the decommissioning will need to be resolved. In certain situations dam owners may be given time to adjust to new regulations, where retrofit is needed. For example, legislation may permit public or private operators to delay major civil works until retrofit cycles, or until a dam comes up for re-licensing. Generally, governments would consider these factors when drafting environmental flows legislation and explain how to apply the regulations to new and existing dams.

### *3.3.3 Examples of retrofitting and changing operations*

There are numerous examples from Western countries where the operation of reservoirs has been modified or outlet works on dams have been retrofitted to improve environmental flows (see Table 3.3). In the United States, for example, there has been a wholesale change in the power industry as private, municipal and utility owned hydropower dams have come up for re-licensing and must meet higher standards for environmental releases.

With a few exceptions, environmental flow programmes in developing countries have so far focused on new infrastructure. However, the management of existing dams is expected to receive far more attention over the next few decades. Dams are coming under greater scrutiny for modernization and performance improvement opportunities. Management of the reservoir sediment, dam safety, climate change adaptation, and other environmental performance increasingly feature on the agenda of dam operators (see Table 3.3).

*"THE MANAGEMENT OF EXISTING DAMS IS TO RECEIVE MORE ATTENTION."*

Australia's comprehensive evaluation of environmental flow policies for the Snowy Mountains project in 1997 is an example of the type of work already being carried out in this area. This large, integrated water and hydroelectric power project has six major dams, 45 kilometres of interconnected tunnels and 80 kilometres of aqueducts. It diverts water from the east flowing Snowy River catchment west to the Murray and Murrumbidgee Rivers for irrigation and generation of power. The Federal Government established the Snowy Water Inquiry as part of its power sector reform. It was a well-resourced investigation programme with full provisions for stakeholder consultation and public hearings. It looked at environmental flows, catchment management actions and river rehabilitation works in all affected rivers. Based on the Inquiry, the two provincial governments involved agreed to restore flows in the Snowy River to 21% of the non-dam mean annual flow, and 27% in the longer term. This was considered appropriate for restoring environmental services in the affected rivers, and ensuring a viable hydroelectric generating business. The 10-year agreement cost about $US 170 million for capital works and monitoring.[61]

## *3.4 Decommissioning infrastructure to restore environmental flows*

The last phase of the project cycle involves a choice of decommissioning or life extension. Many countries have dams approaching the end of their economic life. For these a decision about life extension or removal is required. Often, the public perception is that removal is a radical idea. It is

*Table 3.3 Measures to enhance environmental flows from existing dams*[62]

| Project | Measure / Characteristics |
|---|---|
| Norris Dam, USA | This 81 metre high hydropower dam is on a tributary to the Tennessee river. In 1995 the Tennessee Valley Authority completed studies to improve downstream flow releases.<br><br>Measures adopted included:<br>• installation of two auto-venting power turbines to oxygenate water passing through the turbines, reportedly increasing DO levels by 91%; each unit cost about US$ 2.5 million to install; and<br>• construction of a re-regulating weir 3 km downstream of the dam (US$ 3.5 million) to further boost dissolved oxygen levels, and serve as a pool to release water when the dams was not generating power. This maintained flows according to the EFR schedule regardless of intermittent hydropower releases. |
| Priest Rapids and Wanapum Dams, USA | Two hydropower projects on the Columbia river system (2,000 MW). The Grant County Public Utility worked with local NGO's and civil society to develop an adaptive management plan to improve downstream releases.<br><br>The agreements:<br>• changed the reservoir operation to spill during summer and spring fish migrations to about half the river flow at that period (on average), rather than passing through power turbines (which would already be at capacity);<br>• reduced power output of 20% on an annual basis; and<br>• required an investment of US$ 200 million in fisheries protection measures. |
| Arrow Rock Dam, USA | The Arrow Rock dam built in the early 1900's has valves at three levels to control water releases from the dam. All have exceeded their design life. Three valves that control flow through lower conduits were out of service, inhibiting flood releases and the ability to meet minimum flow releases when the reservoir was partially drawn down.<br><br>In 2000, a multi-stakeholder assessment of the rehabilitation options and associated environment impacts recommended:<br>• replacing lower row of outlet valves in the dam structure (ensign valves) with clamshell gates, and enlarging valves in the mid and upper levels; and<br>• renovating the dam, at a capital cost estimated at US$ 14.6 million. |
| Stave Falls Replacement Project, Canada | In the mid-1990's, British Columbia introduced a requirement for water use plans (WUPs) to define operating strategies for all licensed dams. Regulations require operators to engage local communities in dialogue about options, trade-offs and priorities. A Consultative Committee (CC) was established for the existing Stave Falls dam and power station replacement project. The CC set eight objectives to balance downstream releases from the reservoir, including: industry use of the reservoir; downstream flood protection; hydropower generation; reservoir recreation activities; heritage protection for the First Nations people; wildlife, fish and aquatic biodiversity protection; and maximum flexibility to respond to future changes in operation policy.<br><br>Other features of the project included:<br>• agreement on a new release strategy to maintain downstream water level stability (supporting viability of fish populations, increasing spawning and rearing capacity, and reducing stranding), and to ensure periodic flooding of riparian areas;<br>• other measures to the reduce risk of exposure to elevated levels of total gas pressure;<br>• a CC recommendation to adopt immediately an operating strategy, with an interim review after five years, and a full review after 10 years; and<br>• implementation costs for the plan of an estimated US$ 200,000 per year in avoided power revenue |

certainly opposed by some stakeholders. However, the removal of infrastructure that has exceeded its economic life is a normal consideration and dams are no exception.

Where it is no longer in the public interest, or economically or financially viable, to operate and maintain the dam, removal is an option where it is physically feasible to do so. Experience shows that removing a dam can be less expensive than repairing it, particularly when the services the dam had provided are limited. Changing social values that call for restoration of river flows and ecological services, public safety, reduction of legal liability from a hazard that is uneconomical to repair are all factors that have influenced past decisions to decommission a dam.

*"REMOVING A DAM CAN BE LESS EXPENSIVE THAN REPAIRING IT."*

There are about 500 examples of partial and full decommissioning of dams in North America and Europe. Dams have been removed serving purposes ranging from hydroelectric to flood control and water control. These dams were of various types, including earth fill dams, concrete arch dams and masonry dams. To date, the average height of dams removed in the United States is about 6.5 metres. About 10 percent of the dams removed were over 12 metres, and four dams removed were over 36 metres.[63] The next section provides two examples of decommissioning projects and one example of studies to restore environmental flows.

### 3.4.1 Options for decommissioning

The options for decommissioning depend on the type of dam and the basin context. Broadly, the three main approaches are:

- permanently opening the gates, accompanied by other minor structural provisions;
- partial removal of the dam, or flow regulation structures; or
- full removal of the dam.

Opening the gates is a low cost option. It is feasible in run-of-river dams or storage dams with full-length sluice gates. For example, after a cabinet decision the gates of the Pak Mun dam in Thailand were opened in 2000 to restore fish migration in the Mun River a tributary of the Mekong River. This measure was taken pending a full assessment of the impact of the dam operation on the migration of various species of fish.[64]

Partial removal may be appropriate when the dam is constructed in different sections, for instance, with parts earth fill and parts concrete structures. In these cases, it may be economical and safe to remove only one segment of the dam. Full removal is generally more expensive and often involves the reversal of the procedural steps taken to construct the dam.

Broadly, the main costs of decommissioning are those associated with:

- the physical cost of removing the dam structures;
- the additional cost of special steps, such as the construction of protection works downstream, or the removal, treatment and disposal of contaminated sediment;
- the mitigation of the change in river dynamics returning to normal conditions; and
- the cost of providing replacement services where required (e.g. generating power or implementing demand-side management, or alternative water demand-supply measures).

In economic terms, the benefits derived from restored ecosystem services would be subtracted from the cost of decommissioning. In practice, decommissioning itself can be straightforward and accomplished quickly. Alternatively, it may be staged over several years, particularly when special care is needed to manage sediments that have built up over time in the reservoir.

*Case 3.1 Decommissioning of the Léguer River Dam, France*[65]

This 15m high concrete dam on the Léguer River was built in 1920 to supply power to a paper plant. The 400,000m reservoir located downstream of agricultural areas, experienced extensive eutrophication and 50% silting by 1990. In 1993, the concession expired and the dam was handed back to the State. Concerns also arose about the safety of the dam and ability of the spillway to pass high floods. In decommissioning the dam, the main difficulty was dealing with the reservoir sediment that would threaten downstream fisheries and community drinking water off-takes, if released untreated in an uncontrolled manner. The solution found was to flush the 95,000m of mud along the axis of the stream bed and treat in settling lagoons. The decommissioning work was completed in 1996 without any major problems and a programme rehabilitation and development for the basin and areas near the dam was established. The total costs were US$ 1.0 million and the State with the help of the Loire-Brittany Water Agency paid for and removed the dam.

### *3.4.2 Typical limitations, responses and risks*

Most advocates of decommissioning recognise that it is not appropriate for all large dams. Broadly, the larger the dam and reservoir the less feasible decommissioning becomes. At some stage, the costs and physical limitations become prohibitive. In a water-deficit basin, for example, decommissioning of a major storage dam would not be a viable option in the foreseeable future. Nevertheless, in some settings sediment will eventually render the storage capacity of even a large dam inoperable. Steps will then need to be taken to restore the system to a state of non-regulated flows, similar to a run-of-river project.

The main barriers to improving environmental flows by decommissioning, include:

*Land use change:* Where land use in downstream flood plains or around the reservoir has adjusted to the presence of the dam and altered stream flows. For example, there may be local opposition to changes in reservoir water levels, or full draining where recreational uses, tourist and other facilities have been developed. Downstream, there may be encroachment and land use in the flood plain, where retreat or removal is either politically unacceptable, or too costly.

*Availability and cost of replacement services:* Where the cost of replacing the services provided by the existing dam are high (i.e. water supply, flood control, navigation, irrigation, recreation), or where there is no feasible alternative.

*Downstream sediment releases:* Where agriculture pesticide, toxic industrial pollutions, heavy metals from upstream mining operations, etc.  have accumulated in the reservoir, and their release would threaten downstream human water use activities or ecological values.

*Costs and financing:* Where the costs of decommissioning are high and the government's financial resources are limited, or where issues such as who would pay for decommissioning or replacement services (if required) are unresolved.

To address and resolve some of these questions, a full EIA must be undertaken if the decommissioning option is considered, just as would happen for dam construction.

*Case 3.2 Removal of the Edwards Dam, USA*[66]

This 7.5m high, 280m long dam was built in 1837 for a water mill. Later it was converted to hydropower generation. In 1997, it became the first dam in US history to have its licence renewal refused. The Federal Energy Regulatory Commission (FERC) determined that the power it produced fell short of justifying the adverse environmental impacts. Funds for the dam removal and the associated fisheries restoration programmes were provided by a coalition of upstream dam owners, and no public funds were used. The decommissioning work included:

- the removal of a 30m section of the embankment dam after a gravel cofferdam was built;
- the breaching of the gravel cofferdam and the removal of the dam in stages over a four-month period to reduce sediment releases; and
- the planning of a 10-year programme of fisheries restoration and monitoring.

*Case 3.3 Options assessment related to the Wloclawek Dam, Poland* [67]

WWF Poland prepared an options assessment study that recommended decommissioning the existing the Wloclawek Dam on the mid-reach of the Vistula River in Poland. This assessment was prepared as counter-proposal to build a dam immediately downstream to address a dam safety issue with the existing Wloclawek Dam. The WWF purpose was also to advance river restoration. The Wloclawek Dam is in two parts: an earth dam, on the right side of the river, and a concrete dam with gates, powerhouse and navigation locks on the left side.
The study identified a procedure of:

- construction of a temporary cofferdam upstream and removal of the 300 metre section of earth dam;
- lowering this dam to the river bed to serve as a foundation for a new bridge for the road and rail line currently passing over the existing dam;
- the remaining 300 metre concrete section consisting of gates, powerhouse and navigation lock would be left in place, but the gates themselves would be removed;
- total cost of decommissioning was estimated at US$ 48 million;
- this compared to an investment of US$ 83 million in the option to repair and modernize the current dam (producing 60 MW; the navigation lock is unused), and US$ 800 million to build a second dam downstream with additional power generation facilities.

### *3.4.3 Processes to engage stakeholders*

Some countries have regulatory processes to assess existing dams, and to decide whether retrofit, renewal, upgrade or decommissioning is appropriate. Others do not. In the United States, assessments have largely developed around processes for licence renewal of existing dams. In Europe, decommissioning has been mainly linked to safety reviews and wider changes in flood management practice. Decommissioning is one option in the context of European Union directives such as the EU Water Framework Directive.[68]

The generic process for decommissioning would have some of the following stages:

*Stage 1. Feasibility study and impact assessment*

- Review all alternatives (dam and non-dam) to the services the dam is currently providing;
- Conduct a feasibility study of decommissioning and parallel environment and social impact assessment(s) using a multi-stakeholder steering group or independent party;
- Develop recommendations for the decommissioning alternative(s).

*Stage 2. Public debate on options*

- Spread public information and encourage public debate;
- Support consensus building with stakeholders;
- Locate sources of funding for decommisioning.

*Stage 3. Detailed design and approval of selected option*

- Develop detailed engineering design with mitigation and management;
- Prepare final EIA/EA plan;
- Organize public review, accept legal appeals and review licence permission.

*Stage 4. Construction, removal and monitoring*

- Change operation, if sufficient;
- Construct and / or remove infrastructure;
- Monitor operations and conduct maintenance;
- Assess remedial actions if required.

# *Chapter 4*

# Covering the Cost

To establish environmental flows it is important to define their costs and benefits and the incentives for their implementation. Given that flow restoration is likely to involve a re-allocation of water from current uses and users to in-stream uses, for example for fish and wildlife, the social and economic impacts are unlikely to be trivial. However, the results of such re-regulation will vary substantially from one situation to another. Outcomes will depend on whether, and to what extent, the net economic returns generated by environmental flows exceed those of the original 'development' of the river's water resources.

A clear conceptual and empirical understanding of the costs and benefits of flow restoration will be important in proposing an environmental flow regime. This can provide an important justification for action and funding. An understanding not just of the costs and benefits, but also of who gains and who loses from environmental flow is important. It can be used to identify stakeholders and provide an understanding of different parties' incentives to participate. Economic analysis of environmental flows will also serve to identify the money transfers, the potential sources of finance and the financial mechanisms necessary to successfully implement environmental flows.

## *4.1 Assessing financing needs*

An accurate assessment of the financing and other resource needs is an integral part of developing environmental flows at any level. Of course, the determination of financing needs does not occur in isolation. The objectives, targets and time frame must be decided in conjunction with the selection of institutional arrangements, incentive mechanisms and technical measures. It is also true that the source of funds may play a role in determining what institutions and methods are employed. For example, if philanthropic foundations are the prime source of available funding, an NGO-led approach may be favoured as opposed to a government-driven approach.

Changes to natural flow regimes are undertaken with the expectation that doing so will provide useful benefits. In cases where public funds or resources are employed, it is expected that the gains of such action to the economy and society will outweigh the resource costs. For example, implicit in the installation of a dam to store water for irrigating fields is the belief that the benefits in terms of increased crop production the 'direct benefits' will exceed the costs of building and maintaining the dam and irrigation system.

Previously, the 'direct costs' that were taken into account were limited to construction and financing costs incurred by project proponents. Today, however, the notion of 'direct' cost has expanded and typically includes efforts to mitigate or reduce the social and environmental impacts associated with altering the natural flow regime of a river. There often remain 'external' impacts that are not known to project developers or that are ignored in the planning, design, construction and operation of the project. Obviously, these are not incorporated into the accounting for a project. The costs, benefits and external impacts that may be associated with a large dam project are summarised in Table 4.1.

The movement towards environmental flows reflects the perspective held by many that water resources have been 'over-developed'. This notion implies that important benefits provided by natu-

*Table 4.1 Indicative costs, benefits and external impacts of building dams*[69]

| | |
|---|---|
| Direct Costs | • Capital costs of construction<br>• Resettlement costs<br>• Environmental mitigation<br>• Operating and maintenance costs<br>• Future decommissioning costs |
| Direct Benefits | • Power<br>• Irrigation<br>• Municipal and industrial water supply<br>• Flood control<br>• Navigation<br>• Recreation and fisheries<br>• Mine tailings storage |
| External Impacts: Environmental, Social and Health Costs, Benefits and Impacts (+ or -) | • Water quality impacts<br>• Impacts on commercial and non-commercial (subsistence) agriculture, timber, wildlife, and fisheries<br>• Impacts on ecosystem and biodiversity<br>• Impacts on emissions of pollutants<br>• Impacts on water-borne disease risks<br>• Social impacts, including impacts on cultural/historic sites, cultural identity, social cohesion, access to social services, etc. |

rally functioning hydrological systems have been degraded or lost, and that a return towards more natural flows would be preferable to the status quo.

The underlying reasons for ignoring the many benefits of the natural flow are numerous and hard to value. They are often either public in nature or accrue to culturally, geographically or economically marginal groups. These characteristics underscore not only the difficulty of identifying and quantifying the direct benefits of environmental flows, but also point to an important conceptual distinction between the costs and benefits of environmental flows.

*"THE BENEFITS OF ENVIRONMENTAL RESTORATION ARE DIFFICULT TO QUANTIFY."*

The main costs of establishing environmental flows are typically those related to offsetting the benefits generated by existing water infrastructure and uses, and the costs of re-engineering this infrastructure. These are typically measured in financial terms, for example the net benefits of hydropower or farming, or the cost of refurbishing a power plant. The price of the goods and services involved is easily observed in the marketplace. The benefits of environmental restoration, however, are often difficult to quantify. In many cases, they do not pass through markets and, thus, have no observable market price or quantity. The household subsistence use of rivers for fish, domestic water, transport and floodplain recession agriculture is difficult and costly to document. Similarly, the satisfaction enjoyed by recreational users and sport-fishers is not fully reflected in a market for scenic views, white-water, or fish. Nor is the psychological satisfaction of those who do not directly interact with the rivers but are nevertheless concerned about the existence of aquatic habitat, function and species, transacted in markets.

Since the benefits of environmental flows are unlikely to pass through markets, their contribution will not show up in an analysis that reflects only cash transactions in markets. They can be identified, however, through an economic analysis that includes what people are willing to pay for these services. Such an analysis assesses the impact of environmental flows on the economic welfare of society as a whole, and may give a very different picture of the costs and benefits.

Modifying existing systems to provide for environmental flows cannot be undertaken without reference to the status quo: the set of costs and benefits that resulted from water resource development and the social, ecological and economic changes that these brought. In assessing financing needs it is crucial to understand these economic 'building-blocks'. What was once the benefit of installing a dam to store water may now become a cost if the dam's operation is modified. Similarly, switching to an environmental flow regime may convert an existing cost to the project into a benefit to society at large by restoring (semi-)natural flows. An understanding of the transition in the costs and benefits is vital to identify the types of resources and finance required to implement an environmental flow regime. Table 4.2 lists the costs and benefits that result from implementing environmental flows.

*Table 4.2 Costs and benefits of a transition to environmental flows*

| | |
|---|---|
| **Stranded costs** (financial only) | • Remaining financial costs of debt or other finance obtained to build the original facilities that regulated the river in the first place |
| **Direct costs** (financial and economic) | • Capital investments in modification of structures, water delivery systems, etc<br>• Operational and maintenance costs of modifying system to facilitate environmental flows<br>• Capital or operational and maintenance costs of environmental mitigation (where environmental enhancement has occurred after developing water resources)<br>• Resettlement costs (where settlement has occurred in areas now to be inundated) |
| **Opportunity costs** (financial and economic) | • Net benefits foregone in relation to power, irrigation, water supply, flood control, recreational and other uses |
| **Transaction costs** (financial and economic) | • Costs of developing environmental flow regimes and setting targets for specific rivers and facilities<br>• Costs of legislation and litigation<br>• Costs of developing new mechanisms and institutions necessary to implement environmental flow regimes |
| **Cost-savings** (financial and economic) | • Reductions in operational and maintenance costs<br>• Reductions in mitigation expenditures |
| **Direct benefits** (financial, but mostly economic) | • Net benefits of commercial and non-commercial (subsistence) agriculture, timber, recreation, and fisheries<br>• Improvements in water quality<br>• Improvements in aquatic habitat and biodiversity<br>• Reduction in water-borne disease risks<br>• Reduction of previous social impacts |
| **External impacts** (+ or -) (financial, but mostly economic) | • Impacts on third parties (i.e. those not directly using the water or amenities provided by the dam or other facility)<br>• Impacts on ecosystem and biodiversity (as adjusted to the existing infrastructure) |

Note: A financial impact has a monetary consequence on the person or group involved. Economic impacts include financial impacts but also non-monetary impacts that have real resource or opportunity costs for those involved. Examples of the latter include the harvesting and consumption of fish and crops on a subsistence basis, as well as fishing and recreation for purely sporting and aesthetic purposes.

