Mainstreaming Environmental Flow Requirements into Water Resources Investments and Policy Reforms

Findings, Lessons and Recommendations from Recent Experience

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Foreword (to be prepared later)

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List of Acronyms

AWM	Agriculture Water Management
BBM	Building Block Method
BNWPP	Bank Netherlands Water Partnership Program
BP	Bank Procedures (World Bank)
CAS	Country Assistance Strategy (World Bank)
COAG	Council of Australian Governments
CWRAS	Country Water Resources Assistance Strategy (World Bank)
DANIDA	Danish International Development Agency
DPL	Development policy lending (World Bank)
DDP	Dam Development project
DRIFT	Downstream Response to Imposed Flow Transformation
EA	Environmental Assessment
EF	Environmental Flows
EFA	Environmental Flow Assessment
EFR	Environmental Flow Requirement
EIA	Environmental Impact Assessment
ELOHA	Ecological Limits of Hydrologic Alteration
ESW	Economic and Sector Work (World Bank)
EU	European Union
FSR	Flow Stress Ranking (environmental flow assessment method)
GDP	Gross Domestic Product
GEF	Global Environment Facility
GES	Good Ecological Status (EU)
GLOWS	Global Water for Sustainability (USAID)
GL/yr	Gigalitre/year
HBP	Hydropower Business Plan
IAP	Infrastructure Action Plan
IFR	Instream Flow Requirements
IUCN	International Union for the Conservation of Nature
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
LHDA	Lesotho Highlands Development Authority
LHWP	Lesotho Highlands Water Project
MDG	Millennium Development Goal
MFL	Maximum Flows and Levels (Florida)
NEPA	National Environment Protection Act (United States)
NGO	Non-Government Organization
NHI	Natural Heritage Institute
NWI	National Water Initiative (Australia)
OKACOM	Okavango River Basin Water Commission
OP	Operational Policy (World Bank)
PAD	Project Appraisal Document (World Bank)
RSA	Republic of South Africa

SAR	Staff Appraisal Document (World Bank)
SDN	Sustainable Development Network (World Bank)
SEA	Strategic Environmental Assessment
TNC	The Nature Conservancy
USAID	United States Agency for International Development
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
USACE	United States Army Corps of Engineers
USAID	United States Agency for International Development
WANI	Water and Nature Initiative (IUCN)
WCD	World Commission for Dams
WFD	Water Framework Directive (European Union)
WMA	Water Management Area (South Africa)
WRSS	Water Resources Sector Strategy (World Bank)
WSS	Water Supply and Sanitation
WUA	Water User Association
WWF	World Wildlife Foundation

Executive Summary

A. OVERVIEW: CONTEXT AND RATIONALE

Introduction

Environmental flows are really about the equitable distribution of access to water. They are central to supporting sustainable development, sharing benefits and addressing poverty alleviation. Investments in water resources infrastructure, especially dams for storage, flood control or regulation, have been essential for economic development (including hydropower generation, food security and irrigation, industrial and urban water supply, flood and drought mitigation) but, when they are improperly planned, designed and/or operated, they can cause problems for downstream ecosystems and communities because of their impact on flow volumes, patterns and quality. These changes have led to a diminution of the downstream ecosystem services that many of the poorest communities rely on for their livelihoods. In order to achieve sustainable development downstream impacts will require increased attention by all parties as countries, through both public and private sector investments, expand their infrastructure in many sectors, especially dams for various purposes.

Climate change is projected to affect water resources supply and demand and these changes in turn will impact on water for the environment. Sea level rise will cause saltwater intrusion and impact estuarine processes that rely on freshwater environmental flows. Adaptation to climate change is likely to involve increased investment on dams and reservoirs in some nations to buffer against increased variability in rainfall and runoff and this will further impact downstream ecosystems, unless the impacts are properly assessed and managed.

The overall goal of the ESW is to help *advance the understanding and integration in operational terms of environmental water allocation into integrated water resources management.* The specific objectives of this ESW report are to:

- Document the changing understanding of environmental flows, both by water resources practitioners and environmental experts within the Bank and in borrowing countries;
- Draw lessons from the experience in implementing environmental flows by the Bank, other international development organizations with experience in this area and a small number of developed countries and developing countries.
- Develop an analytical framework to support more effective integration of environmental flow considerations for informing and guiding:
    - The planning, design and operations decision making of water resources infrastructure projects,
    - The legal, policy, institutional and capacity development related to environmental flows, and
    - Restoration programs.

- Provide recommendations for improvements in technical guidance to better incorporate environmental flow considerations into the preparation and implementation of lending operations.

B. ENVIRONMENTAL FLOWS: SCIENCE, DECISION MAKING AND DEVELOPMENT ASSISTANCE

Fundamentals of Environmental Flows

Provision of flows to maintain downstream aquatic ecosystems and provide services to dependent communities was recognized in the South African policy and legislation in the late 1990s and has now been increasingly adopted in other countries revise their policies. The causes of flow reduction in rivers can also be broader than just water abstraction or storage and regulation by infrastructure – upstream land use changes due to forestry, agriculture and urbanization can also significantly affect flows. Environmental flow impacts can extend beyond rivers to groundwater, estuaries and even coastal areas. There are now many methods, from the very simple to the very complex, for estimating environmental flow requirements. There is an extensive body of experience for the main techniques.

The Entry Points for Bank Involvement

There are four entry points by which the Bank can support countries integrate environmental flows in decision making: (i) water resources policy, legislation and institutional reforms; (ii) river basin planning; (iii) investments in new infrastructure; and (iv) rehabilitation or re-operation of existing infrastructure. Consistent with its commitment to sustainable development the Bank should support measures to promote countries and the private sector integrating environmental flows upstream in the decision making through dialogue on water resources policy, river basin planning and programs that entail major land use changes. The World Bank already has supported some projects with successful environmental flow components and outcomes.

Environmental Flows, IWRM and Environmental Assessment

EFAs are intrinsically a part of Integrated Water Resources Management. Although it is desirable for EFAs to be integrated into SEAs for policy, plan, program or sector-wide lending and EIAs for project-level investments, they have traditionally been undertaken separately.

Bank Adoption of Environmental Flows

An analysis of selected dam projects showed that, until the mid-1990s, Bank support for environmental and social work was heavily focused on evaluation and addressing upstream impacts of dams. By the mid-1990s, these assessments had expanded to include downstream environmental and social issues with about equal frequency, underscoring the evolving concern about downstream impacts. An analysis of Country Water Resources Assistance Strategies however show mixed results concerning the inclusion of environmental flows, with only some countries incorporating them into their planning. There is a limited perception of the need to include environmental flows within the water policies of developing countries, but a good understanding of the importance of environmental flows in catchment scale water resources planning. The Bank Netherlands

Water Partnership Programme has catalysed some notable achievements in introducing environmental flows in infrastructure planning, design and operations and dam rehabilitation and re-operation projects.

International Development Organizations and NGOs
A number of international development organizations and NGOs have been supporting environmental flow assessments at project and basin levels, conducting training courses, and providing information and support material. The Bank has partnered with some of these organizations to produce analytical material on the incorporation of environmental flows into infrastructure development and re-operations.

C. ENVIRONMENTAL FLOW IMPLEMENTATION CASE STUDIES

Selecting and Assessing the Case Studies
Seventeen case studies were selected for an in-depth analysis to identify the lessons from incorporating environmental flows into water resources policy, basin and catchment plans, and new infrastructure projects, and the rehabilitation and re-operation of existing infrastructure. The case studies included eight that were supported by the World Bank. The assessment criteria included factors that influenced its success as well as the institutional drivers that initiated and supported the introduction of environmental flows.

Inclusion of Environmental Flows in Water Resources Policies
An analysis of five policy case studies found that the inclusion of environmental flows in policy should provide for:

- legal standing to environmental water allocations;
- inclusion of environmental water provisions in basin water resources plans;
- assessment of all relevant parts of the water cycle when undertaking EFAs;
- a method for setting environmental objectives in basin plans;
- attention to both recovery of over-allocated systems and protection of unstressed systems;
- clear requirements for stakeholder involvement;
- an independent authority to audit implementation; and
- a mechanism for turning value-laden terms into operational procedures.

Inclusion of Environmental Flows in Basin/Catchment Plans
The lessons that emerged from an analysis of four basin and catchment water resources plans were:

- recognition of environmental flows in water resources policy and legislation provides important backing for including environmental flows in basin/catchment plans;
- there is a need to demonstrate the benefits from environmental water allocations after plans are implemented;
- the term “environmental flows” can be counter- productive if not explained at a early stage;
- participatory methods need to be tailored to suit stakeholder capacity;
- a range of EFA techniques are needed to suit different circumstances; and

- ecological monitoring is essential to provide information for adaptive management.

Inclusion of Environmental Flows in Infrastructure Projects
Four new dams and four restoration projects were reviewed for lessons in assessing and implementing environmental flows:

- there is usually a need to combine engineering improvements and re-operations to provide the volume of water needed for major ecosystem restoration;
- inclusion of environmental flows in water resources policy simplifies the application of EFAs at project level;
- environmental outcomes need to be linked closely to social and economic outcomes;
- EFAs should be conducted for all components of the hydrological cycle;
- traditionally trained water resources professionals can find it difficult to grasp environmental flow concepts;
- water resources plans provide benchmarks for water allocations during project assessments;
- active monitoring is needed to enforce flow allocation decisions and undertake adaptive management;
- it is important to present information in terms that are comprehensible to decision makers;
- economic studies can support arguments for downstream water allocations;
- EFAs are yet to be fully mainstreamed into EIAs;
- the cost of conducting EFAs constitutes a small fraction of project costs; and
- EIAs have not always identified issues associated with downstream water provisions.

D. MAINSTREAMING IMPLICATIONS

Science Achievements
The science underpinning EFAs has advanced considerably. There are now many more methods for defining and information available on the ecological response to different flow components. There is also growing experience in integrating information from across a range of physical, ecological, and socio-economic disciplines. In addition, a wide variety of EFA methods have been developed, backed by considerable field experience, to suit a variety of levels of environmental risk, time and budget constraints, and different data and skill levels. The Bank's support for the Lesotho Highlands Water Project has contributed to the development of Downstream Response to Imposed Flow Transformation (DRIFT) - one of the more comprehensive methods that systematically addresees the downstream biophysical and socioeconomic impacts. There is also a growing body of experience in implementing environmental flows, including monitoring and adaptation of management procedures.

Mainstreaming Achievements
Developed countries including parts of the USA, Australia, New Zealand, and the countries of the EU, together with South Africa, have accepted the need to develop and implement catchment water resources plans that include environmental flows. There is

general public acceptance of the importance of maintaining healthy aquatic environments in these countries. In these countries, where environmental flows have now been mainstreamed into water resources planning, there is an acceptance that the concept of environmental flows should be extended to groundwater as well as to estuaries and even near-shore regions.

Support for Developing Countries

International development organizations and NGOs have been active in providing support for environmental flows in developing countries through assistance with EFA applications, training programs, and provision of support material and internet resources. The Bank has supported some collaborative work with these development partners.. The Bank's major contribution to global good practice has been its restoration of the degraded Tarim Basin and Northern Aral Sea, its assistance with the provision of flood flows in the Senegal Basin, and its role in the Lesotho Highlands Water Project. In these cases, provision of environmental flows has restored (or retained) ecosystems with demonstrable benefits to downstream populations; in the Tarim Basin case, there were also significant benefits to the upstream irrigation communities.

Challenges

Current challenges faced by both the Bank and environmental flows practitioners include:

- overcoming the mis-perceptions arising from the term "environmental flows";
- developing methods for systematically linking biophysical and socioeconomic impacts;
- incorporating the whole water cycle (surface, groundwater and estuaries) into the assessments;
- applying EFAs to land use activities that intercept overland flows;
- including climate change in the assessments;
- integrating environmental flow assessments into strategic, sectoral and project EA; and
- understanding the circumstances when benefit sharing is a viable approach.

Framework for Expanded Bank Engagement with Environmental Flows

The analysis points to a four part framework for improving the Bank's use of environmental flows:

- strengthen Bank capacity in assessing and overseeing environmental flows
- strengthen environmental flow assessments in lending operations through training, support materials and access to international experts;
- promote the integration of environmental flows into policies and plans through dialogue, instruments such as CWRAS, CAS and DPLs, support material for Bank staff; and
- building strong collaborative partnerships with international development organizations, NGOs and the private sector.

Adoption of this framework will increase the Bank's ability to implement its strategy of increasing investment in water resources infrastructure while reducing the risk of detrimental environmental impacts that threaten the livelihoods of downstream communities.

I. OVERVIEW: CONTEXT AND RATIONALE

Chapter 1. Introduction

Environmental flows are about equitable access to water and are central to supporting sustainable development, benefit sharing and poverty alleviation. In order to achieve sustainable development, downstream impacts will require increased attention by all parties as countries, through both public and private sector investments, expand their infrastructure in many sectors, especially dams for various purposes. Consistent with its commitment to sustainable development the Bank should both strengthen the integration of environmental flow assessment in water resources investment planning, design and operations as well as support measures to move the integration of environmental flows further upstream in the decision making process through dialogue on water resources policy, river basin planning and programs that entail major land use changes. The World Bank already has supported few projects with successful environmental flow components and outcomes. This ESW reviews the Bank's engagement with environmental flows over the past 15 years; summarizes the current international understanding of environmental flows and the Bank's experience with incorporation of environmental flows in its policies and procedures; and proposes a framework for better integrating environmental flows in the Bank's work.

Environmental Flows – Equity and Sustainability

Environmental flows are concerned with the equitable sharing and sustainable use of water resources. They form a central, yet under appreciated and inadequately addressed element of Integrated Water Resources Management (IWRM) [1]. They lie at the center of the development debate on environmentally responsible water resources development in the face of the changing societal values as well as changing climate. They will also form an integral part of adaptation responses and strategies for addressing climate change.

The debate about environmental flows is really a debate about the allocation of water between immediate consumption, often through development investments, and the water needed to sustain ecosystem services on which communities and biological diversity have traditionally depended are assured. It is a debate about (a) recognizing that there is a physical limit beyond which a water resource suffers irreversible damage to its ecosystem

[1] World Bank (in prep). Strategic Environmental Assessment and Integrated Water Resources Management and Development. World Bank, Washington DC.

functions and (b) systematically balancing the multiple water needs of society in a transparent, informed and responsible manner - an inherent objective of IWRM.

Environmental flows are the flows needed to maintain important aquatic ecosystem services, and as such, they are at the heart of good practice water resources planning and management. They are defined as: "*The quality, quantity and timing of water flows required to maintain the components, functions, processes, and resilience of aquatic ecosystems which provide goods and services to people*[2]." In some countries, they are regarded as a luxury of a few environmentally conscious people at the expense of scarce water for production needed by many. This mis-perception has arisen largely because the term "environmental flows" conjures up images of water being allocated to the environment at the expense of human use and economic development or being wasted by being allowed to flow to sea[3]. The reality is that, rather than being at the expense of people, environmental flows are essential for providing both direct and indirect benefits that current and future generations rely on[4] (Appendix A).

An Environmental Flow Assessment (EFA) is a process used to understand and define the ecosystem functions supported by the various flow components in a river system. EFA is a distinctive element of IWRM, a framework which many developed and developing countries are gradually embracing. Box 1 highlights the key linkages between environment flows and IWRM.

Box 1. Environment Flows and IWRM linkages

The environment is linked to IWRM in three fundamental ways. First, the aquatic (and related terrestrial) ecosystem provides habitat for fisheries, shrimps, wildlife, and fauna and flora. The aquatic ecosystem is thus a water-consuming sector just like agriculture, energy, and domestic and industrial supply. Second, the design and operation of hydraulic infrastructure for water supply, sewerage, irrigation, hydropower, and flood control often impacts ecosystems, both upstream and downstream of the infrastructure, and communities—farming, pastoral, and fishing—dependent on those ecosystems. Conversely, the reoperation and rehabilitation of existing infrastructure has been used to successfully support the restoration of degraded riverine ecosystems. Third, integrated water resources planning and management is facilitated by policies, laws, strategies, and plans that are multi-sectoral (based on allocation of water for all uses, protection of water quality and control of pollution, protection and restoration of lake basins, watersheds, groundwater aquifers and wetlands; and control and management of invasive species).

Debates about environmental flows have often arisen when major infrastructure projects, especially dams and direct abstractions, are being planned, designed, constructed or

[2] The Nature Conservancy (2006). Environmental Flows. Water for People - Water for Nature. TNC MRCSO1730. The Nature Conservancy, Boulder, Colorado, USA.
[3] Flows into marine waters are essential for many important ecosystem processes in estuaries and near-shore areas. Perceptions that these flows represent wasted water are slowly changing.
[4] The Brisbane declaration, following the 2007 RiverSymposium and Environmental Flows Conference in Brisbane Australia, contains a call to action addressed to all governments.

operated. The development benefits of dams (e.g., for hydropower generation, water supply, irrigation, regulation of flood control) and abstractions are usually well quantified and apparent to decision makers and their detrimental impacts on (upstream[5]) communities affected by reservoir inundation now receive concerted attention through resettlement programs and action plans. But the impacts of dam development on those downstream of the dam are often diffuse, long-term, poorly understood and frequently inadequately addressed. Downstream impacts[6] – biophysical and social - arise primarily from changes in the flow – quantity, timing and quality – patterns of rivers, and typically include:

- Reduced abundance of fish and invertebrates such as prawns and shellfish;
- Reduction in floodplain sediment and nutrient deposition;
- Reductions in areas available for floodplain grazing, cropping and fuelwoods;
- Impediments to riverine navigation and transport;
- Reduction in water to terrestrial habitats (including protected areas) and aquatic habitats important for biodiversity;
- More difficult access to domestic, irrigation and livestock water supplies;
- Changes in estuarine productivity from altered flow patterns and saline intrusion;
- Reductions in groundwater recharge;
- Loss in cultural amenities.

In fact, downstream communities often can be impacted in two fundamental ways when a dam is developed. First, their livelihoods can be disrupted by the changes in the river flow regime from the development itself. Secondly, the benefits of the development (e.g., electricity generated) often end up in distant places such as urban areas, and the local communities rarely share in these benefits of those developments. Therefore, programs for sharing benefits from water infrastructure projects should both address downstream impacts and integrate environmental flows into water resources decision making.

Although most attention in the current debate on environmental flows has been directed to the effects of dams and other water resources infrastructure on downstream flows, other development activities, particularly large scale land use changes, can also affect the access to water of people downstream of the development. For example, conversion of land into farmland or urban development, or forestry plantations in the headwaters of

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[5] Typical impacts upstream of an impoundment would be related to the conversion of a terrestrial into an aquatic habitat, and could entail relocation, resettlement or compensation of land and assets to be inundated or impacted by inundation.

[6]In some cases, significant quantities of water have been exported to other nations or total quantities of water have been affected as flows have been diverted from the rivers to support extensive irrigation, hydropower production, and urban water demands; in other cases, such as in hydropower development and flood control or multi-purpose structures, it is the seasonality of flows and the size and frequency of floods that have been modified. Water quality can also be affected downstream of a dam or other infrastructure, through changes in water temperature and changes in water chemistry or reduced dilution capacity resulting from changes in river flows.

catchments can accelerate runoff or intercept much of the runoff and even access groundwater systems during their establishment phase. These activities can also increase erosion and exacerbate sediment loads and transport. Yet these activities have seldom been considered as requiring environmental flow assessments, even though they can cause significant reductions in downstream river flows and alter river morphology and ecosystem functions.

Climate change as well as infrastructure options to adapt to a warming world are likely to have significant implications for environmental flows. The annual average inflows to rivers and recharge to groundwater systems will be affected by climate change with consequent impacts on aquatic ecosystems and the ecosystem services that they provide. The frequency of extreme events will also be affected by global warming causing changes to the frequency of floods and droughts that some riverine ecosystems rely on. The rise in sea level will affect freshwater inflows into estuarine and coastal ecosystems. Warmer temperature will impact ecosystem processes and demand patterns. The crop water requirements for rainfed and irrigated agriculture will change and this, in turn, will affect the water allocated to the environment. In some parts of the world, adaptation options to climate change will require increased investments in dams and other forms of water resource infrastructure to buffer against the impacts of longer droughts and extreme floods. The downstream impacts of these investments will need to be assessed and factored both during strategic planning and during project preparation, design and operations.

There are a number of reasons for the limited political and institutional attention thus far given to the downstream impacts arising from either infrastructure or land use change. These include the restricted use of EFA in project planning, design and implementation, and the limited adoption of EFA as an integral part of EA. This is in part a reflection of the challenge of identifying the downstream impacts, the absence of a common metric to evaluate the impacts; the diffuseness of the impacts across communities and over space; the absence of uniform methodology to delineate the downstream population impacted by flow changes; the lack of or weak representation of the affected parties in the decision making process; the difficulty of expressing the respective impacts in financial and economic terms; and lack of consensus about acceptable EFA methods.

In general, the debate about environmental flows is about multiple and evolving values of society. It is a debate about power relationships between different groups in societies: water user groups, upstream and downstream interests, urban and rural interests, public and private interests, regulator and regulatee, developer and communities, as well as central and local interests. Consequently, any program to promote the inclusion of environmental flows into public decision making needs to be participatory, include biophysical and socio-economic sciences, express the impacts in understandable ways (using both monetary and non-monetary terminology), and be consistent with the principles of IWRM.

World Bank and Environmental Flows

The understanding about environmental flows within the World Bank has increased over the last 15 years, mirroring the interest in and development of environmental flows globally. The Bank's 1993 Water Resources Management Policy (WRMP)[7], based on the Dublin Principles, stipulated that "The water supply needs of rivers, wetlands, and fisheries will be considered in decisions concerning the operations of reservoirs and the allocation of water" explicitly identifies downstream environmental water needs. The Bank's 2001 Environment Strategy[8] underscored the linkage between water resources management, environmental sustainability, and poverty and emphasized the reliance of poor people on the productivity and environmental services of ecosystems and natural resources. It also emphasized that environmental concerns need to be moved up the decision hierarchy to policy and planning levels if environmental concerns, such as environmental flows, are to be effectively incorporated into project-level investments[9]. In the case of environmental flows, there needs to be a commitment to water policy and environment policy that recognizes water for the environment as a legitimate use of water and authorizes environmental flows with legally binding provisions and support for water allocation planning that includes water allocations for environmental purposes.

The 2003 Water Resource Sector Strategy (WRSS) was a turning point with the adoption of IWRM as a framework for water resources planning and management and its central message of re-engagement "with high reward/high-risk hydraulic infrastructure, using a more effective business model." It considered the environment as a special water using sector as well as a central element of integrated water resources management. The new business model calls for the development of infrastructure in an environmentally and socially responsible manner and this, in turn, implies the need to take full account of both upstream and downstream environmental and social impacts and, where possible, avoid, minimize, mitigate or offset their effects. This business model is aimed at reducing the uncertainties that are often associated with decision making in complex hydraulic infrastructure planning, design and operations.

Following the WRSS, the Bank increased its support for environmental flows via individual infrastructure projects, in river and lake basin management and development, sector-wide programs, and development-policy-based lending. Under the Bank Netherlands Water Partnership Program, windows on environmental flows, river basin management and dam development and other areas of water resources work were opened in 2000 to provide support to World Bank operations on a demand driven basis. In 2003, a series of World Bank technical notes on environmental flows were prepared to support

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[7] World Bank (1993). Water Resources Management Policy. World Bank, Washington DC.

[8] World Bank (2001). Making Sustainable Commitments: An Environment Strategy for the World Bank. World Bank, Washington DC.

[9] The Environment Strategy proposed that Strategic Environmental Assessments (SEAs) be introduced as tools for this purpose.

operations[10]. Thus, the Lesotho Highlands Water Project is an example where environmental flow requirements were incorporated into the design of new infrastructure (the Mohale Dam) and the re-operation of the previous dam (Katse dam), while projects in the Tarim Basin, China and the Aral Sea, Central Asia are examples of successful restoration of downstream ecosystems which had been severely degraded following large scale irrigation and hydropower developments and weak water resources management. The Bank has also provided assistance in water policy reforms and river basin level planning in conjunction with support for infrastructure projects that have incorporated environmental flows. The shift in Bank lending from a project basis to development policy based lending (DPL), programmatic lending, and sector-wide lending has provided further impetus for accelerating the mainstreaming of the environment through sector analysis as well as the use of emerging tools such as strategic environmental assessments (SEAs), country environmental assessments (CEAs), country water resources assistance strategies (CWRAS), and others.

In 2007, the Bank elevated its commitment to sustainable infrastructure investments by integrating two vice presidencies working on infrastructure and environment, social and agriculture and rural development within a Sustainable Development Network (SDN) to ensure a more holistic approach to development. The SDN vision not only calls for mainstreaming the environment, but embodies environmental sustainability as a core element of the Bank's work. This commitment is reflected in the recently updated Infrastructure Action Plan approved by the Bank in 2008, the 2006 Agriculture Water Management Initiative[11], and the Clean Energy Development Framework.

This ESW develops a framework for more systematically incorporating environmental flow considerations into Bank assistance with water policy reform, support for river basin planning, and investments in water resources infrastructure. It is a contribution to a more effective business model for re-engaging in high reward/high-risk hydraulic investments. It supports the integration of environmental flows into DPLs and water centered sector wide assistance and programmatic lending as well as the objectives of the Infrastructure Action Plan, the Agriculture Water Management Initiative, the Climate Change and Water ESW as well as the Strategic Framework for Climate Change and Development to provide environmentally sustainable investments in hydropower, water supply, agricultural water management and flood management systems. Overall, supports the implementation of the SDN vision into Bank operations.

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[10] Davis R. and R. Hirji (Eds). (2003). Environmental Flows: Concepts and Methods. Water Resources and Environment Technical Note C.1. World Bank, Washington D.C.
Davis R. and R. Hirji (Eds). (2003). Environmental Flows: Case Studies. Water Resources and Environment Technical Note C.2. World Bank, Washington D.C.
Davis R. and R. Hirji (Eds). (2003). Environmental Flows: Flood Flows. Water Resources and Environment Technical Note C.3. World Bank, Washington D.C.

[11] World Bank (2006). Reengaging in Agricultural Water Management. Challenges and Options. World Bank, Washington DC.

Objectives of the ESW

The overall goal of this ESW is to help *advance the understanding and integration in operational terms of environmental water allocation into integrated water resources management.* In this regard, this ESW complements the recently completed ESW on Strategic Environment Assessment and Integrated Water Resources Management and Development[12].

The specific objectives of this ESW report are to:

- Document the changing understanding of environmental flows, both by water resources practitioners and environmental experts within the Bank and in borrowing countries;
- Draw lessons from the experience in implementing environmental flows by the Bank, other organizations with experience in this area (UNEP, UNDP, UNESCO, IUCN, IWMI, TNC, NHI, and WWF) and a small number of developed countries (Australia, United States, Canada and European Union) and developing countries and regions (South Africa, Central Asia, China, India, Lesotho, Mekong Basin, Senegal Basin and Tanzania).
- Develop an analytical framework to support more effective integration of environmental flow considerations for informing and guiding:
    - The planning, design and operations decision making of water resources infrastructure projects,
    - The legal, policy, institutional and capacity development related to environmental flows, and
    - Restoration programs.
- Provide recommendations for improvements in technical guidance to better incorporate environmental flow considerations into the preparation and implementation of lending operations.

The report is written primarily for World Bank Task Team Leaders and water resources and environmental specialists engaged with water policy dialogue, river basin planning and water resources investment planning, design, and operational decision making for investment lending. Other audiences include professional organizations, professionals from development organizations, NGOs and client countries engaged in water policies, plans, and projects.

Methodology

The analysis draws on a variety of sources of information. The international literature provided information on current issues and approaches to environmental flows in both developed and developing countries. This was supplemented by information contained in a number of Bank documents[13] and published articles.

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[12] World Bank (in prep). Strategic Environmental Assessment and Integrated Water Resources Management and Development. World Bank, Washington DC.

[13] Davis, J.R. and R. Hirji. (2003). Water Resources and Environment Technical Notes C1-C3. World Bank, Washington D.C.

The changing perception of environmental flows within the World Bank is drawn from a review[14] of the Bank's activities in supporting environmental flows in lending operations and technical assistance. In this ESW, selected water-related infrastructure projects that were prepared during the 1990s were examined to see if there had been an increase in recognition of environmental flow issues following the 1993 WRMP. The Bank's CWRAS were analyzed for their recognition and integration of environmental flows. The assistance under the BNWPP environmental flows window was reviewed.

The main source of information for the lessons on implementing environmental flows came from an in-depth analysis of 17 case studies covering water policy, catchment and basin plans, and investment projects. Eight of the case studies are of projects supported by the World Bank. These case studies were analyzed with a uniform methodology to both evaluate the effectiveness of environmental flow programs and explain factors (or institutional drivers) that may have contributed to those outcomes as well as to identify lessons for implementing environmental flows in a variety of settings. These sources were supplemented by information drawn from other environmental flow projects supported by the Bank and other organizations as well as technical assistance for environmental flows provided through the BNWPP[15] Environmental Flows Window, and from a broad review of the environmental flow programs of international development organizations and NGOs. A separate stand alone technical guidance note on integrating environmental flows into hydropower planning, design and operations decision making was commissioned as a key input into the ESW.

Organization of Report

The report is produced in two volumes. Volume one consists of nine chapters and five appendices. This chapter provides the context and justification for the ESW and outlines the methodology used in the analysis. Chapter 2 provides an introduction to environmental flows, including the reliance of downstream communities on flows, the definition of environmental flows, ecosystem services, the extent to which environmental flows are formally recognized in different countries, the incorporation of environmental flows into polices, plans and projects, the linkage between environmental flows, IWRM and environmental assessment at tactical and strategic levels, and the methods employed to assess environmental water needs. Chapter 3 discusses the adoption of environmental

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The Nature Conservancy (in press). Integrating Environmental Flows in Hydropower Dam Planning, Design and Operations. Technical Guidance Note. World Bank, Washington D.C.

[14] Hirji R. and T. Panella (2003). Evolving policy reforms and experiences for addressing downstream impacts in World Bank water resources projects. River Research and Applications 19(5-6) 667 – 681.

[15] The Bank Netherlands Water Partnership Program (BNWPP) is a programmatic trust fund established in 2000 to increase water security through the sponsorship of novel approaches in Integrated Water Resources Management, and thereby contribute to the reduction of poverty. The Environmental Flows Window has provided technical assistance to 13 countries in preparation for, or during the implementation of, lending activities.

flows in the work of the World Bank. It includes a brief analysis of the evolution of acceptance of environmental flows within the Bank, the inclusion of environmental flow concerns into CWRASs, assistance under the BNWPP environmental flows window, and partnerships with other international development organizations providing assistance in environmental flows. Chapters 4-7 describe the analysis of the 17 environmental flow case studies, chapter 4 describing the criteria used to analyze the case studies. Chapters 5-7 contain the findings from the policy, plan, and project level case studies respectively. Chapter 8 summarizes the achievements to date in integrating environmental flows into water resources decision making and the key remaining challenges. A framework for effectively integration of environmental flows into Bank operations is presented in Chapter 9.

There are six appendices. Appendix A contains the Brisbane Declaration; Appendix B summarizes the design options for releasing environmental flows from dams; Appendix C contains background to environmental flows; Appendix D contains a description of the integration of environmental flows into CWRASs; and Appendix E provides a description of the contributions of the major international development organizations and NGOs providing environmental flows assistance to developing countries and their contact information.

Volume 2 has the seventh appendix, Appendix F. It contains the case study selection and assessment criteria and the detailed 17 case studies.

II. ENVIRONMENTAL FLOWS: SCIENCE, DECISION MAKING AND DEVELOPMENT ASSISTANCE

Chapter 2. Environmental Flows in Water Resources Decision Making

> Water resources developments are essential for growth and but have often led to adverse impacts on downstream communities because of their impact on flow volumes and patterns. These changes have led to a loss of downstream ecosystem services that many communities rely on. The impacts can extend beyond the surface waters to groundwater, estuaries and coastal areas. Their causes can be broader than infrastructure – upstream land use change can also significantly affect flows. Many EFA methods are now available for assessing downstream environmental impacts and can be integrated at various stages of water resources decision making. The four entry points by which the Bank can help countries tackle this issue are: (i) water resources policy reform; (ii) assistance with river basin planning; (iii) investments in new infrastructure; and (iv) rehabilitation or re-operation of existing infrastructure to restore degraded downstream ecosystems. Traditionally the Bank has concentrated on the infrastructure entry point. To be effective, the Bank needs to both strengthen its support for infrastructure investments and broaden its approach to promote environmental flows in water resources policy and basin water plans, and also consider the impacts of major land use changes on downstream flow regimes.

