MACARTHUR FOUNDATION CONSERVATION WHITE PAPER SERIES | 2010

Freshwater White Paper

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EXECUTIVE SUMMARY

Freshwater is vital for the survival of life on earth, yet our planet's freshwater supplies and the ecosystems that regulate and provide freshwater services, such as drinking water, climate regulation, and electricity generation, are becoming increasingly more degraded. Population growth, increasing wealth, thirsty energy technologies and climate change are driving and further worsening freshwater challenges—requiring integrated conservation and development solutions. Water governance is essential to ensure equitable access and allocation, including water to sustain freshwater ecosystem function and service delivery, yet water moves across political boundaries, making management difficult. Ever increasing development pressures intensify our freshwater consumption, and are coupled with climate change impacts, affecting the timing, location and duration of water availability. Some theorize that we have already reached a tipping point, where rates of water abstraction and pollution outpace water replenishment, and ecosystems are no longer able to withstand or bounce back from decades of human induced impacts.

In this white paper, we describe a program of freshwater work for the MacArthur Foundation to help address the global freshwater crisis as it relates to people, species and ecosystems. Program goals include conserving freshwater flows and ecosystems, linking conservation and development agendas, and reversing current policy and market trends where ecosystems are undervalued and are therefore perpetually degraded. The paper is structured into six sections:

- Section 1. Defines the major drivers and characteristics of the freshwater crisis and describes areas of work currently underway to address it. Various freshwater activities pursued and actors engaged are described to portray the current scope and scale of work underway.
- Section 2. Presents four case studies that compare large river basin programs with different freshwater management challenges, contrasting effective and ineffective responses to those challenges. Results highlight elements of successful approaches and identify funding needs.
- Section 3. Summarizes opportunities and potential roles that the MacArthur Foundation could play to further innovation, fill in key gaps, and leverage existing work in freshwater conservation.
- Section 4. Reflects on issues of scale and scope, favoring a regional approach to promote water governance, avoid conservation and development trade-offs, and ensure ecosystem function, species diversity, and service flows.
- Section 5. Describes a freshwater program for the MacArthur Foundation that would build upon its current portfolio and use of incremental and phased in approaches. The program offers delivery of results within three to seven years and leadership within the Philanthropic sector.
- Section 6. Characterizes the results expected from implementing the proposed freshwater program, and suggests additional activities for the medium to longer term.

Several conclusions and recommendations are proposed in this white paper throughout the various sections, which are summarized here as follows:

- Most of the drivers of degradation of freshwater ecosystems are the result of policy and market failures to incorporate the vital role that ecosystems play in providing services. We recommend greater support for: science, to understand where biodiversity and the flow of ecosystem services are concentrated, and to describe ecosystems in biophysical, political and economic terms; planning tools to ensure that conservation and development trade-offs do not take place and that the true costs and benefits of development scenarios are understood within various ecosystem function and resilience contexts; governance, policy and institution building, to ensure that basic conditions are in place for equitable resource allocation and ecosystem and species protection; and markets to incentivize and finance long term conservation, also enabling an exit strategy for philanthropic investment (**Section 1**).