## 4.2 Effects on stakeholder groups

Examining the effects on different stakeholder groups is perhaps the best way to understand the transition to environmental flows and the resulting financing needs. The relevant actors will include all those that have a financial or economic stake in the transition, such as:

- the service provider of out-of-stream water infrastructure who supplies goods or services to end-users (i.e. hydropower producers, irrigation districts/companies, water supply providers and flood control agencies);
- the end-user of out-of-stream water who incurs costs in obtaining water and other complementary inputs transforming these into household or individual consumption (such as households using drinking water or hydropower or boaters on reservoirs) or into products for sale (for instance, farmers using irrigation water for crops);
- the end-user of in-stream water (i.e. the fisher, farmer, business, recreational user, tourist or citizen who benefits in financial or economic terms from environmental flows);
- third parties not directly involved in water management or the provision or receipt of services with or without environmental flows, but nevertheless affected by changes in water allocation (for example, local firms providing non-water goods and services who suffer (or benefit) due to diminished (or increased) demand by affected water users;
- government agencies, non-governmental organizations, or private sector companies that monitor, regulate or manage natural resources including water; and
- the taxpayers and philanthropists who support environmental restoration activities.

For the purposes of illustration the emphasis in this chapter is on 'in-stream' and 'out-of-stream' uses. In many cases where environmental flows will be applied the problem will not be as simple as whether water is in or out of the river. Rather it may be a question of the quality or timing of flows, for example, clean or dirty, fresh or salty, summer or winter, fast or slow moving, continuous or discontinuous. The general principles developed here are likely to apply to these other cases.

*"GROUPS NEGATIVELY AFFECTED WILL NEED TO BE ADEQUATELY COMPENSATED OR REWARDED."*

The resources needed to implement environmental flows consist of those required to physically adapt the existing environmental and engineering system and those needed to ensure the change is socially and economically acceptable. In the past, water resource developments often disregarded the second half of the equation. The lesson to be learned is that the change must be a positive one for all concerned, or at the very least must not put groups at risk. Otherwise, rancour and opposition may put the sustainability of the larger endeavour in question. The implication is that those groups negatively affected in financial or economic terms will need to be adequately compensated or rewarded. Table 4.3 takes each cost and benefit category from previous table and examines which stakeholders would bear the costs or receive benefits if financing was not present to ease the transition to environmental flows.

## 4.3 Sources of finance

To determine financing needs it is necessary to ensure that stakeholders are no worse off with environmental flows than they were under the status quo. Table 4.3 takes each generic stakeholder group identified earlier and looks in general terms at their situation under the status quo and under an environmental flows regime. Where there is a decrease in welfare this gives an indication of the type of financing that is required. Where there is an increase in welfare there is a potential source of financing. A number of financing needs can easily be identified and include:

- stranded costs of debt repayment;
- direct costs of engineering environmental flows;
- payments or compensation to out-of-stream end users that must cut back their water use;
- mitigation costs associated with negative impacts on third parties; and
- transaction costs that must be borne by those agencies, NGOs or companies that implement environmental flows.

*Table 4.3 Impacts on stakeholders of the transition to environmental flows*

| Cost/benefit | Stakeholder group impacts |
|---|---|
| Stranded costs | • Revenue shortfalls for owners and operators of dams, diversion structures and water delivery systems such as hydropower companies and other state-owned enterprises, government and private irrigation districts/companies, municipal water supply agencies/companies |
| Direct costs | • Costs for owners and operators, unless ownership/operation changes hands, in which case costs may be borne directly by government agency, non-governmental organization or other managing entity |
| Opportunity costs | • Power losses for hydropower companies/state-owned enterprises/projects and may affect clients in service areas<br>• Losses of net farm revenue for farmers<br>• Water supply losses for municipal water supply agencies/companies, as well as clients in service areas<br>• Reduction in flood control affects downstream populations and property owners<br>• Loss of recreational opportunities affects agencies/companies providing recreation goods and services, as well as recreational users |
| Transaction costs | • Payment of transaction costs is likely from public sources, thus taxpayers, philanthropists and concerned citizens/business are likely to be affected |
| Cost-savings | • Owners and operators would realize savings |
| Direct benefits | • Benefits accrue to business and households that depend on commercial use of river for fish, recreation, tourism, water supply and agriculture, transport for income generation and livelihoods<br>• Benefits accrue to subsistence households in terms of the satisfaction of basic human needs for food, water, transport, etc<br>• Benefits accrue to individuals in the form of consumptive and non-consumptive uses for recreation, tourism, sport-fishing, etc<br>• Benefits accrue to individuals who value the existence of rivers, and their aquatic habitat and biodiversity, for their own sake<br>• Benefits accrue to individuals, households and social groups that were put at risk by previous efforts to regulate rivers, whether in terms of water-borne disease risks, access to natural resources or loss of cultural identity |
| External impacts (+ or -) | • Impacts on third parties (i.e. those not directly using the water or amenities provided by the dam or other facility but who are affected in economic or social terms by environmental flows)<br>• Impacts on ecosystem and biodiversity (relative to their adapted state vis-à-vis existing infrastructure) |

The principal characteristic of the direct benefits of environmental flows is that the benefits accrue to a diverse range of people and are hard to capture through markets. As with any public good the principal sources of provision are likely to be public in nature. Thus, Table 4.4 identifies taxpayers and philanthropists as a likely source of financing for restoring these public benefits. From a government perspective, providing financing should be contrasted with the alternative of simply mandating change. In some countries, the latter approach may be more feasible, but in many countries any efforts to 'take' existing property rights are likely to be vocally and emotionally resisted. This resistance inevitably ends in litigation, which then requires substantial public funding if the government's case is to be won. Thus, there is a distinct attraction in the direct financing and market-based approaches as an alternative to the more heavy-handed regulatory approach.

*Table 4.4 Financing needs of a transition to environmental flows*

| Effects under 'status quo' *(with infrastructure)* | Effects under environmental flows | Financing required |
|---|---|---|
| SERVICE PROVIDERS | | |
| *Out-of-stream* | | |
| Debt repayment | Debt repayment | Stranded costs |
| Operation and maintenance costs | Reduced costs | Operational and maintenance cost savings |
| Mitigation costs | Reduced costs | Mitigation cost savings |
| | New capital and operational and maintenance costs | Direct costs of environmental flows |
| END USERS | | |
| *Out-of-stream* | | |
| Net benefits of production | Opportunity costs of lost production | Purchase of rights or compensation |
| *In-stream* | | |
| Loss in net benefits due to external impacts | Partial restoration of direct benefits of environmental flows | User fees and other environmental flows cost recovery |
| THIRD PARTIES | | |
| | External impacts (+ or -) | Mitigation costs |
| Costs to government agencies, NGOs, private sector | Transaction costs | Transaction costs |
| Taxpayers and philanthropists | | Financing for restoring public benefits |

Still, regulation itself can be used to create financing for putting water back in rivers through cap and trade systems. An example is the use of these systems in the United States where ground- and surface water are regulated in an integrated manner. In the basins where streams are largely fed by groundwater, groundwater withdrawals can have adverse affects on stream-flow once surface waters are fully allocated. In such cases, efforts are employed to ensure environmental flows are not impaired or derailed by further groundwater development. One approach used is developing a system of pumping credits, allocating these credits and facilitating their trading. In the Edwards Aquifer of Texas, this approach has led to an active market in such credits.[70]

Another approach is to establish a truly conjunctive management of surface and groundwater. The development of further groundwater sources could then be offset not just by reducing other groundwater withdrawals, but also by restoring stream-flow or recharging aquifers. In an innovative programme, the state of Oregon developed rules in 2002 for the mitigation of groundwater development in the Deschutes Basin. Mitigation projects that avoid impacts on surface water may be used to develop mitigation credits which can then be used to offset new, proposed groundwater permits. The credits may be developed by avoiding the consumptive use of surface water, i.e. through conserved water projects, permanent or temporary in-stream transfers of water rights, and allocations of stored water; or by recharging aquifers. Mitigation credits can be held and traded by individuals. Mitigation banks may also trade in credits and are permitted to use leases as well as permanent transfers to generate credits. The Deschutes Water Exchange, a non-profit water brokerage, is the first mitigation bank to take up this challenge.[71]

*"SOME COSTS OF ENVIRONMENTAL FLOWS MAY BE RECOVERED FROM DIRECT BENEFICIARIES."*

The analysis of financing needs also suggests that there may be the opportunity to recover some of the costs of environmental flows from those who directly benefit from them. Fees might be charged for fishing or recreation, and all or a portion of the revenue could be reinvested in environmental flows. This option might be applicable in developed countries where those that engage in such activities would typically be able to afford the fees. The difficulty is that in such countries the general level of wealth has meant that these kinds of activities have often been largely free in the past. For example, only a few efforts to charge for 'public' recreation activities associated with parks have been made, and these have met with considerable resistance. Fees associated with fishing and hunting are more common, but would likely need to be raised given that such revenues will already be allocated. In developing countries it might be inequitable to require riverine groups to pay for services that were initially taken away from them by water resource developments such as dams without adequate compensation. Thus, the prospects for user charges and cost recovery are not promising.

A final financing source identified is the potential for some cost savings from reduced operational and maintenance costs and mitigation expenditure by service providers. These entities may then be capable of making cash or in-kind contributions towards environmental flows. In the United States, for example, investments being made in environmental mitigation and dam safety fail to evaluate if these would simultaneously help to improve flows.

A further incentive for service providers to contribute is the uncertainty of the market versus 'command and control' approaches. Above we assumed that the objectives of environmental flows are to ensure that no group is worse off as a result of environmental flows. In reality, however, environmental 'takings' can and do occur. Service providers and their customers are often wary of the potential of future regulatory action to impinge on their activities. Making contributions to environmental flows would be one way for providers to demonstrate that they are acting in good faith to improve river conditions.

The financing needs associated with the alteration of operating rules for hydropower releases to better meet stream-flow needs will typically relate to the costs of retrofitting equipment and the loss of power revenues. In the case of the Priest Rapids Hydroelectric Project on the Columbia River, USA, the Grant County Public Utility District has invested over US$ 200 million in salmon protection and has an annual commitment in excess of US$ 40 million for this purpose.[72] In addition to direct investments that include the installation of sophisticated fish ladders and a hatchery programme, the utility has agreed to 'spill' water during spring and summer migrations of anadromous fish. It is estimated that this will reduce the 2,000 MW dams' total energy output by 20%. These efforts have been undertaken by the utility as part of its efforts to find a solution to the larger problem of hydropower and fisheries in the Columbia River.

Another variation on this theme is the possibility that service providers will pass on a portion of revenues in order to demonstrate that they are actively pursuing environmental restoration. For example, in 2003 the Bonneville Power Administration (BPA) initiated a Columbia Basin Water Transactions Programme to explore innovative strategies, including water rights transactions for environmental flows, as part of its larger fish and wildlife programme. In 2003 the programme was allocated US$ 2.2 million while the five year programme is to provide an annual funding of US$ 5 million by its second year. This would be a significant portion of the larger BPA Fish and Wildlife Programme responsible for expenditure of US$140 million annually. As administered by the National Fish and Wildlife Foundation, eleven local entities from Oregon, Washington, Montana and Idaho have qualified to participate in the programme. Although the funds are technically federal the local government receives resources from ratepayers as BPA earns its revenues by producing and selling electricity in the Pacific Northwest states.[73]

In other cases, the federal action or the likelihood of federal action if specific measures are not taken can be the impetus for providing financing. In other cases such efforts can also be voluntary. In both Costa Rica and Ecuador innovative cases exist in which municipal water providers have charged ratepayers for watershed restoration activities. In Costa Rica, several cases demonstrate different ways to finance voluntary approaches to optimizing land use for watershed protection and water flows.[74] Since the mid-1990s the Costa Rican government has used revenues from a fuel tax to fund a programme of payments for environmental services. The funds are deposited in a Forestry Investment Fund, which pays landholders to maintain or plant trees. In a number of cases the state funds have been matched by funds from small hydropower producers who pay the portion (one-quarter) of the total payment. Also contributing to the state programme is a municipal water utility that charges its customers an ecological surcharge that is then reinvested. The funds from the 'buyers' are thus used to leverage the state funds to pay farmers in the relevant watershed to engage in reforestation or conservation. In another case from Costa Rica, a small hydropower facility has worked directly with the conservation NGO that owns the upstream area, funnelling funds to the NGO in order to ensure it manages the watershed for the purpose of maintaining flows to the downstream power plant.

In sum, public and private sources of funds derived from taxes, philanthropic giving and the self-interested contributions by water service providers are likely to provide the bulk of financing and resources towards environmental flows. In general, the more likely the threat of associated regulation or the public acceptance of the need for environmental flows, the more likely a partnership can be formed to combine these three financing sources.

### *Case 4.1 Deschutes River Basin – options for financing environmental flows*

An example of how funding plays out in the case of irrigated agriculture and in-stream flow restoration can be found in the Deschutes Basin, Oregon, USA. A recent study examined the potential costs and benefits of restoring flows in the middle portion of the Deschutes River[75] through a number of alternatives including leasing water rights in-stream through donations and annual payments, and the piping of canals with transmission losses of from 50 to 65%). Based on in-stream flow targets from the Oregon Department of Fish and Wildlife, the study examined how much it would cost to enhance summer stream-flow from 0.8 $m^3/s$ to 7.1 $m^3/s$. Using a study by the US Bureau of Reclamation the authors calculate that achieving flow targets solely through piping would cost around US$ 4 million per year. If leasing were the only approach taken, the costs would be US$ 5.6 million, based on studies of the increasing opportunity costs of idling land. The authors suggest that selecting the lowest cost path – involving donated leases, a limited set of lower cost leases and then the least expensive piping alternatives – would cost US$ 2 million per year. These cost figures reflect the direct costs of environmental flows, in the case of piping canals, and the costs of covering the opportunity costs of farmers leaving their water in-stream through leasing.

Transaction costs were not considered in the Deschutes River study. The experience of the Deschutes Resources Conservancy (DRC), a multi-stakeholder group authorized by Congress to fund in-stream flow restoration in the Deschutes using federal and other funds, suggests that these costs are far from being negligible. With a 100-year history of irrigated agriculture there are considerable social, technological, legal, regulatory and administrative hurdles to overcome in actually spending funds of the magnitude suggested by the study, and seeing that these result in water in-stream. In particular, challenges by farming interests have held up or delayed the allocation of water to in-stream uses. Groups opposed to piping of irrigation ditches that add to local property values have also arisen, in one case taking over control of an irrigation district that was about to engage in a large piping project. Complex and sometimes archaic rules for the administration of water rights as well as staff shortages at the regulatory agency, have led to additional difficulties and delays in processing of paperwork. All of these practical considerations add to transaction costs and affect the timely implementation of environmental flows.

If the alternative of permanently transferring water rights in-stream is included alongside leasing and piping, the analysis of financing the Deschutes Basin provides a rich example of the full set of financing needs. The positive, negative and net effects of moving to an environmental flow regime on the financial status of the relevant actors are summarised below.

The service providers in this case are the irrigation districts. They hold the water rights that piping, leasing and transfers put in-stream as environmental flows. Annual water leasing is the least complicated method for meeting environmental flow targets. The administrative requirements are far less complicated than for piping or transfers and the only resource or financing need is for administration costs and payments to water right holders. In the leasing programme administered by the DRC and local irrigation districts, the districts take care of paperwork and the DRC matches this contribution with a small (US$ 7 acre-foot) payment to the water right holder from federal funds.

Piping of canals requires a significant investment by the districts as most public funding in the United States requires a matching contribution from local sources or from beneficiaries. Under Oregon law, the irrigation districts can keep a portion of the water that is saved by piping and apply it to additional lands. Oregon's Conserved Water Statute is unique in enabling those undertaking a conservation programme to benefit by increasing their water right by a portion of the saved water. However, in order to qualify for this benefit a minimum of 25% of the water must be transferred in-stream permanently. In this manner, win-win possibilities are created for both the farmer and the environment, which can serve to attract funding for restoration efforts.

The amount of water ('conserved water') that is legally protected in-stream must be proportional to the amount of public funding so that the financing needs may vary. However, the minimum statutory contribution of 25% of conserved water to in-stream uses means that if irrigation districts do not require at least 25% of financing to be contributed by restoration funds they would be 'losing' water by going through the conserved water process. Typically, the funds provided by the DRC or state funding sources are used to pay for materials, (i.e. pipe), while the districts make their contribution through in-kind provision of labour and machinery to lay the pipe. Given over-allocation of water in the basin the districts typically do not enlarge their acreage rather they leave their portion of the conserved water off the application, thus firming up supply for their customers.

Piping has little economic consequence for district customers (the out-of-stream end users) as they receive their regular allocation of water. Thus, the principal financing need in the case of piping is the direct cost of piping – that is, of the environmental flows. In some cases the negative impact of covering open irrigation ditches upon those living alongside the canals requires mitigation. For example, the district may provide a pond as a water feature to reduce opposition to a piping project. As mentioned above the transaction costs associated with piping in residential or hobby farming areas can also be significant.

Permanent transfers of water in-stream are not currently practised by irrigation districts but may be an alternative as urbanization and demographic growth reduce the demand for irrigation water. With transfers there is no technology involved so each transaction does not carry with it any direct costs. However, water right holders in the district pay 'assessment' fees on their water rights to the district to cover annual operational and maintenance costs, as well as past capital expenditures. Thus, in addition to paying customers directly for their water rights, for example paying the opportunity cost of the use of irrigation water, any effort to transfer water in-stream would require that at a minimum the 'stranded' portion of the assessment costs (e.g. for debt already incurred) be paid back to the district in order to facilitate district agreement to the transaction. The district itself would have a savings in operational and maintenance costs for not having to deliver as much water. Presumably this would have no net impact as the districts are run as non-profit corporations: the districts would just adjust the operational and maintenance part of the assessment cost to reflect the lower charges.

Third party impacts of transfers relate to the social, economic and environmental impact of 'drying' up irrigated land. Invasion of idled land by noxious weeds is of particular concern and requires financing. In order to mitigate for this negative impact, native desert vegetation can be replanted. Responsibility for this may fall on the landowner or it may be assumed by an organization such as the DRC. The wider economic impacts of moving from an agricultural economy to one based on recreation and tourism also need to be considered in the Deschutes. The Deschutes River study discussed above highlighted that the move to environmental flows could increase trout angling benefits by up to US$ 700,000 per year but also pointed to the potential for losses in household income from the loss of agricultural activity. Perhaps more critical are the social impacts, perceived and real, of altering historic land use patterns in the basin.

Transaction costs of engaging in transfers also require financing. A project of the DRC, the Deschutes Water Exchange (DWE), is working to develop water markets and facilitate transfers between different uses, including in-stream uses. The DWE relies on public and philanthropic funding to develop market infrastructure and engage in the programme development necessary to carry out transactions for in-stream flow restoration.