Environmental Flows and Water Resources Development

Equitable access to adequate quantities of good quality water is central to growth and sustainable development. Water is a vital input to livelihoods and to most economic sectors - dryland and irrigated agriculture, livestock, forestry, inland and estuarine fisheries and aquaculture, national parks, hydropower, industrial and mineral production, transport and tourism - in both developed and developing countries.

Access to water is also central to poverty alleviation and achieving the MDGs. One of the MDG targets is to halve the proportion of people without sustainable access to safe drinking water and sanitation by 2015 while other MDG targets implicitly require access to clean, safe water. This requires provision of both good quality water and sufficient quantities of water for subsistence.

The development of water resources through dams (small and large), inter-basin transfers, aquifer storage and recovery, levees and dykes, and boreholes provides a buffer against climate variability. Developed countries typically have invested substantially in storage infrastructure and have much greater water storage per capita than most developing countries (Figure 1), even though developing countries especially in the tropics face much greater climate variability than developed countries. Not only do developing countries have less per capita water storage (which increases their vulnerability to extreme climate shocks – floods and droughts), but their existing water resources infrastructure is often unreliable, poorly maintained and incapable of providing buffering capacity against floods and droughts[16]. Water resources infrastructure can also, potentially, play an important role in adapting to climate change by providing water storage during extended dry periods and buffering from floods during wet periods and extreme events.

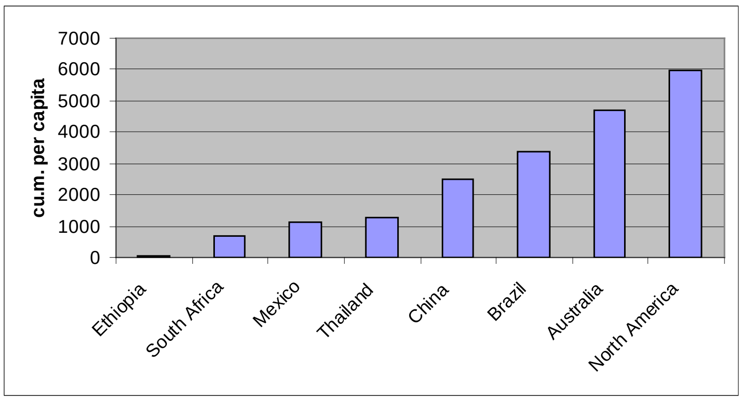

Figure 1. Storage per capita in different countries [17]

South Africa's National Water Act (1998) gives practical recognition of the principles in the MDG by ensuring that all people have a right to a minimum quantity of water. This law also recognized the importance of ensuring a minimum quantity of water to sustain the ecosystem services on which many human activities depend. A number of countries have similar provisions in their water policies and laws that mandate water for essential human and ecosystem needs, and many other countries are considering policy reforms related to environmental water.

[16] Mogaka, H., S. Gichere, R. Davis and R. Hirji (2004). Impacts and Costs of Climate Variability and Water Resources Degradation in Kenya: Rationale for Promoting Improved Water Resources Development and Management. World Bank, Washington DC..
World Bank (2006). Ethiopia: Managing Water Resources to Maximize Sustainable Growth. A World Bank Water Resources Assistance Strategy for Ethiopia. World Bank, Washington D.C.
[17] Grey D. and C. Sadoff (2006). Water for Growth and Development. Theme Paper for 4th World Water Forum. Mexico City. World Bank, Washington DC.

The development of water resources has often altered the flow regimes of rivers[18] thereby affecting ecosystems and contributing to the decline of many species (Figure 2) and resulted in adverse impacts on communities downstream of the development. Appendix C provides details of the current understanding of the impacts of these developments on downstream ecosystems and the development of environmental flow methodologies.

Abstractions of water for irrigation, water supply, inter-basin transfers for any type of use reduce total flow volumes, while dams and other barriers also change the flow patterns.

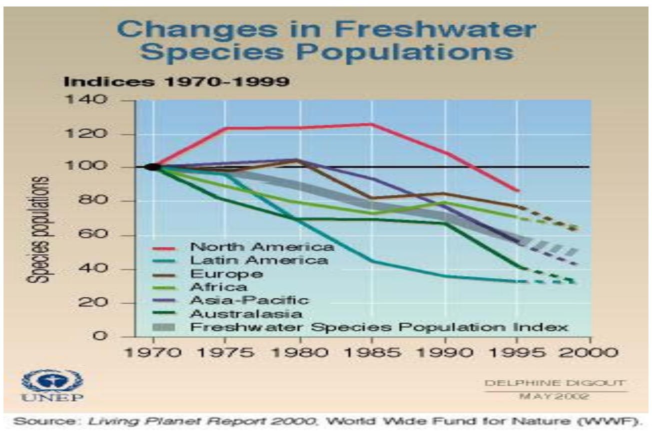

Figure 2. Loss of freshwater species (Source: UNEP)

The 2000 World Commission on Dams report[19] provides a sharp focus on both upstream and downstream ecosystem needs and associated social impacts. It states that "Among the many factors leading to the degradation of watershed ecosystems, dams are the main physical threat, fragmenting and transforming aquatic and terrestrial ecosystems with a range of effects that vary in duration, scale and degree of reversibility." In their Sustainability Guidelines[20], the International Hydropower Association now recognizes the need to provide for environmental flows that maintain downstream ecosystem functions. The major commercial banks providing financing for project developments have adopted a voluntary set of principles[21] - the "Equator Principles" – governing their social and environmental responsibilities for lending to projects of more than $10 million.

[18] The term 'river systems' refers to a river and the hydrologic features connected to it, such as wetlands, floodplains and estuaries.
[19] World Commission on Dams (2000). Dams and Development: A New Framework for Decision-Making. The Report of the World Commission on Dams. Earthscan Publications Ltd, London and Sterling, VA.
[20] International Hydropower Association (2004). Sustainability Guidelines. Sutton, UK.
[21] See http://www.equator-principles.com/ for details

Under these principles, the IFC's categoriziation of project risk is adopted and all projects that fall into categories A or B have to undergo a social and environmental assessment.

Dams are not the only infrastructure investments that can affect flows. Water that is pumped directly from waterbodies or is discharged into waterbodies can affect flow quantities and timings; levees and dykes for flood protection or other purposes disconnect floodplains and wetlands from the rivers and affect physical, chemical and biotic processes; and excessive groundwater pumping can affect river flows where there is connectivity between the river and associated aquifers.

Land use change can also affect downstream river systems. Converting forest to annual agricultural crops typically reduces evapo-transpiration and increases runoff; it can also reduce water abstraction from shallow aquifers (because of the shallow rooting of annual crops) leading to rising water tables and potentially increased base-flows to streams. And expanding cities increase stormwater runoff, reduce groundwater infiltration and increase pollution loads, all of which can impact on river flows. Conversely, afforestation can also increase crop evapo-transpiration and reduce streamflow and straightening of river channels can speed up run-off and increase flood peak magnitude downstream.

Water Dependent Ecosystem Services[22]

Rivers provide many important ecosystems services for communities in both developed and developing countries. Box 2 illustrates the diversity of ecosystem services provided by rivers:

- Provisioning services – e.g. water for food, water, timber
- Regulating services – e.g. flood regulation, prevention of disease, disposal of wastes
- Supporting services - e.g. nutrient cycling
- Cultural services – e.g. aesthetic values.

Many communities, particularly in developing countries, are dependent on these services for providing protein (through fish catches), productive land for agriculture and grazing, timber for firewood, etc. Biodiversity underpins many of these services[23].

Box 2. Examples of Flow-Dependent Ecosystems Services

Provisioning Services - Tonle Sap, Cambodia

Tonle Sap is a large shallow lake in the center of the Cambodian plain. The lake is filled during the wet season from the Mekong River and, depending on the wetness of the season, can expand from about 2,500 km^2 to up to 16,000 km^2. The periodic flooding carries sediment-rich water

[22] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis.
Island Press, Washington, DC.

[23] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

from the Mekong River to the lake that supports a complex foodweb. The Lake basin contains extensive wetlands and flooded forests that are critical to fish breeding.

The lake is an important source of fish for the Cambodian population, providing about 230,000 tonnes p.a. over 75% of Cambodia's annual inland fish catch and 60% of the Cambodians' protein intake. It supports over three million people. In addition, fish migrate from the Tonle Sap to the Mekong River and help restock Mekong River fisheries as far north as Yunnan Province of China.
Source: ILEC (2005). Managing lakes and their Basins for Sustainable Use: A Report for Lake Basin Managers and Stakeholders. International Lake Environment Committee. Kusatsu, Japan.

Regulating Services – Mississippi River, USA
The natural floodplains of the Mississippi River allow floodwaters to extend laterally and so reduce the peaks of floods for downstream communities. However, the floodplains have been progressively cut off from the river by levees and banks, as the floodplain has been developed initially for agriculture and then for industrial and urban development. Whole communities are now built on the flood plain. Also, the progressive constriction of the Mississippi for navigation makes floods higher; thus navigation works degrade the protection afforded by levees.

In 1973 the levees failed under the water pressure from high flows in the Mississippi River and large areas were suddenly inundated. Although the Mississippi crested in St. Louis 2 feet above the level of the 1844 flood, the flow in the river was actually 35 percent less than the earlier flood, illustrating the importance of the floodplain for absorbing large flows. In a study of the causes of the 1973 flood, Belt concluded the flood was "man-made" to a great extent.
Source: C. B. Belt Jr. (1975). The 1973 Flood and Man's Constriction of the Mississippi River. Science 189 (4204) 681 – 684.

Supporting Services – Nakivubo Swamp, Uganda
Uganda's Nakivubo swamp has been receiving partially treated wastewater from Kampala for over 30 years. It contains dense communities of papyrus and *Miscanthidium violaceum*. These plants aid in removal of nutrients from the wastewaters. In the papyrus dominated parts of the swamp, the purification efficiencies are 67% for nitrogen and phosphorus and 99% for faecal coliforms. In the *Miscantheum* dominated parts, the removal efficiencies are lower at 55% for nitrogen, 33% for phosphorus and 89% for faecal coliforms.
Source: Kansiime F. and M. Nalubega (1999). WastewaterTreatment by a Natural Wetland: The Navivubo Swamp, Uganda. Processes and Implications. PhD thesis, Wageningen Agricultural University, Wageningen, The Netherlands.

Cultural Services – Caroni Swamp, Trinidad and Tobago
The Caroni Swamp has considerable biodiversity value for Trinidad and Tobago, with at least 157 birds species frequenting the swamp. Caroni also provides roosting and breeding habitat for a significant number of migratory waterfowl between North and South America. It was especially noteworthy as a roosting site for the Scarlet Ibis - the national bird of Trinidad and Tobago. Yet, the Scarlet Ibis has not had a substantial nesting colony in the swamp for decades with no nesting taking place over much of the last thirty years presumably because of the steady salinization of the Swamp. The increased salinity has been caused by a number of developments including water abstractions for urban water supply, highway embankments (which have drastically altered runoff patterns), siltation, and the opening of an entrance canal for visitors.

Source: Trinidad and Tobago, Ministry of Planning and Development. 1999a. Water Resources Management Strategy for Trinidad and Tobago, Final Report, Main Report. Government of Trinidad and Tobago: Port of Spain.

The ecosystem services provided by rivers are disrupted by changes in volumes, quality and patterns of flows downstream of the development activities. Thus, irrigation abstractions during the dry season can isolate river pools and prevent fish migration; river regulation because of upstream dams can reduce floodplain inundation and opportunities for recessional cropping and grazing; and changes in the volumes and pattern of freshwater flows can cause silting of river reaches and loss of habitat and can reduce dilution of wastewaters discharged into river systems. The IUCN Vision for Water and Nature[24] calls for "leaving water in the system to provide environmental services such as flood mitigation and water cleansing".

Other parts of the hydrologic system, such as groundwater, provide ecosystem services too[25]. Apart from being the major water resource in arid and semi-arid climatic regions, groundwater also supports important groundwater dependent ecosystems such as wetlands and swamps. Many shallow groundwater systems are connected to rivers, providing baseflows in the dry season and being recharged during flood events. Groundwater systems can also be affected by upstream developments. For example, forest plantations that require large volumes of water can reduce recharge to an aquifer thereby lowering watertables and making it more difficult to provide water for stock and domestic purposes further downstream.

Freshwater flows are also vital for estuaries and marine systems. Estuaries are complex ecosystems dependent on both freshwater and marine influences. They provide breeding habitat for fish and invertebrates, often have high recreational and scenic values and can be economically important for transport and shipping. Changes in freshwater inflows can threaten these benefits through closure of river mouths, loss of mangroves and wetland habitats, saltwater intrusion, and reductions in nutrient and sediment inflows.

Different ecosystem functions are maintained by different components of the flow regime (Figure 3). The particular functions depend on the river system but, typically, low flows maintain connectivity of pools and provide for longitudinal movement along the river; small, more frequent floods (or ‘freshets’) can trigger spawning in some species and may remove detritus; and larger, more infrequent floods can water floodplains, and provide for lateral movement to and from the floodplain. An EFA is used to identify the reliance of different ecosystems or organisms (fish, invertebrates, vegetation, etc) on the different flow components and their sensitivity to changes in these components. This knowledge

[24] IUCN (2000). Vision for Water and Nature. A World Strategy for Conservation and Sustainable Management of Water Resources in the 21st Century. IUCN, Gland, Switzerland.

[25] Dyson, M., Bergkamp, G., Scanlon, J. (eds). Flow: The Essentials of Environmental Flows. IUCN, Gland, Switzerland and Cambridge, UK.

is central when decisions are being made on allocating different parts of the flow regime to different water uses.

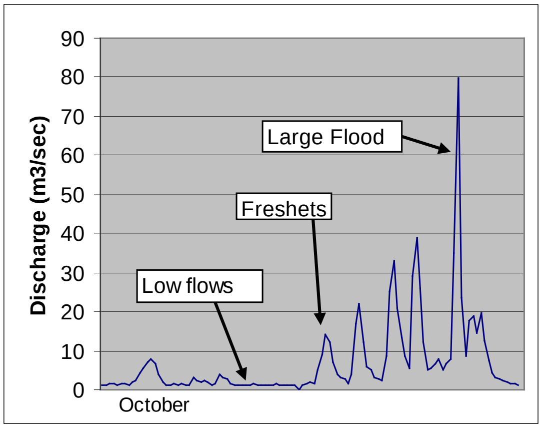

Figure 3. There are various components of the flow regime from base flows during the dry season to smaller floods to occasional large floods

Environmental Flows – Adoption and Methods

Although there are a great number of methods for undertaking EFAs, they fall into a number of discrete groups labeled hydrological index methods, hydraulic rating methods, habitat simulation methods, and holistic methodologies. These methods have been summarized in a number of reviews[26]. Many early environmental flows methods were designed for protection of a single species or to address a single issue. However, managing flows for a single species (and sometimes even for a single ecosystem function such as low flow connectivity) may not result in robust aquatic ecosystems and may even fail to preserve the target species because of their dependence on a wide range of ecosystem functions (foodwebs, habitat, etc). Consequently, holistic methodologies, that typically incorporate all components of the flow regime, are at the cutting edge of EFA

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[26] Tharme, R., (2003). A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. Rivers Research and Applications 19(5-6) 397-441.
Arthington, A.H. and J.M. Zalucki (Eds) (1998). Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Methods. LWRRDC Occasional Paper 27/98.
Davis R. and R. Hirji (2003). Environmental Flows: Concepts and Methods. Water Resources and Environment Technical Note C.1. World Bank, Washington DC.
Dyson, M., Bergkamp, G., Scanlon, J. (eds). Flow: The Essentials of Environmental Flows. IUCN,
Gland, Switzerland and Cambridge, UK

methodology. Applying these methods involves a wide range of water users, and sometimes includes considerations of the social and economic dependence of communities on environmental flows. Holistic methods were developed in South Africa and Australia but are increasingly being trialed in other parts of the world (e.g. Case Studies 7, 8)..

The wide range of methods provides a choice of technique to suit timetables, budgets, and purpose (Table 1).

Table 1. Estimated time and resource requirements of selected EFA methods[27]

Method	Type	Data and Time Requirements	Duration of Assessment	Relative Confidence in Results	Level of Experience
Tennant	Hydrologic index	Moderate to low	2 weeks	Low	USA/extensive
Wetted perimeter	Hydraulic rating	Moderate	2-4 months	Low	USA/extensive
Expert Panel	Holistic	Moderate to low	1-2 months	Medium	South Africa, Australia/extensive
Holistic	Holistic	Moderate to high	6-18 months	Medium-high	Australia, South Africa/extensive
IFIM	Habitat simulation	Very high	2-5 years	High	USA, UK/extensive
DRIFT	Holistic	High to very high	1-3 years	High	Lesotho, South Africa, Tanzania/limited

Environmental Flows and Decision Making

An EFA provides the scientific basis for understanding the relationship between the different flow components and ecosystem responses. But deciding on the how much and at what time(s) water should be allocated to the environment at either river basin or project levels is a decision that can only be taken in the context of all the demands on the water resource. There is no absolute quantity and timing of flows that are required for the environment or for that matter for any other use. Instead a social choice has to be made about what uses are important and to what degree they need to be addressed, and which ecosystem services need to be preserved (and to what degree) to meet society's objectives for a particular water resource. This will then determine the flows that are needed to deliver those services. For example, society may decide to increase irrigated agriculture using a particular groundwater resource, at the expense of some groundwater dependent wetlands that relied on high water tables because the net societal benefits are greater when irrigated agriculture is increased and the benefits of wetlands are decreased.

[27] Davis, J.R. and R. Hirji (2003). Environmental Flows: Concepts and Methods. Water Resources and Environment Technical Note C.1. World Bank, Washington D.C.

These choices have always been made in water resources planning and management. The contribution of environmental flows is that the EFA makes the consequences of different choices on aquatic ecosystems and communities that depend on those ecosystem services explicit and so leads to a better informed decision making process. It enhances equity and sustainability in the decision making process. This is important because downstream individuals and communities who are affected by changes in flow regimes are often relatively un-organized, powerless and voiceless compared to institutions and organizations that want to develop the water resource and their traditional rights to use water are not always recognized in law. It is important that the relationships of the communities to rivers and the needs of these downstream communities are included in decisions about flows

Environmental Flows in Policies, Plans and Projects

As already noted above, there are four entry points for introducing environmental flows into water resources planning and management decision making:

- national water policy, legislation, regulations and institutions
- river and lake basin-level water allocation plans
- single or multi-purpose investment projects, and
- restoration (rehabilitation and re-operation) projects and programs

The last two entry points share some operational and conceptual similarities. Both involve environmental flows downstream of infrastructure and so will sometimes be combined in the following discussion as infrastructure investments.

Environmental flows have become identified, at least within development assistance organizations, with the mitigation of the impacts of dams and other water resources infrastructure. Environmental assessment of proposals for new dams or other infrastructure or rehabilitation of existing infrastructure should include an assessment of the potential downstream environmental and social impacts[28].

Dealing with environmental flow issues only when development projects are proposed is unlikely to lead to equitable or efficient allocation decisions. At these times, the major decisions, for example, about siting and sizing structures[29] or incorporating features such as multiple outlet valves have often been taken, and there is usually limited flexibility to influence major decisions. Such decisions are almost always inefficient in the long run. This is illustrated by the Lesotho Highlands Water Project (Case Study 14), where the Mohale dam outlet valves had to be re-sized and a new valve had to be added to Katse dam to accommodate higher EFA releases and the Lower Kihansi Hydropower Project (Case Study No. 15), in which the process of granting and enforcing the final water right was highly contested.

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[28] The World Bank's 10 Safeguard Policies require an assessment of a range of potential environmental and social impacts.

[29] Ledec, G. and J.D. Quintero (2003). Good Dams and Bad Dams. Environmental Criteria for Site Selection of Hydroelectric Projects. World Bank, Washington DC.

More equitable development outcomes are likely to be achieved if environmental flow considerations are upstreamed to more strategic levels in the decision process. For environmental flows, this means that environmental flow allocations should be included in river basin plans and backed up with national water policy.

There are three reasons for incorporating environmental flows into national water polices:

- Policies give legitimacy to environmental flows as a legally recognized use of water, and thereby shift the focus of project-level discussions to the quantities and timings of water for the environment rather than on whether environmental flows are a legitimate use of water
- Policies can be used to specify the priority to be assigned to environmental water allocations compared to other water uses
- The procedural requirements (notification requirements, institutional responsibilities, timings, participation, relationship to other instruments such as EIAs and SEAs, etc) can be spelt out in the policy, ensuring that plan-level or project-level environmental flow studies are carried out proficiently.

The policy provisions, in turn, are often incorporated in legislation to give them force when being implemented. A water resources strategy is then typically used to spell out the steps to be followed and to identify the institutions responsible for implementing the policy and legislation. A water resources management institution, such as a river basin organization, is thereafter charged with implementing the relevant parts of the water policy and law.

Basin-level water allocation plans, drawn up under water resources legislation, identify the rights of different groups to use water resources and so should include environmental flow requirements. This means that water will be provided to maintain important ecosystem assets and functions during subsequent water management operations; this can include a formal recognition of traditional rights to water. Water allocation plans not only reduce tensions in water scarce regions by making rights and their associated conditions explicit, they also provide a foundation for decisions on development activities that require access to water resources. Water resources policies that contain sections on the provision of environmental water (e.g. Case Studies 1-5) usually require that environmental water be included in basin-level water allocation plans[30].

Thus, provisions for environmental water requirements when investment projects are being planned should be the culmination of a hierarchy of more strategic decisions about environmental water requirements rather than a one-off decision being made without a broader water management context[31].

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[30] Dyson, M., Bergkamp, G., Scanlon, J. (eds). Flow: The Essentials of Environmental Flows. IUCN,
Gland, Switzerland and Cambridge, UK.

[31] This point is being made in The Nature Conservancy and Natural Heritage Institute (2008). Integrating Environmental Flows in Hydropower Dam Planning, Design and Operations. Technical Guidance Note. World Bank, Washington DC when it says "Societal objectives will be best met when regional development plans, which set broad regional, national

Environmental Flows, IWRM and Environmental Assessment

IWRM considers environment as a legitimate use of water and integrates environmental flows in the implementation of IWRM. That is, environmental flows should not need to be promoted specifically if IWRM was properly adopted. However, most developing countries lack the resources to put IWRM into practice and so the reality is that there has been only limited practical implementation of IWRM in the developing world. According to a recent World Bank analysis, environmental flows are seldom included[32]. This ESW squarely places environmental flows in the context of IWRM so that environmental water requirements to support downstream water use becomes an integral part of both strategic (i.e. policy and basin planning) and tactical (i.e. project level) multi-sectoral decision making (Figure 4).

Environmental Impact Assessments (EIAs) are now widely accepted planning tools used to systematically integrate environmental concerns into decisions about investment projects. Most developing countries have now adopted legislation requiring EIAs for infrastructure investments, and development partners (such as the World Bank and Regional Development Banks) require an assessment of environmental and social impacts for projects that they are funding. The World Bank has produced the Environmental Assessment (EA) sourcebook and EA updates covering a wide range of EA-related topics, including those covering various water sectors, to assist with these assessments. These have been complemented by the Environment and Water Resources Technical Notes that address environmental flows among other issues.

However, experience has indicated that undertaking environmental impact assessments at the time a project had already been designed was often too late in the decision process. The most important decisions that ultimately influenced the impacts had already been taken much earlier – when policies, programs and plans were being formulated and approved. Consequently, strategic environmental assessment (SEA) was developed as a tool to move environmental considerations upstream from project-level analysis to the levels of policies, legislation, strategies, programs, and plans.

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and/or river basin objectives for water and energy development and environmental protection, are paired with more detailed local-scale environmental assessments for individual dams or cascades of dams on specific rivers".

[32] World Bank (forthcoming). Strategic Environmental Assessment and Integrated Water Resources. Management and Development. World Bank, Washington DC.

The World Bank has also produced an SEA toolkit which can be accessed at: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/0,,contentMDK:20885941~menuPK:2450778~pagePK:148956~piPK:216618~theSitePK:244381,00.html

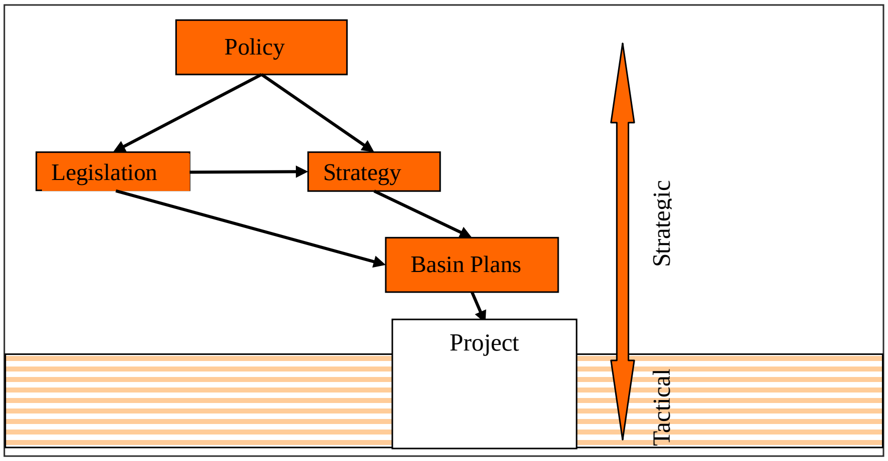

Figure 4. Hierarchy of decisions leading to project-level environmental flow allocation

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In principle, the downstream impacts from infrastructure investments should be assessed as part of project planning and design studies, including the EIA or other appropriate planning instruments. However, in practice, these downstream impacts have not always been fully recognized or accounted for, and the assessment of these downstream impacts has often arisen as a separate process, through EFA, specifically to fill this gap. As a consequence, important opportunities for informing key design decisions are often lost. Water resources planners, EIA practitioners and social scientists need to recognize the importance of impacts that arise downstream of projects and include EFA techniques in their toolkits, so that EFA is effectively absorbed into planning studies, EIAs and SIAs.

Chapter 3. Environmental Flows and the World Bank

> By the 1990s, the World Bank was assessing environmental and social issues in much greater detail in its water resources infrastructure project preparation documents, although with a greater focus on upstream issues. By the late 1990s, this assessment included downstream as well as upstream environmental and social issues with about equal frequency. The CWRASs, which originated in 2004, show a mixed record of inclusion of environmental flows, with some countries envisaging strong engagement with environmental flows. There is a limited appreciation of the need to include environmental flows in water policy reforms, but a good understanding of its importance in river basin or catchment scale water resources planning. The BNWPP has catalysed some notable achievements in introducing environmental flows into dam rehabilitation projects. The Bank has engaged in some fruitful collaboration with other international development organizations engaged in EFA programs.

World Bank Adoption of Environmental Flows

The consensus emerging from the 1992 Dublin Conference on Water and the Environment and the 1992 Environmental Summit at Rio de Janeiro influenced the World Bank and development partners to provide developing countries with assistance with environment in general.

The World Bank, like the global water community, recognized the importance of environmental impacts that occurred downstream and upstream of water resources developments, and has translated this into operations using different tools and avenues. The 1993 WRMP marked the beginning of the Bank's commitment to environmentally sustainable water resources development - "more rigorous attention to minimizing resettlement, maintaining biodiversity, and protecting ecosystems in the design and implementation of water projects."

The evolving understanding of the importance of downstream environmental issues is shown by an analysis of selected World Bank funded dam projects implemented before and after 1996 (given project preparation times, this year was chosen as representing the earliest date when the 1993 policy was likely to have been influential in leading to more recognition of environmental issues in preparation of dam related projects). The main objective of the analysis was to see if there was more attention given to downstream flow-related impacts after the 1993 policy was approved.

Projects which involved construction of a new dam or rehabilitation of existing dams[33] and where the PADs, SARs and EIAs were available in English were selected for analysis. At least one project was selected from each region. Twenty-eight dam projects approved before 1996 and 10 after 1996 were selected for analysis.

The PADs, SARs and EIAs were examined for their inclusion of potential upstream and downstream impacts. The impacts were restricted to the biophysical impacts from changes in flow regime downstream of the dam and changes in the level of the impoundment upstream of the dam (Table 2). To be selected, the impacts had to be clearly identified as arising from the dam itself and not from the construction activity.

Table 2. Biophysical impacts included in the analysis of World Bank funded dam projects

Biophysical Impact	Upstream of dam	Downstream of dam	Comment
Excessive sedimentation	√	√	
Flood control	√	√	Generally beneficial downstream; includes detrimental upstream flooding
Modified fisheries	√	√	Generally beneficial upstream; generally detrimental downstream
Aquatic weeds	√		
Modified irrigation activities	√	√	
Saltwater intrusion		√	
Modified floodplain watering		√	
Bank and shoreline erosion	√	√	
Loss of biodiversity	√	√	
Modified groundwater recharge		√	
Loss of aquatic habitat	√	√	
Alteration to hydrology	√	√	References to changes in flow regime not specifically linked to a biophysical impact for downstream impacts

The depth of consideration of these impacts was classified as Cursory, Considered, or Detailed if the assessment was respectively cursory (typically one or two sentences in passing), at least a paragraph of specific consideration, or a detailed assessment sometimes in quantitative terms. There is considerable subjectivity in making these assignments but they nevertheless provide an indication of the extent of consideration of the biophysical issues in the project preparation documents.

[33] Projects were excluded which involved installation of turbines and other equipment in existing dams or where the rehabilitation did not involve substantial construction which had the potential to affect flows.

Figure 5 shows the number of times an upstream or downstream issue was mentioned in the documents. The number of mentions depends on the number of projects examined in each time period and so comparisons between time periods are is neither important nor meaningful. However, the ratios between upstream and downstream issues within a period reveal the relative emphasis accorded to the regions above and below a dam.

Downstream issues are seldom mentioned in the project preparation documents prior to 1990, compared to upstream issues. Only 27% of the issues prior to 1996 occurred downstream of the dam; after 1996, 51% of issues were downstream of the dam. Over the period 1990-95 and afterwards there was also a dramatic increase in the depth of assessments. Only two out of 38 issues was considered in Detail prior to 1990, but 30 out of 68 were classified as Detailed after 1990. These results are consistent with a significant increase in the depth of treatment of environmental and social issues generally, together with a growing recognition of downstream effects of dams following the implementation of the 1993 Water Resources Management Policy.

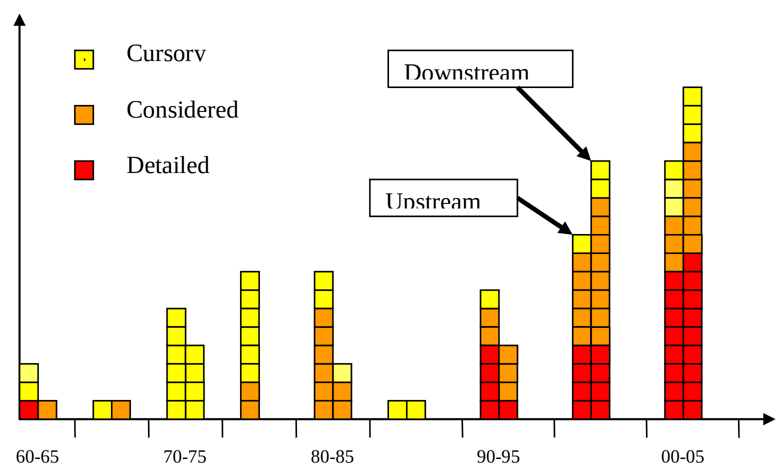

Figure 5. Relative number of examinations of upstream and downstream issues in dam-related project documents

Country Water Resources Assistance Strategies

The Bank introduced Country Water Resources Assistance Strategies (CWRAS) in 2003 to bring coherence to its support for water management across the resources and service spectrum within specific countries and regions. CWRAS identify key strategic water resources issues where the Bank can play an important role in assisting with water resources development and management, including environmental issues.

The Bank has now produced 18 CWRAS. They analyse the major water resources issues facing a country or region and develop a strategic approach the countries can use to tackle these issues.

The CWRAS were analyzed to see the extent to which environmental flow issues were recognized by the countries and the Bank, and whether a strategy to tackle these issues was included in the CWRAS recommendations (Table 3). Specifically, the analysis assessed whether the CWRAS:

- Proposed inclusion of environmental flows issues in national or regional water policy and legislation?
- Proposed inclusion of environmental water requirements in basin water plans?
- Proposed measures to introduce or strengthen downstream EFAs when assessing new infrastructure projects?
- Identified opportunities for providing downstream flows when rehabilitating existing dams and other infrastructure?
- Proposed technical training in EFA and related procedures?

A summary of these analyses is contained in Appendix D.

There was no expectation that environmental flow issues should be mentioned in all CWRASs. Clearly some countries do not face water stress and in others environmental flow issues, even if present, may not be a priority issue. Nevertheless, the extent to which environmental flows are discussed in the CWRAS and incorporated into the recommended Bank strategy serve as another barometer of the degree to which this issue is now being recognized and mainstreamed into water resources planning and management.