- On the ground river basin management is challenging, yet this is the scale that best protects species and ecosystem service flows while minimizing conservation and development trade-offs, and these types of success stories are needed to influence trans-boundary policies and development agendas. We recommend that the MacArthur Foundation favor regional, large river basin scale projects, including those that cross national boundaries (**Sections 2 and 4**).
- New techniques, such as modeling trade-off analyses, environmental flows and dam reoptimization, virtual water trade, water footprinting and water stewardship need to be piloted at local to basin scales with complementary actions at the national to global levels to create new river basin management plans, and water standards, certification systems and markets. We recommend that Foundation support these innovative approaches within a larger portfolio of river basin and policy projects (**Sections 2 and 3**).
- We still know very little about how to best protect freshwater biodiversity and ecosystem function, in spite of growing evidence about freshwater species and services' loss. We recommend that the foundation support: gathering global baseline data on biodiversity, ecosystem function, integrity and health; designating and improving management effectiveness of existing protected areas; and securing strongholds for species and ecosystems through wild rivers and wetlands wilderness programs (**Section 3**).
- We need to acknowledge and manage collectively food, energy and water, given climate change and development pressures, if we want to optimize benefits for people while minimizing the impacts of ecosystem degradation on people and nature. We therefore recommend that the MacArthur Foundation support: integration of climate change datasets and downscaling projections data as well as modeling development and climate change scenarios; advocacy for institutional processes that better integrate sustainable development, and policies that include ecosystem approaches into adaptation and development planning; and developing combined soft and hard engineering approaches within large landscapes or river basins to increase climate change resilience and respond to growing demands for water, food and energy (**Sections 3 and 5**).
- Better governance is also critical to improve sustainable and cooperative river management. We recommend greater support for: creating global to regional agreements for river management at different geopolitical scales and building river basin organizations; developing tools and methods for Integrated River Basin management (IRBM); and implementing Environmental flows (Eflows) within IRBM approaches (**Sections 2 and 3**).
- Markets and consumer choices can influence better corporate and public stewardship of water. To this end, we recommend greater support for: improving water footprinting methods and adapting them to address water quality to the same extent they target water quantity; creating certification standards for water stewardship; developing a pipeline of watershed management and payment for ecosystem service projects, and advancing water markets to target efficiency and quality (**Sections 3 and 5**).

Implementation of the proposed program builds upon MacArthur's hotspot portfolio and follows the foundation's three phased funding approach: 1. Research and planning to develop the core components of a sound river basin management plan; 2. Implementing projects and programs within river basins that achieve particular elements of the river basin plan, and; 3. Consolidating results from activities to ensure achievements occur at the river basin scale (e.g., trans-boundary management, payment for ecosystem services, and water markets such as nutrient trading)(**Section 5**). Expected results include conservation of freshwater services delivered from natural ecosystems, better water stewardship, cost savings and other efficiencies across the broader water sector, and mainstreaming freshwater ecosystem conservation into development, public and corporate agendas (**Section 6**).

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INTRODUCTION

Global Freshwater Crisis

Water is undeniably vital for human livelihoods and survival, as well as most forms of economic growth and production. It is vital for supplying water to drink, water for food, and its management is critical for sustaining human livelihoods and meeting the Millennium Development Goals. Yet, more than 1.4 billion people currently lack reliable access to clean drinking water, and 2.6 billion lack adequate access to sanitation (WWAP 2009). Water-related illness is also rampant among the poorest of the world's poor-- with a child dying an average of every 15 seconds (WHO and UNICEF 2004). More than half of our planet's wetlands have been lost, and freshwater biodiversity has declined 35% from 1970-2005, a much higher rate than the rate occurring in either the forest or marine biomes (Loh 2008; MEA 2005b). Our activities impact the ecosystems and natural processes required to generate supplies of clean fresh water, further threatening human livelihoods as well as hundreds of thousands of freshwater dependent species.

The threats to freshwater ecosystems are severe and they are accelerating. Global water withdrawals have increased six-fold in the past century, and people now consume over 54% of the world's accessible freshwater. Already 1.4 billion people live in river basins that have 'closed' (Falkenmark and Molden 2008), and some of the world's great ecological disasters are over exploited rivers, resulting in collapse in places like the Aral Sea, Lake Chad and the Colorado River delta. Current increases in human population, from 6 to 9 billion people, and growing wealth in many countries is going to continue to fuel this growth as more and more people require water for drinking and for food as primary needs, and also as developing economies switch to more water intensive diets of meat and dairy products (WWAP 2009). In addition to these threats, climate change is not only changing hydrology, but is also increasing water consumption and driving energy and carbon policies that are consuming even more water (i.e., biofuels, hydropower and carbon capture and storage) (Bates *et al.* 2008; WWAP 2009). Finally, it is unfortunately the most biodiverse river basins, such as those in Asia, Africa and South America, that are now at greatest risk from renewed dam construction.

Water access, allocation and use often drive political tensions, which may potentially result in conflict, within or between states. Privatization of water supplies or depletion or pollution of water in a shared river basin can greatly limit access, and has already resulted in violent conflict in many already weak nation states. Water scarcity is both physical and economic[1], and can contribute to poverty, social instability and migration. Tensions over water also have the potential to exacerbate other non-water-related violent conflicts (OECD 2005). Poor water governance is clearly a source of serious intra-state conflict (Joy *et al.* 2007) and is predicted to be a major source of inter-state conflict (The CNA Corporation 2007). Fresh water must be available, and of sufficient quality, in the right times and in the right places, which is impacted by ecological processes, water flows, and up and downstream dynamics.