The benefits of restoration are largely public in nature as the use of the river is not regulated and is enjoyed by fishers, recreational users and tourists alike. In theory, opportunities might exist for cost recovery through fishing fees; however, these will often be already allocated. Thus, in the case of the Deschutes, apart from in-kind contributions from irrigation districts and water right holders, that donate all or a portion of their water to in-stream leasing or transfer, cash financing needs to be found in the public or philanthropic sector. The DRC itself receives a congressional appropriation of federal funds each year which varies but has been of the order of US$ 750,000. It also has successfully obtained other state and federal funds from organizations funding watershed and river restoration, such as the Oregon Watershed Enhancement Board and the National Fish and Wildlife Foundation. Local and state foundations, such as the Bend Foundation, the Meyer Trust and the Oregon Community Funds provide grants for core support and development of the DRC's mission. Even further, by developing enterprise programmes such as the Water Exchange, the DRC expects to generate additional revenues from services provided to private and public sector clients in order to finance further restoration.

Water markets can contribute to environmental flows. Trading of water is not a universal phenomenon, but formal and informal markets exist in a number of countries, including Mexico, India, Pakistan, Chile, the USA and Australia. By and large these markets have developed for the transfer of water and water rights from one out-of-stream use to another, such as from one farmer to another within an irrigation district. As urbanization, population growth and economic development proceed, these markets can also serve to reallocate water from one social use, such as agriculture, to another, such as municipal water supply. Only in the last decade have the possibilities of using water markets to transfer water temporarily or permanently in-stream begun to be exploited.

Many countries and states manage water under a 'beneficial use' doctrine whereby water not beneficially used is lost to the user or right-holder. In this context a key enabling condition for the use of markets to develop environmental flows is the statutory provision that in-stream uses are 'beneficial', that transfers to in-stream use from other uses such as agriculture are permitted, and that there is an entity authorized to hold the rights. Despite much interest in the creation of private 'trusts' to hold these water rights in the Western USA, states allowing in-stream beneficial uses have preferred to adopt a public trust doctrine whereby these rights are held exclusively by the relevant state agency. The buyer interested in creating environmental flows must therefore purchase the water right and transfer it in-stream by, in effect, turning it back to the state. Difficulties with this approach exist as conflict may develop between the roles of state as administrator and as property right holder, and constraints on state budgets may impair efforts to ensure that the in-stream flow rights are monitored and enforced.[76]

*"A 'FREE WATER MARKET' IS UNLIKELY TO BE SUFFICIENT TO REACH ENVIRONMENTAL FLOW OBJECTIVES."*

Implementation of such an approach within a system where rights are privately held may facilitate the transfer of water to in-stream purposes according to the relative economic merits of water in- and out-of-stream. However, a 'free' market in water is unlikely to be sufficient to reach environmental flow objectives, given the larger set of social and economic incentives that are likely to tilt the playing field in favour of out-of-stream uses. Instead,[77] it is important to provide a regulatory framework that can guide the reallocation of water between in- and out-of-stream uses in the direction desired by society.

## 4.4 The economic rationale

As environmental flow implementation will require significant societal resources and the realignment of property rights there is a need to have a clear economic rationale for environmental flows. In simple terms, if the investment of resources in changing the flow regime will not lead to marked improvements in social, environmental and economic conditions, or will be exacerbate existing societal inequities, then there will be little justification for undertaking and financing these changes. The argument for providing financing for environmental flows thus hinges on the demonstration or acceptance of the need to change the status quo.

Hindsight suggests that such a clear rationale and justification was not applied to the development of water resource infrastructure, even when the decision was construed in narrow economic terms. However, there remains a need to justify policy decisions and the investment of taxpayer monies and to provide a clear rationale for environmental flows. This is so, even if a multi-criteria approach that carefully considers the full range of economic, social and environmental impacts is used to compliment a purely economic cost-benefit analysis. However, if it is assumed that all social and environmental effects can be translated into economic terms, the economic approach remains a simple strategy to examining the justification for financing environmental flows.

*"ONE NEEDS A CLEAR ECONOMIC RATIONALE FOR ENVIRONMENTAL FLOWS."*

If the decision to move forward with environmental flows is examined from the perspective of the entire economy, however, rather than from the narrow perspective of financial impacts felt by specific actors, a number of modifications to the losses and gains explored above need to be made. These will actually simplify the net assessment of costs and benefits (see Table 4.5). In an economic cost-benefit analysis of a change in policy, all that matters are the real resource costs and the value of the economic output obtained. All are valued from the perspective of a truly competitive economy.

In this economic analysis, the internal transfers and intermediate products are not considered. Thus, the transfers from taxpayers to the government and NGOs have no net economic effect. Similarly, transfers from government and NGOs to out-of-stream service providers for system modifications and to out-of-stream end-users for financial compensation are omitted from the analysis. They are just intermediate products and transfers, not economic products per se. The economic 'sunk

*Table 4.5 Net effects on stakeholders of a transition to environmental flows*

| Stakeholder | Financial Effect | Economic Effect |
|---|---|---|
| Out-of-stream service provider | Net loss (depending on compensation of stranded costs) | Net loss (but less than financial loss due to omission of stranded costs) |
| Out-of-stream end-user | Net loss (depending on salvage value and compensation paid) | Net loss (but less than financial loss due to tax savings and omission of stranded costs) |
| In-stream end-user | Net gain (if no user charges) | Net gain (much larger than the financial net gain due to the non-market benefits) |
| Government agencies and NGOs | Internal shift and potential increase in revenues | Net loss related only to transaction costs |
| Taxpayers | Increase in payments | No effect |
| Third parties | Minor improvement | Significant improvement |
| Balance | May be net gain but likely to be a net financial loss | The more extreme the modification of natural flows the more likely there is a net economic gain |

costs' reflected in unpaid costs of infrastructure also do not enter into such economic analysis.

The analysis will show that the net costs will be incurred by out-of-stream service providers and end-users. It will further indicate that the transaction costs will be incurred by government agencies and NGOs, while the net benefits will be enjoyed by in-stream end-users. In transforming financial effects into economic effects the gains to in-stream end-users are likely to increase due to the prevalence of public and non-market benefits for in-stream uses. At the same time, a number of costs are eliminated from consideration. For example, stranded costs will be sunk costs in economic terms and tax benefits and subsidies to producers will be transfers not real benefits or resource costs. If transaction costs are reasonable and third party effects are achieved then the net economic result may be positive. In general terms, it can be expected that the further a system has been pushed away from its natural state, the more likely it is that the result of introducing environmental flows will lead to economic gains. If a system is only lightly modified then it is more likely that costs of restoration will exceed the benefits.

Economic analysis will reveal whether a particular project will be beneficial or not, once all costs and benefits are included. The possibility of obtaining either net losses or gains under both the financial and economic analysis of environmental flows suggests the use of a two-by-two matrix to classify possible outcomes in particular situations. As indicated in Table 4.6 the implication of a shortfall in financial terms is that the existing set of incentives is not sufficient to induce a change to environmental flows and, thus, additional financial incentives and financing are required.

The matrix reveals that where a full analysis of costs and benefits shows environmental flows to be beneficial financial incentives may or may not be sufficient. A 'win-win' scenario emerges where the financial flows generated by environmental flows are sufficient and in-line with desired economic results. In such a case, no additional finance is required. However, as indicated earlier it can generally be expected that a financial shortfall will be present and in such cases it is the existence of net benefits to the economy that justify the marshalling of additional resources to implement environmental flows. This is labelled the 'trade-off' scenario as the change to an environmental flow regime implies a negative sum game in which one actor will suffer in financial terms.

> *"A WIN-WIN SCENARIO: FINANCIAL FLOWS ARE SUFFICIENTLY AVAILABLE AND IN-LINE WITH DESIRED ECONOMIC RESULTS."*

*Table 4.6 Financial and economic rationale for financing of environmental flows*

Economic Analysis of Environmental Flows

| Financial Analysis | Not Profitable<br>*(full costs of restoration exceed the full benefits)* | Profitable<br>*(full benefits of flow restoration exceed the full costs)* |
|---|---|---|
| Financial Gap Exists<br>(e.g. expenditures on environmental flows exceed revenues) | BUSINESS AS USUAL Scenario:<br>*Environmental flows should not be an issue*<br>Existing water resource development appears on balance to be favourable, so the existence of insufficient financial incentives to enhance environmental flows is not surprising. Attention should focus on any unresolved inequities of original water resource development. | TRADE-OFF Scenario:<br>*Financing is necessary*<br>The benefits are uncertain, but the methods are proven and relatively inexpensive, hence the risk of regret is low |
| Financial Gap Does Not Exist<br>(e.g. revenues are sufficient to cover needed transfers and transaction costs) | CONUNDRUM Scenario:<br>Existing water resource development appears on balance to be favourable but financial incentives favour enhanced environmental flows. Attention should focus on eliminating perverse incentives or other policy/market failures if environmental flows are occurring spontaneously. If these are resolved revisit the economic analysis as it is probably mistaken and this is a Win-Win Scenario. | WIN-WIN Scenario:<br>*No financing is necessary*<br>Financial incentives are in-line with desired economic results. If environmental flows are not occurring spontaneously then perverse incentives, policy failures, market failures not related to water resources or unaddressed transaction costs may exist. |

Of course the matrix also provides for cases where environmental flows do not make economic sense. Here it is important to recall that in this conceptual presentation all forms and types of impacts are included as 'economic'. This simply affirms the point made earlier in this guide that establishing environmental flows is not a blanket approach, suited to all cases. In other words, many existing water resource developments make economic sense, particularly given the transaction costs that might be incurred in making marginal adjustments. It is also worth emphasising that the movement to address environmental flows issues needs to address ongoing social, political and economic inequities inherent in the initial development of water infrastructure and does not serve only as a physical means of addressing environmental impacts by putting water back in rivers.

The simplification of the impacts of environmental flows into a set of economic costs and benefits provides useful guidance. However, it is also important to consider how applicable this approach is in specific situations. Clearly the number of costs and benefits are considerable. Some will be established using fairly straightforward calculations such as the engineering costs for refurbishing or modifying a hydropower plant or the farm budget analysis to determine opportunity costs of irrigation water. Other cost calculations, such as those associated with decommissioning dams or mounting a cost-

Photo 4.1 Lack of minimal discharge results in severe pollution of the Vishnumati river in Kathmandu (Nepal).

effective programme of voluntary in-stream transfers, will be more speculative.

Looking more specifically at removing dams, it is clear that the experience with removing dams, particularly large dams (over 15 metres) is limited but growing. A publication by a conservation NGO, American Rivers, provides a broad overview of financing for this purpose in the US context.[78] The paper also provides an example of how a number of dams have been removed and retrofitted on the Naugatuck River in Connecticut. State and federal penalties of US$ 300,000 from Clean Water Act violations were used to fund the planning and design work on dam removal. Dam removal was achieved using funds from a wide range of sources including penalties paid by the City of Waterbury for violations bonds and from private partners. Ultimately, the removal and retrofitting of the seven dams came to US$ 8 million.

The extent to which the direct benefits of environmental flows can reliably be estimated will drive the utility of economic valuation for policy-making. While benefit estimation related to natural resources and the environment is greatly improved, and capacity is expanding around the world, it would be misleading to claim that cost-benefit analysis is, or will be, the only legitimate and final technical input to policy decisions of this nature and magnitude. It may provide, on a case-by-case basis, important and useful information on the costs and benefits. However, it is unlikely to give precise or even approximate guidance on optimum level of flows from an economic perspective.

In fact, the role of economic valuation is likely to be much more circumscribed. Inevitably valuation methods will be used to assess specific benefits of environmental flows. If the costs are also known, comparisons are inevitable. Given the partial nature of benefit evaluation, how such cost benefit estimates are used will be important. For example, in the Deschutes Basin, annual benefits of environmental flows in the Middle Deschutes to sport fishers were estimated at US$ 1 million, while the lowest cost approach to achieving such flows was estimated to be US$ 2 million.[79] Rather than summarising the results as a shortfall, given the uncertainties involved in the benefit estimation and the lack of data on the full set of benefits, the results should be presented as: "in the Deschutes Basin for just US$1 million a year all of the benefits (except angling) associated with environmental flows can be achieved".

Benefit valuation per se by those involved in environmental flow issues may be more useful if employed as a means of documenting cases where the imbalance of the status quo use of water has tilted too far towards out-of-stream use. In other words, where the marginal costs of failing to develop environmental flows are an order of magnitude larger than the marginal benefits of existing out-of-stream uses, valuation may provide a convincing illustration of the problem.

The limitations of benefit valuation should not, however, impede the use of economic analysis in estimating the costs of establishing environmental flows. In terms of assessing the direct and opportunity costs, economics can be quite helpful in planning and implementation. The assessment of transaction costs of different approaches and mechanisms to achieving environmental flows is also a valuable endeavour. Clearly the difficulty that environmental flow practitioners may face is that many economists, and particularly academic economists, prefer the challenge inherent in benefit estimation and are often less interested in the more 'mundane' aspects of valuing the opportunity costs of productive activities, for example. With respect to benefit valuation there is always room for improvement of methods and advancement of the knowledge frontier. However, it is important to ensure that money and talent are conserved for the analyses that provide useful guidance to practitioners involved in implementation.

*"THE BURDEN OF PROOF FOR WHY NOT TO ACT, RESTS WITH THE PROPONENTS OF THE STATUS QUO."*

In the real world, then, the availability of a full economic assessment of the impacts of environmental flows will be a rare occurrence. At the same time, the tendency to undervalue and underweight the public benefits of the natural hydrograph has led in too many cases to environmental degradation, social imbalance and poor economic decision-making. In other words, in considering engaging in and financing of environmental flows, the importance of these flows should receive the benefit of the doubt. The burden of proof for why not to take this important step should rest with the proponents of the status quo, not the other way around. This would be the prudent corollary for exercising the precautionary principle with respect to new projects to develop water resources. Unfortunately, this is not always a realistic objective given the economic interests engaged in water resource development, and the uncertainty whether these will really be made better off (or at least, not worse off) by the transition to environmental flows. As this courtesy was not extended to those who lost in the process of developing water resources, fear that environmental 'takings' may occur once the process begins is not unreasonable.

However, for the foreseeable future, there will be some burden of proof to be borne by those proposing environmental flows. Under such an approach, societal actors, through the political process, will judge the priorities of restoration projects and decide on the total allocation of financial and other resources for implementation. Table 4.7 indicates how the degree of certainty regarding the direct benefits of environmental flows can be combined with the cost-efficiency and efficacy of restoring flows. This can assist in determining priorities for the allocation of available finance. Clearly it is preferable to dedicate funds to problem areas where the direct benefits are relatively certain and the methods are proven and cost-effective. However, this case is likely to be the exception rather than the rule.

The remaining problem is how to prioritize situations where cost-effectiveness and efficacy are low, or where the in-stream benefits are small. Priority should be given to cases where results are assured. This implies that in the case, where the methods for realizing such flows are known and

*Table 4.7 Determining priorities for environmental flows*

| Certainty of Direct Benefits of Environmental Flows | Cost-Effectiveness and Efficacy of Methods for Implementing Environmental Flows: Low (*flow restoration methods are unproven and the costs relatively expensive or largely unknown)* | High (*flow restoration methods are proven and relatively inexpensive)* |
|---|---|---|
| Low: Extent of Direct Benefits Uncertain (*e.g. public support or technical evidence is lacking)* | FOURTH PRIORITY<br>The benefits are uncertain and the methods and costs are unproven or largely unknown. Restoring environmental flows would be last in terms of priority. | SECOND PRIORITY<br>The benefits are uncertain, but the methods are proven and relatively inexpensive, hence the risk of regret is low. |
| High: Extent of Direct Benefits Established or Credible (*e.g. public support or technical evidence is present)* | THIRD PRIORITY<br>The benefits are certain but the methods are unproven and costs are high or largely unknown, thus the risk of regret is high. | FIRST PRIORITY<br>The direct benefits are clear and the methods are cost-effective and well-known. Restoring environmental flows in this situation is of the highest priority. |

their costs are low, the uncertainty about benefits and costs should not be used to discriminate against environmental flows. Such cases should be a higher priority than cases where the extent of the benefits are clear, but the methods for and costs of achieving environmental flows are uncertain. Given that implementation of environmental flow regimes remain in their infancy, minimizing the risk of regrets/errors will ensure that disastrous failures in high profile cases are avoided. Success in turn will likely raise interest in pursuing the next project on the priority list.

*"PRIORITY SHOULD BE GIVEN TO CASES WHERE RESULTS ARE ASSURED"*

While economic tools may contribute to justifying the need to invest in environmental flows, they will be just one of many factors in determining society's agenda. That said, understanding the costs and benefits of environmental flows and the distribution of gains and losses will be important to identify the resources and methods needed. This is true particularly where incentives related to the allocation of water between competing uses will be needed or where market mechanisms may serve to facilitate voluntary re-allocation. Over time and with increased experience, cost-effectiveness information can play an important part in planning, priority setting and implementing environmental flows. Once priorities are set the information will be an integral part of the process of selecting the approaches and mechanisms to achieve environmental flow objectives.

Demonstrating that environmental flow targets are met in a cost-effective manner will be an important signal to all parties that the process is transparent and legitimate. It will show that environmental flows are not simply a 'free lunch' for environmental interests, but rather a serious effort to redress situations where river regulation has gone well beyond the long-term optimum point for all concerned.

## *4.5 Finding the right incentives*

Before moving to implementing an environmental flow it is useful to step back and assess the larger institutional, policy and incentive issues associated with the water and other resources involved. In some cases addressing such issues may obviate the need for a project-by-project or river-by-river approach by removing incentives that work against environmental flows. Similarly, the modification of existing incentives may be necessary to ensure that a project-by-project approach can succeed.

Understanding of the term 'incentives' varies and economists have produced numerous typologies. A brief characterization of incentives is therefore warranted. First, the term is understood by economists as incorporating both positive and negative aspects, for example a tax that leads a consumer to give up an activity is an incentive, not a disincentive or negative incentive. Second, although incentives are also construed purely in economic terms, incentives refer to more than just financial rewards and penalties. They are the "the positive and negative changes in outcomes that individuals perceive as likely to result from particular actions taken within a set of rules in a particular physical and social context".[80] Third, it is possible to distinguish between direct and indirect incentives, with direct incentives referring to financial or other inducements and indirect incentives referring to both variable and enabling incentives.[81] Finally, incentives of any kind may be called 'perverse' where they work against their purported aims or have significant adverse side effects.

Direct incentives lead people, groups and organizations to take particular action or inaction. In the case of environmental flows these are the same as the net gains and losses that different stakeholders experience. The key challenge is to ensure that the incentives are consistent with the achievement of environmental flows. This implies the need to compensate those that incur additional costs by providing them with the appropriate payment or other compensation. Thus, farmers asked to give up irrigation water to which they have an established property or use right are likely to require a payment for ceding this right. The question, of course, is how to obtain the financing necessary to cover the costs of developing such transactions and the transaction itself.

### *Case 4.2 Incentives for municipal water conservation*

For municipal water supply providers, efforts concentrate on demand management and water efficient technologies to limit outdoor and indoor use of water. Household metering and block tariff charging (where the price of water rises as the quantity used increases) are two excellent ways to provide incentives for customers to reduce water use. In 1990, the Los Angeles Department of Water and Power (LADWP) initiated an incentive programme for ultra low flush toilets that use 1.6 gallons as opposed to 5 to 7 for standard models.[82] Customers are either provided with rebates on the toilets or, in low-income areas, are provided with a toilet at no cost. In the latter programme a per toilet payment is provided to participating community organization to cover their costs of implementing the programme. The LADWP in turn shares the cost of the low-income programme through the Conservation Credits Programme of the Municipal Water District of Southern California from whom the LADWP purchases its water.

Variable incentives are policy instruments that affect the relative costs and benefits of different economic activities. As such, they can be manipulated to affect the behaviour of the producer or consumer. For example, a government subsidy on farm inputs will increase the relative profitability of agricultural products, hence probably increasing the demand for irrigation water. Variable incentives therefore have the ability to greatly increase or reduce the demand for out-of-stream, as well as in-stream, uses of water. The number of these instruments within the realm of economic and fiscal policy is practically limitless.