Four CWRASs (Yemen, Cambodia, Dominican Republic, and Peru) made no mention of environmental flows or equivalent concerns, and the Iran CWRAS has only a passing mention through a recommended action: "Preparing and compiling necessary guidelines for studying the impacts of executing the water resources development plan on water quality and aquatic eco-systems."

On the other hand, the CWRASs for some countries (e.g. China, Tanzania, Philippines) include thorough treatments of environmental flows. Thus, the China CWRAS described the over-exploitation of groundwater, particularly in the Hai Basin, and the overuse of surface water resulting in inadequate environmental flows in much of northern China. This, along with water pollution, is leading to the decline and deterioration of water resources and damage to freshwater and coastal environments and the CWRAS recommends that environmental protection, including environmental flows, be one of the major themes of future Bank development assistance.

Policy and legislation

Apart from China and Tanzania, no CWRASs mention the inclusion of environmental provisions into national water policies and laws. In both these cases, the countries have already established the relevant instruments. The 2002 Water Law in China includes provisions for environmental and ecological protection, and the 2002 Tanzanian National Water Policy requires that environmental flow provisions be made in basin level planning.

Table 3. Inclusion of Environmental Flow Issue in CWRAS[34]

Country	Regulation by infrastructure	Excessive abstraction	Excessive discharge
Bangladesh	Brief mention of effects of upstream regulation by dams.	Brief mention of effects of upstream abstractions for irrigation.	-
China	Considerable attention to better environmental water management.	Overuse of groundwater and surface water resulting in damage to freshwater and coastal environments	-
East Asia/Pacific Regional	-	Proposes water allocation plans that give priority to environmental water needs	-
Ethiopia	Minor mention of need for environmental flows from hydropower dams.	-	-
India	-	General comment that attitudes need to change to maintain in-stream flows for environmental benefit	-
Iran	Development of dams will lead to deterioration of wetlands	-	-
Iraq	Upstream dams have altered flows to the Marshes, reducing flood pulses	Agricultural and urban water extractions have reduced flows	Inflows of drainage waters have affected flow regimes to the Marshes
Kenya	Brief mention of downstream environmental impacts of dams	Brief mention of ecosystem degradation from water withdrawal at Lake Naivasha and on Tana River	-
Mekong Region	Effects of proposed dams on flows is included	Effects of expansion of irrigation is included in document	-
Mozambique	Detailed consideration of effects of dams on flows	-	-
Pakistan	Dams reducing floods to wetlands and Indus Delta	Withdrawals on delta and riverine wetlands.	-
Philippines	Environmental flow assessments needed for new infrastructure.	Environmental flows required to surface and groundwater systems.	-
Tanzania	Describes problems from dams, and flow related conflicts	Describes need to ensure water retained for environment.	-

34 The CWRAS for Cambodia, Dominican Republic, Honduras, Peru and Yemen did not discuss environmental flow issues.

No CWRAS identified the importance of having national policy or legislation to mandate environmental flows at basin or project levels and consequently the CWRASs did not call for Bank support at this level. Although the Iran CWRAS did identify the need for a new water policy and governance structure, it did not specifically include environmental water requirements within the new policy.

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Planning

Six of the CWRAS identified the need to build environmental flow provisions into basin water plans although only the China and Philippines CWRASs linked environmental water requirements to planning groundwater use. The Pakistan CWRAS says that environmental flows are currently being established in the delta of the Indus and one of the proposed pillars of assistance is to promote IWRM including provisions for environmental flows (Box 3). The Philippines CWRAS calls explicitly for environmental flows in rivers, estuaries and the maintenance of groundwater levels and for Bank assistance with the development of basin plans that include environmental flows. The China CWRAS calls for national guidelines for comprehensive river-basin planning that include a requirement for environmental flows in rivers providing water to ecologically important areas.

Box 3. Environmental Flows to the Indus Delta

The Water Apportionment Accord (WAA) was signed in 1991 by the Pakistan provinces to distribute the Indus River waters among the provinces and command areas. It established the water rights and protects future water rights, including the effect of future storages. A formula is available for sharing river flows. The WAA also includes the need for certain minimum flows (escapages) to the sea to check sea intrusion. The provinces held different views about the necessary flows and it was decided that further studies would be undertaken to establish the minimal escapages needed below Kotri Barrage, the main regulating structure on the lower Indus River.

Three studies were agreed on after intense negotiation between the provinces. Study I was to determine the minimum flow below Kotri Barrage to control seawater intrusion into the Delta; Study II was to address environmental impacts from river water and sediment flows and their seasonal distribution below Kotri Barrage; and Study III was to address environmental concerns about a wide range of issues related to the management of water resources upstream of Kotri Barrage. These reports were then assessed by an independent panel of experts.

The panel of experts recommended an escapage at Kotri Barrage of 5,000 ft^3/sec throughout the year to check seawater intrusion, accommodate the needs for fisheries and environmental sustainability, and to maintain the river channel. They recommended that 25 million acre-feet in any 5 years period be released in a concentrated flood flow to maintain sediment supply to the mangroves and coastal zone. They also recommended that any further upstream development of storage should be preceded by full EFA.

Source: Gonzalez F.J., T. Basson and B. Schultz (2005). Final Report of IPOE for Review of Studies on Water Escapages below Kotri Barrage. No publisher.

A number of CWRAS's deal with transboundary water management. The Bangladesh, Mozambique, Tanzania, and Iraq CWRAs describe efforts to promote transboundary water planning, including provisions of flows to maintain downstream ecosystems. The Iraq CWRAS describes in a number of places, the drying of the Mesopotamian Marshes partly as a result of upstream water use by Turkey and the water developments proposed by Syria. The Mekong CWRAS recognizes the need for countries in the region to better coordinate their development plans. While the Mekong CWRAS is optimistic that environmental sustainability is possible along with development, it provides few explicit proposals to achieve this.

New Infrastructure

Ten of the CWRAS discussed the need for further infrastructure development. Only four of these included an explicit recognition that there needs to be provisions for downstream environmental water needs when planning this infrastructure, although some (such as the Philippines CWRAS) emphasize the importance of environmental flows elsewhere in the document implying that these issues would be included in an environmental assessment of new infrastructure. On the other hand, the China CWRAS places a high priority on strengthening environmental management including environmental flow provisions. It sees loans for physical infrastructure as a vehicle for integrating the particular project with basin wide management in order to address the full range of water issues including environmental objectives.

Infrastructure Rehabilitation

Five CWRASs foreshadowed the need to rehabilitate existing water resources infrastructure, especially dams that had been poorly maintained. Thus the Pakistan CWRAS identified a large stock of old infrastructure that needed rehabilitation as well as the need to build new dams. Much of this old infrastructure has resulted in downstream environmental problems - the India CWRAS describes the "environmental debt" that hangs over the country's water infrastructure and is still not widely recognized by senior decision makers. Only two CWRASs specifically stated that there were opportunities to remedy these issues. The most notable was opportunity with the renegotiated ownership of the Cahora Bassa dam in Mozambique (together with two new project proposals) to restore environmental flows to rehabilitate some of the damaged downstream ecosystems on the Zambesi River.

The Bangladesh CWRAS called for environmental flow studies on the Ganges River to assess the human and environmental impacts of existing and proposed infrastructure and to provide a scientific basis for determining environmental flows. However, since this infrastructure was in India, the CWRAS did not contain any rehabilitation proposals. The Kenya CWRAS recognizes that existing dams have causes downstream social and environmental problems and calls for better project planning in future but did not envisage any rehabilitation or changes in operating rules.

Training

Few of the CWRAS mention the need to develop skills and experience in environmental flows. The Tanzanian CWRAS is distinctive in its inclusion of a comprehensive environmental flows training program (Box 4). The Pakistan CWRAS also includes the training of a new generation of water resources specialists in all aspects of water planning and management, presumably including environmental flow provision, while the Iran CWRAS calls for training on a range of topics including in "water and the environment".

Box 4. Proposed Environmental Flows Program for Tanzania

The 10-point plan (supported under the BNWPP Environmental window) includes a wide range of activities required to build a long-term sustainable program in Tanzania that supports institutionalization of EFA into water resources planning and management decision making. Some activities are large and will take several years; others are small and can be implemented rapidly. These activities are very broadly in the chronological order in which they would be undertaken, though some may overlap or be done in parallel.

1. Training course – "getting experience of EF frameworks and methods"
2. Defining an assessment framework - "turning policy into action"
3. Trial application of EF methods – "practicing what we've learned"
4. Visits to foreign case studies – "seeing what others have done"
5. Technical workshop/symposium - "discussing our techniques"
6. Technical support – "checking what's been done"
7. National database – "assembling a library of knowledge"
8. Networking – "sharing experience"
9. Research – "improving our understanding"
10. Communications strategy – "spreading the word"

Source: World Bank (2006). Tanzania Water Resources Assistance Strategy: Improving Water Security for Sustaining Livelihoods and Growth. Report No. 35327-TZ. World Bank, Washington D.C.

Bank Netherlands Water Partnership Program

The Government of Netherlands established the Bank-Netherlands Water Partnership Program (BNWPP) following the Second World Water Forum in The Hague in March

2000. The BNWPP supports World Bank operations and promotes innovative approaches for integrated water resources management (IWRM) in the Bank's client countries and the broader development community. The BNWPP operates through subprograms (called windows) corresponding to various IWRM topics. Each window has a team of experts who provide assistance to World Bank task managers to improve the quality of their ongoing operations. The BNWPP also supports knowledge generation activities and development of best practice materials[35].

One of the windows specifically deals with Environmental Flow Allocation[36]. Its objective is to assist World Bank client countries integrate environmental flow considerations into water resources management and project development activities. The window draws from a panel of international experts who are available to assist Bank staff and borrowing country staff with on environmental flow issues. Not all activities draw on these experts. The window has provided support to a number of Bank projects where environmental flow requirements need to be assessed and incorporated into decision making - many of these activities are in their early stages of implementation. Table 4 summarizes some of the main assistance activities.

Overall, the BNWPP Environmental Flows Window has provided good support to Bank activities. Support to the Lesotho Highlands Water Project resulted in an analysis of the economic impacts of different environmental flow options as well as a thorough review of the lessons emerging from this Project; support for the Ningbo Water and Environment Project in China led to an assessment of the downstream impacts of the development; support to the Lower Kihansi Environmental Management Project helped develop longer term capacity in Tanzania in environmental flows; and the expert funded to introduce environmental flows to the Mekong River Commission was subsequently hired by the Commission to advise on the introduction of EFA in the basin. The Window has also supported a number of operations (hydropower, irrigation, river basin management) to introduce environmental flows and implement environmental flow assessments in other countries - Ukraine, Azerbaijan, Uzbekistan and Ecuador.

There have been other Window supported activities where the results have yet to be realized. The extensive training and guidance to Water Resources Department and the Chilika Development Authority in the Chilika Basin (India), for example, has yet to result in the integration of environmental flow allocations in the operating rules for the Naraj Barrage, and it is not clear whether the support for water resources policy reform in Mexico will lead to the inclusion of environmental flows in the national water policy.

[35] World Bank (2001). Improving Performance in Water Management - Bank Netherlands Water Partnership Program Project Brief. World Bank, Washington, D.C.

[36] There are two other windows, river basin management and dam development, also potentially would integrate environmental flow considerations. The activities supported under these two windows have however not been reviewed.

Table 4. Selected BNWPP assistance to World Bank projects

Project	Region	Sector	Type of BNWPP Activity	Issues	Outcomes	Status
Lesotho Highlands Water Project	Africa	Water supply	Economic analysis of EFA and dissemination of environmental flow policy development and implementation results.	• Assessing environmental flow requirements • Establishing flows following earlier Treaty agreement • Redesign of outlets to accommodate required flows • Enforcing flow agreement	• Acceptance by Lesotho of necessary environmental flows • Development of comprehensive assessment method (DRIFT) • Successful redesign of outlet structure • Performance audit of Instream Flow Requirement Policy every 5 years.	Completed
Lower Kihansi Environmental Management Project	Africa	Hydropower	TA in national EFA capacity building effort.	• Discovery of rare and threatened ecosystem after dam commenced • High national dependence of water for electricity production • High cost of retro-fitting dam for additional flows	• Off-site breeding of threatened toad species • Agreement on environmental flow provisions and water right for hydropower • Development of a catchment management plan • Establishment of professional training course in EFA	Phase 1 completed. Phase 2 support on-going.
Mekong River Water Utilization Project	East Asia and Pacific	Hydropower, irrigation	Initial TA on EFAs for the Mekong River to help the MRC establish and implement flow rules	• Proposed development of upstream dams in transboundary setting • High dependence of downstream fishing and agricultural production on flow regime • Divergence of development objectives amongst basin countries • Maintenance of significant aquatic ecosystems	• Development of hydrologic and hydraulic models • Examination of flow implications of development scenarios • BNWPP expert hired as an EFA advisor to the MRC	BNWPP support completed. Mekong EFA on-going.
Orissa Water Resources Project, India	South Asia	Irrigation	TA for establishing environmentally sensitive operational rules for Naraj Barrage	• Changes in flows to Chilika lagoon and increased sediment loads from the catchment led to reduced exchanges with the ocean • Reduction in fish catches, effects on lake's biodiversity, decreased salinity, increased flooding; and weed infestation • Loss of livelihoods lead to civil disturbance	• Hydrological models developed • Technical training completed of Orissa State water resources staff • Improved understanding at management level of relevance of environmental flows and procedures for establishing flow requirements	Completed
Ningbo Water and Environment Project	East Asia and Pacific	Water supply	TA to advise on monitoring needs and environmental water	• Diversion of water for urban supply will desiccate the Ningbo River	• Awareness of environmental flow concepts and techniques	On-going

			requirements	downstream of dam • Aesthetic and environmental issues from water loss	• Training in EFA methods • Development of an environmental flow scientific programme	
Mexico	Latin America and Caribbean	Water policy	TA reviewing impacts of water policies and programs on environmental needs; use of economic instruments for providing environmental water	• Water policy being reformed to deal with conflicting demands • No experience with environmental water considerations		On-going
Rehabilitation of the Kura-Araz Basin, Azerbaijian	Europe and Central Asia	Irrigation	TA on incorporating environmental water requirements into new and rehabilitated infrastructure projects	• Severely degraded wetlands and lakes	• Training sessions for managers on environmental flow concepts and best practice	Completed
Hydropower Umbrella Project, Ecuador	Latin America and Caribbean	Hydropower	Preliminary assessment of environmental flow needs for two proposed hydropower plants	• Rivers degraded, rare endangered fish species are present • Ecuador has no environmental flow policy or experience	• Preliminary assessment of environmental flow needs; full analysis not undertaken	Completed

World Bank Safeguard Policies

The World Bank's 10 safeguard policies support the integration of environmental and social concerns into project design and the decision processes of borrowing countries (Box 5). These policies apply to investment lending operations including sector investment loans, financial intermediary lending, rapid response, Global Environment Facility and carbon finance operations. Although not covered by the safeguard policies, Development Policy Lending (DPL) operations, which are covered by OP 8.60/BP 8.60, are also subject to environmental and social review through the use of SEA, Poverty and Social Impact Analysis (PSIA) and other instruments. Investment lending and DPL operations are subject to the Bank's Disclosure Policy and provide for public consultation and disclosure. All of these policies may deal with topics relevant to downstream impacts depending on the scope and nature of a proposed development program or project.

Box 5. World Bank Safeguard Policies

OP/BP 4.01 Environmental assessment—An umbrella policy requiring environmental assessments to cover a broad range of potential impacts.
OP/BP 4.04 Natural habitats —Avoiding the degradation or conversion of natural habitats unless there are no feasible alternatives and there are significant net benefits.
OP 4.09 Pest management—Promoting environmental and biological pest management for both public health and agricultural projects. Chemical methods can be supported where justified.
OP/BP 4.12 Involuntary Resettlement —Avoiding resettlement where possible and, where not, ensuring that resettled people are fully consulted, share in project benefits, and their standard of living is not reduced.
OD 4.20 Indigenous Peoples—Ensuring that Indigenous Peoples are involved in fully informed discussions so that they do not suffer adverse effects, and that they receive culturally compatible social and economic benefits from Bank-financed projects.
OP 4.36 Forestry—Harnessing the potential of forests to reduce poverty, while integrating forests into sustainable economic development and protecting the environmental services and values of forests
OP/BP 4.37 Dam safety—Ensuring that new dams are constructed and operated to internationally accepted standards of safety and existing dams used in a project undergo safety inspection and any necessary upgrades.
OP/BP 4.11 Physical Cultural Resources—Avoiding or mitigating adverse impacts on physical cultural resources such as valuable historical and scientific information, assets for economic and social development, and integral parts of a people's cultural identity and practices.
OP/BP 7.50 Projects on international waterways—Informing affected riparian countries of proposed projects on international waterways and, if there are objections, referring the proposal to independent experts.
OP/BP 7.60 Projects in Disputed Areas—Ascertaining that the governments concerned agree that the undertaking of a project in disputed areas does not damage claims made by other governments.

There is extensive support material available to help apply the Environmental Assessment safeguard policy (OP/BP4.01), especially the Environmental Assessment handbook and a series of Updates which deal with specialized topics. In addition, the Water Resources and Environmental Technical Notes on environmental flows provide a general introduction to environmental flows.

Partner Agency Collaboration

The World Bank is also collaborating with several international development organizations (Danish International Development Agency (DANIDA), International Water Management Institute (IWMI), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), United Nations Educational, Scientific and Cultural Organization (UNESCO) and US Agency for International Development (USAID)) and international NGOs (including International Union for the Conservation of Nature (IUCN), Natural Heritage Institute (NHI), The Nature Conservancy (TNC) and the World Wildlife Foundation (WWF)) that offer assistance to developing countries to address and undertake EFAs and protect downstream ecosystems. Such assistance ranges from practical, longer-term technical assistance with EFAs for specific restoration work and new infrastructure projects; to technical assistance and financial assistance with the inclusion of downstream flow concerns into river basin plans; to shorter term training and capacity building; to provision of resources for water resource and environmental specialists.

The Bank has collaborated with these international development organizations and NGOs at several levels - global, regional, national and basin – and has drawn on their experience and expertise in EFA and also their presence on the ground. Thus, for example, TNC and NHI have produced a technical note for the Bank on integrating environmental flows into hydropower dam planning, design and operations (Box 6)[37] as a contribution to this ESW, and the NHI is collaborating with the GEF, the African Development Bank and the World Bank to examine the feasibility of re-operating existing dams in order to improve their environmental performance. Appendix E highlights selective but relevant environmental flow related work of the various organizations. It is intended to inform Bank staff of the types of activities and potential opportunities for future collaboration. However, there are opportunities to increase the level of collaboration to combine their experience in EFAs and in training with the Bank's experience in implementing infrastructure projects and water policy reforms.

Box 6. Designing Hydropower Dams to Include Environmental Flows

There are a number of structural and operational considerations in hydropower (and other dams) dam development that can facilitate integration of environmental flow objectives, including:

- Variable outlet and turbine-generator capacities
- Multi-level, selective withdrawal outlet structures
- Re-regulation reservoirs
- Power grid interconnection
- Coordinated operations of cascades of dams
- Flood management in floodplains

[37] The Nature Conservancy and Natural Heritage Institute (forthcoming). Integrating Environmental Flows in Hydropower Dam Planning, Design and Operations. Technical Guidance Note. World Bank, Washington DC.

- Sediment bypass structures & sediment sluice gates
- Fish passage structures

These should be considered from the earliest stages of planning and designing the dam.

The operating objectives for dam projects are likely to change over time, in response to changing social priorities, scientific and technological advancements, and climate change. This places a premium on maintaining flexibility to modify dam operations. Many recent experiences suggest that it is possible to improve the environmental performance of existing dams (called "re-operation") in a cost-effective manner, and sometimes with little or no social or economic disruption. Re-operation can be accomplished by implementing various water or energy management techniques that increase the flexibility of reservoir storage and releases such that environmental flows can be released into the downstream channel and floodplain. However, it will be far easier and more cost-effective to integrate environmental flow considerations into the planning and design of dams than to modify or retrofit the design and operation of existing schemes.

Source: The Nature Conservancy and Natural Heritage Institute (forthcoming). Integrating Environmental Flows in Hydropower Dam Planning, Design and Operations. Technical Guidance Note. World Bank, Washington DC.

III. ENVIRONMENTAL FLOW IMPLEMENTATION CASE STUDIES

Chapter 4. Case Study Assessment

> A total of seventeen case studies, including ~~The~~ five policy case studies, four plan case studies and eight project case studies, were analyzed against a set of good practice criteria developed from those published by the International Association for Impact Assessment for Strategic Environmental Assessments (to evaluate the effectiveness in the implementation of ~~-~~environmental flow considerations in decision making at different levels-policy, plan and project). The evaluation criteria as well as the ~~se~~ seventeen case studies are presented in Volume 2 of this report. The case studies were also analyzed to establish the institutional drivers that lead to both the inclusion of environmental flows in the case study and the implementation of the environmental flow recommendations. The findings from these analyses are contained in Chapters 5-7.

Case Studies

Five policy-level, four catchment/basin plan level, and eight project-level environmental flows case studies were selected for analysis to identify the factors that promoted or impeded successful EFA in policies, plans and projects. The case studies were also analysed for the drivers that initiated the EFAs and supported their implementation.

These case studies provided a diversity of institutional settings, geographic regions and levels of economic development (Appendix F, Volume 2). In order to draw on the best available experience, the case studies included eight World Bank supported and nine non-World Bank cases.

Good Practice Criteria

The International Association for Impact Assessment (IAIA) has published a set of good-practice principles for producing SEAs[38] and these have been adapted and used to analyse 10 SEA case studies in a previous World Bank ESW[39]. EFAs are a special type of EA – project level EFAs are a type of EIA and basin/catchment plan EFAs are a type of SEA. Consequently, the criteria used to assess the project-level and plan-level environmental flows case studies were developed from these SEA assessment criteria. The good practice policy level criteria were developed around the need for policy support for implementing these plan and project level EFAs.

[38] IAIA (2002). "Strategic Environmental Assessment: Performance Criteria." IAIA Special Publication No. 1.. International Association for Impact Assessment, Fargo, ND, USA.

[39] World Bank (forthcoming). Strategic Environmental Assessment and Integrated Water Resources Management and Development. World Bank, Washington DC.

The following good practice assessment criteria were used for the policy case studies analyzed here:

- Recognition: environmental allocations were recognized in the policy (and legislation) as legitimate uses of water and necessary for provision of ecosystem services
- Comprehensiveness: all components of the water cycle are included in the policy provisions, and national and transboundary environmental flow concerns are included
- Environmental water mechanism: the policy (and legislation) identify a mechanism for establishing environmental objectives and providing water for the environment
- Participation: the policy (and legislation) include provisions for encouraging stakeholder participation in formulating environmental flow requirements, and participating in the making and implementation of decisions
- Assessment method and data: the policy and legislation provide guidance on the use of information
- Reviewing, monitoring and enforcement: the policy (and legislation) includes provisions for reviewing, monitoring and reporting environmental outcomes

Both basin/catchment plans and water resources projects were assessed for the extent to which they incorporated:

- Recognition: the legitimacy of environmental flows was recognized by all parties when the plan was being formulated and implemented, of the project proposal was being assessed
- Comprehensiveness: all relevant components of the water cycle were included in the EFA.
- Participation: stakeholders with an interest in environmental flow outcomes were engaged in the process
- Assessment method and data: recognized methods and reliable data were used in the EFA
- Integration: there was integration between environmental impacts and the consequent social and economic impacts of water allocation decisions
- Cost effective: the EFA methods were cost effective and the provision of environmental flows within the plan resulted in cost effective outcomes, and
- Influential: the EFA had a beneficial influence on the allocation of water for environmental purposes within the plan, as well as more widely.

Institutional Drivers

To be effective, an EFA also need to be embedded in an appropriate enabling environment and championed and driven by strong and powerful influences and so this analysis also assessed the drivers that lead to the initiation of the inclusion of environmental flows in water resources policy (policy-level case studies) and the drivers that brought about the EFAs at basin/catchment plan and project levels.

The basin/catchment and project-level case studies were analyzed against a set of institutional drivers that were originally identified for project-level EIAs[40] but that are also relevant for project and plan level EFAs. They are described in Box 7.

Box 7. Drivers for Environmental Flows in Plans and Projects

Judicial drivers. The courts have a formal role in ensuring that government organizations implement EFA provisions in the relevant legislation. Judicial drivers are widely used in the United States, where the judiciary has a constitutionally sanctioned role in reviewing government procedures.

Procedural drivers. Legislation, regulations, and guidelines provide formal drivers over the procedures to be followed when EFAs are conducted for basin water allocation plans or project impact assessments. However, procedural drivers are seldom effective without the availability of other drivers such as evaluative or professional drivers. By themselves, they can lead to well-written EFAs that are ignored. These drivers also include external agreements such as international conventions and regional agreements.

Evaluative drivers. Evaluative drivers exist when there is an institution responsible for assessing the quality of implementation of policy requirements, or plan or project level EFAs. These independent assessors may have the power to return catchment or basin plans or EFAs for revision; may be able to fine lack of compliance with policy requirements; or may rely on publicity to generate effective implementation of policy.

Instrumental drivers. The requirements of international development partners provide an additional driver for EFAs. Thus, many development partners have formal requirements for EFAs as part of the due diligence attached to loans. There can also be informal instrumental drivers operating where the development partner advocates environmental flow considerations when supporting water policy reforms. Instrumental drivers can play a central role in developing countries, where legislative and evaluative drivers are absent.

Professional drivers. The considered judgment of planners, professional associations and other professionals undertaking policy development, catchment/basin plans or project developments can act as a powerful driver for EFAs. Professionals can be influenced by international developments in EFA or, more broadly, in environmental sustainability.

Public drivers. These drivers rely on informed public citizens, community based organizations and non governmental organizations who are motivated and confident enough to make their views about environmental equity known to government. They may be more relevant in developed countries, which have a tradition of active public engagement in the decisions of government, but may also be important in developing countries. A stimulus is often provided by local, national or international NGOs, who make assessment and then inform the public.

[40] Ortolano L., B. Jenkins, and R.P. Abracosa (1987). Speculations on when and why EIA is effective. Environmental Impact Assessment Review 7: 285–292.

Source: Modified from Ortolano L., B. Jenkins, and R.P. Abracosa (1987). Speculations on when and why EIA is effective. Environmental Impact Assessment Review 7: 285–292.

However, the drivers that lead to the inclusion of environmental flows into water resources policies differ from the ones that operate for plans and projects. Environmental flow provisions are included in policy when the policies themselves are being revised, and so the policy drivers need to include both those that lead to the policy reforms as well as those that operate specifically to include environmental flows into the new policies. Three types of policy reform drivers were apparent in the case studies and four drivers operated for environmental flow provisions (Box 8).

Box 8. Drivers for Environmental Flows in Policies

Policy Reform

Convening. In a federal system, the superior government can use its influence to convene and lead policy reforms even when the responsibility for the policy lies at a subsidiary level. This convening power is sometimes supplemented with financial assistance from the federal level to help the subsidiary levels of government implement the policy reforms.

Singularity. A singular event, such as a drought, can precipitate policy reforms if it is clear that the current water policy is inadequate to handle the event. While such events act as triggers for reform, there is often a backlog of issues, including provision of water for the environment, that need to be incorporated into the new policy beyond the particular deficiency that triggered the reform.

Public. Public pressure, because of perceived deficiencies in water resources management, can act as a powerful stimulus for reform.

Environmental Flow Inclusion

I*nstitutional***.** Water managers and other professionals within government can support the inclusion of environmental flow provisions in policy because they are aware of the benefits that these flows confer on downstream environments and communities.

*Evaluative***.** A specific organization can be identified in the policy with the oversight of environmental flow provisions to ensure that they are implemented. The organization is typically at least partially independent of government since it is overseeing the performance of government organizatiosn. This driver acts to implement the environmental flow provisions rather than to introduce them into policy.

*Public***.** Where the public concerned about the decline in downstream environments because of water abstractions and other developments, they can exert considerable pressure for environmental flow provisions to be included in policy reforms.

*Scientific Professional***.** Scientific organizations and individual scientists can use their standing in government and in the community to highlight the issues arising from disruptions to downstream flows and to propose policy provisions to help restore downstream environments.

*International Developments***.** The proclamations from major international conventions, such as the 1992 Rio Summit, can exert considerable influence on the contents of new policies.

Chapter 5. Policy Case Studies: Lessons

The analysis of the five policy case studies identified a number of lessons, the most important of which are that the inclusion of environmental flows in policy should include: legal standing (recognition and protection) to environmental water allocations; environmental water provisions in basin water resources plans; all relevant parts of the water cycle; a method for setting environmental objectives in basin plans; attention to both recovery of over-allocated systems and protection of unstressed systems; clear requirements for stakeholder involvement; an independent authority to audit implementation; and a mechanism for turning value-laden terms into operational procedures. The drivers for the inclusion of environmental flows in policy included international consensus, readiness to take advantage of singular events such as drought, and public pressure for improved aquatic environments.

Background

South Africa, Australia, Florida (USA) and the European Union (EU) were selected for the policy case studies, because these represent the major countries where environmental flows have been introduced through water policies (Table 5). In these countries, the policies have now been implemented for a number of years and so they offer good opportunities for learning lessons. Australia and the EU also provide opportunities to learn from environmental flow provisions in transboundary policy settings. The fifth water policy case study, Tanzania, provides an example where environmental flows are required in the national water policy of a developing country.

Table 5. Characteristics of Selected National Water Policies

Case Study	Country/Region	GDP per capita (US$)[41]	Institutional Setting	Sector	Date Completed
National Water Initiative	Australia	$35,990	Federation of States	Multi-sectoral	1994; revised 2004
Water Framework Directive	European Union	$4,089 – $89,571	Union of countries	Multi-sectoral	2000
Florida Water Policy	USA	$44,970 (USA)	State government within federal system	Multi-sectoral	1972; subsequent amendments

[41] From World Bank Doing Business 2008 site.
http://www.doingbusiness.org/ExploreEconomies/EconomyCharacteristics.aspx

National Water Policy	South Africa	$5,390	Unitary government	Multi-sectoral	1997
National Water Policy	Tanzania	$350	Unitary government	Multi-sectoral	2002

Assessment of Effectiveness

Recognition

Assigning priorities to environmental water is an important indicator of the importance to be attached to environmental allocations. All five water policies recognize the importance of ensuring that water is allocated to the environment although the EU Water Framework Directive treats environmental flows as a secondary issue compared to water quality issues and maintenance of ecosystem health. The priority accorded to environmental flows compared to other uses of water differs between the countries. The South African and Tanzanian policies assign explicit priority positions (1st or 2nd priority) to environmental water allocations. The EU, Australia and Florida policies do not mandate a priority, although the Florida Implementation Rule implies that environmental water allocations have a high priority, except in times of drought. While the concept of assigning the environment first or second priority in the water allocation process makes its importance clear, specific priorities in water allocation are difficult to put into practice. When water allocation decisions are made in a basin plan, there will inevitably be trade-offs between environmental and other water uses. Unless there is an explicit procedure or mechanism for putting these priorities in place, it is not clear how the concept of allocation priority is to be interpreted when making these trade-offs.

The link between environmental health, provision of ecosystem services and human benefits needs to be made explicit in national water policy of developing countries. This link is clearly stated in the South African, Australian and Tanzanian policies. Because the EU WFD is focused on ecosystem health rather than specifically on environmental flows, it does not make these links clear and does not link the protection of ecosystem health to human benefit. Rather ecosystem health is seen as an end in its own right. Similarly the Florida Implementation Rule promotes minimum flows and levels to protect environmental values but does not link these to the ecosystem benefits that humans enjoy. And the minimum flows and levels are only instituted for ecosystem protection for surface waters; maintaining minimum levels for groundwater is for the physical sustainability of the resource rather than for any groundwater dependent ecosystems.

It takes considerable political will and administrative drive to implement environmental flow provisions. While the policies, except for the European Union WFD, all provide clear recognition of environmental flows, the implementation of these policy provisions differs considerably across the countries. The South African policy has been implemented slowly because of the extensive consultation requirements in the legislation and the reluctance of water users with existing entitlements to accept that the water resources are over-allocated and that the environment is a legitimate and priority water user. On the other hand, in Tanzania, where the water reforms are not bound up with a major social change agenda, the implementation of the water policy is moving ahead even before the water resources legislation has been passed. In Australia, even though many components of the water reforms have now been implemented, the rollout of water plans has been slower than intended (although 145 catchment and groundwater plans have now been completed) and in Florida the MFLs were not implemented until 20 years after the Act had been passed (although 237 MFLs have now been established and 114 are pending).