The UN stated at the 2001 World Water Forum that people in developing countries must have access to locally sustainable drinking water resources, sanitation facilities, and health and hygiene education programs (http://www.unwater.org/). To achieve this, development banks and agencies suggest that freshwater must be managed to: meet household water and sanitation needs; balance

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[1] Physical water scarcity results when supplies are limited across time or space (i.e., due to arid or other local environmental conditions, over abstraction or mismanagement such as upstream pollution). Economic scarcity results when supplies are distributed unequally across populations of people (i.e., due to insufficient financial resources, poor governance, and/or political and ethnic conflict) (www.iwmi.org;wri.org).

those with the needs of agriculture (uses more than 70% of total available water supply) and industry; develop cities and towns in rural and urban environments—and to recognize the underlying role that healthy ecosystems play in providing for these water-related needs; as well as their role helping people and species to respond and adapt to the adverse impacts of global economic and climatic change (www.adb.org/; http://web.worldbank.org; http://www.unwater.org/;www.siwi.org;www.wri.org).

Importance of Ecosystems and Nature for Biodiversity and Freshwater Security

About 3% of the total amount of water on the planet is fresh, and half of that is locked up in icecaps and glaciers, so it is unavailable for human use. The principal sources of fresh water that are available to humans reside in freshwater systems and associated habitats such as lakes, rivers, wetlands, and shallow groundwater aquifers. For these reasons, freshwater ecosystems, and the watersheds and basins throughout which freshwaters flow, are vital for human and freshwater dependent species survival[2]. We also refer to the freshwater-related ecosystem services. Ecosystem services (ES) are the ecological conditions and processes that regulate and provide for human well-being (Daily, 1997). The Millennium Ecosystem Assessment found that natural ecosystems provide drinking, washing, fisheries, agriculture, transportation, industrial processes, and energy generation and electrical generation services–benefitting billions of people (MEA 2005a). Less tangible, yet critical freshwater-related services such as flood control, purification of waste, and delivery of nutrient-rich sediments to floodplains are also valuable roles ecosystems play (Baron et al. 2002; Postel and Richter 2003; Wallace et al. 2003; Emerton and Bos 2004).

Freshwater ecosystems are home to the highest concentrations of species compared to terrestrial or marine ecosystems. The extensive geographic barriers between freshwater ecosystems has led to particularly high levels of endemism. Regrettably, this species richness coupled with limited resilience and growing threats mean that freshwater dependant species are in substantial decline and top lists of taxa significantly threatened with extinction. A study of 10,000 fishes revealed habitat alteration and introduced species were the largest threats, followed in decreasing order by overfishing, pollution, disease/parasites, hybridization and deliberate eradication (Harrison and Stiassny 1999). More than 126,000 species rely upon freshwater for some or all of their life cycle. The MEA identified the major threats to freshwater ecosystems coming from dams and infrastructure, excessive water extraction, climate change, invasive species, over-fishing and pollution (MEA 2005b).

Freshwater ecosystems cannot be separated from terrestrial habitats in terms of freshwater flows and the hydrologic cycle. For example, groundwater recharge happens above ground but flows underground, evaporation from soils into the atmosphere then falls again as precipitation, and transpiration from plants returns water to the atmosphere. Similarly, land and water use and management activities must be examined together, particularly when working towards goals of healthy ecosystems, diverse species populations, and clean and sufficient supplies of freshwater for people. Links between ecosystems and watersheds, which govern the patterns and timing of water flows, provide a complete picture linking bio-physical to ecological and economic considerations (particularly when administrative boundaries are aligned with watersheds).

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[2] Through use of the general term 'freshwater ecosystems' in this white paper, we refer to the habitats noted, as well as all ecosystems and watersheds through which freshwaters flow (i.e., linked terrestrial and freshwaters ecosystems of watersheds; as well as ridge to reef, and underground systems). The Convention on Biodiversity defines such ecosystems as "inland waters biodiversity." The Ramsar Convention on Wetlands defines wetlands broadly, ranging from cave systems, mound springs, floodplains, rivers, ephemeral wetlands, lakes (www.cbd.int/; www.ramsar.org/). Watersheds, basins or catchments are comprised of a drainage basin (or basins) which include both stream and overland flow, whose runoff either enters the ocean along an identified segment of coastline (coastal segment) or enters an internal, landlocked drainage basin.