Photo 4.2 An Indian woman walks across a dried lake bed carrying pitchers on her head to collect water in Rajkot district of Gujarat.

*"A CLEAR LEGAL AND ADMINISTRATIVE PATHWAY IS NEEDED BEFORE AGENCIES WILL COMMIT RESOURCES."*

The challenges that arise therefore are best presented as the need to ensure a level playing field between in-stream and out-of-stream uses at various levels of economic policy. Below, some examples of variable incentives are listed:

- Credit policies: where credit is available or subsidized for agriculture but not for wildlife or other natural uses of land. This may lead to perverse incentives that encourage landowners to engage in non-productive uses of out-of-stream water or make agricultural activities with low economic returns appear viable from a financial standpoint.
- Sectoral fiscal incentives: production, input and export policies that subsidize agriculture and favour hydropower against other energy sources will prop up such activities. A failure to price water or to price it inappropriately (i.e. by the acre and not by volume in agriculture) will not provide the correct signals for investments in water conservation.
- Public investment policy: project selection criteria may discriminate in favour of large capital-intensive water infrastructure projects as opposed to recurring expenditures on habitat restoration. For example in the mid 1900s the US government used a 2% discount rate to evaluated water projects such as large dams and flood control infrastructure. At such a low rate practically all such projects were deemed viable from a cost-benefit perspective – so much so that the number of projects authorized far exceeded the available appropriations of funds.

'Enabling incentives' refer to those policy and institutional factors that form the enabling environment for the production and consumption of goods and services. In the case of environmental flows, for example, a clear legal and administrative pathway to protect water in-stream will be necessary before agencies commit resources to implement environmental flows. A number of other enabling conditions for successful water resources management and environmental flows include:

- clear policy, legal, and institutional frameworks governing water allocation, water use and/or water rights;
- clear administrative rules governing the transfer of water from out-of-stream to in-stream uses and the dedication of sufficient agency resources to this task;
- provisions for a regulatory approach to time-bound licensing of water resources infrastructure such as dams;
- capacity and political will to enforce existing rules and regulations regarding approved uses of water, including in-stream flows;
- flexible mechanisms for resolving conflicts over water rights between indigenous and state systems and between in- and out-of-stream uses;
- educational, training and research systems that enable the development of professional capacity in the different disciplines and fields relevant to environmental flows; and
- support for organizations and the media to build cultural awareness and stewardship principles with respect to the ecological and biodiversity values of environmental flows.

In sum, the challenge faced in achieving environmental flows comes down to avoiding three generic types of failure:

- market failure, i.e. absence of property rights and/or other deficiencies that limit financial support for environmental flows;
- policy failure, i.e. avoiding perverse incentives or incentives that tilt the 'playing field' against the use of water for in-stream purposes; and
- institutional failure, i.e. ensuring that the institutional framework and capacity contribute to, rather than against, environmental flows.

However, the types of variable and enabling incentive issues raised above should be carefully considered before concluding that what is needed is simply the necessary finance and a few useful methods for putting water back in the river.

## 4.6 Voluntary approaches

In broad terms efforts to establish environmental flows will rely on either a regulatory or a voluntary approach. The distinction is somewhat simplistic, given that in many cases voluntary approaches will either emerge from a regulatory framework per se or be supported by complementary regulations. However, the important distinction is between a voluntary approach that provides a set amount of financing for environmental flows and creates the market conditions to favour voluntary exchanges, and an approach that commands these flows to happen regardless of the cost. In the latter case compensation to stakeholders may be paid or they may simply lose their access to or right over water. This will depend on how water is allocated and managed, and larger issues related to political order, the rule of law and the sanctity of property rights.

Voluntary direct financing and market-based approaches follow a different process. Targets are established and the enabling environment is readied for the establishment of environmental flows.

The extent to which the targets are met depends on a host of factors. They include principally the extent to which finance is available to cover the cost of restoring the natural hydro-graph and the development of markets and market mechanisms that lower the transaction costs of such transfers. A number of alternatives and experiences with financing environmental flows and developing market approaches are given throughout this chapter.

Efforts to promote voluntary approaches rely on the argument that they are a more economically efficient method for reallocating water between out-of-stream and in-stream uses. This is achieved through better matching of supply and demand, and possibly also incentives for technical innovation if the instrument is correctly designed. Improving the cost effectiveness of market-based approaches is often a critical aspect of making them effective. For example, in 2001 the release of federal irrigation water in the Upper Klamath Basin in Oregon, USA was drastically curtailed to protect flows for endangered suckerfish and coho salmon . The economic cost to irrigators was US$ 33 million in terms of lost production. State and federal efforts to assist the farmers, for example through direct payments and well-drilling came to almost US$ 50 million. Federal water irrigates approximately 40% of irrigated lands in the Klamath Basin. Unfortunately, these lands are far more productive than other irrigated lands in the Basin. If efforts had been made to idle land, based on a market approach of idling the least productive land first, the costs in terms of lost production could have been as low as US$ 6.3 million.[83]

The institutional and tenure system governing land and water in a specific context will greatly affect the suitability of a specific voluntary approach relative to the command and control approach. For example, market-based approaches may not be appropriate where water is publicly owned and managed at local level, as is the case in France. Even where these approaches apply, a choice may actually exist as to which approaches to follow or how to combine these approaches. Standard approaches using information on a number of decision criteria are best applied in selecting the appropriate mix of approaches. Such a multi-criteria approach will need to identify the criteria most relevant to the context but are likely to include cost, environmental sustainability, equity, feasibility of implementation and transaction costs.

## *4.7 Key questions*

A number of key financial and economic questions need to be addressed in order to develop a successful programme or project of environmental flows:

*What will it cost?* It can logically be expected that the costs of environmental flows will vary considerably. The principal financial costs of environmental flows will be the engineering costs and/or payments made to those who must give up economic uses of water previously developed. However, the transaction costs, whether financial, economic or social should not be underestimated.

*"MOST FINANCING WILL COME FROM THE PUBLIC COFFERS AND PHILANTHROPIC SOURCES."*

*Who will pay?* Most of the cash financing for environmental flows will have to come from the public coffers or private philanthropic sources. Where water is conserved, instead of giving up its use, existing water users may well make a significant contribution through in-kind contributions or in cash terms. Specific opportunities may exist for charging the new beneficiaries, but there are important constraints on this in both developed and developing economies.

*Why finance environmental flows?* In many cases the development of water resources has surpassed the point at which such development was economically, socially or environmentally viable. Massive regulation and modification of riverine ecosystems has occurred largely because the benefits provided by these systems are largely public, while the benefits of water resource developments are more easily captured by private interests. This tide is now reversing as people's preference for more natural systems is growing and the understanding of the damage wrought to the health and welfare of marginalized groups is improving.

*How to get incentives right?* Many incentives exist that favour economic activities associated with the status quo. Removing these obstacles is difficult, but it pays to at least understand them – as working against them may prove even more challenging than confronting them. Providing conditions that enable alternative means of achieving environmental flows may be preferable and more feasible to dismantling the status quo right away.

*What are the alternatives?* A large and growing number of voluntary, market-based approaches exist as alternatives to the traditional command and control approach. The application of such approaches ultimately will depend on a regulatory framework that is conducive to establishing environmental flows. The primary advantage of using conservation, water markets, watershed payments and other approaches is that they are likely to be able to convert available finance into cost-effective solutions. As these mechanisms mature and replicate their advantages in terms of lowering transaction costs and avoiding heavy-handed, regulatory approaches to the reallocation of water for environmental purposes, we should find voluntary approaches an important niche in promoting environmental flows.

# Chapter 5

# Creating a Policy and Legal Framework

## 5.1 Defining the context

A regime for the effective management of environmental flows will need to be carefully designed within the context of each country's unique circumstances. Success in promoting an environmental flows regime will require a good understanding of the policy, institutional and regulatory steps that will be needed to succeed. It will also require a clear understanding that the general steps to be taken will need to be adapted and applied in the local context. Exactly how the general steps are applied will vary from country to country, and often within countries at the sub-national level.

To gain an understanding of the international and national context within which environmental flows are being addressed, both international and national law, policy and institutional set-up should be considered. The extent to which an understanding of the international context is required will, however, vary according to the level at which one is entering the debate. For some, a good understanding of the applicable international law and other non-binding instruments will be essential. For others, this may appear to be of little direct relevance.

The first step is to determine what legally binding and soft law instruments exist that may have an influence on the policy decisions and actions taken at the national level. This can be established by researching which treaties the country in question is party to, as well as the soft law instruments it has supported.[84] The purpose of taking this step is to consider the global and regional obligations that will need to be followed, and to consider how these obligations can best be implemented through domestic law and policy. There are also many guidelines and statements that are not legally binding but can still provide very helpful guidance to a country in developing their own environmental flow strategy.[85]

The second step is to determine what the country's Constitution says, if anything, about water resources and the environment;[86] what policies and regulations exist at the national and sub-national levels, and which institutions are responsible for their administration. This can be a time consuming task as it involves a review of policies and regulations that may impact upon environmental flows from an economic, social and environmental perspective.

For example, there may be a social policy about providing communities with access to water or an economic policy about providing water to new areas for irrigation. These may not have found their way into environmental policy or regulation, or have been the subject of discussion between different government portfolios. Furthermore, some water management functions may have been devolved to local government or to statutory and non-statutory bodies. Likewise the management of infrastructure may be the responsibility of a regional or federal government authority or even a private sector manager.

## 5.2 International law and other instruments

Very seldom do treaties or soft law instruments directly address environmental flows in a single provision. It is therefore necessary to explore whether other provisions, such as those relating to non-navigational uses of rivers or the protection of the environment, address the issue sufficiently from a more general perspective.

The concept of environmental flows is part of a broader notion of taking an ecosystem approach to integrated water resources management. As such, the relevant international instruments are not only those directly dealing with water resources, but also those that have a primary focus on the protection of nature and ecosystems. In other words, it will be necessary to look at a broad range of international instruments: from 'river' conventions right through to more general multilateral environmental agreements such as the Convention on Biological Diversity (CBD).

*"UNDERSTANDING THE APPLICABLE INTERNATIONAL LAW AND OTHER NON-BINDING INSTRUMENTS."*

### 5.2.1 'River' treaties

There are three examples of framework international river[87] agreements relevant in this context:

(1) The Barcelona Convention and Statute on the Regime of Navigable Waterways of International Concern;[88]

(2) The Convention relating to the Development of Hydraulic Power Affecting More Than One State;[89] and

(3) The United Nations Convention on the Law of Non-navigational Uses of International Watercourses (UN Convention).[90]

The first two treaties were adopted back in the 1920s, and they are both in force. The latter treaty provides that in the case a Party to the Convention desires to carry out operations for the development of hydraulic power, it has an obligation to enter into negotiations with affected riparian states with a view to concluding an agreement before executing the operations.

In 1970, the United Nations General Assembly recommended that the International Law Commission (ILC)[91] conduct a study on the law on non-navigational uses of international watercourses with a view to its codification and progressive development. After more than 20 years of intensive work, the ILC presented the UN with Draft Articles on the Law of Non-navigational uses of International Watercourses. Based on this body of work, a multilateral treaty was finally adopted by the UN General Assembly on 21 May 1997.

The United Nations Convention on the Law of Non-navigational Uses of International Watercourses is the only global framework treaty to address the use of rivers for purposes other than navigation. It sets out the fundamental duties and rights of States, and provides a framework of co-operation for the Contracting Parties, which can be adjusted in agreements between States sharing a watercourse. It requires States to protect and preserve the ecosystems of international watercourses, control the sources of pollution and to take preventive action on alien species. States located within an international watercourse have an obligation to co-operate in the regulation of the watercourse. They are thus obliged to work together on any hydraulic works or any other continuing measure to alter, vary or otherwise control the flow of the waters of the international watercourse. Countries must also take, individually or jointly, measures in the international watercourses to preserve the marine environment, including the estuaries.

There are several agreements covering particular watercourses that contain general principles of international water law applicable to environmental flows. Yet others include similar principles but go a little further by establishing more specific provisions on the regulation of river flows. A few good examples of these agreements are:

- The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki Convention);[92]
- The Mekong River Agreement;[93]
- The Protocol on Shared Watercourses Systems in the Southern Africa Development Community;[94] and
- The Convention on Co-operation for the Protection and Sustainable Use of the Waters of the Portuguese-Spanish River Basins.

The Helsinki Convention is of particular relevance to environmental flows. It was negotiated under the United Nations Economic Commission for Europe and has 33 Contracting Parties, including the European Community. The Convention has the following objectives:

- to prevent, reduce and control pollution of water causing or likely to cause transboundary impacts;
- to ensure that transboundary waters are used in a reasonable and equitable way, taking special account of their transboundary character in the case of activities which cause or are likely to cause transboundary impact;
- to ensure that transboundary waters are used with the aim of ecologically sound and rational water management, conservation of water resources and environmental protection; and
- to ensure conservation and, when necessary, restoration of ecosystems.

*Case 5.1 The Mekong River Agreement,*

The Mekong River Agreement was signed in 1995 between Cambodia, Lao PDR, Thailand and Vietnam, to create the Mekong River Commission and replace an earlier agreement establishing the Interim Mekong Committee. It sets up a framework for co-operation between the riparian States in all fields of the river basin's sustainable development. Parties have to protect the environment of the basin from pollution and other harmful effects resulting from development plans and uses of the waters and related resources. The Agreement specifically requires minimum stream flows for the protection of ecosystems, indicating that States will co-operate in maintaining flows "of not less than the acceptable minimum monthly natural flow during each month in the dry season". The Joint Committee, which is the implementation body of the Mekong River Commission, is in charge of adopting the necessary guidelines for the location and levels of the flows.

The definition of transboundary impact includes a wide range of activities that may have an effect on the watercourse ecosystem and thus relate to the provision of environmental flows. Transboundary impact is defined as "any significant adverse effect on the environment resulting from a change in the conditions of transboundary waters caused by a human activity, the physical origin of which is situated wholly or in part within an area under the jurisdiction of a Party, or an area under the jurisdiction of another Party. Such effects on the environment include effects on human health and safety, flora, fauna, soil, air, water, climate, landscape and historical monuments or other physical structures or the interaction among these factors; they also include effects on the cultural heritage or socio-economic conditions resulting from alterations to those factors" (Article 12).

Parties are encouraged to negotiate common management approaches for shared rivers, and adjust existing agreements to the provisions of the Convention. Agreements negotiated under the umbrella of the Helsinki Convention have reflected this trend, as well as an integrated approach to utilization and conservation of the entire basin; e.g. the 1994 Convention for the Protection and Sustainable Use of the Danube River, and the 1999 Convention on the Protection of the Rhine.

### 5.2.2 'Non-river' treaties

Several international 'non-river' treaties address conservation and sustainable use of river basins as part of a wider mandate/approach, and can thus be seen to relate to the management of environmental flows.

The Convention of Wetlands of International Importance, especially for Waterfowl Habitats (Ramsar Convention)[95] is the first of these treaties. This Convention seeks to ensure the wise use of all wetlands and provides for the more stringent conservation of those wetlands listed in the List of Wetlands of International Importance. The original emphasis of the Convention on waterfowls has been extended by the Conference of the Parties (COP) established under the Convention to cover other species and to consider the importance of wetlands for, among other things, the improvement of water management.

The Convention has adopted several guidelines which, while non-binding in nature, encourage Parties to introduce measures to manage environmental flows. The most relevant ones are the guidelines for reviewing laws and institutions to promote the conservation and wise use of wetlands. The guidelines for integrating wetland conservation and wise use into river basin management and the recently-adopted guidelines for the allocation and management of water for maintaining the ecological functions of wetlands can also be of use.

In managing for environmental flows, the role of wetlands cannot be overstated. Healthy river systems include wetlands as a vital component. Wetlands are described as the 'kidneys' of the landscape because of the functions they perform in hydrologic cycles and because they are the downstream receivers of wastes. They have been found to clean polluted waters, prevent floods, protect shorelines, and recharge groundwater aquifers.

During the Eighth Conference of Parties to the Ramsar Convention, (Valencia (Spain) 2002), Parties adopted guidelines for the allocation and management of water for maintaining the ecological functions of wetlands. The resolution recognises the variety of services that wetlands can provide and the necessity to allocate water for the maintenance of their natural ecological character. The resolution emphasises the following seven principles: sustainability, clarity of process, equity in participation and decision-making processes, credibility of science, transparency in implementation, flexibility of management and accountability of decisions. The resolution also contains five groups of guidelines aiming at operationalizing the principles. These guidelines relate to policy and legislation on water allocations for wetland ecosystems, the valuation of wetland ecosystems, environmental flow assessments downstream of dams, determining water allocations for a particular wetland ecosystem, and implementing water allocations to wetlands.

Like the Ramsar Convention, the Convention concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention)[96] also operates on the basis of specific site-listings. However, it contains a more stringent and independent regime for site selection. It also imposes more rigorous obligations on the Parties to the Convention and includes a number of provisions concerning reporting and inspection. The value of this Convention for environmental flows is through the protection granted to sites that have been listed as areas of outstanding universal value based upon their natural heritage values where such sites include a lake, a river, or the upper catchment of a watercourse. The Ramsar Convention and the World Heritage Convention operate on the basis of voluntary lists.[97] However, once a wetland, river or specific site has been inscribed in the list, it comes under international scrutiny.

Also indirectly relevant for environmental flows management is the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).[98] This treaty, as opposed to Ramsar and the World Heritage Convention, adopts a species focused approach and establishes a framework within which 'Range States' (States with jurisdiction over any part of the range of a particular species) can co-operate to prevent migratory species from becoming endangered. Among the conservation mechanisms provided by the Convention are the development of separate agreements among Parties that are 'Range States' of a particular listed species or groups of species, and their habitat, for the conservation of those species. The Bonn Convention can be useful for the conservation of environmental flows when rivers and wetlands constitute the habitat of protected species and the maintenance of water flows is necessary to ensure the survival of a migratory species.

The Convention on Biological Diversity is a framework treaty seeking to achieve the conservation of the earth's biological diversity. Its objectives are very wide and the substantive obligations of the Parties to the Convention are expressed in very broad terms. It applies to biological diversity of all sources (terrestrial, marine and other aquatic sources) and therefore has a relationship to environmental flows. The CBD establishes a comprehensive regime for the conservation of ecosystems and biological resources. Its objectives are: (i) the conservation of the biological diversity; (ii) the sustainable use of its components; and (iii) the equitable sharing of the benefits arising out of the utilization of the genetic resources.

Contracting Parties have an obligation to co-operate in the conservation of biological diversity in areas beyond national jurisdictions, and develop new or adapt existing national strategies, plans and programmes for the conservation and sustainable use of biological diversity. They are required to integrate biological diversity into sectoral or cross-sectoral plans, programmes and policies. Particularly important for environmental flows are those provisions of the CBD concerning in situ conservation and those on EIA and reduction of adverse impacts. The Conference of the Parties has adopted several resolutions dealing with inland waters' biodiversity. These decisions deal with the institutional and legal arrangements for the management of inland water ecosystems, the adoption of plans, programmes and strategies and the integration of biodiversity into other relevant policies.

Although some of the commitments that have been explored above are quite ambiguous and give an ample margin of discretion to the Parties in their implementation, they nonetheless, collectively, already provide a sound basis for an evolving and comprehensive international regime concerning environmental flows. In most cases, there are good opportunities for civil society to exert some pressure on Parties to comply with the treaty provisions and to also offer technical assistance and expertise.

### *5.2.3 Rights and duties of states in international rivers*

The international community has been unable to reach agreement on the adoption of a comprehensive global treaty concerning the conservation and use of rivers. The 1997 UN Convention referred to above[99] only went so far as to provide universal principles and certain recommendations and guidelines which serve to guide the management policies of transboundary rivers. These principles and guidelines provide useful guidance to riparian States sharing a watercourse. In order for these principles to acquire real meaning, they need to be brought into operation through the adoption of specific rules applicable to a particular watercourse. The principles referred to above, which have been included in the UN 1997 Convention and other relevant agreements are:

- the equitable utilization of international watercourses;[100]
- the duty not to cause significant harm to other riparian states;[101]
- the obligation to co-operate in good faith;[102] and
- the exchange of data and information on a regular basis.[103]

### *Box 5.1 The International Law Association (ILA) rules*

The International Law Association, a prestigious non-governmental academic organization founded in 1873, adopted the Helsinki Rules on the Uses of Waters of International Rivers. These rules, adopted in 1966, have been completed later on with additional rules including, for example, environmental protection of the status of groundwater. They are currently under revision by the Water Resources Committee of the ILA.