Giving environmental water entitlements at least equal standing in law to consumptive water entitlements provides security to environmental water allocations. In South Africa, the ecological reserve, along with the basic human needs reserve, is enshrined in the law as the only water right. All other uses need permits for use after the reserve has been established. The Australian NWI does not give this special position to environment water provisions, but does require that environmental water be given the same statutory recognition as consumptive water entitlements. This not only places environmental water allocations on the same footing as other water uses, but it opens the door for trading in environmental water entitlements and allocations.

Water and environment policy and legislation provide legitimacy and guidance to EFAs at plan and project levels. All policies, except the Tanzanian policy, are now supported with legislation. This provides legitimacy to the environmental water provisions of the policies and guidance about the mechanisms to use for implementing these provisions. While legislation is important, Tanzania provides an example where it is not necessary to wait for the legislation before preparing for water allocation planning. A trial environmental flow assessment has commenced in one basin and several EFAs are either underway or are being planned in other basins.

Passing a policy with provisions for environmental flows does not mean that sectoral harmonization will follow. It is essential to have the concepts of environmental flows recognized as legitimate by the professional staff of the relevant water resources and environment organizations and water-dependent sectoral institutions. The case studies illustrate the diversity of acceptance of environmental flows across different organizations. In Florida, the EU and Australia there is now a general acceptance of the importance of providing water for the environment. In Tanzania, the Water Resources Department under the Ministry of Water and Irrigation exhibits the greatest understanding and has taken the lead in implementing environmental flows; the environment organizations contribute but do not take the lead although they are now working on building capacity for EFAs. Some Tanzanian Ministries, typically those involved in hydropower development and the Irrigation Department appear indifferent to environmental flow considerations. A similar tension exists within the South African Department of Water Affairs and Forestry between the staff who advocate the importance of providing flows that maintain ecosystem services, and the more development oriented sections of the Department. The same difficulty was encountered in the assessment of environmental flows for Chilika Lagoon, India (Case Study 13) where the State Water Resources Department engineers found difficulty in grasping the ecological and social concepts behind environmental flows.

Comprehensiveness

Environmental provisions need to be comprehensive across the water cycle, to include surface and groundwater, estuaries and near-shore regions. The five policies are comprehensive in recognizing the importance of environmental functions of the surface freshwater cycle continuum (lakes, rivers, wetlands, floodplains, etc), although only the South African and Australian policies include the importance of controlling land uses that intercept overland and sub-surface flows because of their potential to remove water that is needed to support downstream ecosystem functions. These interception activities can remove significant quantities of water and should be included in the water policies of countries where forestry or other high water demand land uses are prevalent.

The Florida policy gives equal weight to surface and groundwater (in recognition of this it uses the term "environmental flows and levels"), while Tanzanian and South African policies have sections on groundwater. However, groundwater is not explicitly included in the South African definition of the ecological reserve[42]. The 1994 Australian Council of Australian Governments (COAG) water policy was very weak in recognizing the importance of groundwater in sustaining environmental functioning; this omission was recognized to cause significant consequences and was remedied in the 2004 NWI agreement. More recently, the Australian Water Act 2007 requires that the use of water in the Murray Darling Basin be subject to an integrated surface and groundwater cap (Box 9).

Box 9. Managing the Whole Water Cycle

The consequence of focusing on surface water and neglecting groundwater is shown by the perverse outcome from the cap on surface water use in Australia's Murray Darling Basin. During the 1980s and 1990s water abstractions had grown rapidly in the Murray Darling Basin primarily to service the growth of irrigated crops. Because of concerns about the damage being done to the aquatic environment, in 1995 a cap was placed on further abstractions from surface waters beyond the abstractions that would have been diverted in the 1993/4 year.

While the cap has (with a few exceptions) been adhered to and surface water abstractions have remained steady at about 11,200 Gl/yr, there has been a dramatic increase in groundwater use within the Basin. Groundwater licences have been issued that could allow the extraction of 3,261 GL/yr, around 34% of the surface water allocation. It is estimated that 186 GL/yr of streamflow has already been captured due to the growth in groundwater extraction from the introduction of the Cap until 1999/00 because of connectivity between surface and groundwater and this figure will grow as abstractions from less directly connected groundwater system start to impact on rivers.

A review of the cap in 2000 recommended that the surface water cap be replaced with an integrated surface and groundwater cap that was based on the water needed for ecosystem

[42] van Wyk, E., C.M. Breen, D.J. Roux, K. H. Rogers, T. Sherwill, and B.W. van Wilgen (2006). The Ecological Reserve: Towards a common understanding for river management in South Africa. Water South Africa 32 403-409.

functioning, rather than water abstraction in an arbitrary year. This recommendation has now been enacted in the 2007 Water Act.

Source: Murray Darling Basin Commission (2000). Review of the Operation of the Cap: Overview Report of the Murray-Darling Basin Commission. Murray Darling Basin Commission, Canberra, Australia.

The need for freshwater inflows to maintain estuarine ecosystem functions is absent from the Australian NWI policy and only mentioned in passing in the South African policy and legislation. The European Union WFD explicitly recognizes the importance of providing river flows into estuaries and, in the Florida, the MFLs apply to coastal waters and estuaries. The Tanzanian policy states explicitly that water for the environment is required to maintain "the health and viability of riverine and estuary eco-systems". However, the extent to which environmental flows for estuaries is actually incorporated into water allocation plans is difficult to determine. It has been included, although not always well integrated, in some Australian catchment plans. South Africa, which does not give strong recognition to estuarine water needs in its policy, is an international leader in determining the flows needed to maintain estuarine values.

Climate change should be accounted for when establishing environmental flow provisions. However, none of the policies explicitly link climate change in the assessment of environmental flows. Climate change is included as one of the inputs to water allocation planning in the Australian NWI but is not linked specifically to the potential effects on ecosystem functions; there is an allusion to "human activities (that) are beginning to have a noticeable impact on our climate" in the South African policy although this is not linked to ecosystem functioning. Climate change is not included in the EU WFD, the Florida Implementation Rule or the Tanzanian water policy. These are important omissions since climate change is predicted to have significant effects on water availability and use in many of these countries and consequently on the functioning of aquatic ecosystems. It will force governments and communities to make choices in the ecosystems that should be protected and those that are too expensive, in water terms, to be maintained.

It is possible to develop transboundary water policy with an environmental component but it is difficult. Transboundary water sharing figures prominently in the South African water policy, although transboundary sharing is not specifically linked to ecosystem water needs. Even the Australian and Florida water policies have transboundary (inter-State) concerns. The Australian policy requires that environmental and other public benefits be achieved through joint arrangements for shared water resources, while the Florida water policy has inter-state agreement with the states of Georgia and Alabama as one of its objectives, although this objective is not linked to environmental water allocations. It has taken substantial expenditure and national leadership to bring about the environmental water improvements across the seven Australian jurisdictions and the progress has been considerably slower than envisaged when the water reforms commenced in 1994. In the EU, establishing a consistent environmental flow policy across such a diverse region has proven to be expensive and time consuming, but may provide the basis for easier transboundary water management in the longer term. The

Lesotho Highlands Water Project (Case Study 14) provides another example where the new environmental flows policy is part of the transboundary water agreement, and the Senegal Basin Water Charter (Case Study 16) and the Mekong Basin Agreement (Case Study 7) both contains specific provisions for environmental flows.

Environmental Water Mechanisms

The environmental objectives in a basin plan can be established using a variety of approaches. The South African and Tanzanian policies and legislation establish a national river classification system, where a national program is used to establish a quality class for each significant water resource. This class then acts as an environmental goal for the management of that water resource. Different waterbodies will be assigned to different quality classes, depending on factors such as the uses of the water resource, its biodiversity values, etc. In the EU policy, by way of contrast, the environmental objectives for all water resources are the same - at least Good Ecological Status (with some specific exceptions).

The Australian and Florida policies are different again in that neither introduces a national classification system. Instead the environmental objectives are established as part of the catchment level water allocation planning based on local, national and international objectives.

All approaches have advantages and disadvantages. The EU approach, with its mandated uniform minimum environmental quality objective, minimizes the possibility that ecological outcomes will be diluted in the stakeholder negotiations, particularly where the river or groundwater system is already heavily committed with existing licenses. The South African, Tanzanian, Australian and Florida approaches are potentially more flexible and cost effective, since not all waterbodies have to be brought to the same environmental standard if there are competing water uses that have higher priority.

Market mechanisms can be used for providing environmental water but require an established infrastructure. While the Tanzanian and South African policies recognize the potential of using market mechanisms for water trading, only the Australian policy requires that market mechanisms be used for trading water allocations and entitlements for environmental purposes. However, even though here are functioning water markets in Australia, this component of the policy has been implemented quite slowly. Large quantities of environmental water have now been bought on the water market but there has yet to be active trading in environmental water entitlements.

Once allocated, it is very difficult to recover water for the environment in over-allocated systems. Recovery of over-allocated systems receives particular emphasis in the South African, EU, Florida and Australian policies. However, the implementation of this requirement differs greatly. In South African, although there is yet to be action to recover water for the environment, the Water Resource Strategy acknowledges that about 50% of Water Management Areas (WMAs) are currently over-allocated. In Australia, where there are a number of catchments that are clearly degraded because of lack of flows, there is little official acknowledgement of over-allocation. Even so, many billions of dollars have been allocated to recovering water for the environment in stressed catchments in

Australia.   In Florida, too, there is little official acceptance of over-allocation, with only one catchment being declared as over-allocated.

It is clear from the experience to date in Australia, the EU, Florida and South Africa that recovering water for the environment once it has been allocated to a consumptive water use is extremely difficult and politically unpopular. This has been identified as one of the major impediments to environmentally sustainable water management in both Australia[43] and the EU. Even purchasing water at market prices from willing sellers in over-allocated systems has proven unpopular in some parts of Australia. While legislative provisions for recovering water for the environment have yet to be used in South Africa, provisions in the National Water Act require new water licences to be issued to replace existing entitlements. This will provide an opportunity to reduce current allocations and recover water for environmental purposes if systems are over-allocated. The experience is similar in the EU. When the Guadiana River basin authority in Spain tried to reclaim allocated water resources, users took at 15,000 separate court cases that stalled the process.

The focus on recovery of over-allocated systems can divert attention from protecting presently unstressed systems. The Australian and EU policies place considerable emphasis on the recovery of presently over-allocated systems to environmentally sustainable levels of extraction. However, the experience in Florida is that this emphasis on stressed and potentially stressed waterbodies means that more pristine systems are sometimes allowed to degrade substantially before any attention is placed on them. Consequently, the Florida policy requires the identification of waterbodies that will potentially be stressed within 20 years and the development of a recovery or prevention strategy. This forward-looking provision thus focuses attention on the management of systems that need protection.

Participation

Participation is increasing accepted as necessary even when its requirements in the policy are not very clear. The participation requirements varied considerably across the policies. The South African policy, legislation and strategy had extensive stakeholder participation requirements while the Australian and Florida policies required participation at specific stages of the development of water allocation plans. The European Union WFD has broad, timed requirements for public information and opportunities for public comment in river basin management planning but no specific stakeholder involvement requirements in establishing environmental flows. In Tanzania, there is only a general requirement that concerned stakeholders are consulted when the national water resource management plan is drawn up; there are no explicit requirements for stakeholder consultations when the basin water resource management plans are developed.

In spite of this diversity of requirements, in practice, there has been considerable emphasis on stakeholder participation when the policy provisions were put into practice.

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[43] National Water Commission (2007). National Water Initiative. First Biennial Assessment of Progress in Implementation. National Water Commission, Canberra.

For example, the first Tanzanian EFA undertaken in anticipation of a river basin water resource management plan (Case Study 8) has undertaken extensive stakeholder involvement activities in spite of the absence of direction in the policy. Similarly, the Water Management Districts in Florida go well beyond the formal participation requirements when they established their water management plans.

Stakeholder participation can impede implementation unless carefully designed to suit a country's circumstances. However, participation can also act as an impediment to policy implementation if the policy requirements do not match the capacity of stakeholders or resources to undertake effective participation. Participatory requirements have resulted in delays in introducing environmental water provisions in South Africa and obstruction of efforts to recover from over-use in the case of the Upper Guadiana Basin in Spain (Case Study 2).

Assessment Method and Data

Provisions for 'best available science' in water policy can be used to impede policy implementation. Both the 1994 and 2004 policies in Australia required that best available science should be used to assess environmental water needs. By way of contrast, the South African water policy does not mention whether the information used has to be "best available" or not. In spite of these different policy requirements, both countries have been at the forefront of developing environmental flow assessment methods and applying them with high quality scientific information. The Tanzanian policy also requires "Water for the environment shall be determined on the best scientific information available". The European Union WFD does not require any particular standard of scientific input to environmental water decisions but does require member states to give responsibility for achieving Good Status to a "competent" authority with the necessary scientific skills and mandate. Furthermore, there has been an extensive scientific effort across the EU to develop assessment procedures that are based on high quality scientific information. On the other hand, Florida also requires that decisions be based on best available information but this has proven to be an impediment to progress in environmental water allocation because of concerns that decisions based on anything other than the highest quality scientific information will be challenged in courts.

Value laden terms in water policies need to be supplemented with specific interpretation and implementation mechanisms. All five policies contain value laden terms, such as "significantly harmful to water resources or ecology" (Florida), "environmentally sustainable levels of extraction" (Australia), and "degraded beyond recovery" (South Africa) to describe water resources that are unacceptably environmentally stressed. However, these terms are very difficult to define operationally. To decide on what constitutes "significant harm", "sustainable levels of extraction" and "degraded beyond recovery" requires social decisions on the ecosystem services to be provided for different social groups. It would be difficult enough to make these social judgments if there was good evidence about the consequences of different decisions, but in reality there is often little information available on the consequences of the different choices. For example, in the EU, scientists themselves do not agree on some biological, ecological or hydrological issues. The European Union and Australia have mounted significant efforts to define these terms operationally.

Reviewing, Monitoring and Enforcement

Establishing an independent oversight authority, with power to levy sanctions, can be an effective mechanism to implement environmental water provisions. The Australian National Water Initiative requires regular reviews of progress in implementing the Initiative by the Australian State governments. A special authority – the National Water Commission – has been established to oversee the implementation and to undertake the reviews and was armed, for the first two years, with authority to recommend the withholding of payments to the State governments if there was inadequate progress with the broad range of water reform measures. This has proven to be a real incentive for compliance. The European Union WFD also requires each country to report on their progress in implementing the Directive to the European Union. They can be fined for lack of compliance. Even though no fines have been levied yet, the provision has acted as a powerful lever for action by countries that see non-compliance as politically damaging.

These oversight mechanisms have been implemented in the two federated systems within the policy case studies. The individual country water policies do not include provisions for reviewing the implementation of the policies, although the Australian and EU experiences show the benefits of establishing reporting requirements and oversight of progress in implementation.

Environmental indicators need to be established and the monitoring program should be focused on these outcomes rather than only on hydrologic measures. Both Australian and South African policies require monitoring of water plan outcomes; i.e. monitoring environmental outcomes. South Africa is developing and ecosystem monitoring program and various Australian States have developed programs although their detail and focus on environmental outcomes varies greatly. The Florida legislation also requires annual reporting by both Water Management Districts and the Department of Environment Protection on establishing and meeting the MFLs. However these reports have been restricted to hydrological measures and do not provide information on ecological outcomes.

Institutional Drivers

Environmental flows were just a component of broader water reforms in the five case studies. Thus, the drivers consist of two parts – drivers for the overall water policy reforms and drivers that were specific to the inclusion of environmental flows in the policies (Table 6).

A singular event can be a powerful inducement to policy reform if professional and public drivers are organized to take advantage. The policies reforms in three of the five case studies were driven, at least partly, by drought which focused attention on equitable water management. In Florida, Tanzania and Australia severe droughts highlighted the over-allocation of water resources and the resulting stress on environmental functions. In Tanzania, the environmental aspects of this poor planning and management only became apparent later, as highly contested water rights issues gained high political visibility (Box 10). The South African case study was driven by a different singular event – the general reforms accompanying the democratic government in 1994 – but also against a backdrop of growing water shortages. These unusual events, while difficult to predict and plan for, provide powerful stimuli for reforming water policies with the concomitant opportunity for ensuring environmental sustainability and provisions for environmental flows are included in the new policies.

Box 10. Water Use Conflicts in Usangu Plains, Tanzania.

Water shortages in the Great Ruaha basin, Tanzania, have resulted in intense competition between irrigators and pastoralists, particularly during the dry season. In the Usangu Plains of the Basin, water scarcity has caused tensions over access to both land and water. There was a perception among farmers that increasing numbers of cattle were placing greater demand on water and forage during the dry season both within and around the Utengule Swamps. At the same time, the gradual expansion of areas under irrigation by farmers decreased land that was previously available for grazing and the availability of water for livestock. The pastoralists and their cattle trespassed on cultivated fields to access water sources during the dry season, causing severe damage to the crops and cultivated fields, intensifying the hostility between farmers and pastoralists.

A DFID-supported study was initiated to obtain a scientifically credible explanation for the water shortages in the Great Ruaha basin. Its findings made it clear that livestock numbers in Usangu were smaller than previously claimed and that livestock water and pasture needs were within the carrying capacity of the basin. They were not the cause of either the water shortage or the environmental degradation within the basin.

WWF Tanzania, in close cooperation with the Rufiji Basin Water Office, is undertaking a study to identify and investigate options to restore flows to the Great Ruaha River flowing through the Ruaha National Park in Tanzania. The study will develop a shortlist of flow options and a high-level analysis of the preferred options. The WWF has established an electronic forum to promote wide discussion of the pre-feasibility assessment of potential options.

Source: Project Report: The sustainable management of the Usangu Wetland and its Catchment. December 1998- March 2002. Ministry of Water and Livestock Development, Tanzania.
pers comm. Dr Constantin von der Heyden, WWF Tanzania.

Public pressure can be a powerful driver for policy reform. Public pressure was central to both the water reforms and/or the inclusion of environmental flows in the new water policies in all cases except the EU Water Framework directive. In South Africa there was a strong pressure from the black majority to reform the water laws so that they had equitable access to the country's water resources; generally, they had much less interest in environmental flows, even though the services delivered by these flows were ostensibly to their benefit. In Florida and Australia the public pressure included an awareness of environmental degradation and a desire to see a return of environmental values.

Well organized scientific institutions can play a leading role in introducing environmental flows when policy reforms are occurring. This is most clearly seen in the South African reforms, where the scientific organizations were well organized and used the opportunity of the reforms to work with government officials to incorporate extensive environmental water provisions into the policy White Paper.

International agreements that reflect an emerging consensus can be an effective motivator for the inclusion of environmental flows in national policies and legislation. The global consensus that emerged in the early 1990s about the importance of environmental sustainability, including in water resources management (e.g. the Dublin Principles), was an important, albeit secondary, influence on the inclusion of environmental flows in the South African and Australian policies (the Florida policy and legislation pre-dated this consensus by a decade). In Tanzania, there was a rising awareness amongst government officials about the weakness in the existing water resources planning and management decision making process and the emerging international consensus that included environmental water concerns.

Summary of Policy Lessons

A number of lessons emerge from the analysis of environmental flows in the five national water policies:

- Countries in both developed and developing countries are integrating environmental flow provisions into the water resources policies
- Gobal leaders in environmental flows include both developed (Florida, EU and Australia) and developing countries (South Africa and Tanzania)
- Some of the important aspects to be included in environmental flows provisions in policies include:
    - Legal recognition of environmental flows with, ideally, equal legal standing to consumptive water uses
    - Linkage between environmental flows and ecosystem services provided by the flows
    - Inclusion of all relevant parts of the water cycle – especially surface water and groundwater – when establishing environmental flow provisions
    - A method for determining environmental objectives and outcomes at basin level
    - Attention to both recovery of water for the environment in over-allocated systems and protection of environmental flows in systems not yet under stress
    - Clear requirements for stakeholder participation in environmental flow decisions that do not impede progress
    - An independent authority to audit performance of the policy is highly desirable
    - Requirements for best available science in making environmental water allocations as long as this does not inhibit implementation of the policy requirements
- Implementation challenges include:
    - Continued political support to implement the environmental flow provisions of the policy
    - Re-orienting sectoral Ministries to the need to include environmental water provisions in their policies and practices.
    - Obtaining stakeholder support for environmental water provisions, especially in over-allocated catchments and basins
    - Establishing environmental goals and the benefits delivered by associated ecosystem services

- Turning value-laden terms such as “over-allocation”, “sustainable levels of extraction”, etc into practical procedures
- Matching the EFA procedures to the budget and time available while still meeting the requirement for “best available science”.

Table 6. Institutional drivers for water policy reform and inclusion of environmental flows in policies

	Policy Initiation and Implementation			Environmental Flow Inclusion[44]				
	Convening	Singularity	Public	Institutional	Evaluative	Public	Scientific Professional	International Developments
Australia	Federal government initiated national water reforms, and provided financial assistance for their implementation.	Drought had accentuated the need for improved water management.	Strong public pressure to make the Australian water management more efficient and environmentally sensitive.	Professional water managers had supported the inclusion of environmental flows in water policy.	An independent organization was established to drive the reforms.	Strong public pressure to arrest the environmental decline of water resources.	Scientific studies had publicized the decline of environmental assets and leading scientists advocated environmental flows.	International consensus added support for environmental water reforms.
European Union	EU established to provide harmonized legislation and procedures across Union.			WSS sector supported ecosystem health to reduce treatment costs. Other water using sectors supported ecosystem health because it could provide green credentials.	The EU has power to sanction countries not meeting implementation standards		Ecosystem professionals advocated that ecosystem health was best indicator of sustainable development.	
Florida		Severe drought had accentuated the need for improved water management.	There was public pressure to manage water resources better in the face of the			Public and environmental groups advocated environmental restoration,		

[44] Environmental flows were not specifically included in the European Union WFD – the drivers in this case refer to the policy's focus on ecosystem health.

			drought.			especially Everglades		
South Africa		Installation of democratic government led to a policy to support redistribution of resources	Public pressure for water reforms as part of democratic change.				Scientific organizations were active in advocating the inclusion of environmental flows in the policy	International consensus added support for environmental water reforms.
Tanzania		Drought, inadequate investment, poor water management led to electricity and food shortages.	Public disquiet with the poor performance of the water sector, especially hydropower, contributed to the revision of the Water Policy.	River basin officers and DWR played a key role in the inclusion of environmental flows in policy		The Ruaha National Park has been very vocal about the drying up of the Ruaha river during dry seasons		International consensus added support for environmental water reforms. Also influenced by water reforms in South Africa.

Chapter 6. Basin Plan Case Studies: Lessons

Four basin and catchment water resources plans were assessed. The lessons that emerged were: recognition of environmental flows in water resources policy and legislation provides important backing for including environmental flows in the plans; there is a need to demonstrate the benefits from environmental water allocations after plans are implemented; the term "environmental flows" can be counter- productive if not explained at a early stage; participatory methods need to be tailored to suit stakeholder capacity; a range of EFA techniques are needed to suit different circumstances; and ecological monitoring is essential to provide information for adaptive management.

Basin/Catchment Case Study Characteristics

Four catchment or Basin-level water planning studies that included EFAs were selected for case studies (Box 11). They included one from a developed country – Australia – and three from developing countries and regions – South Africa, Tanzania and the Mekong region. Finally eight single and multipurpose projects covering a diversity of sectors – hydropower generation, irrigation, inter-basin water transfer, water supply and ecosystem restoration – were selected for project level case studies. Two were supported by World Bank funding.

Box 11. Basin Level Environmental Flow Assessments

Kruger National Park, South Africa.
There have been a number of studies into environmental water needs of the seven major rivers flowing through the Kruger National Park. These studies were initially driven by drought during the 1980s when there was concern that the Park rivers were drying up because of upstream abstractions. Some of the EFA techniques, then being developed in South Africa such as the Building Block Method, were used to establish Instream Flow Requirements. However, these IFRs were not implemented because there was no mechanism for allocating water to provide the Park with a greater share. The advent of the National Water Policy and National Water Act in the late 1990s provided such a mechanism. The estimates of water required to support the Park's ecosystems have been refined through more recent studies in order to provide estimates of the Ecological Reserve as defined in the Act.

Mekong Basin, South East Asia
The Mekong Basin Agreement between the countries of the lower Mekong Basin includes provisions for minimum flows and for the reverse flow to Tonle Sap in Cambodia to be maintained. The GEF and World Bank helped the Mekong River Commission implement these provisions through a 3-stage process to establish the environmental flow needs. However, the recommended flows were reduced from the status of a Rule to a Guideline because there was a perception that they would impede development, even by the downstream countries.

Pangani Basin, Tanzania
The Pangani Basin has experienced severe competition for water between the hydropower and irrigation sectors. Under the Tanzanian National Water Policy, each Basin Water Office will be required to establish a water resources management plan, including provisions for environmental water allocations. The Pangani Basin Water Office and IUCN have commenced a trial EFA in the basin to establish the environmental flow requirements under a number of different scenarios. This has also been used as an opportunity to train staff from other Basin Water Offices as well as academics and Ministry staff in EFA procedures.

Pioneer Catchment, Australia
Under the 1994 COAG Water Agreement and the subsequent National Water Initiative, all Australian states are required to develop water allocation plans, including environmental flow provisions, in all significant surface and groundwater systems. The Pioneer Catchment Water Allocation Plan was completed in 2002 as part of that commitment. The EFA for the plan was developed as a technical exercise using a holistic assessment technique, and the environmental water requirements were then incorporated into the final catchment plan. The plan includes a monitoring plan and early indications are that the environmental objectives are being met.

Assessment of Effectiveness

Recognition

Recognition of environmental flows in legislation and policy can simplify their incorporation into water allocation plans and project assessments. Policy and legislation provides legitimacy for acceptance and implementation of environmental flow determinations. In the Kruger National Park, the Instream Flow Requirements, first determined in the 1990s, were not implemented because they were not backed by legislative requirements and did not have mechanisms for implementation. However, once the National Water Act was passed, these IFRs were used to develop high confidence reserve determinations for the rivers of the Park which will be incorporated into the catchment strategies to be drawn up by the CMAs. Even so, there was still a lack of acceptance by upstream extractive water users about the limitations imposed on their taking of water. Similarly, in Tanzania, the Pangani Basin trial EFA, the Mara catchment EFA and the Wami Basin EFA are being conducted with the knowledge that the new Tanzanian Water Resources Act will soon be passed – in the meantime, these EFAs and that for the LKEMP (Case Study 15) were legitimized by the National Water Policy which requires environmental water allocations to be included in basin plans. There is however a danger that EFAs developed ahead of legislation may not meet the legal requirement for inclusion in a basin plan.

Following implementation, there is a need to demonstrate the benefits of environmental flows. The Pioneer catchment provides an example where environmental flows were incorporated into a water allocation plan under legislation, the Queensland Water Act 2000, and were accepted by all parties as a legitimate use of water. Even so, agricultural water users in the catchment do need to be reassured that the environmental flows result in clear environmental outcomes – increases in native fish, healthy wetlands, maintenance of the estuarine mangroves, etc. (This illustrates the importance of an environmental monitoring program, public reporting and adaptive management.

It is difficult to get agreement on transboundary environmental water planning. The Mekong Basin provides the only case study example of basin planning for environmental flows within a transboundary setting[45]. It illustrates the tension between development aspirations and provision of ecosystem services when each nation is focused on water sharing rather than benefit sharing. Even though the Mekong Agreement contains requirements for minimum flows and maintenance of the reverse flows to Tonle Sap, the concept of environmental flows has not been fully accepted by all basin countries because of its perceived restrictions on development.

Comprehensivesness

All relevant components of the water cycle should be considered in the EFA. The Pangani Basin and Pioneer catchment EFAs illustrate the hydrological integration of estuarine and freshwater needs for environmental flows. Both also demonstrate the consideration of ecosystem services from both surface and groundwaters. The Pangani basin EFA is the only one of the four basin level case studies to include the effects of climate change in its scenarios. All but one of the scenarios assessed included the best estimate of the effects of climate change on the basin's water resources.

Participation

Participation is important but needs to be realistic; it should be tailored to suit the capacities of the stakeholders and the policies of the country, and build capacity in IWRM. Local communities, did not have a history of participating in decisions about resource use in the catchments of the Kruger National Park. Although they were keen to improve their access to water they lacked the institutional forum, and perhaps, the confidence to work with the predominantly white constituencies and capacity to fully engage in discussions. In the Mekong Basin, it was difficult to develop a full stakeholder engagement program, when there were such strong differences in government attitudes, stakeholder capacities and multiple languages. The initial EFAs were undertaken as technical assessments with limited stakeholder engagement, while a fully inclusive study is yet to be fully implemented because of funding limitations and lack of comprehensive support from the Basin countries. In both the original Instream Flow Requirements (IFR) studies and the more recent Reserve determinations in the Kruger National Park, there was only limited direct engagement by local groups although the impacts of flow decisions on their livelihoods was taken account of by the planners. Experience suggests that it takes time to develop the capacity for stakeholders to participate effectively in activities such as EFA. Specific capacity building activities are currently underway, including development of a common vision, establishment of local objectives and stakeholder involvement in monitoring activities.

Publication of submissions and government responses can assist transparency in decision making. The Pioneer catchment (Case Study 9) illustrates an effective mechanism for promoting transparency. Under the Queensland Water Act 2000, all submissions to the water planning process have to be published, together with the government's response to each submission, within 30 days of the plan being approved.

[45] Although the Pangani Basin and the catchments of the Kruger National Park are transboundary, the EFAs in these cases were carried out in just one country.

Stakeholder engagement in transboundary settings is particularly difficult. This is illustrated by the Mekong Basin (Case Study 7). Not only did the different stakeholders within the basin have different languages, capacities and objectives, but the different governments had very different attitudes towards the involvement of local groups in national development decisions.

Assessment Method and Data

For both plan and project EFAs, a range of techniques are needed within a country to meet different levels of environmental risk and to suit different budgets and timeframes. All four basin/catchment case studies used versions of the holistic approaches to developing EFAs, based on both general flow-ecology relationships and specialized field studies. The BBM method was used initially in the Kruger National Park low flows, followed by the Flow Stress Ranking (FSR) method; the Benchmarking method was employed in the Pioneer catchment; and modified versions of the DRIFT method were used in the Pangani Basin and the third phase of the Mekong Basin. In the case of the Pangani basin, the experienced international consultants devised a procedure that assessed the flow requirements of the major ecosystem components.

The experience in both Australia and South Africa is that a country needs to implement a range of EFA techniques for incorporating EFAs in basin-level plans to suit budget, skill and information needs as well as the severity of the pressure on the environment. Thus, South Africa has adopted four levels of EFA procedure (Box 12), while Australian States, such as New South Wales, have two basic EFA methods with each being applied with more or less intensity to suit the circumstances.

Similarly, in the project case studies, the assessment methods varied from the simple estimates of restored lake levels that were undertaken for the Aral Sea case study, to the hydrological and hydraulic modeling undertaken for the Chilika lagoon study, to the detailed and expensive flow assessment method (DRIF~~I~~T) undertaken for the Lesotho Highlands Water Project. The high cost of DRIFT (nearly US$2m) and the time needed (over 2 years) was justified because it was important to have defensible and comprehensive results for a very large project (US$2.9 billion) that were grounded in specific impacts to convince skeptical managers in the LHDA.

Where possible, field data should be used to supplement desktop assessments. The collection of field data was an important component of all palnning studies in order to establish defensible flow-ecology relationships. While much of the data collected under the Kruger National Park Rivers Research Program was not directly useable in the EFAs, the understanding and knowledge of the scientists engaged in the program was a very valuable resource for the EFAs. The Pioneer catchment EFA relied on two years of field data assessments to illustrate the risks to different organisms from the two flow scenarios examined, while the Pangani Basin study has undertaken data collection in the freshwater and estuarine reaches of the Basin. The second and third phases of the Mekong Basin study also use field data.

Box 12. Levels of Environmental Flow Analyses used in South Africa

The South African Department of Water Affairs and Forestry has developed four levels for determining environmental water needs - Desktop, Rapid, Intermediate or Comprehensive. The method used depends on the environmental pressure faced by the waterbody and the funds and time available. The Desktop and Rapid determinations are largely based on applications of the BBM to determine instream flow requirements[46]. The Intermediate and Comprehensive determinations, which can be based on the BBM, DRIFT or HFSR methods, involve specific local data collection and hydraulic modeling[47].

An ecological monitoring program is a key part of a basin plan. Establishing an environmental monitoring program is an important, but often neglected, part of implementing environmental flows. An Ecological Reserve Monitoring Program is being developed for some catchments of Kruger National Park but, of the case studies, only the Pioneer catchment (Case Study 9) has advanced to the stage where such a monitoring and reporting program is operational. In this plan, five environmental assets have been identified and annual reports are being produced on the delivery of environmental flows and the state of these assets. Under the Queensland Water Act 2000, the Minister for Water is required to prepare a regular report outlining progress on the implementation of a water resources plan and the achievement of the plan's objectives. These monitoring and reporting requirements not only provide feedback about the success of the measures in the plan but also provide a public driver for the continued attention by government to providing environmental flows.