Moreover, the large part of the earth's continental freshwater (50.1%) is frozen in icecaps and glaciers. The importance of this frozen water to global flows of water, and the ecology and human livelihoods these support, should not be underestimated. The impacts of climate change are also accelerating glacial melting and supplies of freshwater may be overabundant flowing from some places like the Himalayas and high Andes, but will be lost in the medium to longer term as natural water storage is no longer available. Climate change is both an independent, and co-dependent variable, which, when coupled with development, will greatly impact clean water availability and flooding vulnerability. Development decision-making, does not unfortunately typically recognize the vital role that ecosystems play in providing for freshwater-related services, nor does it account for adverse trade-offs that can occur between services, if larger scale landscapes and ecosystem processes are not considered. For example, forestation to sequester carbon may be an important measure to combat climate change, but this needs to be planned carefully since immature trees transpire a lot of water and may reduce inflows into already over-exploited rivers.

Box 1. Freshwater Ecosystem Services Critical for Human Well Being

- People in Cambodia obtain about 60-80% of their total animal protein from the inland fishery in the Tonle Sap and associated floodplains.
- Intact mangroves in Thailand have a total net present economic value (marketed products such as fish and non-marketed services such as protection from storm damage) of at least $1,000 per hectare compared with about $200 per hectare when converted to shrimp farms.
- Over 60% of the world's food is produced from green water (mostly soil moisture from rainwater, rather than irrigation). In sub-Saharan Africa this figure reaches 95%.
- Fresh water is crucial to climate stability. Wet peatlands, covering only 3-4 % of the earth's surface, are estimated to hold 540 gigatons of carbon, representing 25-30% of global carbon contained in terrestrial vegetation and soils.

IIED 2007; MEA 2005b; Falkenmark and Rockstrom 2005; UNDP 2006.

Global understanding of ecosystem services – and the key role of water - has been growing. The UN Millennium Ecosystem Assessment (MEA 2005a) and its wetlands and water synthesis (MEA 2005b), the UNEP Global Environmental Outlook 4 (UNEP 2007), and other reports demonstrate the role of ecosystem services in managing climate change and freshwater ecosystems (Dudley et al. 2010; Trumper et al. 2009). The Economics of Ecosystems and Biodiversity (TEEB) study (ten Brink et al. 2009) goes a step further by proposing systems to value these services, while the Ramsar Convention and Convention on Biological Diversity have published specific guidance for valuing the benefits derived from wetland ecosystem services (De Groot *et al.* 2006). The term "ecosystem services" is not yet widely adopted by international agencies yet the Ramsar Convention on Wetlands' uses "ecosystem benefits/services" and requires member states to maintain them in managing their wetlands (Ramsar 2008a). The UN Food and Agriculture Organization has also established a payments for environmental services program (FAO 2009). The ES concept is powerful because it establishes a linkage between nature and human well-being, which provides a strong rationale to conserve and manage ecosystems more carefully (Pagiola et al 2002). Examples are becoming increasingly more evident of how people are dependent upon natural ecosystem delivered services for their survival (Box **1**). One estimate put the global value of all freshwater services at USD $7 trillion a year (in 2008 dollars), which is around 15% of the total estimated value of the world's ecosystem services (Costanza et al. 1997).

SECTION 1: MAJOR AREAS OF FRESHWATER WORK, SOLUTIONS AND PLAYERS INVOLVED

Freshwater work includes policies, markets, financing, science and tools and on the ground implementation. These actions target the major threat drivers and provide the means for changing - current land and water use practices to ensure management of ecosystems and delivery of multiple freshwater ecosystem services and benefits. Freshwater work is pursued from global to regional as well as national to local levels, and is driven by governments, academic institutions, think tanks, NGOs and/or development agencies, and the private sector. Some of the most relevant concepts are explained in ***Box 2***. Highlights of the various kinds of players (NGOs, think tanks, Development Agencies, etc.) and the kinds of work they pursued can be found in ***Appendix 1.***