The Helsinki Rules endorse the concept of the drainage basin being the foundation for the management of international rivers, which it defines as the "geographical area extending over two or more States determined by the watershed limits of the system of waters, including surface and underground waters, flowing into a common terminus". The 1997 UN Convention does not use this concept and adopts the more restrictive one of the international watercourse.

Article IV of the Rules embraces the rule of equitable utilization, which limits national sovereignty and establishes that each basin State is entitled to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin, after considering factors such as climate, population, prior uses and alternative sources. This rule is complemented by others, including that there is no category of uses enjoying any preference over another; that existing activities may be deemed equitable and reasonable, unless the riparian State challenging them establishes their inequity, and that no State may reserve future uses of the watercourse for itself.

A major contribution of the Helsinki Rules is to protect the "beneficial" uses of the waters, meaning those that are economically or socially valuable. As a result, one could argue in favour of the inclusion of water for the environment as one of the socially valuable uses of the waters.

Although the Rules are not part of a treaty, they have been used on several occasions for treaty making purposes, such as in the case of the River Plate Basin Treaty between Argentina, Bolivia, Brazil, Paraguay and Uruguay.

## *5.2.4 Non-binding instruments*

In addition to the treaties and agreements outlined above, there is also a group of instruments, difficult to define, that cannot be considered 'law' in a strict sense , but are relevant nonetheless. In most cases, the rules set out in these instruments have been carefully negotiated, often with the intention of providing general guidance; they therefore have significance and do not entirely lack authority (see Box 5.1).

Within this category of instruments known as 'soft law', one can include instruments such as codes of conduct, guidelines, principles, recommendations, resolutions, and standards. They have been adopted by organizations such as the United Nations Environment Programme, the International Maritime Organization and the International Atomic Energy Agency. The significance of these instruments lies in the fact that they demonstrate a certain general consent and that they contribute to the development of new rules of national and international law.

Guiding principles for the regulation of environmental flows are to be found in a range of soft law instruments, such as Agenda 21.[105] Agenda 21 includes the concept of sustainable development of natural resources. Chapter 18 takes a holistic view of managing water resources, and in particular establishes the importance of integrated water resources management in river basins.

The appropriate level of management for water resources, including environmental flows, is stated as the level of the basin or sub-basin. While this is certainly a vital component of management for environmental flows, it is an incomplete assessment of the breadth of concerns requiring consideration in appropriately managing for environmental flows. The importance of managing for environmental flows is specifically addressed elsewhere in Chapter 18 and includes the maintenance of river health for human health and quality of life.

Integrated water resources management is therefore based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization. Any environmental flow regime should at a minimum ensure flows through ecosystems at levels that maintain their integrity. Taking a river basin approach to managing water resources, which recognises water as not only an integral part of the ecosystem, but also a social and economic good necessary for life, is a clear objective of Agenda 21.

The World Summit on Sustainable Development (Johannesburg 2002) was a follow-up on Agenda 21. Its Plan of Implementation offers specific guidance on how States may employ management strategies for environmental flows. The Plan of Implementation affirms the need to develop integrated water resources management and water efficiency plans by 2005, with support to developing countries, through actions at all levels to:

- develop and implement national/regional strategies, plans and programmes with regard to integrated river basin, watershed and groundwater management, and introduce measures to improve the efficiency of water infrastructure to reduce losses and increase recycling of water;
- employ the full range of policy instruments, including regulation, monitoring, voluntary measures, market and information-based tools, land-use management and cost recovery of water services, without cost recovery objectives becoming a barrier to access to safe water by poor people, and adopt an integrated water basin approach; and[106]
- improve the efficient use of water resources and promote their allocation among competing uses in a way that gives priority to the satisfaction of basic human needs and balances the requirement of preserving or restoring ecosystems and their functions, in particular, in fragile environments, with human domestic, industrial and agricultural needs, including safe guarding drinking water quality; and
- develop programmes for mitigating the effects of extreme water-related events.

The management of environmental flows in transboundary rivers is an international issue and therefore subject to international law. The correct interpretation and application of relevant principles is the first step towards building a more comprehensive regime for managing environmental flows in a transboundary context, as well as within the jurisdiction of one country.

## *5.3 National policies and legislation*

In most cases, existing national legislation has yet to establish a clear and systematic set of rules legitimizing the provision of water for environmental flows. Only a limited number of countries have so far recognised the importance of non-consumptive uses of water and have developed specific legislation to provide for it. The best recent examples of legislation being developed to address environmental flows can be found in South Africa and Australia.[107]

Legislative techniques that have been utilized include a legal requirement for the provision of a minimum environmental flow, the adoption of wild and scenic rivers legislation, the application of the public trust doctrine, and the regulated management of flows to provide for environmental benefits. In particular when dealing with over allocated rivers, this has in some cases included provisions for the compulsory and voluntary acquisition of existing water rights. Examples of these techniques are given at the end of this section.

**Photo 5.1 A Thai farmer pumps water in Pathum Thani, Thailand. During 1999, orange and rice farmers pumped large quantities of water from rivers during the worst dry season in decades due to El Nino.**

### *Case 5.2 The State, as public trustee, required to protect water courses: the Mono Lake case*

In 1983 the Supreme Court of California decided to protect the inherent rights of waterways independent from those of human beings in the National Audubon Society v. Superior Court Case. This decision exemplifies the progressive application of the public trust doctrine for the protection of water courses. Mono Lake is the second largest lake in California, supplied mainly by five freshwater streams from Sierra Nevada snowmelts. In 1940, the California Water Board granted a permit to appropriate virtually the entire flow of these streams to the City of Los Angeles. The resulting water deviations caused the level of the lake to drop and the surface area to diminish by one-third. It also let to an increase in its salinity and the scenic beauty and ecological values of Mono Lake were greatly threatened. The National Audubon Society (NAS), filed suit to enjoin the City of Los Angeles not to divert the water flows by arguing that the public trust doctrine imposes an affirmative duty on the Water Board to protect the shores, bed and waters of Mono Lake.

The most powerful and relevant component of the decision was the court's imposition of an affirmative duty on the Water Board, as public trustee, to consider the environmental impact resulting from the current water allocation and to reallocate water if deemed necessary to protect Mono Lake's ecosystem.

Obviously the decision would entail a balancing act between two fundamental interests: the freshwater needs of the citizens of city of Los Angeles and those of the species and ecosystems native to Mono Lake.

The significance of the Mono Lake decision to environmental flows is that it has developed and enriched the definition of the public trust. In addition, it has imposed a continuous affirmative duty on States, as trustees, to consider the environmental impact of the use and diversion of watercourses.

*Minimum flow requirements*

Some countries have required the provision of a minimum flow for each individual stream type. The Swiss Water Protection Act[108] establishes specific minimum flow values for different average flow rates, which must be maintained or increased in certain cases, depending on geographic and ecological factors.

*Regulated management of flows*

The regulated management of flows to provide for environmental benefits has been used in the Murray-Darling Basin in Australia, principally through specific decisions reached under the agreement that established the basin wide initiative.

*Wild and scenic rivers legislation*

Some countries have adopted so-called 'wild and scenic' rivers legislation, which involves the preservation of unique streams in their free flowing state from any obstructions. This is the case of the United States' Wild and Scenic Rivers Act.[109]

*'Public trust' doctrine*

The use of the public trust doctrine, which developed around the notion of guaranteeing public access to certain natural resources such as rivers. American Courts have used this doctrine to redefine water rights to preserve in-stream flows and protect certain riverine wetlands.

*Statutory management plans*

Some countries require the development of statutory management plans that must set aside the minimum amount of water required to maintain the health of the river, with allocations for consumptive use being restricted to the amount of water exceeding this requirement. The South Australian Water Resources Act[110] has adopted this approach.

*A combination of techniques*

An interesting development, consisting of a combination of some of the methods previously described is the one represented by the reserve in the new South African Water Act.[111]

*"IN MANY CASES, NATIONAL LEGISLATION FOR ENVIRONMENTAL FLOWS HAS YET TO BE ESTABLISHED."*

*Case 5.3 South Africa's National Water Act*

The South African National Water Act adopted in 1998 granted water resources the status of public good, under state control and subject to obtaining a licence. Under the new Act, the National Government is the custodian of the water resources and its powers are exercised as a public trust. It has the responsibility for the equitable allocation and usage of water and the transfer of water between catchments and international water matters.

The Act establishes the 'reserve' consisting of an unallocated portion of water that is not subject to competition with other water uses. It refers to both quality and quantity of water and has two segments: the basic human need reserve and the ecological reserve. The first one refers to the amount of water for drinking, food and personal hygiene and the second one to the amount of water required to protect the aquatic ecosystems. The determination of the reserve is the responsibility of the Minister, who can establish the reserve for all or part of a specific water resource. In addition, under the new Act the Minister, after consultation, can regulate activities that may reduce in-stream flows.

## *5.4 Practical steps and challenges*

The following section contains an indicative list of matters to be considered when embarking on the process of establishing a regime for environmental flows. The steps suggested here will vary with time and place, particularly as the global water agenda or the agenda for a particular region evolves. In working through these steps, good use can be made of ECOLEX, the 'Gateway to environmental law' (www.ecolex.org).

*Step 1. Check on multilateral environmental agreements*

Determine whether the country is a Party to any of the following multilateral environmental agreements: the Convention on Biological Diversity, the Ramsar Convention, the Convention on Migratory Species, and the World Heritage Convention.

*Step 2. Check on global river agreements*

Determine whether the country is a Party to any of the following global river agreements: the Barcelona Convention and Statute on the Regime of Navigable Waterways of International Concern; the Convention relating to the Development of Hydraulic Power Affecting More Than One State; and whether it has signed the United Nations Convention on the Law of Non-navigational Uses of International Watercourses.

*Step 3. Check on regional river agreements*

Determine whether the country is a Party to any of the following regional river agreements: the Helsinki Convention on the Protection and Use of Transboundary Watercourses and International Lakes, the Mekong River Agreement, the Protocol on Shared Watercourses Systems in the Southern Africa Development Community (SADC). If the country is a member of the European Union (EU) or is in the group of countries joining the EU in the near future, it will be worth looking at the provisions of the Water Framework Directive, adopted by the Council and the Parliament in 2000.

*Step 4. Check for binding provisions in treaties and customary law*

Some of the above treaties contain binding provisions relating to the protection of aquatic ecosystems. It is important to pay special attention to these. In addition, some of them, such as the Ramsar Convention, have adopted guidelines which can assist in preparing legal frameworks on wetlands conservation and allocate enough water for ecosystems. Also remember that International law is not only reflected in treaties, but also in custom, although customary law in this area is increasingly becoming reflected in treaties.

*Step 5. Check recent international water policy documents*

Explore the provisions of global documents such as Agenda 21, the Bonn Freshwater Conference Keys and the WSSD Plan of Implementation. These documents indicate some useful steps for organizing your national water policies. It is also important to explore whether the country has taken part in or endorsed any global initiatives, such as the Report of the World Commission on Dams, which might provide further guidance in the process of developing a national policy and legislation for managing environmental flows.

*Step 6. Check constitutional provisions to environment and water*

Determine whether the country has any specific Constitutional provisions relating to the right to a clean and healthy environment or the right to access to water. Also look to see what it says, if anything, about the sharing of power to legislate over such issues.

*Step 7. Check national and sub-national laws and agreements on water and natural resources*
Find out what laws exist at national, sub-national and local level dealing with water and natural resource management more generally. It will be important to also consider any customary practices of traditional communities. These might include uses and/or customs connected with the management and protection of water resources that are not yet properly protected under the law.

*"A 'ONE-SIZE-FITS-ALL' MINDSET WILL NOT WORK."*

Once the above analysis is completed, the next stage will be to explore in detail the policy and legislative framework. When it comes to legislation, it is important to remember that no one approach will be appropriate for every case. A 'one-size-fits-all' mindset will not work here. Legislators make laws to address issues of public concern within their own jurisdiction, taking into account their country's particular circumstances, and answering to their own electorates.

Model legislation is developed neither through engaging local communities, nor by drawing upon the wisdom of locally elected officials. Further, it is not drafted in the context of local conditions. Model legislation is perhaps an interesting academic exercise, but reality indicates that there is no 'quick fix'. To develop a legislative framework to effectively control water pollution and allocate enough water for ecological needs, 'fine tuning' is needed. However, while model legislation is not the answer, it is possible to elicit, both from work carried out at the international level, and from successful and not-so-successful case studies, relevant guidelines or key principles. These could guide the development of policy, and institutional and regulatory framework.

The major issues to arise, however, will be largely determined by the manner in which the river system has already been modified and the extent and nature of the 'rights' that have been created, either legally or through people's legitimate expectations based upon past practice. Systems that have not been significantly modified, or where there are few existing rights, are the simplest to deal with. However, experience tells us that it is those systems that are already under stress from over-allocation that attract the most community, media and political attention. Clearly, it is preferable to address the issue of managing for environmental flows well before this critical point is reached.

A serious attempt to manage for environmental flows will not occur unless clear policy decisions have been taken at the appropriate level of government. The level at which decisions are taken will vary according to the circumstances. In many cases a decision of a basin management organization as well a national or sub-national government will be required.

Above we explored the fact that international conventions may refer to environmental flows indirectly. The same applies to policy decisions that may give the 'green light' to move ahead while not referring directly to environmental flows. A policy decision may, for example, use language such as that chosen for the Johannesburg Plan of Implementation, namely to "Improve the efficient use of water resources and promote their allocation amongst competing uses in a way that gives priority to the satisfaction of basic human needs and balances the requirement of preserving or restoring ecosystems and their functions, in particular in fragile environments, with human domestic, industrial and agriculture needs, including safeguarding drinking water quality".[112]

Drawing upon the above given principles, several issues will need to be addressed that will require a policy response.

*Issue 1. Determining the scale at which to work*
Policy-makers will need to decide the scale at which environmental flows will be managed. The internationally endorsed approach is to seek to manage water resources in an integrated fashion at the basin level. If water resources are not being managed at such a scale the task of managing for environmental flows faces significant hurdles.

*Issue 2. Applying the subsidiarity principle*
The principle of subsidiarity, which is about dealing with issues at the lowest appropriate level capable of handling them, should be applied to the management of water resources. This often involves difficult political choices of the level at which particular decisions are taken and enforced, and how and where financial resources are raised and expended. In the context of managing environmental flows, the initial policy decision and the development of a legislative framework must be taken at the highest possible level. However, the 'on the ground' implementation will often involve day to day decisions being taken at the sub-national and local levels. While circumstances will vary, the need to involve all levels in the development and implementation of a successful regime for environmental flows will remain.

*Issue 3. Defining rights over access to water*
Creating a robust water allocation system that clearly defines rights over access to water is critical. This will include addressing the often controversial, yet fundamental, issue of defining property rights to water. Domestic trade in water entitlements is one market-based tool that has been used in several countries, including Australia and Chile. Experience gained in Australia has demonstrated that "an essential pre-requisite to trading in water rights is the adequate definition of those rights as a form of property separate from title to land".[113]

*Issue 4. Determining whether a compensation scheme is necessary*
You will need to determine how to address the inevitable questions of whether, how and by whom compensation might be payable when water rights are varied.. Where flows are obtained by governments retiring existing entitlements, there may also be an expectation on the part of those giving up entitlements that the water will be held 'in trust'. This may give rise to the need to determine who will be responsible for 'holding' and managing the environmental flows. Flows may be held by an 'environment manager', or may simply be a minimum amount of water that must be retained in-stream.

*Issue 5. Creating a legal regime that is capable of being adaptive*
Creating a system that has sufficient adaptive capacity - to respond to changing conditions is a vital part of a successful regime. This should be based on sound monitoring of the system, and will require legislation that provides a clear sense of direction without locking into a level of detail that is not capable of modification and refinement. An ongoing process of developing detailed and legally-binding management plans, within the context of clear legislative guidelines, is a means of providing for adaptive capacity. This is the approach that has been adopted both in South Africa and in most Australian States.

*Issue 6. Providing for genuine community engagement*
Providing for ongoing and genuine community engagement as a means for incorporating community values and traditional knowledge into the development of policy, regulations and management plans must not be left to chance. It must be built into the framework legislation. This 'community' includes the user community and all others with an interest in the sustainable management of the system, or an interest with a particular part of the system.

*Issue 7. Anticipating liability issues*
It is important to be able to deal effectively with specific legal issues that will inevitably arise, including liability for the damage that may be caused by managing for environmental flows. This could for example be done through flooding or reducing access entitlements or restricting commercial activi-

ties such as impacts on hydroelectric companies. These issues need to be anticipated in advance and addressed in the legislative framework.

*Issue 8. Creating a regime that is capable of implementation*

Creating a system that is sufficiently clear and robust to facilitate effective, implementation, compliance and enforcement measures is extremely important. The 'system', including the legislative framework, is only as good as the results it achieves on the ground. It must be developed taking into account local conditions. This will not only require the creation of new or reoriented legislation and institutions, it will also need well-trained staff to carry out a new range of functions.

Fish needs water
NO WATER NO FUTURE
HANDS OFF OUR WATER

*Chapter 6*

# Generating Political Momentum

## *6.1 Be prepared!*

The development of a regime of environmental flows will evolve in a different way in each country. There is no 'formula' for getting environmental flows on the political agenda, just as there is no model legislation for establishing environmental flows. What is universal is that developing such a regime is never going to be easy. While environmental flows are absolutely essential to maintaining healthy river systems, they will require a long and sustained effort.

This chapter offers some suggestions and useful pointers to assist those involved in the political process of developing a regime of environmental flows, and those seeking to support such a process. Success will ultimately depend upon effective interaction with local people, from politicians to farmers, and the ability to communicate the need for environmental flows in the context of the local conditions.

It is important to be well prepared when getting into environmental flows. Five critical steps need to be kept in mind:

*Step 1.* Know what environmental flows is about. Use this guide, and other appropriate sources of information, to be as well informed as possible on the issue;

*Step 2.* Know the river basin and the resources it contains, both natural and man made. For instance, whether it is used for irrigated agriculture, for industry, or for recreational fishing;

*Step 3.* Know about the river benefits to local people who rely on the river. For instance, whether it is used to earn a living, for drinking water, recreational pursuits or cultural or spiritual reasons;

*Step 4.* Know what local groups have been established that have an interest in the basin. Examples might include irrigation trusts, fishing clubs, economic development boards or environmental groups;

*Step 5.* Know the local laws and what they have to say about managing water resources and the other natural resources of the basin.

It is best to start by recognising that what will be needed in any country to achieve an environmental flows regime is a statement of public policy and supporting legislation to give effect to that policy decision. Then comes the successful implementation of the policy and legislation. As is discussed later, this will mean dealing with different levels of government as the process emphasis moves from public policy decisions, to legislative frameworks, to supporting regulations and local management plans.

A critical step in influencing work on environmental flows is the identification of key decision-makers and others with the power and/or influence to push environmental flows onto the policy and legislative agendas. It is also necessary to know who will have the responsibility for driving through such a process and who will ultimately be responsible for implementing the regime. This may not be as easy as it sounds, in particular in federal systems and where authority has already been devolved to the catchment or local level.

*"A CRITICAL STEP IS THE IDENTIFICATION OF KEY DECISION MAKERS."*

The power to get environmental flows on the policy and legislative agendas will normally reside with the government portfolio that has responsibility for water resources management. In some cases this may in fact be shared, including where outsourcing and devolution of responsibility has already become a reality.