Integration

For both basin plans and projects, environmental outcomes can be integrated with social and economic outcomes either as part of the EFA process or during the decision making process. The case studies illustrate two approaches to integrating the environmental assessment with social and economic issues. The Pioneer catchment EFA dealt only with environmental water needs and did not explicitly integrate these needs with social or environmental uses of the water. These environmental water needs were then traded off against other demands on the catchment's water resources during the water allocation planning process. Similarly, the Bridge River Consultative Committee (Case Study 12) used both intuitive and formal methods to combine the environmental, social and economic

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[46] King, J.M. and R.E.Tharme (1994) Assessment of the Instream Flow Incremental Methodology and Initial Development of Alternative Methodologies for South Africa. Water Research Commission Report No. 295/94. Pretoria, South Africa.
Tharme,R.E. and King JM (1998). Development of the Building Block Methodology for Instream Flow Assessments, and supporting research on the efforts of different magnitude flows on riverine ecosystems. Water Research Commission Report No. 576/198. Pretoria, South Africa.
King, J.M., R.E. Tharme and M.S. de Villiers (eds) (2000). Environmental Flow Assessments for Rivers: Manual for the Building Block Methodology. Water Research Commission Report No. TT 131/00. Pretoria, South Africa.

[47] Pers comm. D. Grouw, March 2008.

outcomes for different flow scenarios in the Bridge River assessment). One consequence of this approach is that, without a very transparent decision making process, it is difficult to assess the extent to which the environmental flows in the final plan protect the environmental assets and ecosystem functions in the catchment.

The Pangani basin EFA and the Lesotho Highlands Water Development Project illustrate an alternative approach. The assessment of different environmental flow scenarios included the social and economic benefits to the communities directly dependent on the river flows. In a similar way, the second and third phases of the Mekong Basin study progressively include social and environmental benefits from the different environmental flow scenarios. In that case, it was clear that an analysis that was focused just on environmental outcomes would not have been accepted.

Cost Effectiveness

There is little information available about the cost of the basin and catchment EFAs. The Pangani EFA trial cost approximately $500,000 over three years but this figure includes the training and establishment costs that would not be incurred elsewhere. Nevertheless, an EFA which included the extent of field work that was included in these EFAs will be expensive and a lower cost approach might be more appropriate for other catchments in developing countries.

The Pioneer catchment EFA was one of the first EFAs carried out in Queensland as part of the development of catchment water allocation plans across Australia. The assessment was judged to be too costly for widespread application if the intensity of scientific investigation remained at the level employed in this catchment. Consequently, there has been a rationalization of EFAs with less intensive approaches being employed in Queensland catchments where the ecological risks are judged to be lower.

Influential

The Pioneer, Kruger National Park and Pangani EFAs have all been influential in different ways. The Pioneer EFA results fed directly into the water allocation planning of the Pioneer catchment; the environmental assets now receive environmental flows, although the extent to which the flows in the EFA are actually delivered is difficult to assess. This work has not had influence outside the catchment because there was already a general program to roll out water allocation plans across the country.

The extensive environmental flow investigations in the Kruger National Park have been highly influential both within the catchments surrounding the Park and more widely. The early IFR determinations formed the basis of the subsequent ecological reserves, although these determinations have yet to be formalized in water allocation plans for the Park's catchments. The EFAs also gave confidence to those developing the South African Water Policy and legislation that it was possible to estimate the flows needed to maintain aquatic environments.

While the trial Pangani EFA has yet to be completed and the Basin water resource management plan has yet to commence, the study has already been influential in both training a cadre of academics and government staff in the practical aspects of EFA (with some trained staff now participating in EFAs in other Basins) and in increasing awareness of environmental flow issues in this Basin.

It is more difficult to mount an influential EFA in transboundary water management. The EFA in the Mekong Basin, the only fully transboundary EFA in the plan case studies, has produced some valuable documentation on basin hydrology and has brought about changes in attitudes towards environmental water provisions, but is yet to result in the provision of environmental flow provisions. The minimum flow rules that were recommended as a result of the initial EFA was subsequently reduced in status to guidelines and the third phase of the EFA has been hampered by a lack of senior support at political and administrative levels.

Institutional Drivers

Table 7 shows the institutional drivers that operated in the four basin/catchment case studies.

Procedural drivers were important motivators for all four planning case studies. However, the details differ about the roles of these drivers. The Pioneer catchment EFA was a direct response to the legal requirement for water allocation plans to be developed for all major surface and groundwater catchments in Australia and was accepted by all sectors without issue. The Mekong EFA was undertaken in response to the Mekong Agreement. The Pangani EFA was undertaken in anticipation of the Tanzanian Water legislation being passed; the trial would probably not have occurred in this basin without the IUCN acting as an additional driver because of their interest in locating a suitable basin to conduct an EFA demonstration study. The Kruger National Park EFAs were only driven by procedural requirements after the passing of the 1998 National Water Act; prior to this the professional and public drivers had not been sufficiently strong to lead to agreed allocations by the DWAF of water for maintaining the Park's ecosystems.

However, other factors, apart from these institutional drivers, were important in initiating some of the case studies. The concern amongst some of the countries of the Mekong basin about proposed developments in the upstream China tributaries of the Mekong River was a powerful impetus for seeking rules for sharing the waters of the Basin. The GEF and World Bank provided support for an EFA to implement some of the provisions of the Mekong Agreement.

Table 7. Institutional drivers for undertaking environmental flow assessments at basin and catchment scales

	Procedural	Evaluative	Instrumental	Professional	Public
Kruger National Park	The 1998 National Water Act provided the justification for the establishment of the ecological reserve in the Park rivers.			There was concern amongst Park managers and scientists about the effects of water abstractions and proposed dams on the Park's biodiversity.	NGOs were concerned about the impacts of dam proposals on the Park's biodiversity.
Mekong Basin	The Mekong Agreement requires protection of low flows and the reversal of flows to Tonle Sap		The World Bank and GEF included environmental flow assessments as part of their development assistance		International, regional and national NGOs had raised concerns about development proposals on the Mekong River
Pangani Basin	Tanzanian National water Policy and draft Water Resources Act require EFAs		The IUCN supported the EFA trial as part of its Water and Nature Initiative.		
Pioneer Catchment	The 1994 COAG agreement and the 2000 Queensland Water Act required EFAs as part of catchment level water allocation plans	The NCC and NWC reviews of progress with implementation of the NWI provided an evaluative driver for the EFA.		The government water managers supported the formal allocation of water for the environment to prevent the catchment becoming stressed.	Public opinion was strongly in favor of environmental sustainability both in the Pioneer catchment and more generally

Chapter 7. Project Case Studies: Lessons

Four new dams and four restoration projects were reviewed for lessons in assessing and implementing environmental flows. The major lessons to emerge were: for restoration projects, there is usually a need to combine engineering improvements and re-operations to provide the volume of water needed; inclusion in water resources policy provides legitimacy for environmental water allocations; environmental outcomes need to be linked closely to social and economic outcomes; EFAs should be conducted for all ecosystem components; traditionally trained water resources professionals can find it difficult to grasp environmental flow concepts; water resources plans provide benchmarks for water allocations during project assessments; and active monitoring is needed to enforce flow allocation decisions and undertake adaptive management. It is important to present information in terms that are comprehensible to decision makers; economic studies can support arguments for downstream water allocations. EFAs are yet to be mainstreamed into water resources planning processes such as EIA. While EFAs constitute small fractions of project costs these expenditures can be significant in the context of overall costs for feasibility studies and EIA..

Characteristics of the Project Case Studies

The project level case studies include EFAs conducted as part of the development of a new dam (Berg River Dam, South Africa; and Mohale dam as part of the LHWP in Lesotho), replacement of old infrastructure (Naraj Barrage, Mahanadi River, India and irrigation canals Tarim basin, China), reconstruction/modification of existing infrastructure (Berg Strait dyke, Aral Sea; Lower Kihansi, Tanzania; and Katse dam as part of the Lesotho Highlands Water Project in Lesotho), and re-operations for existing infrastructure (Bridge River, Canada; Manantali dam, Senegal Basin; dams on Syr Darya River, Aral Sea basin; and Tarim Basin, China). Table 8 summarizes the characteristics of the case studies, and Table 9 summarizes the major findings from the assessment.

Some of the lessons for the rehabilitation and re-operation case studies differ from those for the new infrastructure. Two of the major infrastructure rehabilitation and ecosystem restoration case studies - the Tarim Basin, China and the Aral Sea, Central Asia – involved very inefficient infrastructure so that there were opportunities to improve efficiency and redistribute the ‘saved’ water to environment as well as to increased production. At the Manantali dam, in the Senegal Basin, the hydropower turbines had not been installed for a decade after the dam was built, giving an opportunity to demonstrate through experimental flood release studies the value of environmental flows to downstream communities in time for their needs to be included in the final water sharing arrangements.

Table 8. Characteristics of Project Case Studies

Case Study	Country/Region	GDP per capita (US$)[48]	Institutional Setting	Sector	Purpose	Date Completed
Aral Sea	Central Asia	$260-$43,000	Transboundary	Environmental Restoration	Re-operations and restoration. Dyke upgrading	GEF project 2003; World Bank project still active
Berg River	South Africa	$5,390	Catchment	Water supply	New dam, operating rules	In progress
Bridge River	Canada	$36,170	Sub-catchment	Hydropower	Re-operations	2001
Chilika Lagoon	India	$820	Sub-catchment	Irrigation Flood control	Restoration and re-operations	2004
Lesotho Highlands Water Project	Lesotho	$1,030	Transboundary	Inter-basin transfer (water supply)	Reconstruction of outlet structure in old dam, and new dam, new release policy	2006
Lower Kihansi Power Project	Tanzania	$350	Sub-catchment	Hydropower	Reconstruction of outlet structure in new dam, spray augmentation using artificial sprinklers	In progress
Senegal	West Africa	$750	Transboundary	Multi-purpose	Reoperation and restoration	Regional Hydropower Development Project completed 2005
Tarim Basin	China	$2,010	Sub-Basin	Irrigation	Irrigation canal reconstruction and re-operations	2005

Once rights to water from infrastructure developments have been established it is usually difficult to redistribute them through rehabilitation projects. This is most apparent in countries, such as Australia and South Africa, which are now facing major costs to return water to the environment in over-allocated systems[49]. Not all the costs are financial. In Australia, the political costs of buying back water licences from irrigators is probably even greater than the financial cost and, in Tanzania, the government faced significant political costs because the water being reserved for the unique ecosystem in the Lower

[48] From World Bank Doing Business 2008 site. http://www.doingbusiness.org/ExploreEconomies/EconomyCharacteristics.aspx
[49] Currently $10 billion has been allocated for returning water to the environment in the Murray Darling Basin in Australia.

Kihansi Gorge meant that electricity generation could not be expanded further in a nation facing enormous electricity shortages and high demand..

For restoration of degraded downstream ecosystems, engineering improvements are often needed to enhance to provide the flow volumes needed. To restore the Northern Aral Sea upstream dam operating structures had to be modified to better control water releases and a dyke was constructed across the Beg Strait to retain the Sea's water. Similarly, Chilika Lagoon in India, Kihansi Dam in Tanzania, and the Tarim Basin in China all required engineering interventions (respectively, a new entrance to the ocean and a channel across the lagoon, a modified outlet structure from the Kihansi Dam and an artificial sprinkler system, and lining of irrigation channels to conserve water) along with the establishment of environmental flows for the recovery of downstream ecosystems.

Assessment of Effectiveness

Recognition

Procedural drivers can help water resource managers accept the concepts of environmental flows. The intuitive acceptance of environmental flows in the Aral Sea and Tarim Basin case studies (Box 13), the two ecosystems that have been most heavily degraded out of these case studies, can be contrasted with the initial reluctance to accept the concept in the Berg River, Lesotho Highlands, Chilika lagoon, Lower Kihansi, Bridge River and Senegal Basin cases. In these cases, the operating authorities were predominantly staffed by engineers with a mandate for infrastructure development and operations. However, in all these cases, with the exception of Chilika Lagoon, the operating authorities came to understand and accept the relevance and legitimacy of environmental flow concepts. For the Lower Kihansi and Senegal River cases, this acceptance was assisted by the procedural drivers of a new policy and a new transboundary agreement respectively; for the Bridge River and Berg River cases, the acceptance came about because the benefits of providing downstream flows became more evident as the EFA studies progressed. In fact, in the Bridge River case, the re-operation procedures resulted in increased power generation as well as improved downstream benefits.

Table 9. Major Findings from Project Case Studies

	Recognition	Comprehensiveness	Participation	Assessment Method	Integration	Cost Effective	Influential
Aral Sea	The water needed to restore the NAS was unquestioned by local communities and government although not called ‘environmental flows’.	Flow needs were both those required to refill the NAS and the reduction of floods in upstream areas. However, the hydrograph was not decomposed into components.	Success of NAS recovery partly due to strong engagement by local Aral Sea communities and government.	No EFA carried out or quantitative modeling apart from simple estimates of water balance and levels in NAS.	Social/economic benefits integral to project and not quantified in advance.		Refilling of Northern Aral Sea fishing industry re-established; Lake Sudoche recovery raised interest in other lake restorations
Berg River	After initial reluctance, environmental flows have been strongly supported by government since the National Water Act was passed. Strong community support for environmental flows.	The study considered a range of flow components, including the estuary (although this was not proceeded with).		Initial EFA based on Building Block Methodology, subsequently extended with field studies. Extensive monitoring program integrated with adaptive management.	EFA fully integrated with the EIA during project preparation.	Capital expenditure: $ 6.6-14.9 million	The EFA has been influential in determining the initial operating rules, with further adaptation proposed as data arrives from monitoring program. Yet to be influential outside of the Berg River.
Bridge River	The dam operating authority preferred to maintain the agreed downstream releases, until threat of a court case persuaded them to investigate the downstream ecosystem water needs. Strong community acceptance of the concept of environmental flows for specific species	Originally considered only minimum flows; subsequent study investigated the flows needed for a range of organisms.	Consultative Committee drove the process. Strong engagement and ownership from all sectors, except First Nations.	A systematic method based on multi-criteria decision making was used. The modeling results were couched in terms of agreed indicators that all decision makers understood. Environmental monitoring program integrated with adaptive management.	Separate technical studies integrated intuitively and formally during decision making. Flow modeling combined with water quality modeling.	EFA cost: $600,000 Monitoring and implementation: $520,000 p.a.	More power generation and better environmental outcomes; influenced other Water Use Plans;

	protection.						
Chilika Lagoon	The successful restoration of the lagoon through engineering works blunted interest in establishing environmental flows from Naraj Barrage.	Assessment focused on environmental flows to the lagoon only, but included some water quality aspects.	Institutional stakeholders had little engagement in the environmental flow determination because the engineering work had been successful for the short term. Community stakeholders were consulted as much as their capacity permitted.	Hydraulic and hydrologic modeling combined with ecological outcomes, although formal EFA method was not followed. Lagoon recovery is monitored but not linked to flows from Barrage.	Flow modeling combined with water quality modeling.		
Lower Kihansi Gorge	Water resource institutions rather than environmental institutions took the lead with e-flows. Reluctance by dam operating authority to provide water for downstream ecosystem. Tanzanian government organizations understood relevance of concept and insisted on provision of flows.	Flow needs restricted to the gorge ecosystem but focused on unique mechanism of spray dependence.	No downstream communities. The concerns of the international environmental groups were represented through the Tanzanian environmental organizations.	Extensive fieldwork and experimentation to link flows through Gorge with extent of spray and ecological response. No formal EFA method applicable. Monitoring a critical component - used for enforcement.	No economic benefits; social benefits were integral to outcomes but not quantified.		Stabilization of lower Gorge; improved knowledge of Environmental flows within government; interest in catchment level environmental water plans
Lesotho Highlands	Managers initially persisted with an agreed minimum flow. .	Initial concept was of minimum flows. Subsequent studies using DRIFT were fully comprehensive for in-channel and floodplain watering..	Downstream communities were consulted through the DRIFT process, but their influence on decisions was quite limited.	DRIFT EFA method developed for this project. Also method for presentation of complex results developed.	The DRIFT technique integrates environmental/social /economic outcomes. EFA meant to be integrated with EIA	EFA: $2 million Compensation: $14 million	Downstream environmental health targets met or exceeded; DRIFT technique used more widely

					but delayed. Flow modeling combined with water quality modeling.		
Senegal Basin	Initial reluctance to accept the concept by managers but attitudes changed once the Water Charter was signed.	Includes estuarine delta water needs as well as floodplain and in-channel.	Downstream communities were involved with the assistance of a NGO.	Hydrological models used to predict extent of floodplain inundation. No ecological monitoring conducted.	Separate economic and social studies integrated during decision making with environmental and hydrological modeling. Groundwater and surface water studies integrated.		
Tarim Basin	Water needed to restore the green corridor was unquestioned by government because restoration was their priority.	The flows were confined to those needed to re-establish the Green Corridor. Included ground and surface water modeling of irrigation districts.	WUAs and Irrigation District Committees formed and consulted but not drivers.	No specific EFA technique used; but hydrologic and hydrogeological models used to predict water savings. Monitoring of water use and downstream ecological response was integral to project.	Economic and social benefits were integral to the project but EFA was not carried out. Groundwater and surface water both modeled but not integrated.	Increased agricultural production > cost of water efficiency work.	Increased cropping and improved environmental outcomes

The concept of environmental flows has never been fully accepted by the Water Resources Department and other Orissa State government departments (Chilika lagoon) partly because the benefits to the lagoon were more distant than the immediate benefits from opening a new mouth to the ocean; and partly because the high staff turnover prevented the development of a corporate approach. The World Bank facilitated the EFA, but this was completed after the Bank project was closed. Thus, the Bank was unable to further influence the State government to ensure that its recommendations were incorporated into the Naraj Barrage operating rules.

Box 13. The Tarim Basin Restoration

The Tarim River, in western China, has been increasingly used for irrigated agriculture over the last 50 years to the point where it has ceased to flow in its lower reaches since the 1970s. Lake Taitema, a terminal lake, has not received water from the river for many years. The "green corridor" in the 300km of the river above Lake Taitema has became ecologically stressed, reducing the vegetative barrier to encroachment of the Taklamakan and Kukule Deserts which border the river in that area. The advance of the deserts and the threat that they would link up and sever the transport links was a significant concern to the national government.

The Bank supported Tarim II Project used geomembranes to line the leaky water distribution channels and significantly reduce water losses together with drainage improvements. The saved water was used to both improve agricultural production in the irrigation districts and to return water to the lower reaches of the Tarim River. The project also improved management arrangements for the Basin's water by establishing the Tarim Basin Water Resources Commission. The Commission made it clear that it would enforce the quotas established for irrigation abstractions.

As a result of the project, canal seepage losses have been reduced by between 600 and 800 million m3 per annum; 41,000 ha of new irrigated land was developed; the incomes of farmers have risen substantially; Lake Taitema has increased to 200 km2; and riverine vegetation shown a dramatic improvement.

Sources: *World Bank (1998). Project Appraisal Document: Tarim Basin II Project, China (P046563). World Bank, Washington DC,*
Hou, P., R.J.S. Beeton, R.W. Carter, X.G. Dong and X. Li, (2006) Responses to environmental flows in the lower Tarim River, Xinjiang, China: Groundwater. Journal of Environmental Management, 83(4), 371-382.

Catchment-level water allocation plans provide benchmarks for project-level decisions on water allocations. Difficult decisions about sharing water from infrastructure development can be assisted if there are water policies and laws that define environmental water as a legitimate user of water protected by the force of law or a water allocation plan is in place. Such a plan establishes the agreed distribution of water or benefits from river flows and acts as a benchmark for any re-distributing of benefits from infrastructure. The Lesotho Highlands Water Project would have been simplified if there had been such a plan in existence before the dams were developed.

Environmental flow provisions need to be monitored and enforced. Enforcing environmental flow provisions, like all allocations, requires vigilance. While the Lesotho Highlands

Development Authority has formally agreed to the environmental flow provisions, there has been a lack of understanding and acceptance by operational managers and staff and the agreed environmental flows have not always been released in a timely manner nor in adequate quantities, e.g., important flood releases were not made. Similarly, diligent monitoring by the Rufiji Basin Water Office showed that the environmental flows from the Lower Kihansi dam during the first two years of operation were about 30% less than the flows that the power utility reported it was providing. This became evident after the monitoring system became operational.

Comprehensiveness

The concept that environmental flows are a matter of retaining minimum flows in rivers and estuaries arose in a number of case studies. Examples include:

- the Treaty Minimum flow that was agreed in the 1968 Treaty to build the Lesotho Highlands Water Scheme
- the inclusion of minimum flows in the Mekong Agreement,
- the 1998 proposal from BC Hydro to the Department of Fisheries and Oceans to provide minimum flows, and
- the Senegal Basin Water Charter which specified "minimum flows and other ecosystem services".

However, the EFAs carried out in these and other cases assessed all components of the flow regime and often recommended that a number of flow components (e.g. dry and wet season flows, freshets and occasional large floods) be retained to provide a range of downstream ecosystem services.

EFA studies should consider all downstream dependent ecosystems. A number of case studies included consideration of flows to maintain ecosystem services in estuaries and groundwater systems as well as surface water. Thus, the Chilika EFA was principally focused on flows to the Chilika lagoon. The original environmental flow plans of the OMVS in the Senegal basin did not include provisions for freshwater flows into the delta and estuary of the Senegal River. Once the importance of these flows was realized, the OMVS approved a Water Charter (Box 14) which included the delivery of water to these downstream environmentally sensitive areas, as well as provision of flood flows for the mid-river floodplains and groundwater recharge in the floodplain. The Berg River EFA considered the need for flows to maintain the river's estuary but decided that this was not an important aspect at that time. It has subsequently carried out detailed work on the estuarine reserve. Only the Tarim basin case study included an explicit consideration of the effects of returning water to the environment on groundwaters. In the Senegal case, the groundwater recharge was a secondary benefit.

Box 14. The Senegal Basin Water Charter

In May 2002, the Governments of Mali, Senegal and Mauritania signed a Water Charter. The objective of the Charter is to "provide for efficient allocation of the waters of the Senegal River among many different sectors, such as domestic uses, urban and water supply, irrigation and agriculture, hydropower production, navigation, fisheries, while paying attention to minimum stream flows and other ecosystem services". The Charter guarantees an annual artificial flooding (Article 14) and minimal environmental flows (Article 6), except under extra-ordinary circumstances.

The Charter contains the principles and procedures for the allocation of water and establishes a Permanent Water Commission (PWC) to serve as an advisory body to the OMVS's Council of Ministers.

The Water Charter extended stakeholder involvement within the Senegal basin to include farmers and NGOs. Further stakeholder participation was stimulated by the GEF project, which included participation in its design and implementation. Now local coordination committees exist throughout all countries of the basin.

Source: World Bank, 2006. Project Appraisal Document. Senegal River Basin Water Resources Development Project. Washington, DC

None of these project EFAs considered the effects of climate change on the flows needed to maintain downstream ecosystem services.

Participation

While the involvement of stakeholders was always central to achieving successful environmental flow outcomes, the methods employed and the responsibility assigned need to be tailored to suit local circumstances. The Bridge River EFA was at one extreme where the Consultative Committee drove the EFA process with BC Hydro providing the secretariat; at the other extreme, the irrigators in the Tarim Basin were involved through their WUAs and Irrigation District Committees but the real decision making authority resided with government departments and the national government. However, both projects resulted in successful environmental and production outcomes. The restoration of the Northern Aral Sea provides another instructive example. Although the World Bank project included a component for a Basin Consultative Group in the Syr Darya Control and Northern Aral Sea project, the Group was never formed because of the difficulties in developing this group across the five countries of the basin. Nevertheless, the communities directly affected by the shrinking of the Northern Aral Sea were highly motivated to engage in the project and provide assistance.

Stakeholder engagement mechanisms need to be designed around the capacity of communities to engage in decision making. The project where the EFA studies have not yet been influential, the restoration of Chilika Lagoon, was an example where institutional stakeholders were not engaged with the process. The Stakeholder Executive Committee was not formed until late in the project and the institutions, generally, did not engage in the EFA process. Nevertheless, local communities around the lagoon were consulted and did provide feedback of value to the EFA team although their ability to comment on the technical options was very limited. Similarly, the affected communities in the Lesotho Highlands and the Senegal River Valley were limited by their understanding of the technical aspects of the assessment. In the former case, the lack of policy in Lesotho hampered the participatory process – there was no guidance on the role expected of the communities or the extent of consultation. There was a tendency for the LHDA to inform these communities rather than listen to their requirements.

Finally, the Lower Kihansi EFA provides a unique example where there were no downstream communities directly affected by the change in river flows. The affected stakeholders were the international community who, through the Biodiversity Convention, has expressed the objective of protecting endangered species and ecosystems. These stakeholders were represented in the decision making by the appropriate river basin and environmental organizations and also by international NGOs who had originally raised the alarm over the loss of the downstream ecosystem.

Assessment method and data

Information is of little value if it is not couched in terms that the audience can understand. One lesson emerging from the Lesotho Highlands project is that the results of the scientific studies within the EFA must be comprehensible to managers who are faced with deciding on the allocation of water to the different water uses. In that example, the scientists undertaking the EFA devised a simple, understandable system for conveying the downstream consequences of different flow scenarios. Similarly, the information provided to stakeholders needs to be in a form that is understandable. In the case of the Berg River EFA, the language used by ecologists and other scientists was found to be a barrier to understanding the implications of different options. For this reason, the results of the scientific investigations in the Bridge River studies were couched in terms of the performance indicators for seven outcomes that had been agreed by the Consultative Committee (Box 15).

Box 15. Structured Assessment for the Bridge River Re-Operation, Canada

The members on the Consultative Committee charged with developing the re-operation plan for the dams on the Bridge River came from a wide range of backgrounds. In order to work together effectively, they followed a systematic approach that consisted of six key steps, and was based on multi-attribute techniques and value focused thinking[50].

The steps begin with clear articulation of objectives. Performance measures were developed that describe the extent to which each alternative operating regime contributed to or detracted from each objective. Usually quantitative, the performance measures force specificity to the objectives, better educate each participant on the needs of others and create a basis on which to collect decision-focused information.

The following objectives were agreed for the Bridge River Water Use Plan:

- Fisheries: maximize the abundance and diversity of fish
- Wildlife: maximize the area and productivity of wetland and riparian habitat.
- Recreation and Tourism: maximize the quality of recreation and tourism experience
- Power: maximize the value of the power produced
- Flood Management: minimize adverse effects of flooding on personal safety or property
- Dam Safety: ensure that facility operations meet requirements of BC Hydro's Dam Safety Program
- Water Supply/Quality: preserve access to and maintain the quality of water.

In total, more than 20 alternatives were run through BC Hydro's operations model and the consequences for each objective were discussed by the Consultative Committee against the agreed performance measures. Preferences and values were documented and areas of agreement sought. The CC members eventually agreed upon a single recommended operating alternative.

Source: Bridge River Water Use Plan - Case Study 12. This report.

[50] Keeney, R. (1992). Value-Focused Thinking. Harvard University Press, Boston.

Environmental flow monitoring programs need to assess the ecological outcomes, not just the flows themselves. Only some of the EFAs included monitoring components. Whether for rehabilitation/restoration cases or for new infrastructure, monitoring programs should be focused on ecological and social outcomes. Thus, the Bridge River monitoring program assesses whether the downstream ecological outcomes (fish recovery, etc) are achieved; the monitoring program in the Tarim Basin has assessed not only the adherence to the water abstraction quotas but also the extent to which the downstream riparian areas have recovered; the Lower Kihansi monitoring program not only checks whether the agreed bypass flows have been provided but also the extent to which the Gorge ecosystem has recovered; and a monitoring program has been established in the Berg River since 2002 to provide a baseline against which the effects of the new dam can be measured (Box 16). However, the Senegal Basin does not appear to have an ecological monitoring program; the Chilka lagoon monitoring program is not designed to distinguish the effects of any environmental flows from other influences; and the Aral Sea monitoring program, established as part of the Syr Darya Control and Northern Aral Sea project, will require trained staff in the newly formed Kazakhstan Ministry of Natural Resources and Environmental Protection before it will be effective.

Box 16. Monitoring Program for the Berg River Dam, South Africa

The Record of Decision (RoD) for the Berg River dam in South Africa required a detailed monitoring program to be established to provide the basis for an adaptive management framework implementing the ecological reserve. Thus, the RoD required sufficient baseline information to be collected prior completion of the dam to assess the effectiveness of the environmental flows. The environmental flows will be revised if the monitoring demonstrates that the dam has an unacceptable ecological affect on the river or estuary.

The baseline monitoring programme, initiated in 2002, included eight specialist studies for the riverine environment, nine specialist studies for the estuary and a series of general catchment reports that included groundwater elements. The aim was to monitor the effects of the flow regime downstream of the dam. Data collection was completed in 2005 and a conceptual model was developed for determining and managing changes brought about by the dam. The programme focused on the flow regime and the physical, chemical and biological characteristics that the environmental flow is intended to support.

This comprehensive monitoring provides the baseline against which the project's environmental allocations are assessed and will be used to establish a comprehensive Reserve for both the river and the estuary. The issue of appropriate flood releases is now under discussion in the light of advances in environmental flow assessment methodologies, the information available from the three-year baseline monitoring programme, and concerns over water quality, especially salinity.

It is an example of best practice in environmental monitoring being used for adaptive management.

Source: *Berg River Water Project - Case Study 11. This report.*

Integration

Although arguments for environmental flows usually rest on equity considerations, there can also be valuable economic benefits from the provision of environmental flows. Such a study was undertaken in the Senegal Basin where an analysis showed the high economic value of the floodplain. This had not been appreciated by senior decision makers in the Senegal Basin countries and was instrumental in the agreement to permit flood releases from Manantali dam. In the case of the Lesotho Highlands Power Project, the benefits of different flow scenarios to downstream communities as well as the income lost from other uses of the water, were quantified in an economic study. Even though the downstream benefits were considerably less than the lost income, these economic arguments played a role in showing that there were real economic benefits from releasing environmental flows. The Berg River case study provides another example of the benefits of undertaking a full economic analysis of the value of water and the services that it supports.

EFAs are yet to be adopted as a mainstream part of EIA procedures for infrastructure assessment. The proposed Berg River dam is the only example amongst the project case studies where the EFA was combined with the project EIA during the feasibility study. Although this is a sign that EFAs are being mainstreamed into project assessment, this integration remains a goal yet to be fully achieved in most projects. The LHWP EFA was also a part of the project EIA but was only completed after project appraisal because of the need to proceed rapidly to Phase 1B of the project in order to retain the workforce from Phase 1A and avoid startup costs. In hindsight the goodwill of the Bank in agreeing to this accelerated commencement of Phase 1B had consequences on the subsequent decision making process.

Cost effective

The evidence, while quite limited, is that EFAs are often a relatively small cost of new infrastructure developments. These costs of EFAs for infrastructure projects can be divided into four components:

1. the cost of undertaking the EFA
2. the cost of compensation for affected downstream communities
3. the cost of modifying the infrastructure (for rehabilitation cases)
4. the cost of ongoing monitoring and enforcement.

There is little information available on these costs. The best information comes from the Lesotho Highlands Development Project where the EFA (for Phase 1 structures that have now been completed and for Phase 2 dam that has yet to be designed) was estimated to cost US$2 million (0.07% of project costs) and the compensation is estimated to cost US$14 million (0.5% of project costs).

The Bridge River EFA cost approximately US$650,000 and the on-going monitoring is estimated to cost about US$550,000 p.a. These cost, while substantial, are considerably less than the legal costs that BC Hydro would have faced if it had elected to maintain its stance that it was not responsible for uses of the water other than hydropower production, and it would not have benefited from the improved hydropower production that resulted from the new operating rules.

Data on the cost of the Berg River EFA are not available. However, an economic study estimated that the cost of water released for downstream environmental purposes would be substantial. With no environmental flows, it would be 5.09 years until an additional water supply scheme would be required for Cape Town; with ‘drought relief’ environmental flow releases, this would reduce to 4.9 years and would require an additional capital expenditure of US$6.6 million; with a ‘full maintenance’ environmental flow rule, the time to a new water supply scheme would reduce to 3.6 years and the capital cost of providing the flows would be US$14.9 million.

While there are no specific costs available for the environmental component of the Tarim II project, it is reported that the financial benefits from the improved agricultural production, alone, were greater than the cost of the Tarim II project (US$90million) without including the benefits from the recovery of the lower Tarim River.

It can be very expensive to retrofit existing infrastructure to provide environmental flows. The Lower Kihansi Environmental Management Project was essentially a project to restore a heavily stressed ecosystem to recover from not undertaking and implementing an EFA when the dam was first built. While some of the cost of this project would have been incurred if the EFA had been undertaken originally, much of the $11 million can be attributed to the restoration effort that resulted from inadequate environmental flow provisions. In another example, the outlet structures at both the Katse (after dam was constructed) and Mohale dams (during dam design) in the Lesotho Highlands Water Project had to be modified at considerable cost to be able to provide the agreed environmental flows.

Influential

Environmental flows can lead to more efficient water use and benefits to both environmental and consumptive water users. There were a number of win-win examples amongst the rehabilitation case studies. The re-operation rules for the Bridge River dams in Canada resulted in more power being generated as well as better delivery of water to downstream environments. The Tarim Basin upgrades, similarly, resulted in an increase in crop production as well as significantly increased flows to the downstream riverine environments. And the rehabilitation of the dams on the Syr Darya together with improved operating procedures meant that the environment of the Aral Sea as well as the fisheries industry have partially recovered while more power has been generated from the hydropower dams and flooding has been reduced in upstream areas.

Environmental monitoring of environmental flows is essential for establishing baselines, enforcement reasons, and for adaptive management. The monitoring program was established in the Berg River in 2002 in order to provide a number of years of baseline information against which the effects of the new dam can be measured. The under-reporting of flow releases from the Lower Kihansi dam was only detected because of an independent monitoring program conducted by the Rufiji Basin Water Office, and the quotas on water abstraction were only adhered to in the Tarim Basin irrigation districts because of the monitoring and enforcement program.

Because the ecological response was uncertain in parts of the river downstream of dams in the Bridge River, the environmental flow plan required an adaptive management approach. The expected ecological response would be monitored under different flow release patterns and the dam operating procedures would be modified after 2012 to employ the most effective release patterns. The monitoring program instituted as part of the environmental water releases in the Lesotho Highlands Water Project show that the river health targets have been met or exceeded except in two reaches where there are problems with an endangered fish species (Table 10).

Table 10. Lesotho Highlands River Condition Target Monitoring Results[51]

Reach	Targeted River Condition Target	Measured River Condition Target	Measured Relative to Target
Reach 1	3	3	On Target
Reach 2	4	3	Better
Reach 3	4	2-3	Better
Reach 4	3	2	Better
Reach 5	2	2	On Target
Reach 6	2	3	Worse
Reach 7	4	3-4	Better
Reach 9	2	3	Worse

Successful environmental flow studies can have wider influence. Thus, the recovery of Lake Sudoche has give the government of Uzbekistan the confidence to use environmental flows for the recovery of other degraded lakes; the partial recovery of the Northern Aral Sea has led the government of Kazakhstan to consider rehabilitating other impacted waterbodies; the procedures used to develop improved operations at the Bridge River hydropower dams have influenced other Water Use Plans in British Columbia; and the DRIFT method, developed during the Lesotho Highlands EFA, has now been applied in a number of other countries.

Institutional Drivers

Public concerns were a significant driver for rehabilitation and re-operation projects. The restorations of the Aral Sea, Lake Sudoche, and the Green Corridor of the Tarim Basin (Table 11) had the potential for providing such obvious ecosystem benefits to downstream people that the water needed for restoration was regarded as social and economic flows rather than environmental flows. In the case of the Senegal River basin, there were clear benefits to the mid-river and lower river populations from maintaining some level of annual flood flows below Manantali Dam and, although initially restricted in having their voices heard, these populations were assisted by NGOs to make their case. Although not a primary motivator, the rise in public concern about environmental degradation and threats to native fish was an important background driver leading to the re-operations of the dams on the Bridge River, Canada.

[51] Watson P.L. (2006). Managing the River as well as the Dam. Designing and Implementing an Environmental Flow Policy. Lessons Learned from the Lesotho Highlands Water Project. World Bank, Washington D.C.

When the loss of ecosystem services is clearly apparent, there is no dispute about re-establishing environmental flows. The governments involved with two of the most effective restoration projects, the Aral Sea and the Tarim Basin, had internalized environmental flows to the point where restoring flows to downstream areas were the major objectives of the projects. This can be contrasted with the Mekong Basin case study where the term "environmental flows" was seen by some countries as a potential impediment to development.

Judicial drivers are seldom influential. The Bridge River case study provides the only example amongst the case studies where a judicial driver has been one of the drivers for undertaking an EFA. In this case, it was the threat of being taken to court by a federal agency that motivated BC Hydro to voluntarily undertake a review of their operating rules to improve downstream environmental outcomes. This is the only example amongst the case studies where the operating authority had elected to voluntarily undertake an EFA.

Procedural drivers support initiatives underway. In two of the cases – Chilika lagoon and Tarim basin – the State Water Plan and legislation were (respectively) consistent but not influential in initiating and implementing the EFAs. In other cases – Berg River, Kihansi Gorge, and Senegal River – the procedural drivers provided supportive backing for EFA initiatives that were already underway.

NGOs can play a valuable role in bringing the need for environmental flows to public and government attention. NGOs contributed to the initiation of EFAs in a number of cases but were a primary driving force only in the Lower Kihansi project where their pressure accelerated the response of both the Tanzanian government and the World Bank to restore the threatened ecosystem. The Rufiji Basin Water Office became, perhaps, the most important institution for implementing the environmental flows. It was central to negotiating the agreed bypass flows as part of the final water right and for monitoring and enforcing the conditions of the water right.

The need to address downstream issues, including through the use of EFAs, when assessing large infrastructure projects needs to more fully recognized and addressed in the planning and conduct of feasibility studies and EIAs. For new infrastructure, it is notable that in several cases the EIAs did not give adequate attention to downstream environmental flow issues when the projects were initially approved in a number of instances. This occurred with the Power VI project (Kihansi Gorge) where it was assumed that there were no sensitive downstream ecosystems; the Lesotho Highlands Water project where it was assumed that a nominal minimum flow included in the transboundary agreement would meet downstream needs; and the Tarim basin project where the Tarim I project improved the management of the upstream irrigation districts but did not improve flows to rehabilitate the downstream Green Corridor. This was also the case in the Manantali Dam on the Senegal River did not adequately consider downstream impacts. In all cases, follow up interventions were needed to rectify issues that emerged.

Table 11. Drivers for new infrastructure and restoration projects

	Judicial	Procedural	Evaluative	Instrumental	Professional	Public
New infrastructure						
Berg River		After 1998 the National Water Act provided a legislative driver for the conduct and implementation of the flow assessment.			At an early stage, scientific groups advocated the inclusion of environmental flows in planning for the dam.	Public awareness of the Cape Floral Kingdom acted as a backdrop to discussions about effects of the dam.
Chilika Lagoon		State Water Plan gave legitimacy to environmental flows but was not a specific driver.		The World Bank required an EFA as part of the loan to reconstruct Naraj Barrage but the recommendations are yet to be implemented.		Pressure from lagoon communities to manage flooding and restore lagoon ecosystems was an indirect pressure to provide environmental flows.
Lower Kihansi Gorge			The Rufiji River Basin Office became an evaluator of implementation.	Field based review by Government and World Bank provided basis for restoration program.		International NGOs place considerable pressure on the Tanzanian government and World Bank to maintain the threatened ecosystem
Lesotho Highlands Water Project				The World Bank safeguards initially did not include EFs into Phase 1A EIA; subsequently, they were the major driver for Phase 1B	The South African experience and requirements acted as an indirect professional driver.	
Rehabilitation and Re-Operation						
Aral Sea						Local communities were major drivers. Extensive NGO publicity about degradation provided

						pressure for international action.
Bridge River	Threat of legal action by federal Department drove BC Hydro to develop an environmental flow investigation.		External review of power generation called for Water User Plans.			Public concerns over the health of salmon stocks. Environmental groups were advocating flow management.
Senegal River		The Senegal Water Charter, when passed, contained clauses to provide downstream flows.		Word Bank became engaged late in projected implementation when it provided funding for turbines.		NGO studies showed importance of restoring floodplains.
Tarim Basin		National water law supportive but was not a driver.			Main driver was government priority to protect downstream transport.	

IV. MAINSTREAMING IMPLICATIONS

Chapter 8. Achievements and Challenges

> The World Bank response to environmental flows has both been shaped by, and has contributed to, global good practice. It has assisted one country (Tanzania) introduce environmental flows into its water policy reforms, contributed to the introduction of environmental flows concepts in the Mekong Basin, and has introduced environmental flow concepts into a number of other countries through the BNWPP Environmental Flow window. The Bank has also helped establish environmental flows in the Senegal River basin. However, its major contribution to global good practice comes from its restoration of the degraded Tarim Basin and Northern Aral Sea and its assistance in the Lesotho Highlands Water Project. Current challenges faced by both the Bank and the environmental flows practitioners include incorporating the whole water cycle into the assessments; extending EFAs to include activities that intercept overland flows; including climate change in the assessments; more effectively integrating environmental flow assessments into project and strategic EA; and understanding the circumstances when benefit sharing is a viable approach.

Environmental Flows Achievements

Environmental flows work within the World Bank is both shaped by the evolving global EF knowledge, practice and implementation and also helps shape the repository of global knowledge and experience on environmental flows.

Providing water for the environment has now been institutionalized and mainstreamed in an increasing number of developed countries such as Australia, New Zealand, the United States and the countries of the EU. In these countries the period of major water resources infrastructure development is now over (although the need to adapt to climate change may lead to a renewed interest in infrastructure investment) and the focus has been on the rollout of basin or catchment level water allocation plans that include environmental water provisions. South Africa, a country with an economy in transition, is also preparing to rollout catchment water resources plans. In all these countries, there is now broad acceptance of the importance of protecting the aquatic environment and general support for environmental water provisions in the water allocation plans.

In these countries, the focus of environmental flow assessments has continued to broaden beyond provision of water to rivers and associated wetlands, to include other hydrologic components including estuaries and near-shore areas, and linked groundwater systems. However, there is not yet the same level of expertise and depth of experience in assessing the environmental water requirements for these new areas as there is for downstream river systems.

In developing countries, on the other hand[52], there has been a greater focus on the assessment of the downstream impacts of new infrastructure or the restoration of downstream aquatic ecosystems that have been degraded from existing infrastructure. While the World Bank has not had much experience in major basin water allocation planning programs, it has been a partner in some of the more notable achievements in ecosystem restoration in developing countries such as China (Tarim), the Senegal Basin, and Central Asia (Northern Aral Sea).

The science of environmental flows has advanced considerably in the last 20 years from a focus on individual aquatic species (although there are circumstances where this continues to be relevant) to a much broader concern about ecosystem protection or restoration. A wide range of scientifically credible assessment methods are now available – from simple desktop approaches to complex, field-based holistic methods - with considerable experience to back up many of them. Some of the holistic methods combine hydrologic and environmental science with social and economic assessments. There is now experience in organizing multi-disciplinary teams to carry out these holistic assessments.

International development organizations and NGOs have been active in promoting a understanding of environmental flows in developing countries, holding training courses, providing assistance in conducting EFAs, and developing support material and information sources. The World Bank has also contributed to this richer information environment through its BNWPP Environmental Flows window and the development of support documentation that has been distributed widely.

Science Achievements

Understanding Environmental Flows

Over the last 15 years hydrology and aquatic ecology has advanced considerably so that there is now a much better understanding of the dependence of both species and ecosystems on flows in freshwater systems, and a broadly agreed conceptualization amongst scientists of the way to parameterize riverine flows in an ecologically meaningful way.

The ecological response of wetlands and floodplains to different flow regimes is now quite well known in many parts of the world; there is an increasing understanding of the flow needs of in-stream species (especially fish and invertebrates); the effects of disturbances on foodwebs is increasingly well understood; and the effects of different flow regimes on substrate and physical habitat is improving. However, these and other advances in knowledge are usually limited to the local regions where the scientific

[52] There are exceptions such as Tanzania which is embarking on a basin water allocation planning program including environmental flow provisions.

information was collected and it remains difficult to develop useful generalizations that can be applied more widely.

However, the same level of understanding of ecological responses is not yet available in the new areas where EFAs are being applied such as linked groundwater systems, estuaries and near-shore areas.

Hydrological science has advanced to the point where there are a wide range of river system models available (although the accuracy of these model predictions is almost always limited by the absence of good flow data) that can provide ecologically useful flow predictions. Hydraulic models can provide estimates of levels and flow velocities and the first generation of floodplain hydraulic models are available that can predict the extent (and sometimes duration) of floodplain wetting. However, these need accurate floodplain

EFAs require the integration of information from a range of scientific disciplines – hydrology, ecology, geomorphology, and hydrogeology. In some cases, this integration includes information from the economic and social sciences. There has been increasing experience in forming teams of scientists and experts from these different disciplines that can work together in spite of different terminologies, approaches and scientific cultures.

Development of Environmental Flow Assessment Methods

Over the last 15 years, there has been s a considerable body of experience developed in applications of the extensive range of EFA techniques to impacts of individual projects as well as basin-wide studies. This experience is available through publications[53], and a website[54]. Much support material has now been produced for environmental flow applications including technical documents, a newsletter, webpages, and a periodic conference on environmental flows methods and applications. There is sufficient understanding in their strengths and weaknesses to be able to customize the techniques to suit each application. This customization is illustrated in the Mekong Basin and Pangani case studies (Case Studies 7 and 8).

Current Challenges

Terminology. The misperceptions that arise from the term “environmental flows” can lead to a rejection of environmental flow assessments by managers. While it would be helpful to adopt a new term, such as “social flows” or “environmental and social flows”, the reality is that “environmental flows” is now so widely used that it would be very difficult to get acceptance for a new term.

Incorporating non-riverine impacts. EFA techniques have been primarily developed to assess the effects of changes in river flows on ecosystem services. The techniques need

[53] E.g. Postel S. and B. Richter (2003). Rivers of life: Managing water for people and nature. Island Press, Washington D.C.
[54] http://dw.iwmi.org/ehdb/wetland/index.asp

to be extended to include impacts on lakes[55], groundwater, estuaries and near-shore systems. While these water bodies have been included in some EFA assessments, including in some of the present case studies, there is not yet a systematic procedure for integrating these non-riverine components of the hydrologic cycle in EFAs.

Interceptions of overland flow and groundwater recharge. The impacts of land use changes and land management activities on river flows and groundwater systems is still not properly integrated into EFAs. There are some useful empirical relationships[56] that can be used to estimate the annual average interceptions of water by land use changes but there is still insufficient information available to make detailed assessments of the downstream environmental impacts of these activities.

Environmental water allocations in the face of climate change. The ecosystem services that people rely on will be affected by the changes in flow volumes and timings induced by climate change in complex ways that are not yet properly understood (Box 17). In addition, there will be climate change influences on water demand for irrigation, industry and municipal water use. These shifts in location, quantity, timing and sources of water demand will have implications for providing water for environmental services.

Environmental assets and ecosystem services will need to be re-assessed under a changed climate. The multiple effects of climate change on environmental flows have yet to be factored into EFAs and water allocation plans in a systematic way.

Box 17. Climate change and evapo-transpiration

The natural assumption is that, with the observed increase in air temperatures attributed to climate change, there would be a corresponding increase in the potential rate of evaporation. However, the evidence is that the atmospheric demand, as measured by pan evaporation, has been decreasing over the past 50 years.

The reason for this counter-intuitive result lies in the fact that evaporation is more sensitive to changes in net radiation, vapour pressure deficit (VPD) of the air, and wind speed than to air temperature. Because vapour pressure has increased with global temperatures, relative humidity has remained about the same. Consequently, pan evaporation is particularly sensitive to wind speed. There has been a reduction in average wind speed reported in the United States, China, India, Thailand, the Tibetan Plateau, New Zealand and Australia and this has been the main driver of the observed decreases in pan evaporation. It is difficult to assess whether these reductions in long term average wind speed are local effects attributable to changes in the immediate environment of the pans (e.g., growing trees or other obstacles progressively obstructing the air flow), or a more regional phenomenon.

[55] Young W.J. (2004). Water Allocation and Environmental Flows in Lake Basin Management. Thematic paper to Lake Basin Management Initiative, International Lake Environment Management Committee, Kusatsu, Japan.
[56] Zhang, L., W. Dawes and G. Walker. (1999). Predicting the effect of vegetation changes on catchment average water balance. Cooperative Research Centre for Catchment Hydrology Technical Report 99/12. Canberra, Australia

Source: Roderick, M. L., L. D. Rotstayn, G. D. Farquhar, and M. T. Hobbins (2007). On the attribution of changing pan evaporation, Geophys. Res. Lett., 34, L1740.

Integrated environmental flow assessments. Where EFAs have been carried out for surface and groundwater resources, the assessments have usually been carried out separately. However, in many cases there are hydrological inter-dependencies between surface and groundwaters and the assessments should be undertaken for the integrated system. Thus, some environmental assets depend on both surface and groundwater at different times of year and the maintenance of the ecosystem services from these assets will require the joint planning of surface and groundwater availability. However, with the current lack of understanding of physical connectivity and, in many cases, social dependence on the joint resource, the assessment of environmental flow needs is usually undertaken separately for surface and groundwater systems.

Environmental Flows and Environmental Assessment. In general, the EIA community has yet to absorb environmental flows into EIA (for project level assessments) and SEA (for more strategic level assessments). Partly this is because EIAs and SEAs were developed by the environment sector, while EFAs were developed within the water resources sector.

Another aspect of this integration is to ensure that water resources and environment policies and legislations are harmonized within countries. The Bank can also contribute to this outcome by promoting harmonization when assisting with policy reforms.

Environmental flows and benefit sharing. Environmental flows are based on the concept of water sharing – that is, the flows in river or groundwater systems should be shared equitably. Upstream infrastructure projects typically generate considerable economic benefits and, in many cases, these benefits accrue to populations that are distant from the water sources.

Benefit sharing provides an alternative approach to water sharing, where the economic benefits from the development project are shared with the affected people both upstream and downstream of the development. However, the circumstances when benefit sharing is a better alternative than water sharing are yet to be studies and understood.

Integrating Environmental Flows into Decisions

Policy achievements

Environmental flow considerations have been incorporated into the water resources policies of a number of countries, as illustrated by the case studies of South Africa, Australia, the EU, Florida and Tanzania in this document. While most of the examples of environmental flow recognition in policy have been, to date, in economically developed countries, there are now an increasing number of developing countries considering the inclusion of environmental flows.

There has been good progress in implementing the policy provisions for environmental flows under the Florida, Australian and South African policies. In Florida, minimum flows and levels have now been established in 237 waterbodies and additional MFLs continue to be established, although not to the originally proposed schedule. In Australia, environmental flow provisions have been incorporated into 148 catchment and groundwater allocation plans, although, as in Florida, these have slipped behind the agreed schedule. South Africa has established interim ecological reserves in all catchments.

The World Bank's main achievement at policy level has been its assistance to the government of Tanzania in the formulation of new water policy and draft legislation and the environment policy, legislation and regulations. These instruments incorporate provisions for environmental flows. The Bank is currently providing technical assistance to Mexico in the revision of its water policy and has identified assistance with policy reform in the China CWRAS. It is also supporting policy dialogue in the energy sector in some Indian states and on water resources in general in Pakistan.

Plan Achievements

Catchment plans with environmental water provisions have now been rolled out across Europe under the Water Framework Directive and across Australia under the water reform agenda, while South Africa and Tanzania are preparing to develop basin-level water resources plans with environmental flow provisions. Although water resources plans are yet to be established in the catchments of the Kruger National Park in South Africa, this region is particularly noteworthy because of its influence both nationally and internationally in the development of understandings and approaches to the inclusion of environmental flow considerations in catchment planning.

The Bank has contributed by assisting with basin-level water resources planning including environmental water allocations in the Mekong Basin and the Senegal Basin. In the former, an international environmental flows expert was introduced to the MRC through BNWPP technical assistance and the World Bank was the implementing agency for the GEF Water Utilization Project which provided assistance for the implementation of the 1995 Mekong Agreement with its environmental flow provisions. In the latter, the Bank provided support for the implementation of the Senegal Basin Water Charter and the provision of environmental water releases following the installation of turbines at Manantali dam.

Infrastructure Projects

There are a growing number of examples where environmental flows have been incorporated into the operations of both new infrastructure and the rehabilitation and re-operation of existing infrastructure.

The revision of the operating rules for the dams on the Bridge River in Canada resulted in both improved environmental outcomes and increased power production. This project was also noteworthy for the responsibility given to the Stakeholder Committee to develop the re-operation rules for the dams, and for the adaptive management plan which included alternative release schedules to determine which provided greatest downstream benefits. In another example, the TNC has established a successful partnership with and the United States Army Corps of Engineer and are reviewing the operating rules at 26 dams in the USA. TNC provides technical guidance on the operations of the various USACE dams.

The EFA carried out for the Berg River dam in South Africa provides a good practice example of EFAs for new infrastructure development. It was the first large water resources infrastructure development project in South Africa to be designed, constructed and operated within the framework of the National Water Act, with provisions for basin human needs and ecological Reserve. It was developed in accordance with the guidelines of the World Commission on Dams. It also illustrates an adaptive approach to the determination of environmental flow requirements from a preliminary assessment carried out as part of pre-feasibility investigations, to a more detailed assessment as part of the feasibility studies, to a series of subsequent workshops and specialist meetings to obtain detailed specialist inputs. A comprehensive determination of the Reserve is expected following finalization of the three-year monitoring program.

The World Bank has been a significant contributor to the growing body of experience in this area, particularly through its ability to extend its support through all stages of project decision making, from initial discussion, through conduct of EFAs, to implementation of the agreed flow regimes, to support for monitoring and enforcement programs. The Bank has also used its convening powers to facilitate discussions and support scientific studies and dialogue to reach agreements between nations over environmental flows, especially in selected transboundary cases. The governments of the Senegal Basin signed the Water Charter in 2002 that included provisions for flows to maintain important downstream ecosystem functions. The operating rules for the Manantali Dam now include water releases to provide artificial floods for parts of the mid-river floodplains. In addition, programmes were implemented to release water through the river embankments to re-inundate the Diawling National Park in the delta using water stored behind the Diama dam near the mouth of the river.

The Bank-supported Lesotho Highlands Water Project has established an Environmental Flow Policy and Procedures for operating the Katse and Mohale dams. This constitutes the first systematic effort by the World Bank to support the development and implementation of downstream mitigation and compensation programs during project development, has been described by an independent audit as being "at the forefront of global practice[57]" (Box 18).

Box 18. Achievements of the Lesotho Highlands Water Project

The DRIFT method for environmental flow assessment was developed and applied during this project by leading South African environmental flow consultants. It is an important contribution to the science of environmental flows. It is the first fully integrative methodology combining environmental, social and economic factors in assessing the impacts of different flow scenarios.

[57] Lesotho Highlands Development Authority (2007) Instream Flow Requirements Audit for Phase 1 Dams of the Lesotho Highlands Water Project. Lesotho Highlands Development Authority, Maseru, Lesotho.

It has now been applied to other environmental flow studies within South Africa and, in modified form, in the Pangani and the Mekong basin studies.

The EFA was carried out thoroughly enough to convince skeptical development authorities of the case for providing for downstream water-dependent communities, including economic studies into the financial effects of providing different levels of environmental flow releases.
The thorough social surveys found that approximately 39,000 people directly and indirectly dependent on water and water related resources would be affected downstream of the dam – many times the original estimate and an order of magnitude higher than the number of people impacted upstream of the dam.

The original minimum flows stipulated under the 1986 Lesotho Highlands Water Project Treaty were increased by a factor of 3 and 4 for the Mohale and Katse dams respectively under the new EF policy for operating the dams as a result of the EFA studies and economic analysis
The Mohale dam outlet valves were re-sized to accommodate the anticipated higher flows, and a new valve was added to Katse dam to accommodate higher EFA releases. Compensation payments have been negotiated for the remaining losses in ecosystem services for downstream communities, using a negotiated formula involving distance from the dam and using the results of the monitoring program.

A monitoring program has been established and early indications are that, under the agreed flow release policy, the river health targets have been met or exceeded in all except two reaches.
The project outcomes included better than predicted ecological impacts, compensation to downstream communities, with little impact on the project's economic rate of return. This best practice work has contributed to improving the political image of a high risk project that has faced 2 inspection panel complaints and major corruption charges.

Source: Watson P.L (2006). Managing the River as well as the Dam. Designing and Implementing an Environmental Flow Policy. Lessons Learned from the Lesotho Highlands Water Project. World Bank, Washington D.C.

The Bank's support for the recovery of the Northern Aral Sea and the Tarim Basin II project have also yielded significant outcomes. The Aral Sea had been widely publicized as an example of an ecosystem that was virtually unrecoverable. However, the rapid recovery of the Northern Aral Sea under the World Banks's Syr Darya Control and Northern Aral Sea Project has shown what can be achieved with adequate funding, strong local and government commitment and strong Bank leadership, and an understanding of technical and operational impediments at upstream infrastructure.

The Tarim River was a severely degraded ecosystem that was imposing considerable costs on local communities and was posing a strategic threat to one of China's major transport routes. With World Bank technical and financial assistance, the Chinese provincial government restored flows to the lower river and Lake Taitema while also increasing agricultural production and incomes in the irrigation districts.

Resource Material and Assistance

International development organizations and NGOs have produced many support documents, websites, databases, training courses and discussion for countries interested in undertaking EFAs for project proposals or for basin plans. The World Bank has contributed to these support materials through its Water Resources and Environment Technical Notes on environmental flows.

The World Bank BNWPP funded environmental flows expert panel has provided assistance to 16 countries through a mixture of training courses, workshops and assistance in introducing and undertaking EFAs. A number of international development organizations and NGOs have run training courses in environmental flows that have been influential, such as the courses run by IUCN in meso-America to develop a network of informed and influential champions for environmental flows.

Chapter 9. Framework for Mainstreaming Environmental Flows

> A four part mainstreaming framework, consisting of increasing Bank capacity; strengthening the use of EFA in project planning, design and operations including environmental assessments; promoting the integration of environmental flows in the policies and plans of developing countries; and expandingbuilding strong collaborative partnerships with international development organizations, NGOs and the private sector will increase the Bank's ability to implement its strategies and action plans that support increased investment in water resources infrastructure and reduce the risk of detrimental environmental impacts that threaten the livelihoods of downstream communities.

Environmental flows are central to supporting sustainable development, sharing benefits and addressing poverty. In some circumstances, environmental flow assessments can also lead to more efficient water use and benefits to both environmental and consumptive water users. Effective integration of environmental flows in decision making is a necessary requirement for promoting environmentally responsible water resources development in the face of changing societal values and reduced water availability under climate change. It is also critical to promoting environmentally responsible climate change adaptation strategies. It should also be an integral part of programs for sharing benefits from water infrastructure development. In order to achieve environmentally sustainable and socially responsible development, *more systematic and timely attention will need to be paid to downstream impacts using scientifically credible EFA methods* as countries, through public and private sector investments, expand their infrastructure, especially dams, in many sectors (for water sup[ply, irrigation, hydropower, flood control and navigation).

The Way Forward

The overall goal of this economic and sector work is *"to help advance the Bank's understanding and integration in operational terms of environmental water allocation into integrated water resources management."* Achieving this goal is essential for supporting the implementation of a number of recent Bank strategies and action plans including the Infrastructure Action Plan, investments in Hydropower, the Agriculture Water Management Initiative, the Water Supply and Sanitation Business Plan and the Strategic Framework for Climate Change and Development in an environmentally responsible manner, consistent with the SDN vision to mainstream environment in World Bank operations.

The preceding chapters demonstrate how central environmental flows are to IWRM, how they will be affected by climate change impacts, and how they are central to climate change adaptation responses in the water sector. They highlight the evolving understanding of, knowledge about, and the integration of, environmental flows into water resources decision making at the policy, plan and project levels within and outside the Bank. They also illustrate the complexities and challenges associated with implementation of EFA across a wide spectrum of management decisions that cover many sectoral uses of water and span many parts of the world

There is a growing body of experience in implementing environmental flows, including monitoring and adaptation of management procedures. Chapter 5, 6 and 7 summarized lessons from the integration of environmental flows in the formulation and implementation of water policies, river basin/catchment plans, and design and operations of infrastructure development and rehabilitation projects.

The earlier chapters also provide indicators of the direction that the Bank and its clients need to take to support better integration of environmental flows in policy reforms, river basin plans and infrastructure investment planning, design and operations. *A key lesson is the high financial, social, economic, reputational and political costs associated with not undertaking (or undertaking late) a thorough EFA when projects are being prepared*. The evidence, while limited, is that EFAs often are a relatively small cost of new infrastructure developments, whereas the cost of retrofitting existing infrastructure to increase the capacity and provide the flexibility for environmental flows can be very expensive.

Another important lesson concerns the critical links between environmental flows and riverine community livelihoods that are underscored by two African case studies (Senegal Basin and the Lesotho Highlands Water Project). In the former, the ~~Bank supported the~~ Water Charter signed by the Governments of Mali, Senegal and Mauritania ~~which~~ gave recognition to the provision of flows to water the mid-river floodplain and ensured the maintenance of agricultural and fishing activities.

The latter case (LHWP)~~study~~ broke important new ground in a number of important ways not only in supporting the development and application of a state of the art EFA methodology, but also in applying a well structured approach that links resource losses associated with reduced river flows to community livelihoods and addressing social impacts related to environmental flows. In the absence of any known clearly defined methods, procedures and guidelines globally for addressing downstream social impacts of dams, the LHWP environmental flow experience offers important lessons for:

- Understanding how different downstream social impacts are from upstream social impacts,
- Recognizing the difference in magnitude in the numbers of people that can be impacted downstream of the dams (about 39,000) compared to upstream of the dam (around 4,000),
- Developing an approach for systematically defining the impacted communities (or "the population at risk") downstream of dams,

- Delineating the downstream socioeconomic impacts associated with changes in river flows,
- Defining approaches for addressing and mitigating the social impacts associated with significant changes in river flows and their limitations (in addressing impacts in proximal reaches versus distal reaches), and
- The challenges of developing and implementing a successful environmental flow policy for operating new dams.

The successful EFA work in project implementation (illustrated from the various policy, plan and project case studies) was a result of strong leadership by individual TTLs and other factors instead of formal requirements or formal directions for initiatives related to integrating environmental flows or restoration of degraded ecosystems. *Mainstreaming EFA in water resources decision making (under a better business model) will however require a fundamental shift by the Bank from an ad hoc approach to an institutionalized approach – that is more structured, systematic and timely – to support the integration of EFA into Bank water resources infrastructure planning, design and operations and policy dialogue.*

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There are also clear lessons from the directions taken by countries such as Australia, South Africa and the countries of the EU that the Bank can learn from as it moves forward to support implementation of the SDN vision:

- environmental flow considerations need to be moved up to the more strategic levels of policy and basin plans to ensure that there is a strong basis for environmental water allocations
- Where possible, environmental flow considerations should be integrated with existing IWRM and EA processes, such as the development of basin level water resources plans
- environmental flows should be concerned with any development activities, including land use changes, that affect flow regimes with consequences for downstream ecosystems and dependent communities
- the full range of downstream aquatic ecosystems, including estuaries and near shore areas, should be included in EFAs
- environmental flow assessments should integrate surface and groundwater requirements where there are linked systems
- climate change effects - through changes in water availability, changes in environmental assets, and changes in demand patterns - will be an important consideration in including environmental flows in policies, making provisions in basin/catchment plans, and assessing project-level impacts.

Finally, there are a number of international development organizations and NGOs that have accumulated considerable expertise in undertaking EFAs and providing training and other support to developing countries. Their experience can complement the Bank's ability to convene development partners and work with developing countries throughout the full decision making process.

A Framework for Bank Action

Strengthen Bank Capacity

- Promote the development of a common understanding across the water and environmental communities about the concepts, methods and good practices related to environmental flows, including the need to incorporate EFAs into Environmental Assessment at both project (EIAs) and strategic (SEAs) levels; and
- Build the Bank's in-house capacity in EFA by broadening the pool of ecologists, social scientists, and environmental and water specialists trained in EFA.

Strengthen Environmental Flows Assessments in Project Lending

- More broadly disseminate existing guidance material (from within and outside the Bank) concerning the use of EFA in program and project settings and conduct training for Bank and borrower staff on this emerging issue;
- Identify settings, approaches and methods for the selected application of EFA in the preparation and implementation of project level feasibility studies and SEAs/EIAs as part of the planning and supervision process;
- Prepare an EA Sourcebook Update concerning the use of EFAs in SEA and EIA;
- Prepare a technical note that defines a methodology for addressing downstream social impacts of water resources infrastructure project;
- Test the application of EFAs to include infrastructure other than dams (such as levees and dykes for flood protection and excessive groundwater pumping) that can affect river flows, as well as non-infrastructure activities such as investments in large scale land use change and their effects on downstream flows and ecosystem services;
- Broaden the concept of environmental flows for appropriate pilot projects to include all affected downstream ecosystems including groundwater systems, lakes, estuaries and coastal regions; and
- Develop support material for Bank staff and counterparts in borrowing countries, such as case studies, training material, technical notes, and analyses of effectiveness.