What gets on 'the agenda' may also be affected by the use of fiscal measures by one part of government to influence another, as is graphically illustrated by the impact of the National Competition Policy in Australia. The National Competition Policy, April 1995[114] was an agreement between the Commonwealth and State and Territory Governments to progress a nationally co-ordinated approach to micro-economic reform in return for a series of national competition tranche payments. The reform agenda included so called 'related' reforms.[115] Through these the following issues where entrenched on the national policy agenda: identifying and managing assets, efficient pricing, trade in water rights, environmental flows and community involvement. More specifically, this strategic framework included provisions relating to urban and rural pricing, separating water allocations or entitlements from land title, institutional reform, water trading, third party access to infrastructure, environmental flows and community consultation. This example demonstrates the need to think

Photo 6.1 South Africa's Minister of Water Resources, Ronnie Kasrils, shows the results of the River Health Programme.

broadly when addressing the issue of 'power', including the positive influence that access to financial resources can have in moving the policy and legislative agendas forward.

Identifying sources of influence to get environmental flows on 'the agenda' thus requires an understanding of who might be prepared to commit resources to see the issue seriously addressed. This is where a sound knowledge of the concerns of the international community can come to the fore, especially where development assistance is a major source of funding.

The upshot of all of this is that public policy-makers, legislators, governments, line ministries, public policy advisors, bureaucrats and political staff, are the key audiences that need to be communicated with. This can be through direct communication and/or through indirect means, such as the media, as we will explore below.

Given the necessary momentum for establishing a regime for environmental flows, many actors will need to be involved, from the highest levels of government right through to local communities. Pressure for change and the ultimate catalyst for change can take many different forms. Rather than try and guess up front what will best work in any particular case it is better to move ahead on as many fronts as possible and then adapt your strategy as you go along.

## 6.2 Convincing the community

### 6.2.1 Engaging legislators, governments and line ministries

The exact nature and power of parliaments, governments, ministries and bureaucracies varies from country to country, and often within a country. Whatever system is operational, no matter the differences, one will most likely need to influence all of them to have any success.

One is also likely to have to work directly with different levels of parliaments and governments at different stages along the way, for example:

- National parliaments and governments for policy and legislative frameworks;
- Line ministries for supporting regulations;
- Sub-national governments, basin authorities or statutory catchment boards, for management plans.

It is essential to have the necessary policy and legislative frameworks in place for without this all else will fail. Hence this should be the first focus of attention. Local groups and individuals may not always be aware of what has been endorsed through international processes. While it is important to understand what has been 'agreed' to in global and regional fora, it is unwise to rely upon these when seeking to persuade elected officials from any level, be it national, provincial or local.[116] Keep it local, but always in the context of broader objectives. A sound knowledge of what has been agreed through international processes may assist in attracting funds for development assistance.

In countries where national parliaments are made up of popularly elected officials, one can reasonably expect that they will try and be responsive to local views, in particular the views of people who are within their own electorate.

If one represents a civil society group and wants to succeed in influencing legislators, governments and line ministries, thinking about who has influence over them would be a good starting point. This will most likely include senior bureaucrats, political advisers, industry groups, research institutions, users, community groups and the media. Each situation will differ. International groups, in particular those that can help attract resources, can also exert influence, but local groups will continue to carry great influence. There is no directory of 'influential groups', and much local knowledge is needed to establish this.

If the same clear message comes from a broad range of different groups to legislators, governments and line ministries, the best results can be expected. If this cannot be achieved, being alert to the areas of disagreement between groups as legitimate issues and presenting practical means of achieving (and funding) necessary trade-offs between competing interests will assist.

To get the initial critical policy decision it is important to keep the message simple. First strive to get general acceptance of the principle. Once the principle is generally accepted then policy and legislative frameworks can be developed and put into effect. The last stage is to determine the particular management regime for each river in the basin, which is when specific trade-offs will have to be made. While this will vary from country to country, line ministries and departments tend to manage a compartmentalized agenda, separating social, economic and environmental factors in policy and regulation-making. Processes such as the cabinet process, where all ministers meet under the chairmanship of the leader of the government, are intended to promote 'whole of government' approaches, but the success of such processes varies significantly.

In many cases the most effective way to engage governments will be to focus not only on those who are directly responsible for the environment portfolio. As these are often the weakest portfolio in a government, it is important instead to engage those who have responsibility for the economic development and social agendas. Working through sustainable development planning processes or, where applicable, the development of poverty reduction strategy papers, are other good avenues to take.

When speaking to public policy decision-makers, it is useful to remember the following key points:

- know what environmental flows are about;
- know something about the background of policy-makers and key constituencies;
- know the existing laws related to water resource management, and what needs to be done at each level to build in a regime for environmental flows;
- know what to ask for and whether the target audience has any power or influence to make it happen;.[117]
- know the decision-making process, within the parliament and government and within bureaucracies, at all relevant levels;
- know what issues are likely to be of concern to all local stakeholders and have an answer to them;
- know the key messages as there may only be one shot at delivering them;
- follow-up promptly any request for more information.

### *6.2.2 The interests of user groups*

The role of user groups can be viewed from several perspectives. User groups can become your most powerful allies in promoting environmental flows. This is particularly the case where there is recognition that their resource security is being threatened by a decline in the health of the river system. Are local fishers seeing a big drop in their catch due to impacts on spawning grounds? Are irrigators finding that their water is becoming too salty? Are tourists being turned away by unhealthy river conditions? Or are the costs of treating water becoming too high? All are symptoms of a lack of environmental flows and can be used to create awareness and garner support from users.

User groups can also include those that will need to be effectively regulated to ensure that the resource is not being drawn upon in an unsustainable manner, such as industry groups. These are principally profit driven and the importance of environmental flows needs to be portrayed in an economic context. Environmental flows are not just about protecting animals and plants. They are essential for a healthy, working river system. For example, providing an adequate environmental flow will improve water quality thereby ensuring its suitability for irrigated agriculture and minimizing treatment costs for human consumption.

Well-established regimes for environmental flows will also help ensure long-term resource security for major water consumers, thereby making it easier to attract investments in water dependent ventures. This is an important point to make! But first understand what it means under the local conditions at hand.

*"USER GROUPS CAN BECOME POWERFUL ALLIES IN PROMOTING ENVIRONMENTAL FLOWS."*

Once a decision is taken to establish a regime for environmental flows there will be a need to ensure that the regime is effectively implemented and enforced.[118] This may require efforts to ensure that there is industry compliance with the regime, which needs to be thought of ahead of time. This can include a mix of specific regulatory requirements and economic incentives such as taxes and levies.

When thinking about this, it is worth remembering that the motivating factors within the private sector that will be important in optimizing interest in, and a commitment to, compliance with an environmental flows regime will include:

- maintenance of a competitive advantage and seizing market opportunities;
- maximization of profit, including through reducing expenditure;
- maintenance of public image and consumer relations; and
- avoidance of prosecution for failure to comply with legal requirements.

Competing community interests will inevitably lead to trade-offs. These trade-offs can be managed through a range of tools, including fiscal incentives and effective combinations of economic, regulatory and voluntary (self-regulatory) approaches. Familiarity with the different tools available for achieving environmental flows is important for those seeking to demonstrate that this approach does not imply simple 'command and control' regulation.

An example where user groups have pushed the environmental flow agenda comes from the Columbia River. The Columbia River Basin is a large system located in north-west United States and south-west Canada which has historically prided itself as being the largest salmon producing river system in the world. Dam construction, particularly throughout the 1950s and 1960s significantly altered the hydrological regime of many of the rivers within this system, and in several cases, provisions were not made for salmon migration and spawning requirements. The Snake River, a tributary of the Columbia River, contains four dams, Lower Granite, Little Goose, Lower Monumental and Ice Harbor, all imposing severe impediments to salmon migration. In a landmark decision on 16 February 2001,[119] these dams were determined to be in violation of the Clean Water Act (Federal Legislation).

The case was fought by a coalition of both conservation and fishing groups, including the National Wildlife Federation (NWF), Sierra Club, Idaho Rivers United, American Rivers, Pacific Coast Federation of Fisherman's Associations, Institute for Fisheries Resources, Washington Wildlife Federation and Idaho Wildlife Federation joined also by the Nez Perce Tribe. The responsible federal agency was ordered by the court to develop a plan to bring these dams into compliance with the Clean Water Act as well as water quality regulations in Washington State. The successful plaintiff coalition argued that the dams harmed endangered salmon and steelhead by slowing river flows and increasing both temperatures and dissolved nitrogen levels.

### 6.2.3 Engaging community groups

Local community groups play an important role in influencing the views of politicians and in generally raising awareness. They can also be essential partners in implementing environmental flows. Not surprisingly, community groups will be most influenced by local impacts and opportunities, and the unavoidable issue of trade-offs will often not come to the fore until you address the needs and expectations of such groups.

Community groups will be most important when it comes to the implementation of environmental flows. Therefore it is important that they have the opportunity to become involved in the dialogue from the outset, namely at the time policy and legislative frameworks are being discussed. Moving to establish a regime for environmental flows should not come as a surprise to local community groups, or users.

In effectively engaging community groups, it is particularly important that social and economic considerations be considered in tandem with environmental factors. In many cases local people will include indigenous peoples, and others, who attach a cultural or spiritual value to the river or basin. Such values are less tangible than others but they are equally important to understand and address.

Recent work has suggested that engaging stakeholder groups is a matter of 'sharing benefits rather than sharing water'.[120] This involves placing emphasis on the identification and mutual understanding of all the benefits that can be obtained, in this case by maintaining environmental flows, by all parties. In practice it is likely to be a mix of looking at how the water is being shared and how the benefits are being distributed.

The maintenance, management and regulation of environmental flows will be most relevant to community groups if the local benefits are properly identified and equitably shared. This is easier said than done and there is no substitute for hard work in resolving these issues basin by basin, river by river. There are no shortcuts.

In the Murray-Darling Basin in Australia, community groups have played an important role in a difficult process that involves satisfactorily resolving difficult issues of common interest in a federal system, political manoeuvring, a drive for micro-economic reform, and an improving knowledge base. No one factor has been decisive of itself, but a main driver has been clear evidence of a deteriorating natural resource base. This has propelled a determination on the part of the community, and politicians, to reverse the decline to protect both productive capacity and environmental values.

*"ENVIRONMENTAL FLOWS WILL BE MOST RELEVANT IF LOCAL BENEFITS ARE PROPERLY IDENTIFIED AND EQUITABLY SHARED."*

The voluntary decision to cap diversions of water from the system in 1995 was a momentous one, and the decision to adopt a vision for a healthy river system was a major milestone. The most difficult decisions are yet to come, but what is clear is that the community will be an integral part of whatever options are taken and nothing is going to stop the momentum to see more water returned to the system. This reflects a dramatic shift in community values over a relatively short period of time.

## 6.3 Communicating the right message

Creating the right message is probably the most important part of the process of promoting environmental flows. Promoting the wrong message can set the political process back years, in particular if one sews the wrong message in the minds of politicians and key users. It is worth spending the time to get it right.

The major public policy drivers seek to represent social, economic and environmental considerations, and developing the 'right' message will need to effectively demonstrate that environmental flows are essential for sound social, economic and environmental reasons. While the message will vary according to country-specific conditions, it is generally acknowledged that to achieve water security, the main challenges to be faced are to ensure that basic human needs are met, functioning ecosystems are protected, and optimum benefit is derived from consumptive use. This requires risks to be adequately managed, water to be accorded its true value and water resources overall to be governed wisely. But how can all of this be expressed in a way that is interesting and readily understood in practical terms?

The 'right' message needs to emphasise that environmental flows are vital for healthy functioning river systems, which in turn are critical for attracting investment, achieving long-term economic prosperity and the conservation of biodiversity. Environmental flows work for people as much as for nature. Environmental flows will also involve the need to make trade-offs, that is an unavoidable fact. No need to be shy about saying it!

Developing the right message also means that all of the benefits of environmental flows need to be clearly articulated. Linkages between the benefits should be emphasised, for example by outlining the range of environmental and economic benefits that healthy systems provide. The link between poverty and water resources can also be used. Furthermore, the general threat to water resources from pollution, unsustainable extraction, land-use change, and climate change form a similarly useful basis for the key messages.

*"ENVIRONMENTAL FLOWS WORK FOR PEOPLE AS MUCH AS FOR NATURE."*

Advocates of environmental flows could also focus on benefits such as the impact on environmental water quality and quantity in the case of nutrient runoff from agriculture, the release or intrusion of saline water, or the release of cold, deoxygenated water from dams. These can all be further expanded as the particular circumstances require. Alternatively, the adverse impacts of a lack of environmental flows need to be showcased, not only in their environmental contexts, but also for the social and economic implications that follow. For example, if water becomes too saline it will become unsuitable for human consumption, irrigated agriculture, and native species that are not sufficiently salt tolerant.

However, the balancing of conflicting social, economic and environmental values is difficult, and a very clear message needs to be that trade-offs will be inevitable and that deciding upon these will require an open and transparent consultative process.

The 'right' message, incorporating the social, economic and environmental importance of environmental flows for healthy river systems, opens a critical role for communications and the media. Informing society, fostering participation and support from the community and users, and generating political momentum at the national and sub-national levels all happens through communication with target audiences.

The communication around the implementation of environmental flows thus needs to be well thought through. A communication strategy must be developed at an early stage, based on the actual problem, the expected results, and the perceptions of the different stakeholders. It should articulate clear stages for the campaign, from awareness-raising of the problems to be addressed, to supplying information about the interests and options involved, to fostering participation and then, finally, to the communication of outcomes.

One specific aspect to take into account is the trade-offs between uses and users: not everyone will be delighted with the measures that may be implemented! The communication strategy must expect to deal with public outrage, conflicts and controversy. The best way for dealing with this is to ensure an open and transparent process where the end result is clearly the best solution for the future. The communication message will come across best if these points are reiterated, when it provides a balanced and reasonable perspective on all interests and when it makes clear that the outcome will be better than the existing situation.

The role of the media within such a strategy cannot be overstated. Although its role may vary according to the political situation in the country in question, the media will almost certainly represent a critical forum where the 'right' message can be either successfully spread - or not. The message presented by the media will influence the nature of public opinion and political resolve.

The power of the media is in its capacity to reach and influence people, including politicians. Where the communication strategy aims to reach the media, you need to formulate a simple and clear message, starting with a clear understanding of the impact of environmental flows on people and the environment. But be careful: the media is unlikely to simply copy your message verbatim. They will seek out specific points of interest or put your message in a positive or negative perspective.

When the goal is to raise awareness, it may be necessary to emphasise the negative consequences of failing to provide for environmental flows to get attention. The message being disseminated needs then to resonate strongly with those most affected so that the general public can clearly understand.

An example of the use of such negative impacts comes from the Murray-Darling Basin. In 1999 an independent Salinity Audit released by the Basin's Ministerial Council showed that assuming no measures would be taken over the next 20-50 years, salinity levels at the intake of Adelaide's water supply on the River Murray would exceed World Heath Organization standards for drinking water. Further, many tributaries would have salinity levels far exceeding these levels, including the tolerable levels for both irrigation and maintaining native habitat. This resulted in serious alarm from the community, in particular the 1.2 million residents of the City of Adelaide. Political momentum gathered, and national and state based media outlets ran a constant flow of stories and articles dedicated to the health of the system. Community and political awareness reached an all time high, and it became generally accepted that too much water was being taken from the system. Something had to be done and governments and Parliaments needed to act.

*"TRANSLATE TECHNICAL ISSUES INTO SIMPLE LANGUAGE AND USE REAL-LIFE EXAMPLES."*

It is important to reflect issues in an informative way, both for the general public and the media. Environmental flows need to be relevant to non-technical people. In the past, issues such as environmental flows have often tended to have a specific environmental focus. Integrating social and economic considerations will help elevate the importance of the issue. It will be crucial to translate the technical issues into simple language, to use real-life examples of those issues, and to balance the benefits and costs of environmental flows with illustrations of why the positives greatly outweigh the negatives. Direct contact between the technical staff and involved decision-makers, local people and interest groups may be a useful means to make the translation and build trust between them.

Providing information more effectively will require:

- simplifying social, economic and environmental data and finding visual ways to express the issues;
- giving the perspectives a 'face' by identifying reasonable stakeholders and asking them to express their personal views;
- encouraging media coverage that always identifies and points towards solutions to the problem;
- highlighting the positive aspects as well as negative, acknowledging that an initial focus on

the negative may be needed to gain attention;
- keeping communication channels open: making clear and making sure that there are ample opportunities through various channels for stakeholders to express their views, raise issues, ask questions and that these are taken into account; and
- focusing on the relationship between development and environment and environment and people.

Knowing the issue of environmental flows is one thing, being able to communicate it to the media effectively is another. In dealing with the media you will need to find individuals who are able to translate technical concepts and language into a form the media and the average person can understand. Whether the media decides to run with an issue, and how it runs with it, will often be influenced by the strength of individual relationships. The value of developing good professional relationships with individual journalists cannot be underestimated.

## 6.4 Involving the interest groups

Environmental flows are as much about people as they are about the environment. The importance of managing environmental flows at the lowest appropriate administrative level, and the importance of involving the community, including women, indigenous groups and the private sector, is now widely accepted. It is at the local level that fostering co-operation and balancing a range of competing interests comes sharply into focus. This represents a significant challenge. The issue of engaging people becomes particularly pressing in developing countries where water resource management plays a vital role in poverty alleviation.

With enhanced involvement of all interest groups, a sense of ownership, responsibility and empowerment is likely to emerge. It will also allow the local conditions and specific needs of a region to be more at the forefront of planning. General and often ‘aspirational' principles that are developed at the international level need to be adapted and applied to prevailing local conditions.

Essentially, it is a matter of scale. To concentrate on the level of international agreements often means that focused regional and local specificity is overlooked. Conversely, to focus only on local management practices often means that the broader objectives and mutual goals, especially in transboundary situations, are not fully accounted for. What is needed is a sound knowledge of both. This is where international experts can work with local people to help adapt and apply generally accepted principles to local conditions.

*“AT THE LOCAL LEVEL, FOSTERING CO-OPERATION AND BALANCING A RANGE OF COMPETING INTERESTS COMES SHARPLY INTO FOCUS.“*

Hence, you always need to balance and co-ordinate between top-down and bottom-up processes, to ensure that environmental flows are managed not only taking into account local conditions, but also making sure that basin wide objectives are being achieved.[121]

Management of environmental flows must balance social, economic and environmental benefits. To concentrate on just the environmental benefits would alienate most local groups from the management process. The importance of keeping the process relevant and lively ensures that implementation is optimal and realistic.

It is important to be alert to the fact that over-abstraction of water resources and competing demands within river basins often jeopardizes the development and security of people living and working downstream. The livelihoods that depend on them are increasingly recognised as a vital element of sustainable water management and enhancing their role in the process is imperative. There is great potential to improve co-operation through the facilitation of informed debate and through their increased involvement in water management decisions. The importance of community empowerment is multi-faceted, but at present undervalued in many parts of the world.[122]

## *6.5 Gathering support*

While one person or group is likely to start the ball rolling on environmental flows, it is important to find partners and supporters from all sectors at an early stage. As we have seen, this might include unlikely allies, such as fishers and irrigators, and traditional allies such as concerned environmental groups.

A coalition of support needs to be fostered, with everyone playing their own role of passive supporter or active partner. The aim should be to find credible individuals who are able to champion the issue from as many different perspectives as possible. This will include people who can lead the issue from a science perspective, through to users who can do so in the context of local impacts. Having a strong and influential politician convinced on the issue will be invaluable.


Photo 6.2 Bangladeshi protesters march to press authorities to halt encroachment on the River Buriganga, which disrupted river flow. (November, 2002)

In many cases one might not be able to build a coalition from the start due to strong resistance. In such cases it is important to start by spreading the facts to raise awareness at all levels and to build the support slowly. If the facts are not there, an early part of the work will be to push for more research and a possible redirection in the work of some research institutions. Access to solid facts and figures will be invaluable.

*"A COALITION OF SUPPORT NEEDS TO BE FOSTERED."*

While thorough preparation and careful work in identifying potential partners and supporters is important, one should not get bogged down in creating a bureaucracy or rigid set of plans for moving forward. Success is more likely to come if structure and process are kept simple and the ability exists or is developed to react and adapt as the process moves along.

Finally, never be afraid to ask for help. While the decisions taken in each country will be taken on the basis of local conditions, international support can be invaluable in providing scientific credibility, comparative studies and access to resources, not to mention moral support!

*Chapter 7*

# Building Capacity for Design and Implementation

## *7.1 No awareness, no action*

In any part of the world, today's water resource management consists primarily of water delivery - whether to meet demand, manage pollutants, or for water treatment - and there is limited capacity to assess and implement environmental flows. Environmental flows is only a young branch of science, little more than two decades old, and most people remain unaware of its relevance and usefulness as a water management tool. There is likely to be some general understanding that aquatic ecosystems change as we disturb them. But, little awareness commonly exists about the freshwater needs of rivers, wetlands, lakes, estuaries, and some parts of near-shore marine systems, for their own health and survival. Also, there may be little awareness of the specific quantity, quality and timing of water supplies to these systems and the link between the amount of water remaining in a system and its condition. Similarly, there may be no appreciation of the fact that groundwater may need to be managed to keep surface waters healthy, or that conditions can be managed to a large extent through knowledgeable management of river flows.

*"IN MANY COUNTRIES LITTLE IS KNOWN ABOUT THREATENED AQUATIC ECOSYSTEMS."*

The lack of awareness could well extend to all actors relevant to water management, including the politicians, policy-makers, water lawyers, economists, water managers, water engineers and modellers, aquatic and social scientists and representatives of their research funding bodies. Also stakeholders such as government departments, NGOs and local communities are likely to be unaware. Many countries face a situation where little is known about threatened aquatic ecosystems and their dependence on freshwater flows. In many places there is little understanding of how these ecosystems function or of their importance as providers of goods and services. Water managers and politicians may not be in the habit of listening to aquatic scientists or including them in real water-resource management issues.

On the other hand, scientists that focus primarily on academic matters may not be in the position to provide practical information for managers and decision-makers to use. Water engineers and lawyers, who have probably played the major role in advising managers and decision-makers, may be concentrating on water delivery and sanitation. They often have little awareness of how these could be impacting the targeted donor or receiving systems, or even why impacts on these systems should be a source of concern. Similarly, the public may also be unaware of these issues. In spite of this, the national cost of deteriorating and poorly functioning ecosystems will be borne by them all, through for example taxes, loss of land, reduced life of sediment-filled reservoirs, failing fisheries, increasing severity of floods, and deteriorating quality of life.

In extreme cases, there may be no capacity to locate or bring together any relevant specialists and data due to very low government funding or poor scientific support. A lack of relevant historical records of the nature of the ecosystem of concern, including river flow and rainfall data can also complicate matters drastically. If accompanied by incomplete information on human demographics, such as population numbers and distributions, health profiles and land use, the situation might be rather difficult.

However, in all of these situations, from the most data/skills rich to data/skills poor, a start can be made on adjusting to a more sustainable use of water resources through environmental flows. Even countries where elaborate modelling techniques are now employed started with simple approaches based on some hydrological understanding and basic ecological ideas.

## *7.2 Identifying and addressing gaps in capacity*

As a starting point, three concepts need to be recognised and accepted:

- aquatic systems provide water and other goods and services and are a fragile and vulnerable resource;
- deterioration of this resource has quality-of-life implications for people; and
- the resource should therefore be actively managed.

Different groups of people can create awareness and enhance progress in individual ways, in government, research funding bodies, scientists and engineers, stakeholders and communicators, as discussed below.

### *7.2.1 Politicians, lawyers and water managers*

Societal needs drive water-resource developments and in the past the actual decisions on these developments were largely based on engineering and economic criteria. Based on this approach, a global picture of the wealth and other benefits that come from harnessing water for off-stream use has emerged during the last century. The last two decades, however, have yielded growing proof of the costs of this. Complex links between water and ecosystem health are being revealed that are now reasonably understood by scientists, but still in the early stages of being communicated to a wider audience. Some governments have grasped the importance of the issues, but many are still driven by the immediacy of providing basic services for growing populations. If countries are to embrace the concept of sustainable use of resources, however, politicians, lawyers and water managers, need to develop a greater awareness of the nature of ecosystems and the implications of disturbing them.

*Politicians*

Politicians are increasingly being expected to consider trade-offs that define the best balance between water for public supply, industry and intensive irrigation, and water to maintain environmental processes, natural resources and biodiversity. It will be important for them to understand that many impacts of water developments become apparent years if not decades later. This is so, because ecosystems change slowly and impacts may be far removed from the site of the development. A dam built in the upper reaches of a river, for instance, could eventually lead to the failure of a commercial marine fishery hundreds of kilometres downstream; the flood loss resulting in the river mouth closing and fish being unable to enter the estuary nursery area. Myriad examples of seemingly unrelated causes and effects are now emerging, triggering the search for a new approach that will access all the costs and benefits of water-resource developments. Environmental flow assessments contribute to this new approach. They contribute to describing the short and long term, near and long distance ecological and related socio-economic costs and benefits of a water-management option. These can now be considered alongside the traditional engineering and economic pictures.

Using this new kind of understanding, politicians will increasingly be faced with situations where they have to weigh up very complex trade-offs. They may have to consider a series of scenarios, each of which describes the costs and benefits of one way of designing or operating a water development. Each scenario could have different engineering, economic, ecological and social implications. There could be tangible costs such as the loss of land through bank erosion, or of a floodplain fishery, and intangible costs such as a decline in the quality of life, a change in health profiles, or the eradication of something of spiritual or cultural value.

*"POLITICIANS WILL NEED TO WEIGH COMPLEX TRADE-OFFS."*

Increasingly, intangible values not amenable to monetary evaluation are being shown as important in the lives of ordinary people, and are often of most importance to the poorest. Decision-making processes that can assess these aspects of scenarios may be available, but more often they will have to be developed. As it is unlikely that a single scenario will appeal to all stakeholders, the process of deciding on one needs to be participatory and transparent.

The challenge politicians face is thus threefold: (a) to understand that water resources developments have costs as well as benefits; (b) to recognise that the trade-offs that need to be made between these will differ from catchment to catchment; (c) and to find the right trade-off for any one system through a participatory and transparent process. The ecological and social inputs will need to be comprehensive and have the same status as the engineering and economic ones.

*Water lawyers*

In many universities, water law is only gradually emerging as a speciality area for study separate from general environmental law.[123] Lawyers specializing in this area may therefore have to develop their own expertise through relevant employment. Specialist water lawyers may help write and implement the Water Act of a country, but prior experience in this area might not prepare them for the new kinds of water law that require protection of ecosystems. An evolution of a nation's water law in terms of how allocations of water entitlements are made proceeds as follows:

- the water law lays out the rights of people to water, with little or no regard to the welfare of the aquatic ecosystems involved;
- the water law recognises aquatic ecosystems as users of water, competing with other potential user groups such as agriculture, industry and urban areas; and
- the water law recognises aquatic ecosystems as fundamental landscape resource units supplying water and associated goods and services of benefit to humans, whose water needs for their own maintenance, along with those for basic human needs (cooking, drinking, washing), must be met before any other water demand.

Different countries are at different stages in this sequence. One of the most advanced is the South African Water Act 1998, which recognises only two rights to water: for ecosystem protection and for basic human needs. These are brought together as the Reserve, with all other water demands controlled by permits and met only after the Reserve is secured (See Table 7.1) To comply with this law, the ecological part of the Reserve has to be set for every major watercourse in the country. The implications of this are profound because of the link between water volume and ecosystem condition: the ecological Reserve cannot be set for any one system until the appropriate trade-off between its future condition and other uses of water has been agreed by society. Other examples of advanced water law are the South Australian Water Resources Act 1997 and the New South Wales Water Act 2000.

*Table 7.1 The four principles in South Africa's Water Act of 1998 that relate to the reserve.*

| Principle | Details |
|---|---|
| 7 | The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use. |
| 8 | The water required to ensure that all people have access to sufficient water shall be reserved. |
| 9 | The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems. |
| 10 | The water required to meet the basic human needs (Principle 8) and the needs of the environment (Principle 9) shall be identified as "the Reserve" and shall enjoy priority by right. The use of water for all other purposes shall be subject to authorization. |

Implementation and enforcement of these new kinds of law are difficult and have few precedents. Water lawyers working in this field should be aware that natural ecosystems are complex and often unpredictable, and understand the level of uncertainty of the information provided by engineers, managers and scientists. They need to be willing and able to strive for a common language and understanding with these other professionals, in order to write laws that offer the necessary level of protection but can realistically be enforced. To do this, they should work closely with water managers and environmental flow scientific practitioners, and be involved from the earliest stages of policy development.

*Water managers*

Water managers implement and enforce the nation's water laws and advise governments on problem areas needing resolution. They need a better understanding than either politicians or lawyers of the nature of aquatic ecosystems, because their day-to-day management actions will directly affect them. Ecosystems differ from place to place, and change over time. River systems will be at different levels of naturalness depending on past disturbances. These factors will obviously influence how the systems respond to management interventions.

Although managers cannot be expected to predict in detail how ecosystems will respond, they should have a good overall awareness of how any one kind of system is likely to change. They should know appropriate scientific disciplines that can provide advice. In particular, they should be aware that ecology is a multi-faceted discipline just as engineering is, and that no one ecologist can advise on all aspects of an ecosystem.

*"WATER MANAGERS PLAY A VITAL ROLE IN BRINGING SPECIALISTS TOGETHER."*

They can gain this understanding by employing and working in new kinds of multi-disciplinary teams of engineers and scientists. Disciplines commonly involved are ground and surface water-hydrology, hydraulics, sedimentology, fluvial geomorphology, ecology (fish, invertebrates, frogs, reptiles, water birds, aquatic and water-dependent terrestrial mammals, and riparian, marginal and aquatic plants), micro-biology and aquatic chemistry. Where common-property subsistence users of the ecosystem's natural resources are likely to be affected, then additional disciplines could be water supply, public health, livestock health, anthropology, sociology and resource economics. The manager plays a vital role by bringing these specialists together and helping forge a common language.

Working in the teams, managers learn to ask different and more appropriate questions. They realize that there is no simple ecological answer to the questions: "What is the environmental flow for this river?" as this is a societal decision driven by the trade-off between development and ecosystem conservation. Instead, they should come to understand how an ecosystem changes if particular decisions are taken. Thereby they help create the scenarios that the decision-maker will consider. They also learn to recognise 'red flag' situations that would have undesirable results because of the sensitivity of the target ecosystem or the nature of the intervention. They learn to interpret relevant research findings and help guide scientists on how to provide the information in a form that managers can use. When the team has finished its investigations, it should be able to provide an array of possible intervention options and how each could affect the ecosystem and society as a whole. Although managers, engineers and scientists might collaborate to describe the options, the selection of one is then usually a political decision.

The whole concept of sustainable use can fail if the right decisions are made but managers do not implement them diligently. Delivering appropriate environmental flows, perhaps against the wishes of some other potential water users, is probably the most difficult part of the complete process of assessment and implementation, and there are few guidelines to follow. Additionally, because of the inherent complexity and unpredictability of ecosystems, managers may have to compound this difficulty by practising adaptive management. To assist in this, both the delivery of the environmental flows needed and the condition of the ecosystem in question will need to be monitored. If the chosen environmental flow is being delivered but the desired condition is not being achieved, then either the target condition or the flow regime might have to be adjusted. It helps if the law provides for this kind of adaptive management and if institutional capacity exists in the water authority.

*Using scenarios*

In moving toward the sustainable use of water, national water departments will gradually transform from being suppliers of water, to becoming holistic managers of the nation's aquatic ecosystems. An early and important move is to impart the same level of importance in water-development plans to ecological and social aspects as to engineering and economic ones. Relevant ecological studies of the targeted system need to start at the same time as the engineering ones, and a structured social programme linking to all interested parties should run through all the planning phases. As the scenarios are created describing the range of options available for the development – including the 'no development' option – governments need a decision-making process in place to consider them and select one.

The scenario chosen could contain a description of a flow regime, which will become the environmental flow for that river, and a description of the expected river condition linked to this, which will become the agreed-on 'desired state' for that river. Each river in a country could eventually have a different environmental flow, a different desired state and a different set of costs and benefits for people. This will reflect differences in the location and nature of each river, and society's choice of what they value most about each one. Implementation and management of those choices are then simplified to the extent that they are working with society's overall wish rather than possibly against it.

Few tertiary education establishments have begun to embrace this subject at a level that will provide governments with guidance. Some centres of experience exist internationally, particularly in governments, universities and ecological consultancies in countries renowned for their environmental flow work. Areas that have been prominent in the field are North America/United Kingdom/Europe, South Africa and Australia. The two latter countries have led the development of holistic methods (see Chapter 2), and South Africa has introduced a strong social component to its methods that describes the implications of management interventions not only on the ecosystem but also on its common-property subsistence users. A useful starting point could be to visit relevant projects in one or more of these countries.

### *7.2.2 Science, research and development*

A flow assessment can be conducted in data-poor to data-rich situations, but confidence in its output increases with the level of understanding of the ecosystem. Research helps scientists understand the nature and functioning of the system, which in turn helps them develop the ability to predict how the system would react to disturbance. It is now possible, for instance, to predict how planned flow changes will change bank-side vegetation communities, water quality, channel features, fisheries, and thus peoples' lives.

The kind of knowledge needed can only be built up over a number of years. As an example, South Africa entered the field of environmental flow assessments in the late 1980s, and within a decade had an experienced national body of aquatic scientists advising the government in this field. This led directly to the inclusion of structured ecosystem protection in the country's 1998 Water Act. The decade of development was backed by the national Department of Water Affairs and Forestry, and by research funding bodies that responded strongly to management needs. Directed research by senior scientists was funded on the links between flow and a whole range of ecosystem characteristics, gradually building a new understanding of how ecosystems function and thus the capacity to predict likely outcomes of proposed management actions.

*"A GOOD WORKING RELATIONSHIP BETWEEN MANAGERS, SCIENTISTS AND FINANCIERS IS VITAL."*

The importance of a good working relationship between managers, scientists and financiers cannot be over-stated. All three have different roles and all are essential if good science is to transform into good management. Scientists need to be aware of areas where managers require help and be willing to submit proposals to do the necessary research. Financiers need to be aware, often well ahead of current research and management within their countries, of fields of research that could help managers and be willing to fund this. Managers need to be willing to guide the researchers on their needs and use the research results. If any of these three groups fail in their role, the other two become much less effective: good research proposals might be submitted but never funded; valuable research might be completed but never used.

Funding bodies are critical actors to get environmental flows established. If they wish to be proactive in this field, they can discuss with water managers the need for environmental flows, help locate scientists who have or would like to develop the necessary skills and knowledge, and convene meetings of managers and scientists to address needs. They could also lead the search for and support a national 'champion': someone who could be funded to lead national development within this field. Those co-ordinating research funding need to be quite visionary, understanding the role of the various disciplines, promoting multi-disciplinary research and seeing beyond established research to the nation's future needs.

*Scientists, engineers and other experts*

Engineers and economists have traditionally played key professional and advisory roles in water resources management. However, biophysical and social scientists are playing increasingly prominent roles as countries move toward sustainable use. Their respective areas of involvement and the kinds of learning needed are outlined below.

*Biophysical scientists*

In the past, most biophysical scientists were excluded from management activities and followed more academic lines of research. However, in recent years a new kind of applied biophysical scientist has emerged, who works more closely on management activities. These scientists have recognised that many water-resource issues cannot await the results of intensive research programmes. Management decisions will continue to be made without much scientific input if they withhold advice pending better data. They reason that however few data exist on an ecosystem, informed scientists and experts will probably understand its nature and functioning better than a engineers or managers. They have thus engaged in offering advice based on 'best available knowledge' and on key data that can be collected quickly.

If managers need scientific guidance at this low level of confidence, then it is fair that they support research to improve inputs over the long term. Scientists need to argue their case for this, clearly articulating the conditions under which they offer guidance, their knowledge gaps, their level of confidence and research needed. Failure to invest in such research means that ecosystems will continue to be managed at the level of knowledge and ignorance that caused the degradation in the first place. Moving forward co-operatively with incomplete understanding will, on the other hand, quickly reveal to the manager and scientist the vital knowledge and research gaps. A long-term objective should be to convert good science into good management. Scientists can provide information on ecosystems, in the same way an engineer does for a municipality or irrigation scheme.

*Water engineers*

Most water engineers work in fields related to water supply, water purification, irrigation or flood control. In the past, much of their learning was geared toward resolving problems and getting results fast. Because of this, they might have had to act with imperfect knowledge, using techniques that included large safety factors and models that were relatively coarse. Whilst concentrating simply on the physical manipulation of aquatic ecosystems, this produced the required results in the short term. One inevitable side effect, however, was environmental degradation. As concerns about this grew, ecologists have begun to work with engineers on water-resource management issues. Each discipline is learning what the other can offer. Engineers specializing in sediment transport, for instance, have started working with fluvial geomorphologists, and hydrologists are now co-operating with ecologists on an increasingly wide scale.

*"MANY TRADITIONAL ENGINEERING TECHNIQUES AND MODELS ARE BEING CHALLENGED."*

As the science–engineering links have progressed, many traditional engineering techniques and models are being challenged as not sufficiently refined to answer ecological questions. For example, an hydraulic model used at a coarse scale to predict flood heights may not be accurate enough at a fine scale to predict if a very low flow is sufficiently deep to allow fish passage. Hydrological models that used to predict from rainfall records the monthly bulk amounts of water available for a town's supply will not be able to predict the daily conditions faced by aquatic plants and animals. These more detailed data are needed, however, when attempting to describe the ecosystem implications of planned management interventions. Daily and hourly hydrological models have gradually become available over the last two decades or so, as have hydraulic models designed to simulate low flows and aquatic habitat. But more model development is needed, and this can only be guaranteed to be relevant for environmental flow applications if there are strong links with ecologists who are specialist practitioners in this field.

Other areas where water engineers linking through to ecosystem management are starting to hone their skills are, inter alia:

- dam design, including multiple off-takes, water-quality and thermal sensors, and continuous recording of reservoir inflow and dam outflow, so that water quantities, water quality, water temperature, and sediments required for downstream ecosystem maintenance can be delivered and can be monitored to audit delivery;
- dam operation linked to current climate, so that not only can environmental flows be delivered to the required place at the required time, but also linked to current climate so that the downstream system continues to experience wet and dry cycles of years;
- more refined water-quality models, so that nutrients and other relevant factors can be modelled at a level of resolution at which ecological reactions might be expected to occur.

Again, development should proceed in close co-operation with ecologists experienced in this field.

*Environment and nature conservation officials*

Aquatic scientists working for national or regional environmental and nature conservation bodies may have less opportunity for formal research than their colleagues in universities and research institutions. However, they are usually invaluable repositories of a great amount of formal data and informal knowledge about the ecosystems in their care. Where hard data on ecosystems are scarce, their general understanding of the systems might be all that is available when starting environmental flow applications. Their knowledge may be more holistic than that of the academic researcher, who often focuses on one small part of the ecosystem, and they often have an intuitive feel of how flow changes will affect the ecosystem. Much of the early development of holistic approaches to environmental flow assessments (Chapter 2) involved developing techniques to tap into their knowledge.

A useful combination could be to team academic researchers with conservation scientists, as they can collaborate on in-depth learning of environmental flow methods and research, and together provide relevant and realistic contributions to environmental flow assessments.