Promote integration of environmental flows at policy and planning levels

- Promote basin/catchment plans that include environmental flow allocations, where relevant, through country dialogue;
- Use CASs and CWRASs to promote Bank assistance with basin/catchment planning and water policy reform so that the benefits of environmental water allocations for poverty alleviation and the achievement of the MDGs are integrated into country assistance;
- Test the use of environmental flow assessments in a small sample of sectoral adjustment lending operations, including where the sectoral changes will lead to large-scale land use conversion;
- Promote the harmonization of sectoral policies with environmental flows concepts in developing countries and the understanding of sectoral institutions about the

importance of considering the impact of their policies on downstream communities;

- Develop support material for Bank staff on the inclusion of environmental flows into basin and catchment planning and into water resources policy and legislation reforms; and
- Draw lessons from developed countries which have experience in environmental flows in catchment planning.

ExpandDevelop collaborative relationships

- Expand collaboration with NGOs (IUCN, WWF, TNC, NHI and others) and international organizations (UNEP, Ramsar Secretariat, IWMI and UNESCO) to take advantage of their experience in conducting EFAs and building environmental flows capacity in developing countries;
- StrengthenDevelop collaborative relationships with industry associations, such as IHA and private sector financing, to extend their current recognition of environmental flows as desirable hydrological outcomes to include the social and economic outcomes that result from the ecosystem services delivered by the downstream flows; and
- Lessons from the ESW would be integrated into and the activities outlined above would be coordinated with ongoing initiative of SDV and the Water Anchor for enhancing benefits to local communities from hydropower projects.

By adopting this framework, the Bank will be better placed to fulfill its strategy of increased investment in water resources infrastructure using a new business model that includes better consideration of the environmental, social and economic impacts of the investment.

Table 11. A Framework for Adopting and Integrating Environmental Flows into Bank Work

Outcome	Decision level	Bank Instrument	Support Material	Collaboration
Integrate EFA into planning studies for infrastructure including EIA and SEA.	New investment programs and projects; rehabilitation/re-operation projects;	Increase focus on downstream biophysical issues in program and project design, making use of existing Technical Notes on EFA.	EA Update on environmental flows; Training material; Other support material including case studies.	Collaborate with experienced international agencies and NGOs; IHA and other relevant industry groups.
Integrate downstream social impacts in infrastructure planning	New investment programs and projects; rehabilitation/re-operation projects;	Increase focus on downstream social issues in program and project design making use Bank experiences in previous projects (e.g., LHWP)	Technical Note on downstream social issues, impacts and mitigation and compensation options; Training material; Other support material including case studies.	Collaborate with SDV on the initiative for enhancing local benefits from hydropower projects.
Broaden application of EFA to non-infrastructure projects	New investment projects	Include environmental flow consideration in CAS and CWAS. Test application of EFA to selected operations of this type.	EA Update on environmental flows; Training material; Other support material.	Draw on experiences in countries where interception activities are assessed for their flow impacts.
Ensure EFAs include all affected downstream ecosystems	Investment and non-investment projects and basin/catchment plans	Increase focus on downstream issues in program and project design making use of existing Technical Notes on the EFA.	Technical documents; training material.	Collaborate with experienced international agencies and NGOs.
Promote inclusion of EFAs into basin and catchment plans	Basin/catchment plans	Include EFAs in proposals for land use plans in CAS and CWRAS.	Technical documents; training material.	Collaborate with experienced international agencies and NGOs.
Promote inclusion of environmental flow considerations in water resources and environment policies	National policy and transboundary agreements	Include downstream ecosystem impacts in proposals for environment and water resources policies in CAS and CWAS.	Technical and analytical documents; training material.	Draw on experiences in countries which have implemented water policies with environmental flow components.
Harmonize sectoral policies with water resources policy	National policy	Include harmonization with water resources and environment policies in proposals for policy reform in CAS.	Technical and analytical documents.	Draw on experiences in countries which have implemented water and other sectoral policies with environmental flow components.

V. APPENDICES

Appendix A: The Brisbane Declaration

Environmental Flows[58] are Essential for Freshwater Ecosystem Health and Human Well-Being

This declaration presents summary findings and a global action agenda that address the urgent need to protect rivers globally, as proclaimed at the 10th International River*symposium* and International Environmental Flows Conference, held in Brisbane, Australia, on 3-6 September 2007. The conference was attended by more than 750 scientists, economists, engineers, resource managers and policy makers from more than 50 countries.

Key findings include:
Freshwater ecosystems are the foundation of our social, cultural, and economic well-being. Healthy freshwater ecosystems – rivers, lakes, floodplains, wetlands, and estuaries – provide clean water, food, fiber, energy and many other benefits that support economies and livelihoods around the world. They are essential to human health and well-being.

Freshwater ecosystems are seriously impaired and continue to degrade at alarming rates. Aquatic species are declining more rapidly than terrestrial and marine species. As freshwater ecosystems degrade, human communities lose important social, cultural, and economic benefits; estuaries lose productivity; invasive plants and animals flourish; and the natural resilience of rivers, lakes, wetlands, and estuaries weakens. The severe cumulative impact is global in scope.

Water flowing to the sea is not wasted. Fresh water that flows into the ocean nourishes estuaries, which provide abundant food supplies, buffer infrastructure against storms and tidal surges, and dilute and evacuate pollutants.

Flow alteration imperils freshwater and estuarine ecosystems. These ecosystems have evolved with, and depend upon, naturally variable flows of high-quality fresh water. Greater attention to environmental flow needs must be exercised when attempting to manage floods; supply water to cities, farms, and industries; generate power; and facilitate navigation, recreation, and drainage.

Environmental flow management provides the water flows needed to sustain freshwater and estuarine ecosystems in coexistence with agriculture, industry, and cities. The goal of environmental flow management is to restore and maintain the socially valued benefits of healthy, resilient freshwater ecosystems through participatory decision making informed by sound science. Ground-water and floodplain management are integral to environmental flow management.

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[58] *Environmental flows* describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.

Climate change intensifies the urgency. Sound environmental flow management hedges against potentially serious and irreversible damage to freshwater ecosystems from climate change impacts by maintaining and enhancing ecosystem resiliency.

Progress has been made, but much more attention is needed. Several governments have instituted innovative water policies that explicitly recognise environmental flow needs. Environmental flow needs are increasingly being considered in water infrastructure development and are being maintained or restored through releases of water from dams, limitations on ground-water and surface-water diversions, and management of land-use practices. Even so, the progress made to date falls far short of the global effort needed to sustain healthy freshwater ecosystems and the economies, livelihoods, and human well-being that depend upon them.

Global Action Agenda

The delegates to the 10th International River*symposium* and Environmental Flows Conference call upon all governments, development banks, donors, river basin organisations, water and energy associations, multilateral and bilateral institutions, community-based organisations, research institutions, and the private sector across the globe to commit to the following actions for restoring and maintaining environmental flows:

Estimate environmental flow needs everywhere immediately. Environmental flow needs are currently unknown for the vast majority of freshwater and estuarine ecosystems. Scientifically credible methodologies quantify the variable – not just minimum – flows needed for each water body by explicitly linking environmental flows to specific ecological functions and social values. Recent advances enable rapid, region-wide, scientifically credible environmental flow assessments.

Integrate environmental flow management into every aspect of land and water management. Environmental flow assessment and management should be a basic requirement of Integrated Water Resource Management (IWRM); environmental impact assessment (EIA); strategic environmental assessment (SEA); infrastructure and industrial development and certification; and land-use, water-use, and energy-production strategies.

Establish institutional frameworks. Consistent integration of environmental flows into land and water management requires laws, regulations, policies and programs that: (1) recognise environmental flows as integral to sustainable water management, (2) establish precautionary limits on allowable depletions and alterations of natural flow, (3) treat ground water and surface water as a single hydrologic resource, and (4) maintain environmental flows across political boundaries.

Integrate water quality management. Minimising and treating wastewater reduces the need to maintain un-naturally high streamflow for dilution purposes. Properly-treated wastewater discharges can be an important source of water for meeting environmental flow needs.

Actively engage all stakeholders. Effective environmental flow management involves all potentially affected parties and relevant stakeholders and considers the full range of human needs and values tied to freshwater ecosystems. Stakeholders suffering losses of ecosystem service benefits should be identified and properly compensated in development schemes.

Implement and enforce environmental flow standards. Expressly limit the depletion and alteration of natural water flows according to physical and legal availability, and accounting for environmental flow needs. Where these needs are uncertain, apply the precautionary principle and base flow standards on best available knowledge. Where flows are already highly altered, utilise management strategies, including water trading, conservation, floodplain restoration, and dam re-operation, to restore environmental flows to appropriate levels.

Identify and conserve a global network of free-flowing rivers. Dams and dry reaches of rivers prevent fish migration and sediment transport, physically limiting the benefits of environmental flows. Protecting high-value river systems from development ensures that environmental flows and hydrological connectivity are maintained from river headwaters to mouths. It is far less costly and more effective to protect ecosystems from degradation than to restore them.

Build capacity. Train experts to scientifically assess environmental flow needs. Empower local communities to participate effectively in water management and policy-making. Improve engineering expertise to incorporate environmental flow management in sustainable water supply, flood management, and hydropower generation.

Learn by doing. Routinely monitor relationships between flow alteration and ecological response before and during environmental flow management, and refine flow provisions accordingly. Present results to all stakeholders and to the global community of environmental flow practitioners.

Appendix B: Infrastructure Design Features for Environmental Flows from Dams

The following description of the physical infrastructure features that are needed to deliver the environmental flows is taken from a recent report to the World Bank[59].

Water Release Infrastructure

Variable Outlet and Turbine-Generator Capacities

The ability of a dam operator to provide a range of flows for downstream environmental purposes is ultimately dependent upon a dam's outlet and turbine-generator capacities. Many hydropower dams lack adequate turbine-generator capacity to make large releases, such as the controlled floods that may be highly desirable for maintaining the ecological health of downstream floodplain ecosystems and estuaries, without sacrificing power generation. Because of these constraints, some fraction of controlled flood discharges must be released through the dam's flood spillway. This sacrifice of power generation causes dam operators to resist such controlled flood releases. This is the situation at the Manantali Dam in the Senegal River basin. At that dam, some 2000 m^3 /sec of water would need to be released to inundate the floodplain to support 50,000 hectares of recessional agricultural production, yet the outlet and turbine-generator capacity is only capable of delivering 480 m^3/sec. The rest of the required flow would need to be released through the spillway, thereby compromising hydropower generation. Necessary structural modifications to expand the powerhouse capacity from 480 to 2000 m^3/sec would be very expensive at this point, but had the powerhouse capacity and reservoir storage tradeoff been optimized in the first place, the economics of providing floodplain inundation would likely have been more favorable.

Ecological problems can also arise when flow releases change rapidly up or down (called "ramping"). Ecologically-damaging ramping occurs when a dam suddenly begins spilling high volumes of water during a flood, or when substantially greater volumes of water are released when additional turbines are activated. This can lead to high mortalities in fish and other animals in the river or on the floodplain or cause undesirable erosion and sedimentation problems downstream. Conversely, when releases from a hydropower dam are being reduced for the purposes of rebuilding water levels (head) in a storage reservoir by shutting down outlets, river flows can be curtailed too abruptly and leave less-mobile animals such as mussels and small fish and their eggs high and dry at the river's edge. Providing a gradation in turbine-generator sizes and reservoir outlets in a dam's design will minimize problems with these flow transitions. Further, construction

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[59] The Nature Conservancy and the Natural Heritage Institute (forthcoming). Integrating Environmental Flows in Hydropower Dam Planning, Design and Operations. Technical Guidance Note. World Bank, Washington D.C.

of ‘re-regulating dams’ downstream of a hydropower dam can catch and partially even out fluctuations by releasing water in run-of-the-river fashion.

When designing the outlet and turbine-generator capacity of a new dam, it is highly desirable to incorporate a wide range of water release capabilities, as well as adequate transmission capacity to convey the electricity, such that the full array of dam operating objectives – ranging from hydropower generation to environmental flow releases – can be accommodated. By providing a range of outlet sizes, such as by incorporating multiple turbine-generator units of varying sizes, dam operators will be able to meet a variety of dam operating objectives.

Multi-level (Selective Withdrawal) Outlet Structures

The water in many reservoirs can become stratified, with considerable differences in water temperature with depth in the reservoir. Water near the bottom of a reservoir may contain very little dissolved oxygen, and this anoxic condition can cause chemical reactions that lead to undesirable water quality conditions in deep water zones. The release of this water with low oxygen levels and undesirable chemicals can create serious problems for fish and other aquatic animals downstream of the dam. Multi-level outlet structures (also called “selective withdrawal” structures) can be constructed to provide dam operators with the flexibility to release water from different reservoir levels, depending upon the time of year, differences in water quality and temperature, and downstream management objectives.

Re-Regulation Reservoirs

The impacts of hydropower generation on natural river flows can be mitigated to some degree by constructing a “re-regulating” dam, usually built immediately downstream of the lowest hydropower dam. The re-regulating dam can be operated to “smooth out” the unnatural fluctuations caused by hydropower operations even while it is generating electricity, releasing water in a pattern much closer to reservoir inflows. The ability of a re-regulating dam to restore natural flow patterns will depend upon the extent to which the upstream hydropower dam has altered them; essentially the same volume of storage capacity is needed to both alter flows at the hydropower dam and to restore flows at the re-regulating dam. If hourly downstream fluctuations are undesirable, a relatively small re-regulating dam below the powerhouse can be a positive asset to hydropower and to the environment by providing a more steady downstream discharge during the day. However, if a large reservoir is being used to reshape the hydrograph over several months, that same storage volume would be needed in the re-regulating reservoir to reshape the hydrograph back to a more natural pattern. The same benefit can be achieved by dedicating the lower-most hydropower dam in a cascade to re-regulate flows, which can be of considerable benefit to the downstream environment.

Other Design Infrastructure

While provision of adequate environmental flow releases will go a long way toward maintaining adequate habitat conditions and ecosystem services in rivers affected by dam development, other ecosystem protection measures may be needed.

Sediment Bypasses and Sluice Gates

Sediment trapping in reservoirs presents serious challenges for water storage by reducing available storage capacity and creating the risk of uncontrolled dam overtopping and collapse. Sediment moving through a reservoir and into hydropower intakes can severely damage turbines and shorten their lifespan.

It may also disrupt geomorphic processes that create high value habitat below the reservoir, especially in watersheds with high sediment production rates. If the water being released from the dam retains sufficient ability to erode the downstream river channel and banks, but sediment is not available from upstream to replace the eroded sediment, considerable channel down-cutting and instability can result, thereby endangering structures such as roads, bridges and levees and altering the physical habitats supporting aquatic life. The loss of sediment supply to downstream deltas and coastal areas can result in considerable erosion of beaches and islands of great importance for people and nature as well.

The implementation of sediment management measures – in the contributing watershed and in the reservoir – can greatly extend the design life of a dam and lead to other economic benefits, such as reducing the costs of maintaining hydropower turbines. Passing sediment around or through a dam can also help alleviate dam-related impacts in the downstream river ecosystem. The World Bank's publication on the RESCON software[60] provides several useful approaches for managing sediment and evaluating the cost-effectiveness of sediment management measures. Some of the approaches discussed in that publication are summarized here.

In addition to providing dead storage to accommodate sediment deposition in a reservoir, new dam designs are including features to move sediment around or through the reservoir. These features are generally of two types. Sediment bypass structures are designed to route sediment inflows into a bypass outlet (a channel upstream of or in a reservoir that bypasses the dam and rejoins the river below the dam) and subsequently discharge sediment and water below the dam, thereby keeping sediment from flowing into hydropower turbines. Sediment flushing involves opening sediment sluice gates or other low-level outlets and lowering reservoir levels to cause water in the reservoir to begin to flow through the reservoir and outlets. This flow needs to attain sufficient velocity to flush the sediments that have accumulated in the reservoir. This type of reservoir flushing entails considerable trade-off with power generation, however, because the reservoir level (head) must be lowered considerably, thereby compromising power generation potential during flushing. It can also complicate environmental flow management due to the fact that reservoir storage must be refilled following sediment flushing, reducing downstream flow releases during refill. Moreover, in large reservoirs, the sediment tends to deposit at the inflow end of the reservoir rather than behind the dam, limiting the ability to flush it through the sluice gates.

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[60] Palmieri, A., F. Shah, G. Annandale, and A. Dinar Reservoir Conservation Volume I: The RESCON Approach, Washington, D.C.: World Bank, 2003.

Fish Passage Structures

Structures such as “fish ladders” have commonly been used to enable fish and other mobile aquatic organisms to move up- and downstream of a dam. However, the higher the dam wall, the harder and more expensive it is to build effective fish passages. Every dam, including those with fish passage structures, is likely to block the passage of some portion of the migratory fish. Each species will have particular design requirements for successful passage. For example, until recently, Australian dam builders constructed ‘horizontal baffle’ fish ladders suitable for jumping salmonid fish (i.e., trout, salmon) imported from the Northern Hemisphere. However, most of Australia’s native fish do not jump and did not use these fish ladders, requiring instead ‘vertical slot’ fish ladders that allow these species to rest in eddies at each step. Aquatic wildlife may migrate along river banks, requiring passages on each side of a barrier, or follow the ‘scent’ of a strong water flow, requiring a strong current to flow from the wildlife passage to attract the animals to the entrance. Rock ramp fishways that mimic natural waterways may be the most effective wildlife passages, whereas at the other end of the spectrum, fish lifts and ‘catch and truck’ operations are likely to assist only a modest portion of the migratory animals. Any dam without wildlife passage is likely to have a severe local impact on species diversity.

Appendix C: Background to Environmental Flows

Defining Environmental Flows

The flows needed to maintain important ecosystem services are termed environmental flows. This report has adopted the following definition, "*Environmental flows are the quality, quantity and timing of water flows required to maintain the components, functions, processes, and resilience of aquatic ecosystems which provide goods and services to people*[61]."

This definition is general enough to include water for both surface and groundwater systems and focuses on the need to maintain downstream ecosystem services valued by people. Water can be provided for environmental outcomes in two broad ways – by specific releases of water from water storages and by restrictions on abstractions from water systems. The former is termed "active management" and the latter is termed "restrictive management"[62]. The former approach is usually only possible for regulated river systems where there are reservoirs holding environmental water allocations[63]; the latter approach is more broadly applicable to regulated and unregulated systems as well as to groundwater. It also recognizes the importance of ecosystems in providing services (use values) to people.

There has been a gradual increase in acceptance and integration of the environmental and social issues into decision making about dams where the decision making was initially under the domain of engineers alone, but over the last 4 decades has expanded to include economists, environmental specialists, social scientists, and upstream displaced people. Most recently, it has included greater attention to downstream ecosystems and communities (Figure C.1).

Environmental flows are particularly important in river system management. Although diffuse and point source pollution, introduction of exotic species, riparian degradation, and removal of aquatic habitat can all affect the provision of ecosystem services, the flow regime is of central importance because so many ecosystem functions depend on it. One aquatic ecologist has likened flow to "the maestro that orchestrates pattern and process in rivers"[64]. There are four primary ways in which flows influence aquatic ecosystems[65]:

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61 The Nature Conservancy (2006). Environmental Flows. Water for People - Water for Nature. TNC MRCSO1730. The Nature Conservancy, Boulder, Colorado, USA.

62 Acreman, M.C., Dunbar, 2004 Methods for defining environmental river flow requirements – a review. *Hydrology and Earth System Sciences*. 8, 5, 861-876

63 There are special circumstances where water can be purposefully released into a water system as return flows from urban and irrigation uses but these are difficult to manage for environmental outcomes and seldom used.

64 Walker K.F., F. Sheldon and J.T. Puckridge (1995). A perspective on dryland river ecosystems. Regulated Rivers 11 85-104. Quoted in S. Postel and B. Richter (2003), Rivers for Life: Managing Water for People and Nature. Island Press, Washington DC.

- Shaping physical habitats such as riffles, pools, islands, and bars in rivers and floodplains. Flow alteration can lead to severely modified channel and floodplain habitats, thereby affecting the physical diversity needed to support diverse aquatic communities.
- Affecting life cycle processes. Many aquatic species depend upon specific water flow conditions during life stages such as reproduction.
- Altering mobility of organisms. Many species need to move upstream and downstream or from the river to the floodplain during their life cycles. Flow alteration that impairs connections between these different habitat areas can limit their mobility.
- Creating conducive conditions for the invasion of exotic and introduced species.

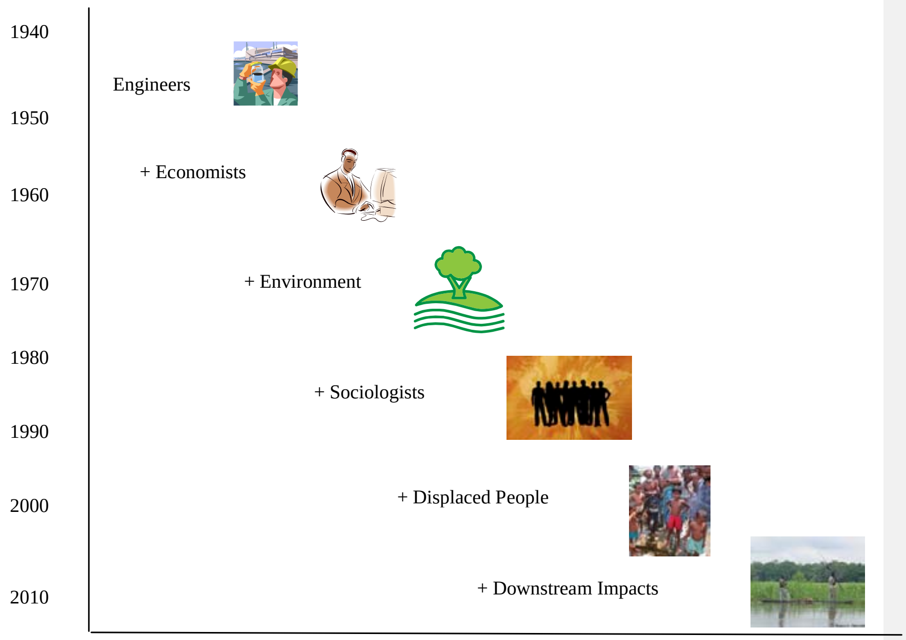

Figure C.1 The evolution dam planning practice (modified after Goodland (undated))

Different ecosystem functions are maintained by different components of the flow regime (Figure C.2). The particular functions depend on the river system but, typically, low flows maintain connectivity of pools and provide for longitudinal movement along the river; small, more frequent floods (or 'freshets') can trigger spawning in some species

[65] Bunn S.E. and A.H. Arthington (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management, 30 (4) 492-507.

and may remove detritus; and larger, more infrequent floods can water floodplains, and provide for lateral movement to and from the floodplain. An Environmental Flow Assessment (EFA) is used to understand and define the ecosystem functions supported by the various flow components in a particular river system. That is, an EFA will identify the reliance of different ecosystems or organisms (fish, invertebrates, vegetation, etc) on the flow components and their sensitivity to changes in these components. This knowledge is central when decisions are being made on allocating different parts of the flow regime to different water uses.

Other terms are sometimes used instead of 'environmental flows'. Some of these alternative terms reveal limitations in earlier conceptions of environmental flows:

- "bypass flows"is used in the Lower Kihansi project to describe the releases made from the dam into the Lower Kihansi Gorge ecosystem
- "escapages" is the term used to describe the Indus River flow at Kotri barrage to check saltwater intrusion, accommodate fisheries and environmental sustainability and maintain river channel
- 'minimum flows' was coined to describe the retention of enough flow to maintain river connectivity, especially for fish passage. But this is usually only one component of the flow regime that needs to be maintained and there are few instances where an environmental flow consists of just a minimum flow.
- 'instream flows' implies the flows needed to maintain ecosystem services from flows within the river channel. But this excludes the often important floodplain flows that overtop the channel
- 'environmental water allocation' is used to describe water specifically allocated for environmental purposes, usually held in a dam or storage.
- 'ecological reserve' was coined in South Africa to describe the water allocated for downstream ecological functioning[66]. However, the term 'reserve' implies water held back in reservoirs or impoundments whereas environmental water can also be assigned through controls on abstractions and discharges.
- 'natural flows' implies that the environmental flows need to mimic the natural flow variability. In fact, environmental flows can deviate significantly from the natural flow regime when some flow components are maintained because of their important functions and other components are lost because they are considered to be un-essential to the river ecosystem and can therefore be assigned to some development needs.
- surplus water' implies that some components of the flow regime have no ecosystem value and are available for assigning to consumptive or other purposes at no cost to the environment. In reality all components of the flow regime provide some ecological function. Even flows to the ocean are not wasted water – they provide nutrients to estuaries and near-shore areas, trigger spawning is some fish and invertebrate species, and shape physical habitat.
- 'compensation flows' is used in the 1986 Lesotho Highlands Water Project Treaty between South Africa and Lesotho. The term is confusing since it implies that the

[66] In South African law, the ecological reserve is distinguished from the social reserve which is water allocated for basic human needs (Case Study 4).

remaining downstream flows are actually a compensation for the benefits that have been lost by abstracting the rest of the flows.

However, it should be emphasized that none of the terms, including "environmental flows", give sufficient prominence to the social and economic importance of these flows. There is thus a misleading implication that only the environment, and not the people dependent on the environment, is the beneficiary of environmental flows.

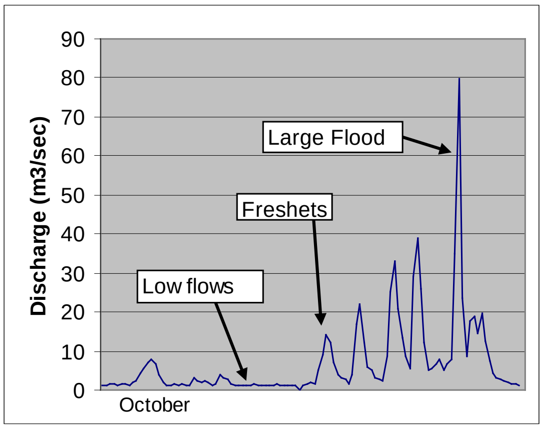

Figure C.2 There are various components of the flow regime from base flows during the dry season to smaller floods to occasional large floods.

Evolving Environmental Flows Practice

Tharme[67], in a review undertaken in 2001, identified 51 countries that were applying or considering applying environmental flow methodologies. Moore[68] conducted a survey in 2004 of environmental flows and identified 42 countries (64 countries were surveyed) where an environmental flows study had been undertaken. When Moore's results are combined with the earlier results of Tharme, at least 71 countries now use the concept worldwide. A number of countries that responded positively to Moore's survey were in regions which had shown minimal recognition or application of the concept in the past, demonstrating the emergence of the concept over the last several years.

[67] Tharme, R., (2003). A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. Rivers Research and Applications 19(5-6) 397-441.
[68] Moore M. (2004). Perceptions and interpretations of Environmental Flows and implications for future water resource management. A Survey Study. MSc thesis. Department of Water and Environmental Studies, Linköping University, Sweden.

At this stage, the majority of experience in environmental flows comes from developed countries - 70% of respondents from developed countries stated that the concept is being applied in their areas, compared to fewer than 25% of respondents from developing countries. Nevertheless, most survey respondents from developing countries were aware of or actively involved in implementation of the concept of environmental flows and all but a very small number thought that environmental flows was a beneficial concept, showing that there is considerable potential for promoting environmental flows in development assistance.

Thus, EFA methods can be used to find an optimal flow regime that meets a well defined objective, such as protection of a specific species, or to identify the relationship between flow regime and ecosystem response, so that the effects of changes in flow can be predicted. The former are typified by the hydrological index and hydraulic rating methods many of which were developed in the USA for protection of rare or endangered species (Box C.1). The latter approach is necessary when the environmental effects of different flow scenarios are being examined and so is the approach used when water allocation decisions are being made.

More recently, holistic methods have been developed that are specifically designed for data-poor situations such as are commonly found in developing countries. These methods are intended to be relatively inexpensive and easy to apply[69]. They have been documented in a database established by IWMI[70].

Box C.1. Wetted Perimeter Methods

Wetted perimeter methods were developed to provide a measure of habitat under different flow conditions. They have been widely used throughout the world. These methods are based on the assumption that the submerged area of river banks and bottom provides a measure of suitable habitat for various species including fish, invertebrates and aquatic plants. The method is based on the assumption that fish survival is related to food production which, in turn, is related to the area of submerged riverbed. There is also an assumption that there are thresholds in the flow where the area of habitat changes abruptly because of changes in the channel cross-section.

The method is relatively quick to apply and there is now considerable experience in its application, particularly in the US and Australia. However, the central assumption about the link between wetted area and habitat has been challenged by aquatic ecologists, and the method does not incorporate other important influences on fish productivity apart from food availability.

Source: Dyson, M.,G. Bergkamp, J. Scanlon (eds). Flow: The Essentials of Environmental Flows. IUCN, Gland, Switzerland and Cambridge, UK.

[69] Apse, C., A.H. Arthington, B.P. Bledsoe, S.E. Bunn, D. Merritt, R.J. Naiman, N.L. Poff, B. Richter, K.H. Rogers, R. Tharme, and A.T. Warner (2007). Ecological Limits of Hydrologic Alteration: An Approach for Setting Regional Environmental Flow Standards. North American Benthological Society Annual Meeting, Columbia, South Carolina, USA.

[70] http://dw.iwmi.org/ehdb/efm/efm.asp.

Information for Environmental Flow Assessments

Scientific knowledge is central to making decisions on water allocation at either basin plan or project level. Scientific knowledge provides reliable information on the predicted response of aquatic ecosystems to changes in the quantities, timings and durations of flows; this is particularly important because the response of ecological systems to changes in flow is seldom linear. Thus, reducing a component of the natural flow regime will not necessarily have a proportionately reduced ecological outcome. Halving the peak flood flow will not transport half the sediment, and halving the overbank flow will not usually inundate half the floodplain[71]. Unless these critical thresholds are understood there is a possibility that progressive changes to the flow regime will have had little apparent effect until the threshold is reached and then there is an abrupt decline in ecosystem function.

Scientific knowledge is also important for understanding surface water hydrology and groundwater hydrogeology, the changes in water availability as a result of climate change, water quality links with flow changes, and the effects of land use change on runoff characteristics.

Scientific knowledge about ecosystem responses is not always available entirely or in adequate form or quantity, particularly in developing countries. Traditional knowledge about the responses of vegetation, fish, birds, etc to different flow quantities and timings can provide valuable information (Box C.2) and can be used to supplement limited data and scientific knowledge.

Box C.2. Using Indigenous Knowledge, Rio Patuca, Honduras

With most of the nation's hydropower potential still undeveloped, Honduras has decided to construct a hydropower dam on the Rio Patuca, the country's longest river and the third longest river in Central America.

The Patuca's lower reach passes through a region of immense cultural and biological value. The river provides important ecosystem services to Tawaka, Miskito, and Pech communities along the banks of the river. Fisheries serve as their major source of protein; sediment deposition during annual flooding that improves the fertility of low-lying agricultural fields; and the river is their primary means of transportation. The Empresa Nacional de Energia Electrica, the Honduran energy agency, asked The Nature Conservancy (TNC) to provide guidance on a flow regime below the proposed dam that would maintain the river's biodiversity and ecosystem services.

Due to a paucity of technical information, TNC used traditional ecological knowledge about fisheries, agriculture and transportation, derived from the communities along the river, as the basis for flow recommendations. Community members provided information on flow levels through two sources of spatial information: cross-sectional surveys of the river and historical watermarks, and hand-drawn maps of each community, which was synthesized with other regional information to develop conceptual models of the linkages between flows and important

[71] Gordon, N.D., T.A. McMahon, B.L. Findlayson, C.J. Gippel and R.J. Nathan (2004). Stream Hydrology: An Introduction for Ecologists (2nd Ed). John Wiley & Sons, Chichester, UK.

fish species. These sources of information, augmented by hydrological analysis of a thirty-year record of daily flows, provided the foundation for the environmental flow assessment.

Source: The Nature Conservancy (forthcoming). Integrating Environmental Flows in Hydropower Dam Planning, Design and Operations. Technical Guidance Note. World Bank, Washington DC. http://www.nature.org/initiatives/freshwater/files/final_patuca_case_study_low_res_new_logo.pdf

Downstream individuals and communities who are affected by changes in flow regimes are often relatively un-organized and powerless compared to groups who want to develop the water resource and their traditional rights to use water are not always recognized in law. It is important that the relationships of the communities to rivers and the needs of these downstream communities are included in decisions about flows through

- Making their objectives and reliance on flows explicit
- Quantifying the links between different flow components and these objectives, and
- Involving them in the decision process when choices are made about modifying components of the flow regime.

Most EFA methods have focused on assessing biophysical impacts. It is only recently that EFA methods, such as Downstream Response to Imposed Flow Transformation (DRIFT)[72] developed under the Lesotho Highlands water Project (Case Study 14), are attempting to systematically quantify downstream social impacts associated with biophysical impacts. Methods, such as DRIFT, identify the reliance of communities on flows and quantify the links between flows and objectives. However, the extent to which stakeholders are involved in decisions about water allocation is determined by water (and sometimes environment) policy and legislation as well as by power structures and customary law. In many developing countries, downstream communities (including those with customary water rights) have no tradition of being involved in decisions and constitute voiceless constituencies[73].

[72] King, J., C. Brown and H. Sabet (2003). A scenario-based holistic approach to environmental flow assessment for rivers. River Research and Applications 19(5-6) 619 – 639**.**

[73] Hirji R. and P.L. Watson (2007). Environmental Flow Policy Development and Implementation: Lessons from the Lesotho Highlands Water Project. International RiverSymposium, Brisbane, Australia.

Appendix D: Water Environmental Issues in World Bank Country Water Resources Assistance Strategies

Bangladesh

Bangladesh, more than most countries, depends on water derived ecosystem services for its survival. The Bangladesh CWRAS reflects this with recognition that the country is heavily dependent on the Ganges and Brahmaputra Rivers. Fisheries production is under threat from reductions in dry season flows and loss of key aquatic habitats and disruption to migratory pathways (80% of rural Bangladeshis depend on aquatic resources); there are water shortages in the south-west; the Sundarban ecosystems are deteriorating; and water transport has contracted because of reduced flows (from 8,500 km of navigable waterways in winter in 1970 to 3,800 km today).

These downstream effects arise partly from developments in both Bangladesh and India. The Ganges Water Treaty provides a stable framework within which Bangladesh can begin to plan for the development of the main rivers. Specifically, it provides some assurance of upstream discharges so that the Gorai River augmentation project could be implemented with some promise. There are risks. The Gorai augmentation study did not adequately deal with the issue that the Ganges discharge at the Gorai offtake may be too low and this reduces the volume of water available for redirection into the Gorai. A second area of concern is that the operation of the gates at Farakka has led to a steeper recession limb of the hydrograph. As a result, there are more residual bars and pools that restrict free channel flow.

The CWRAS proposes a strategy for Bank engagement that includes a full-scale assessment of human and environmental impacts of development on the Ganges River, establishing a scientific basis for determining environmental flows. The CWRAS says that the scientifically based assessment of environmental flows is necessary to promote understanding between the upper and lower riparian countries to help develop benefit sharing agreements for the river.

China

The CWRAS bluntly says that China is not maximizing its benefits from Bank involvement. It should make greater use of the Bank's technical capacity. One of the recommendations is that China should use Bank's financing for management of water environmental issues such as eco-system restoration of rivers, wetlands, lakes and coastal waters.

The CWRAS notes that over-exploitation of groundwater, particularly in the Hai Basin, and overuse of surface water resulting in inadequate environmental flows in much of northern China, along with increasing groundwater and surface water pollution in many parts of the country, are contributing to the decline and deterioration of water resources and damage to freshwater and coastal environments. More broadly, China needs to protect and restore the environment, otherwise environmental degradation will result in huge negative impacts on the quality of life of Chinese people.

The CWRAS proposes six themes for assistance, the first of which is to improve environmental water management. This includes national guidelines for comprehensive river-basin planning which include a requirement for environmental flows in rivers providing water to ecologically important areas. The Bank can assist in this area. The sixth advocates further investment in new water resources infrastructure but oddly, given the above priority to rehabilitate environmentally degraded waterbodies, does not mention that these need to be designed to protect downstream environments.

The 2002 Water Law contains provisions for water allocation for ecological and environmental protection and restoration and the CWRAS proposes that the Bank assist in revising the laws and in implementing them. The CWRAS strongly advocates much greater attention to provision of water for environmental flows and proposes that China draw on the Bank’s expertise in this area.

Dominican Republic

The Dominican Republic has severe water quality, flooding and watershed degradation problems. There is no water resources policy or strategy and the water law needs revision. The CWRAS focuses on addressing these issues and proposes that the Bank can assist with watershed protection as well as with revisions to the General Water Law. Although it notes that there are water allocation issues, there is no mention of downstream impacts from upstream development apart from sedimentation from watershed erosion.

The country is seeking funding for construction of infrastructure including dams but there is no mention of the steps to be taken for controlling their upstream and downstream impacts.

East Asia Pacific Region

There is a clear recognition of the downstream impacts of upstream water uses in this regional CWRAS. It provides examples, including the Tarim Basin (Case Study 17) and the Mekong Basin (Case Study 7) where environmental flows have been included in development assistance.

The CWRAS accepts that the Bank will reinvest in water resources infrastructure in the EAP region but questions legitimacy of government initiatives and processes, including adequate consideration for the environmental impacts. It describes the shift of benefits from downstream water users to those upstream or off-stream without using the language of environmental flows.

The CWRAS proposes seven themes for assistance. The first is to preserve the environment and the land and water resource base. This requires the development of basin water resource plans that include environmental flows to protect rivers and coastal zones and to sustain ecologically important areas. This has not historically been done in EAP but this is now changing as shown by the Mekong and Tarim Basin examples. The third theme is for rehabilitation of existing water resources infrastructure and construction of new infrastructure. Although the need to provide for environmental flows is not specifically mentioned in this theme, it is clear that this development has to be accompanied by improved management and protection of environmental and social needs.

Ethiopia

The CWRAS includes very little mention of environmental flow issues. It does state that urbanization, industry, and services all create additional water demand potentially diminishing both water quantity and quality. Abstraction for these purposes will lower flow levels and have severe negative impacts on downstream users and the environment.

The CWRAS, in line with the energy strategy and the Water Sector Development Plan, advocates an expansion of hydro-power and multi-purpose development but makes only a passing mention of deleterious downstream effects: "water releases for power generation must be weighed against requirements for irrigation, all in line with system requirements such as environmental flows."

Honduras

Hydropower projects are subject to severe siltation. A new General Water Law is needed. (document incomplete).

India

Although environmental protection and restoration are important in Indian water management, the CWRAS focuses primarily on governance and institutional issues. The Indian state water apparatus is still focussed on a command and control approach and is yet to shift to a modern approach based on incentives, participation, devolution and environmental sustainability. Consequently, the CWRAS says, water managers ignore the accumulated "environmental debt" (including vanishing wetlands and polluted rivers and aquifers).

The CWRAS accepts that more water storage is needed to provide security, especially in the face of climate change, but this should be accompanied by more responsible management. However, dams are still seen within India as a solution without the understanding that they can solve one person's problem at the expense of someone 'downstream'. The CWRAS argues that new investments need to be accompanied by greater care to safeguard existing downstream uses, and attention also needs to be paid for improving the reliability of supplying existing demands and for meeting historically deprived environmental uses.

Unlike other CWRAS, the document does not present a strategy for Bank engagement with the water sector. Instead it provides 12 rules to guide the government of India in its water management. The India CAS already contains a major increase in water resources assistance. There was strong endorsement in discussions leading up to the CWRAS of the Bank's re-engagement in the full range of water-related issues and agreement that the government needed to complement its traditional focus on infrastructure with a growing emphasis on management.

Iran

The CWRAS describes the Iranian water management as "unevolved". Although both water policy and law require that water be managed at basin level, the number of basin organizations has not yet been established. Consequently there is no call yet for basin level water allocation planning or environmental water allocations.

However, the CWRAS says that there is a recognition that construction of dams will lead to less water for aquatic ecosystems. There are no guidelines or requirements at present for protecting downstream environments but the CWRAS proposes that social equity and environmental criteria should be established to mitigate the negative impacts of water resources developments.

The CWRAS identifies a number of areas where Iran needs training and capacity building, including in understanding water and environment.

Iraq

The Iraq CWRAS contains a significant section on the loss of environmental flows, primarily in the Euphrates River, that has contributed to the devastation of the Mesopotamian Marshes at the confluence of the Euphrates and Tigris Rivers74. About 94% of the Euphrates flow comes from Turkey with the remaining 6% from Syria. Both countries have developed large hydropower dams in the headwaters that have intercepted over 50% of the flows and the planned irrigation developments will intercept even more. The CWRAS points out that the full irrigation development will have major impacts on water quality as well as leading to further environmental degradation in the Marshes. Environmental flows are not just a matter of quantity; timing is also important for marsh inundation, as large volumes of water are required in a concerted surge to flood the marshland.

The CWRAS recognizes the need for in-stream flows for both strictly environmental and navigation needs, although these environmental flow needs are not elaborated on. Iraq's hydropower generation lies on the Euphrates River and so is also directly linked to the transboundary agenda. Managing these issues is seen as a transboundary technical process to manage flows optimally at the basin scale.

Much of the country's water resource infrastructure is degraded and even dangerous. The rehabilitation of these assets is identified in the CWRAS as a priority. There are no plans for constructing new dams. However, there is no mention of the opportunity for establishing environmental flows below rehabilitated dams, even though the importance of these flows is clearly apparent in the transboundary case.

Finally, the CWRAS includes the development of a new water policy and governance arrangements as a priority but there is little detail on the content of the new policy.

Kenya

There is little mention of environmental flow issues in the Kenyan CWRAS apart from recognition that there are downstream environmental and social problems from existing hydropower dams and at least one irrigation scheme. The issue include reduced fish catches, loss of spiritual value and danger from unannounced high flows. This is the result of poor infrastructure planning. The CWRAS calls for upstream and downstream communities to be more engaged in preparation for new developments.

[74] The Marshes now occupy only about 10% of their original area. Apart from the upstream impoundments and diversions, the Hussein government undertook deliberate engineering works to drain the Marshes in retaliation for a revolt by the Marsh Arabs following the First Gulf War.

Kenya's 1999 Water Policy identifies catchments as the basic units for water allocation planning and management. However, this intention has not been translated into practice. The 2002 Water Act also identified a reserve to safeguard basic human and ecosystem needs. However, it too has not been implemented.

Mekong region

This transboundary CWRAS says that at present there is inadequate coordination of development in the Mekong region with consequent social and environmental risks. Thus, there is currently great momentum for hydropower development and this will reduce floods and increase dry season flows. Main stem dams on the lower Mekong will impede fish movement. However, the document believes that it is possible to have sustainable development of the Mekong's water resources while avoiding or minimizing negative impacts on the interests of other riparian countries and on important environmental and social values.

Although the environmental flow rule was reduced in status to a guideline (Case Study 7), the CWRAS sees the intense interest during this debate as a positive sign of engagement over the topic of environmental flows.

The Mekong Water Resources Partnership Program Action and Dialogue Priority Framework (which the CWRAS supports) should include projects at sub-regional scale that promote, amongst other things, environmental programs and that mainstream environmental and social safeguards. Overall, the CWRAS identifies potential downstream environmental effects of development but does not recommend specific actions to avoid these problems.

Mozambique

The CWRAS recognizes the importance of providing an ecological reserve and calls for environmental water requirements to be established in each river basin. However, the major environmental flow issue (and opportunity) facing Mozambique arises from the downstream effects of the Cahora Bassa dam which was established in 1975 without any provisions for environmental flows. There has been a decline in downstream fisheries, major changes in the Marromeu wetlands and other delta and river-side forests, flood recession agriculture can no longer be practiced, and the estuarine prawn fishery has declined. The CWRAS notes that the change in ownership of the Cahora Bassa dam opens up the opportunity to modify the operations of the dam so that downstream environmental and social considerations are taken into account.

New dams are proposed on the Pungue River to provide water supply to Beira, and on the Zambesi River at Mphanda Nkuwa and Cahora Bassa North for multiple purposes. The Pungue Dam would need to provide downstream flows to prevent salt water intrusion into delta, and the new developments on the Zambezi River would be operated to provide the flows to re-establish downstream ecosystem services.

The CWRAS includes the need for Mozambique to build its capacity for integrated water resources management including hydrological and environmental monitoring.

Pakistan

Although salinity is seen to be the major water-related environmental threat in Pakistan, the CWRAS also identifies flow related issues as being important, particularly in the delta of the Indus River. The delta has become degraded from a number of causes including the reduction in freshwater outflow and the decrease in accompanying sediments and nutrients. The CWRAS states that "it is important to provide some managed flows to sustain the delta to the degree that this is possible" although studies were yet to be competed at that time to determine how much flow was required.

Wetlands are also under severe threat with reductions in flood flows; upstream infrastructure at Tarbela and Mangla are a primary cause. Embankments have now cut floodplains off from their rivers with the consequent loss of buffering capacity during times of flood.

There is also a large stock of old infrastructure that needs rehabilitation as well as a need to build new infrastructure. However, there is no mention of protecting or restoring downstream environments during this infrastructure investment.

The CWRAS pragmatically focuses on the major issues facing Pakistan – improving flows to restore the ecosystems of the Indus estuary is the only activity where the document explicitly advocates environmental flows.

Peru

The CWRAS does not mention environmental water issues. Although it states that a set of environmental policies were approved in 2002 it is but not clear what they included. The major water issues facing Peru include health-rated water quality issues, access to sufficient water supply in dry coastal areas, and institutional reform. Environmental water issues do not appear to be seen to be important.

Philippines

The CWRAS mentions at an early stage that the Philippines faces "over-exploitation of groundwater (particularly in and around the larger cities) and overuse of surface water resulting in inadequate environmental flows for major basins and sub-basins." There is a strong focus in the document on the need for water resources planning, development and management to provide for ecological protection and sustain the environment. This planning should make provision for environmental flows in rivers and coastal zones and to sustain ecologically important areas and the environmental water needs of aquifers should also be determined.

Although the document also states that there is a need for both new water resources infrastructure as well as better management of existing infrastructure, the specific requirements are not spelt out and there is no specific mention of the need to ensure that environmental flows are incorporated into the planning of these projects.

The Bank is assisting with River Basin and Watershed Management Project at the time of the CWRAS. The CWRAS proposes that Bank supported RBM projects should include environmental sustainability components including environmental flows for riverine and coastal benefit.

Tanzania

The Tanzanian CWRAS describes a number of occurrences where neglect of environmental flows during agricultural and hydropower developments have led to downstream issues, especially in the Rufiji Basin. The 2002 National Water Policy includes a requirement for environmental flows. However, the CWRAS states that there were no standards or guidelines for establishing environmental flows, although a program had been designed (but was yet to be implemented) to train water resources staff in environmental flow assessments and implementation.

The CWRAS identified the need to include training in environmental aspects of water planning and management as an area where the Bank could assist. There was also a need to build an understanding amongst sectoral agencies of the importance

Yemen

Yemen has been reforming its water sector from the mid-1990s in response to water shortages. The lack of control over groundwater use had lead to shortages for both agricultural and urban uses. There is considerable concern over the lack of physical sustainability of groundwater at the current rates of use but there is no mention of any environmental impacts from the drop in watertables. Surface catchment problems are focussed on the evident deterioration of watersheds with impacts on downstream communities from upstream abstractions and pollution. Environmental issues do not figure in this description.

The CWRAS critiques the Yemen National Water Sector Strategy Investment Program and identifies a number of omissions and weaknesses. None of these include environmental sustainability issues. The CWRAS advocates that the Bank should invest in a watershed management project to balance upstream and downstream water uses and should support basin planning within the current framework.

The absence of any mention of environmental flow issues for surface or groundwater probably reflects the much higher priority being accorded to physical sustainability and equity issues.

Appendix E: Environmental Flow Programs of International Development Organizations and NGOs

Background

There are several prominent international organizations and NGOs that have offered assistance to developing countries to address and undertake EFAs and protect and restore downstream ecosystems. The assistance ranges from practical, longer-term technical assistance with EFAs for specific infrastructure projects to technical assistance and financial assistance with the inclusion of downstream flow concerns into river basin plans, to shorter term training and capacity building, to provision of resources for water resource and environmental specialists.

The Bank is collaborating with development partners at several levels - global, regional, national and basin - because of their experience, expertise and comparative advantages as well as their presence on the ground. Thus, The Nature Conservancy (TNC) and the Natural Heritage Institute (NHI) have produced a technical guidance note for the Bank on integrating environmental flows into hydropower dam planning, design and operations[75] as a contribution to this ESW. This will be published as a stand alone note. The Bank is also collaborating with the NHI and the GEF to explore opportunities for examining the feasibility of re-operating existing dams and water systems in order to improve their economic and environmental performance. The relevant environmental flow related work of the various agencies is described below to inform Bank staff of the types of activities and potential opportunities for future collaboration. It not intended to be an evaluation of the effectiveness of the various EFA programs of these agencies.

The majority of the assistance offered by international agencies and NGOs is for EFAs for river basin planning and project assessment, particularly re-operation of existing infrastructure, and the provision of training courses. Some of these institutions have also developed a wide range of support material, including printed and electronic documents, databases, a newsletter, training courses, websites and an information network.

While the World Bank has worked with some of the specialist international NGOs in developing technical advisory documents, there are opportunities to increase the level of collaboration to take combine their experience in EFAs and in training with the Bank's experience in implementing projects. Contact details of these various partner agencies and NGOs are provided at the end of this appendix.

International agencies and NGOs have been active in providing assistance to developing countries for incorporating environmental flows in policy reforms, basin and catchment plans and assessments of new and rehabilitated infrastructure projects.

[75] The Nature Conservancy and Natural Heritage Institute (forthcoming). Integrating Environmental Flows in Hydropower Dam Planning, Design and Operations. Technical Guidance Note. World Bank, Washington DC.

Policy and Legislation

A small number of international NGOs have influenced policy and legislation. In the Eastern Himalayas in India, WWF is carrying out an environmental flow scoping study which will provide a platform to promote integration of environmental flows concept at the policy level. IUCN have introduced the concept of environmental flows to the Environment Committee of the Costa Rican parliament at the time a new Water Law was being proposed and members of an expert network, established by IUCN, have subsequently been involved in preparation of the new law. NHI was an author of a statutory mechanism in California for reallocating existing irrigation and municipal water rights to environment flows. The Environmental Water Account – a "water district for the environment" - is now the largest water purchaser in California.

Basin Planning

A number of international agencies and NGOs provide assistance in incorporating environmental flow considerations into river basin plans.
The IUCN, through its Water and Nature Initiative (WANI), is funding case studies in Meso America, the South East Asia and Eastern Africa, including an EFA in the Pangani Basin, Tanzania (Case Study 8). The EFA will contribute to the preparation of the basin water resources plan required under the draft Tanzanian water resources legislation and is helping build capacity in EFA within Tanzania. IUCN has also conducted a demonstration EFA in the Tempisque River Basin[76] in Costa Rica and this has stimulated interest in undertaking an EFA in Costa Rica's Savgre river basin.

WWF is working with the USAID funded Global Water for Sustainability (GLOWS) program in the Mara River basin, transboundary to Kenya and Tanzania to help Ministries in both countries carry out an EFA in preparation for basin planning. The EFA includes the environmental flow needs of the Masai Mara National Reserve and the Serengeti National Park, particularly during the dry season. In addition, WWF and DANIDA have initiated an EFA in the Ruaha Basin in Tanzania. WWF has also identified a suitable methodology and developed an action plan for estimating environmental flows requirements in the Neretva River Basin in Bosnia-Herzegovina.

UNDP, as GEF implementing agency, is planning to conduct EFAs in two international river basins. One is in the Orange-Senqu River basin (Botswana, Lesotho, Namibia, South Africa) and the other is in the Okavango River basin (Angola, Namibia, South Africa) (Box F.1). The EFA will be conducted as part of the transboundary diagnostic analysis required in GEF International Waters projects. UNDP has also been working on the Zarka river basin, Jordan looking at issues of environmental flows as part of the introduction of integrated river basin management concepts.

Box F.1. Flows in the Okavango Basin

The Okavango basin, covering parts of Angola, Namibia and Botswana, is one of the least impacted on the African continent. The flood-pulse system is driven largely by rainfall in the upper parts of the catchment in Angola. The Okavango River forms a large inland delta which

[76] Jimenez, J.A., Calvo, J., Pizarro, F., Gonzalez, E. 2005 *Conceptualisation of environmental flows in Costa Rica. Preliminary determination for the Tempisque River*. IUCN, San José, Costa Rica

comprises a large perennial swamp, a seasonally flooded swamp, seasonally flooded grassland, intermittently flooded land and drylands. The complex includes over 150,000 different islands varying in size from several meters to 10 km in length.

The delta provides unique habitat that supports a rich and diverse biota including some of Africa's largest free-roaming herds of Cape buffalo, zebras, antelope, and elephants. The delta also includes between 2000 and 3000 species of plants, more than 65 species of fish, over 162 arachnid species, and more than 650 species of birds. The associated tourism related activities are the second most important economic activity in Botswana, after diamonds.

Several potential sites for the development of hydropower generation have been identified in the upper reaches and potential irrigation development has been identified in several parts of the Basin. During the 1980s the Government of Botswana proposed a water development project to utilize water from the delta for mining, agriculture and cattle production. The project was rejected after a wide range of deficiencies relating both to the project itself and to the process whereby it was planned and designed were identified.

However, the changing regional political context and the need to ensure socio-economic development in some of the regions most remote and under-developed areas, means that there is continuing pressure to develop the waters of the delta. Consequently, there is a new found urgency to secure environmental allocations for the delta to protect the rich diversity of the delta.

Increasing development pressures, need to address development challenges and increasing peace and stability throughout the basin resulted in establishment of institutional framework to facilitate joint planning. The three riparian countries established the Permanent Okavango River Basin Water Commission (OKACOM) in 1994. This is a tripartite institution aimed at promoting coordinated and environmentally sustainable regional water resources development, while addressing the legitimate social and economic needs of each of the riparian states. The OKACOM Secretariat has responsibility for determining and facilitating water allocations within the Okavango basin. However, there has yet to be a rigorous assessment of the environmental flow requirements of the Okavango River basin.

Source:

The UNEP Global Programme of Action has developed a protocol for carrying out EFAs in Bangladesh. The protocol has been piloted at the Bakkhali River Rubber Dam where there was a need to establish a balance between water for irrigation and dry season flows for fish movement to increase fish production.

IWMI has also been active in promoting EFAs within river basins, particularly in Asia. It is working with IUCN and Vietnamese government agencies to develop an environmental flow programme in the Huong River Basin, Viet Nam[77.] To date, the assistance has been restricted to raising awareness and introducing concepts. IWMI has also applied the TNC's Range of Variability Approach (RVA[78]) to three rivers in the East Rapti River basin, Nepal[79] and to the Walawe river basin in Sri Lanka[80]. However, the lack of ecological data (in the Nepal

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[77] IUCN Vietnam (2005). Environmental Flows: Rapid Flow Assessment for the Huong River Basin, Central Vietnam. IUCN Vietnam, Hanoi, Vietnam.

[78] Richter, B. D., Baumgartner, J. V., Powell, J., Braun D. P. (1996). A Method for Assessing Hydrological Alteration within Ecosystems. Conserv. Biol., 10, 1163-1174.

[79] Smakhtin, V.U., Shilpakar, R.L., Hughes, D.A. (2006). Hydrology-based assessment of environmental flows: an example from Nepal. *Hydrological Sciences Journal,* 51, 2, 207-222

[80] Smakhtin, V.U., Weragala, N. (2005). *An assessment of the hydrology and environmental flows in the Walawe River basin, Sri Lanka*. Working Paper 103, IWMI, Colombo, Sri Lanka.

applications) and the high uncertainty in the estimation of the natural flow regimes limited the applicability of the method.

IWMI has also applied the South African desk-top method (Case Study 3) to assess the environmental flows of rivers in India, including the Cauvery, Krishna, Godavari, Narmada and Mahanadi[81] rivers. The main purpose of the study was "to stimulate the emerging debate on environmental flows and environmental water allocations prospects in the country".

IUCN has run a wetlands programme since the early 1990s in conjunction with Ramsar. This work included the determination of the water needed to maintain ecological functioning of wetland habitats and the delivery of goods and services to local livelihoods. Although this work was not undertaken for basin planning purposes, it would contribute to basin-level water allocation planning. The term environmental flows was not used to describe this work, but it would be classified under this heading today.

Rehabilitating and Re-Optimizing Infrastructure

The NHI specializes in re-optimizing major irrigation, power and flood management systems to effectively add to the supply side of the water balance (Appendix B contains a summary of the infrastructure design features needed for releasing environmental flows). The reoperation techniques, which include economic optimization modeling, conjunctive management of surface and groundwater, reducing physical losses of water in irrigation, and rescheduling total hydropower production and system reliability, provide more water to formerly productive downstream river systems in ways that do not significantly reduce production benefits. Demonstration activities are being considered in the Yangtze, Yellow and Pearl River basins in China and in the Hadejia-Nguru wetlands system in northern Nigeria, and the Akosombo and Kpong dams on the lower Volta in Ghana.

The NHI is also helping optimize surface and groundwater management in the Central Valley of California to provide more water for the environment. It is also exploring a variety of economic incentives that can be used to improve agricultural water use efficiency, with the 'saved' water being dedicated to environmental flow restoration.

The NHI is working with the GEF implementing agencies, to help developing countries re-operate existing dams. Thus, it prepared a project concept to the GEF for a project that will pilot the re-optimization of two dams, in Ghana and Nigeria, to enhance environmental flows as well as power generation and water-related livelihoods.

The hydrology of the Parana River, Brazil has been severely altered by 26 large reservoirs. UNESCO, through its Ecohydrology Programme, is helping restore the ecosystem functioning of this river through a modified procedure for operating the Porto Primavera Dam. This will maintain the biodiversity of a reach of the river and improve local incomes without significant loss of hydro-electric production.

TNC has also worked extensively with dam operators in the USA to modify how and when water is released in order to restore and protect river systems and associated land and

[81] Smakhtin, V.U., Anputhas (2006) *An assessment of environmental flow requirements of Indian river basins*. Research Report 107. Colombo, Sri Lanka: International Water Management Institute.

wetlands. In particular, its collaboration with the U.S. Army Corps of Engineers (USACE) at 26 dams in 13 states across the U.S. has helped define and implement environmental flows through adaptive reservoir management, and this experience is now being rolled out across other dams operated by the USACE.

In Mozambique, TNC is preparing to assist the Zambesi River Authority rebuild the river's health by restoring environmental flows below the Kariba and Cahorra Bassa dams.

WWF has worked with Zambian authorities to improve the operating rules of the Kafue Gorge and Itezhi-tezhi Dams in Zambia in order to improve the management of water resources in the Kafue Flats which are a wetland of international importance under the Ramsar. The aim is to provide a more natural flow regime in order to restore wetland functions and values.

New Infrastructure

NHI and TNC are helping introduce environmental flows concepts in China, Latin America and Africa. TNC has been developing a comprehensive conservation plan for the Upper Yangtze, while collaborating with World Wildlife Fund, which is working on the Lower Yangtze. As part of this, it facilitated a meeting which has led to a draft report that lays the basis for environmental flows in the upper Yangtze. It has more recently been invited to assist the Three Gorges Company in developing environmental flow recommendations.
In Latin America, TNC has been conducting an environmental flow assessment for the Patuca III hydropower plant on the Patuca River in Honduras. The river supports globally important aquatic biodiversity and flows through a reserve for indigenous communities and other protected areas. The EFA will provide the information for protecting these important biological and cultural values. The TNC's payment for environmental services project at Quito, Ecuador includes an environmental flows component. The Conservancy is also assisting with environmental flow analyses for rivers in Colombia and Peru, where new Water Fund projects are following the Quito model.

Training and Capacity Building

A considerable number of international agencies and NGOs offer support for training and capacity building in environmental flows. UNDP promotes capacity building at local, regional, national and global levels through the Cap-net programme implemented by UNDP together with the Global Water Partnership and UNESCO's Institute for Water Education. The programme supports 12 regional and national networks of water-management capacity building institutions around the world. In South Africa, a Cap-Net network called WaterNet[82] is using its members to develop a regional master's programme in water management – this includes training modules that focus on water for the environment to maintain ecosystem functioning.

As well as conducting regular training courses for the USACE, TNC provides environmental flows training at international conferences so that participants from developing countries have opportunities for training in environmental flows.

[82] http://www.waternetonline.ihe.nl/default.php

Some NGOs have conducted awareness raising workshops. Thus, IWMI has run a National Workshop in India on environmental flows that brought together government departments, non-governmental organisations and research institutions. And IUCN has organized workshops to raise awareness and increase understanding of environmental flows in VietNam (Box F.2) and Cambodia. IUCN has also run a training course in meso-America to develop a nucleus of champions of environmental flows.

Box F.2. The Huong River Basin, Vietnam

The Tam Giang-Cau Hai lagoon at the mouth of the Huong River in central VietNam is an important asset for local villagers. It provides fisheries and brackish water for agriculture, transport and harbor facilities and, in recent times, has been used for aquaculture. It is also suitable for tourism development.

A number of dykes and barriers have been erected to prevent flooding along the river and dams and barriers (the most notable is the Thao Long Barrier) above the lagoon now prevent seawater intrusion from the lagoon during the dry season. Two new dams – Ta Trach and Binh Dien dams – have been proposed to provide further flood protection. Provincial officials were keen to develop an ecosystem based approach to managing the basin and its infrastructure and asked IUCN and IWMI to assist. A rapid assessment EFA workshop was held in Hanoi in December 2004.

Prior to the workshop, Vietnamese water managers understood environmental flows to mean minimum flows which were established through a hydrologic formula. They had set this minimum flow to be 31 m^3 sec^{-1} to released from the Thao Long Barrage to flow into the lagoon. It had become the dominant flow requirements in their minds.

The workshop went beyond the usual rapid hydrological assessment to include ecological assessments of different hydrological scenarios, including the effects of the proposed dams. While this rapid assessment was inadequate for establishing defensible environmental flows, it was successful in raising awareness about use of a holistic approach to flow assessment. It also succeeded in identifying possible barriers to EFA implementation and ways to overcome these barriers. It will be important to link further work on environmental flows in this river basin to poverty alleviation and livelihoods.

Source: IUCN Vietnam (2005). Environmental Flows: Rapid Environmental Flow Assessment for the Huong River Basin, Central Vietnam. IUCN Vietnam, Hanoi, Vietnam.

Some training is available electronically. TNC will be making its training courses available online soon and IUCN has established a distance learning electronic training course83 that has modules designed for decision-makers (these modules explain the benefits of Environmental Flows) and technical managers (these modules elaborate on methods for assessment, adaptations to existing or proposed infrastructure, and financing EFAs).

Resource Material and Awareness

There is now a considerable array of electronic and hardcopy resource materials from international organizations and NGOs to assist developing countries (Box F.3).

[83] available at www.waterandnature.org/flow.

Box F.3. Environmental Sustainability in Southern Africa

The Southern Africa Development Community with support from SARDC, IUCN, Sida and World Bank has published a report on environmental sustainability in water resources management. It contains chapters on the role of aquatic ecosystems in water resources management, valuing the environment, and the application of EFA in Southern Africa and is a valuable resource for environmental flows in that region.

The report identifies 10 challenges facing the introduction of EFA in Southern Africa.
1. lack of political will
2. poor harmonization of policies for transboundary resources
3. limited awareness and training in EFA
4. lack of data on Southern African rivers
5. Inherent unpredictability of complex systems
6. unknown influence of climate change on runoff
7. lack of monitoring programs
8. incompatible dam design with the necessary environmental flow releases
9. rectifying poor design of existing dams
10. treating water as a finite resources.

Source: Hirji, R., P. Johnson, P. Maro and C. Matiza Chiuta (Eds) (2002). Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa. SADC, IUCN, SARDC, World Bank: Maseru Lesotho.

Electronically available resources include:

- a global environmental flows network that acts as a central reference point for knowledge and information on environmental flows that is currently spread throughout the world, established by IUCN, IWMI, TNC and a number of other development assistance institutions[84];
- an Environmental Flows newsletter (IWMI and the Global Water Partnership)
- three publicly available data sets developed by IWMI
  - Estimates of environmental flow requirements in world river basins
  - Environmental flow assessment for aquatic ecosystems
  - Quantification of hydrological functions of inland wetlands
- a Flow Restoration Database, which catalogues and organizes case studies of modified dam operations, removal of dams, ground-water pumping, and other strategies to restore river flows (TNC).

Finally, two international environmental flow conferences have now been held, the first in Cape Town, South Africa and the second in 2007 in Brisbane, Australia. A third is planned for South Africa in March 2009.

[84] SIWI, DHI, Centre for Ecology and Hydrology, Swedish Water House and Delft Hydraulics.

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