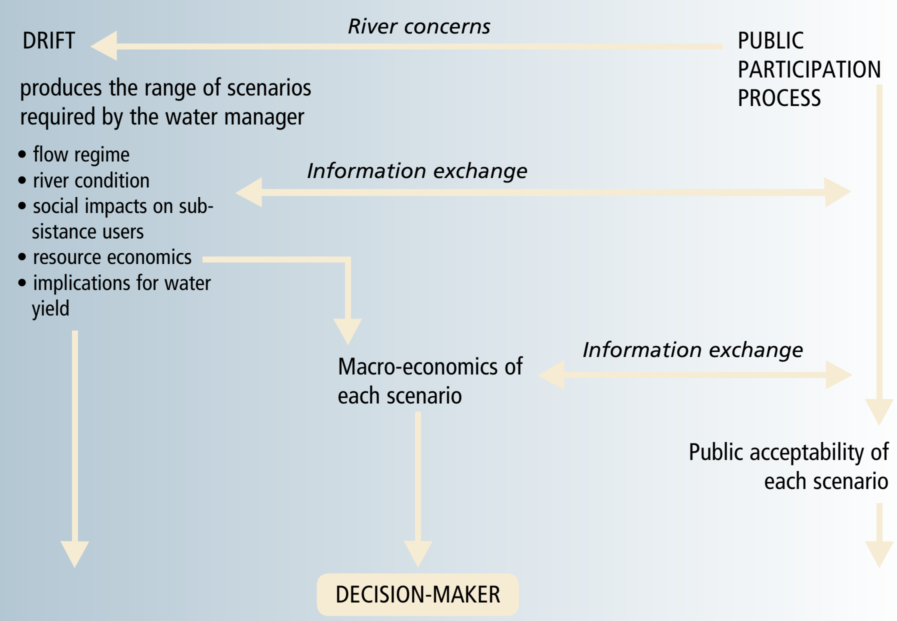
*Social scientists and resource economists*

As environmental concerns play an increasing role in management decisions, social scientists have become more prominent in the field of water resources management. Almost all people may be seen as 'users' of an aquatic ecosystem, whether through direct use of its water or otherwise. To access their concerns, a Public Participation Process (PPP) may be run by social scientists to glean responses from them on the acceptability of the range of scenarios developed during an environmental flow assessment. Each scenario could include the status of many issues of social importance, such as the degree of availability of natural resources, health risks for people and livestock, and whether non-use values of the ecosystem (e.g. cultural and religious) would be affected. Stakeholder responses to the scenarios should be passed on to the decision-maker.

Social scientists specializing in this work are most effective if they understand the descriptions of ecosystem change provided by the biophysical scientists, and can present these in an informed way to stakeholders. This requires a clear commitment to forming a common language and work environment with the biophysical scientists, in the same way that the latter have forged links with engineers and managers over the last two or three decades. To date, few social scientists have attempted to bridge this gap.

A formal PPP might not access those most directly affected by a water development, particularly in developing countries, such as downstream riparian people who directly depend on the river's resources. Often these are the rural poor who may have little understanding of how their river could change, and few other options for replacing lost resources. Recent environmental flow methods, such as DRIFT (Chapter 2), create scenarios that not only predict how the ecosystem will change with flow manipulations, but also how this will impact common-property subsistence users. Social scientists and resource economists play the vital role of ascertaining what resources they use, and how they would be affected if these disappeared. Each scenario produced by the biophysical scientists can include predictions of how each resource would increase or decrease in abundance. Social scientists and economists can then quantify how the riparian users would be affected by the proposed water development. This kind of information has not been available for decision-makers in the past and at present very few specialists have the necessary skills and experience to deliver it (see Box 7.1).

*Box 7.1 The relationship between DRIFT, a Public Participation Process and a regional macro-economic assessment.*




*Building capacity among scientists, engineers and resource economists*

Many university departments have traditionally focused on the pursuit of knowledge and understanding per se. In science, applied research is evolving as an essential part of university training as it is recognised that it should be as well designed, executed and interpreted as any other kind, and by its nature is more directly relevant to management issues. Universities can support and guide applied research that is designed to answer water resources management problems. Particularly in the biophysical sciences, where the links with resource management and people may be weak, support is needed for specialists trying to re-align their thinking to more entrepreneurial and applied approaches.

Many specialists initially work on a supply driven basis: they offer what they know. Approached in a different way however, they could respond much better to a demand and mobilize their knowledge in a different way. To be relevant, all of their water-related data and understanding need to be linked to flow (for biophysical scientists) and ecosystem change (for socio-economic scientists). In this way, they will begin to develop predictive capacity on how flow changes will affect anything they are studying. The manual for the Building Block Methodology,[124] (Chapter 2) provides one set of suggestions on what is needed from each discipline as a contribution to an environmental flow assessment.

Because of the multi-disciplinary nature of such assessments, many different university faculties have a role to play. Engineering, Law, Science and Social and Economical Sciences are among the ones that could offer combined courses on the subject. Most learning presently filtering through at undergraduate and postgraduate levels could well emanate from specialists who have taught themselves, and so most universities will not have relevant expertise. Demand for formal training is growing, and a co-ordinated demand from financiers and managers for such courses might encourage universities to meet what would probably be a substantial demand.

*Stakeholders and communicators*

There are varying degrees to which stakeholders are involved in decision-making, depending to some degree on the amount of power that is transferred to the public. At one extreme, information is provided to the public. At the other, power is delegated to a group of individuals to make decisions. Reflecting the concept of a 'ladder' of citizen participation developed in the literature, approaches have been catagorized as:

1. education and information provision;
2. information feedback;
3. involvement and consultation; and
4. extended involvement.

Related particularly to elements 3 and 4, two other terms are part of the current participation language: consensus building and deliberative processes. Consensus building is defined as "agreement by consent", with the end result of such agreements being commitment both to the agreement and to its purpose. Consensus does not imply full agreement. How the consensus is achieved is paramount - the concept of building consensus implies participative processes that allow discussion, disagreements to be aired, questioning of facts and use of expertise. Consensus building implies a bottom-up approach where stakeholders are enlisted into the drawing-up of initial proposals as well as the consideration of the preferred proposals and solutions.

Deliberative processes, such as community advisory groups and citizens' juries, engage relevant interests in debate, discussion and negotiation, and are presented as needing to be integrated with assessment methods. Deliberative processes imply a new relationship between decision-makers and stakeholders and go beyond traditional participation methods.

Interested and affected parties are best represented in major water-management decisions if they understand what is being proposed and the environmental-flow scenarios that are being considered. It helps if they understand the different ways that ecosystems can change with different scenarios, and the range of impacts and benefits attached to each. Once this is grasped, and a broad understanding developed of why all the specialists are involved, they can make informed input to decision-makers on the level of acceptability of each scenario. It is likely that not all stakeholders will view each scenario in the same way, and that no one scenario will be acceptable to all. In this case, the final decision will be a political one, best served by each group of stakeholders presenting its case in an informed way.

There is an art to presenting scientific information to non-scientists. Many scientists are attempting to develop this skill, but there is a need for experienced communicators. Information needs to pass in three main directions. First, information at varying levels of resolution on resources used, livelihoods threatened and river-related concerns should move from the stakeholders to most of the other specialists groups, to be included in their development of scenarios. Probably the least-developed skill here is in gleaning information from illiterate and isolated subsistence users who cannot envisage how their resources could change and the impact it could have on their lives. Communicators in this area need a good understanding of ecosystem functioning as well as of rural lifestyles, and should be able converse knowledgeably with the biophysical scientists and engineers/managers, and with the riparian people. Second, information on the developed scenarios, which include descriptions of predicted ecosystem change, needs to be passed back to the stakeholders. Third, the level of acceptability of each scenario then has to pass to the decision-maker. True participation of all parties in this process is a complex task, and still in its infancy.

Stakeholders can become better informed by attending presentations by specialists, reading relevant literature, and being willing to take part in meetings where scenarios are explained. Stakeholders that might need representation for any one aquatic ecosystem could include: farmers and irrigators, municipalities, industry and mines, national and regional conservation agencies, international biodiversity and similar treaties, local catchment users with a range of livelihoods, NGOs, and tourism and recreation ministries.

A major issue in stakeholder participation is whether participants represent the views of particular interest groups or are merely representative of a range of interests. Traditionally, participation has often focused on engaging with people who represent a particular interest – for example, the head of a village or a local fishing group. The individuals are expected to relate to the views of their groups and perhaps to act as conduits of information to and from the groups or organizations. In many public participation activities, however, it is more important to recruit or select people to take part who do not represent particular interests but who are representative of the range of different interests and concerns in an area or community. People do not act as reporters of information or discussion in this respect (although they can take this role), but their participation is considered to bring a range of different interests and backgrounds to the discussion. This is more like recruiting a representative sample of an area.

It is the job of the participation facilitator to ensure that everyone is heard equally. Participating well is a skill, however, and selected stakeholders will not always be good at expressing their views or synthesising arguments. The capacity of stakeholders might need to be developed through appropriate training and assistance in participation, in order for the process to operate effectively. This will range from general awareness building amongst the general public on issues concerning environmental flows to training in presentation skills. Stakeholders may also need access to independent specialist support on technical issues.

## *7.3 A strategy for capacity building*

Countries are at different stages of recognising and using environmental flows as a water resources management tool. Their strategies for capacity building in this field will differ because of this. The following is a one example of what could be done. It outlines a ten-point strategy for building capacity on environmental flow assessment for Tanzania.[125] This ten-point plan includes a wide range of activities. Some activities are large and will take several years; others are small and can be implemented rapidly. They are listed very broadly in a suggested chronological order of implementation, though some may overlap or be carried out at the same time.

*Step 1. Training course – Getting experience on frameworks and methods*

The aim of the training course would be to introduce the environmental flows assessment concepts, frameworks, approaches and methods that are available around the world together with their data needs. Such a training course would create awareness rather than the immediate ability to undertake environmental flow assessments. This latter would take time, and ideally involves technical support by experienced users of the methods, at least during the initial applications. Technical support could be achieved, where appropriate, through a network of mentors (see Step 8).

*Step 2. Defining an assessment framework - Turning policy into action*

Implementation of the new National Water Policy for Tanzania, recently approved by the government, requires development of an appropriate assessment framework that links with their Environmental Impact Assessment process and Poverty Reduction Strategy. Such a framework could include classification of the present condition of each Tanzanian river, or parts of it, and of the desired condition. Present and desired conditions could range from pristine to significantly degraded for different rivers, depending on priorities in individual catchments. The environmental flow needed to meet the desired condition for each river would then be assessed.

In contrast, instead of setting a desired condition, this could be negotiated by decision-makers and all interested parties. Scenarios detailing the consequences of several different flow regimes could be assessed in terms of their affect on the river ecosystem, its subsistence users, all other stakeholders, and the regional economy.

Photo 7.1 Experts discuss the ecological consequences of the 1992/1993 drought on the Olifants River.

*Step 3. Trial application of assessment methods - Practising what is learnt*
There are many environmental flow assessment methods, and the best way to understand the different kinds, including what data they need, how much they cost, how long they take, and what their results can be used for, is to take part in a trial application. A single case study in a high-conflict area could be chosen through discussion in the training course (Step 1) or workshop (Step 2), using one or more chosen methods. A restricted number of people (perhaps 20), including key specialists from each relevant discipline, would take part in the activity. The trial application could take place over a full hydrological cycle (one year), though not on a continual full-time basis. A long-term data collection programme could also be established if necessary.

*Step 4. Visits to case studies - Seeing what others have done*
Reading reports of environmental flow assessments on river basins around the world provides valuable information about the practicalities of the environmental flows process, the methods used and their data needs. Actually visiting such river basins, however, and discussing relevant issues with scientists, water managers and stakeholders, provides insight and understanding that cannot be achieved through the written word.

*Step 5. Technical workshops and symposia - Discussing applied techniques*
Developing the necessary expertise should be nurtured through interactions, presentations and discussion at workshops and symposia. Presentations on topics such as hydrology or fish biology to be made by Tanzanian experts who attended the training course and/or contributed to the trial application. Each presentation could use existing data on relevant aquatic ecosystems and, where possible, employ analysis methods learnt during the training course and trial application. For example, a hydrologist could analyse river flow time series, using a simple environmental flow tool such as Richter's hydrological indices (see Chapter 2). This could be compared with 'conventional' hydrological analysis, to highlight the different needs for environmental flow assessments. The meetings could also include some working group sessions to develop topics such as integrating research from different disciplines. Publications from the meetings could define the state of the art of environmental flow assessment in Tanzania.

*Step 6. Technical support - Supporting what is undertaken*
Tanzanian specialists will gain hands-on experience of practical issues related to environmental flow assessments, acquired through involvement in the previous activities. As they progress to full environmental flow assessments, they could be supported by international specialists in the field, who would provide guidance on methods, and independent reviews of both the Terms of Reference for technical studies and the reports of those studies.

*Step 7. National database - Assembling a library of knowledge*
Scientists, practitioners, managers and stakeholders need national and international written material to inform their activities. There is an extensive body of international literature that can provide valuable insights into decision-making frameworks, environmental flow assessment methods, collection and analysis of data and other issues. A national library of such literature and of the location of relevant data holdings, with free access, could be established in a suitable host institution.

*Step 8. Networking - Sharing experience*
Environmental flow assessment is a multi-disciplinary activity. The various experts can best understand each others' perspectives and ways of working by networking. The network should have a co-ordinator or champion, who will be proactive in ensuring interaction between members, running workshops and assembling teams of experts to undertake environmental flow assessments. A particu-

lar task of the network would be to establish a specialist team that could provide future training on environmental flow assessment.

*Step 9. Conducting research - Improving our understanding*

Methods of environmental flow assessment have been developed in various parts of the world, especially in Europe, North America, South Africa, Australia and New Zealand. Many could be customized to fit the Tanzanian situation, and then appropriate supporting data collected. To achieve this, the science of environmental flows would need to be given high priority for research and teaching within universities.

*Step 10. Communications strategy - Spreading the information*

A vital step in establishing a national environmental flow programme is to ensure that everyone understands what environmental flows are, and how they could help promote the sustainable use of water resources. The target audience for awareness building is very wide and includes all relevant sectors such as politicians, lawyers, water managers, scientists and the public. The products required would vary with target audience, but could include brochures, newspaper articles, television interviews and scientific papers. A first step would be to build an affective communications strategy.

Some of the above steps could be applicable to most countries, but many countries will also have other specific needs. These could best be identified through dialogue with specialists in this field.

# Cases and boxes

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82 Colorado School of Law. 1997.

83 Jaeger, W.K., Doppelt, B. 2002. Benefits to Fish, Benefits to Farmers: Improving Streamflow and Water Allocation in the Northwest. Oregon State University, Corvallis.

84 ECOLEX, a joint initiative of IUCN, UNEP and FAO, provides a comprehensive data base of all multilateral environmental agreements and soft law instruments, along with details of the parties to these instruments. See www.ecolex.org

85 The IUCN Environmental Law Centre is in the process of finalizing an extensive data base on water related treaties, national legislation and case law, which will be available on the website. See www.iucn.org/themes/law See also the Atlas of International Freshwater Agreements (UNEP/DEWA/DPDL/RS.02-04), and International Water Law Project (www.internationalwaterlaw.org).

86 For example, does the Constitution include a right to a clean and healthy environment or a right to access to water? For more information on human rights and water visit the Water and Wetlands page of the IUCN Environmental Law Programme website: www.iucn.org/themes/law.

87 In this context, the concept of international rivers is used to indicate a water course which geographically and economically affects the territory and interests of two or more states. In this paper, the concepts of transboundary and shared watercourse are used interchangeably.

88 League of Nations, Treaty Series, Vol. VII, pp. 37.

89 League of Nations, Treaty Series, Vol. XXXVI, pp. 77.

90 May 21, 1997. 36 International Legal Materials (ILM) 700. This convention has not yet entered into force.

91 The ILC is an organ of the United Nations in charge of the codification and progressive development of international law.

92 Adopted on 17 March 1992; entry into force on 6 October 1996. (1991) 30 ILM 800.

93 4 April 1995; 34 ILM 864.

94 Signed in Johannesburg on 28 August 1995 available at http://www.sadcwscu.org.ls.

95 Signed on 2 February 1971, in force since 21 December 1975; 11 ILM 1972.

96 Adopted on 16 November 1972, in force since 17 December 1975; 11 ILM, 1358.

97 Under the Ramsar Convention the List is determined by the State itself. Under the World Heritage Convention proposed sites are inscribed on the list following a decision of the World Heritage Committee.

98 Concluded on 23 June 1979; in force since 1 November 1983. 19 ILM 15.

99 Which has been signed by 16 and ratified by 12 countries.

100 Article 5 and 6, UN Convention.

101 Article 7, UN Convention.

102 Article 8, UN Convention.

103 Article 9, UN Convention.

104 Since it does not have the characteristics distinguishing law from other social rules, e.g. authority and prescription, and are not within the sources of international law described in Article 38 of the International Court of Justice Statute.

105 The Earth's Action Plan adopted at the United Nations Conference on Environment and Development, held at Rio de Janeiro, Brazil in 1992.

106 See also The UN Millennium Development Goals, Part VI, Clause 23.

107 For a review of the South African situation see: Stein, R. 2002. Water Sector Reforms in Southern Africa: Some Case Studies in Hydropolitics in the Developing World: A Southern African Perspective (Turton and Hinwood Eds, 2002) and American University. 2001. South Africa's Water and Dam Safety Legislation: A Commentary and Analysis on the Impact of the World Commission on Dams' Report, Dams and Development, International Law Review, Volume 16, Number 6. For a review of the Australian situation see: Arthington, A. and Pusey B, 2003. Flow Restoration and Protection in Australia, Rivers Research and Applications, and Scanlon J. 2002. From Taking to Capping to Returning: The Story of Restoring Environment Flows in the Murray Darling Basin in Australia, SIWI Annual Conference.

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109 U.S. Wild and Scenic Rivers Act: (P.L. 90-542, as amended), (16 U.S.C. 1271-1287).

110 1997, as amended.

111 National Water Act. Act 36 of 1998.

112 See paragraph 25(c).

113 See Chapter 4.4.6. For a recent case study see Dyson, M. Scanlon, J. 2002. Trading in Water Entitlements in the Murray-Darling Basin in Australia – Realizing the Potential for Environmental Benefits, p14. IUCN ELP Newsletter Issue 1, available at: www.iucn.org/themes/law.

114 See National Competition Council, Compendium of National Policy Agreements – Second Edition, June 1998.

115 See National Competition Council, Compendium of National Policy Agreements at page 99.

116 Some countries may also already have in place a domestic regime that makes provision for environmental flows. If so, then this regime must be understood.

117 The IUCN Environmental Law Programme can assist in providing a range of comparative models. Visit: www.iucn.org/themes/law or contact the IUCN Environmental Law Centre at: waterlaw@elc.iucn.org.

118 Responsibility may reside with another level of government or another ministry/department.

119 National Wildlife Federation and others v. United States Army Corps of Engineers, 132 F.Supp.2d 876 (D. Or. 2001).

120 See the Berlin Recommendations from the International round table on transboundary water management in 1998 and the Report of the World Commission on Dams, 2000.

121 See Agenda 21, para 18.22. Most recently, the WSSD upheld the importance of the role of women and the Plan of Implementation recognises that the outcomes of the Summit should benefit all, particularly women, youth, children and vulnerable groups.

122 The WSSD Political Declaration addressed this deficiency, emphasising the importance of involving all groups in society.

123 For information on where water law is being taught contact the IUCN Environmental Law Centre, Bonn at waterlaw@elc.iucn.org. The inauguration of the IUCN Commission on Environmental Law endorsed Water Law Centre of Excellence, Mandela Institute, Witwatersrand University, South Africa, was held at the IUCN World Parks Congress, Durban, September 2003.

124 King, J.M., Tharme, R.E., de Villiers, M.S. (eds.) 2003. Environmental flow assessments for rivers: manual for the Building Block Methodology. Water Research Commission Technology Transfer Report No. TT131/00. Pretoria, South Africa.

125 Acreman, M.C., King, J.M. 2003. Building capacity to implement an environmental flow programme in Tanzania. Report of a mission to Tanzania, 3-13 December 2002. World Bank Environmental Flows Window, World Bank, Washington,USA.

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The IUCN Water and Nature Initiative is a 5-year action programme to demonstrate that ecosystem-based management and stakeholder participation will help to solve the water dilemma of today – bringing rivers back to life and maintaining the resource base for many.
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