Box 2. Definitions of Key Concepts and Areas of Freshwater Work

Integrated River Basin Management (IRBM) and Integrated Coastal Management are the holistic and sustainable management of water bodies based on natural boundaries. They consider freshwater systems in the context of the rest of the environment taking into account social, environmental and economic factors. IRBM has been adopted by Ramsar, WWF and others to ensure sufficient focus on the environment and ecosystems (UNEP 2007). The Global Water Partnership found that more than 50% of countries were using some kind of integrated water resource management (IWRM) framework in 2006 (GWP 2006), but the conservation community is concerned that IWRM has focused too heavily on economic and social welfare without necessarily ensuring environmental sustainability.

Environmental flows (Eflows) describe the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend upon them. The Eflows concept links the biophysical, including hydrological properties of natural systems, to freshwater-related services proved for people (TNC 2007). Over 200 environmental flow methods have been identified (Tharme 2003). Importantly, managing environmental flows in a river basin context can provide a framework for facilitating societal decisions about sustaining the ecosystem services of forested watersheds, freshwater ecosystems, and coastal waters. This approach can address many shared environmental problems, including habitat change, better protected area management, corridor and migratory pathway protection, aquatic species recruitment, and pollution reduction.

Ecosystem services are the benefits that people receive from ecosystems (MEA 2005a). To ensure that ecosystems are able to provide those services, we must focus on ensuring ecosystem function and resilience, requiring management. International conventions, organizations and governments have more commonly adopted the 'ecosystem approach' (CBD) and 'ecosystem management' to refer to management and service delivery activities and results. UNEP defines ecosystem management as "an approach to natural resource management that focuses on sustaining ecosystems to meet both ecological and human needs in the future. It promotes shared vision of a desired future by integrating social, environmental and economic perspectives to managing geographically defined natural ecological systems" (http://www.unep.org/ecosystemmanagement/).

The **water footprint** of a product (good or service) is the volume of fresh water used to produce the product, summed over the various steps of the production chain. 'Water use' is measured in terms of water volumes consumed (evaporated) and/or polluted. The water footprint is a geographically explicit indicator, not only showing volumes of water use and pollution, but also the locations and timing of water use. **Virtual-water** trade (also known as embedded or hidden water), is the volume of water associated with the import or export of goods or services from one area to another (catchment, country, etc). It includes the total volume of freshwater consumed or polluted to produce the products (Hoekstra and Chapagain 2007; www.waterfootprint.org).

Mitigating Major Threats, Ecosystem Management and Ecosystem Service Delivery

Along with the atmosphere, water is one of the most challenging "common pool" natural resources to manage because it is essential to all life, it crosses political boundaries so readily and it is easily transformed in the production of most goods that societies' require. Policy and institutional failures directly contribute to the service undervaluation problem. Water subsidies for example, encourage environmental degradation. Water policies and regulations might be nonexistent or poorly enforced, resulting in poor governance, large inequities in water access and allocation, and related social costs. Privatization can also have unintended consequences of limiting access to certain portions of the population, particularly in the absence of predetermined water rights and allocations (Richards 2000). Payment for ecosystem services (PES), or compensation for those responsible for providing an ecosystem service is not appropriate in all cases, particularly where land tenure issues are unclear or unresolved.

To assign economic value, define clear policies, and create appropriate markets for ecosystems, we need to first better understand the flow of ecosystem services in biophysical, political and economic terms; at local, regional and national scales. This has been slow and in some cases difficult to accomplish (Chan, et al. 2006). Distinct economic, spatial, and biological data and analyses are in need, as well as decision making tools to translate that information into better development and resource use decisions. The emergence of new measures such as development trade-off analyses, payments for ecosystem services, water footprint, virtual water and water stewardship, illustrate the huge potential for conservation interventions to contribute to sustainability, with solid data and within strong regulatory frameworks. Major areas of freshwater work underway that we will cover in this section of the white paper include: geographic-based interventions, and mitigating the impacts of the most significant development pressures (**Box 3**) on freshwater ecosystems; climate change mitigation and adaptation; land and water resource management and stewardship among the public and private sector; and markets and payment for ecosystem services. We will also characterize philanthropic investments in freshwater.

Box 3. Development Pressures: Agriculture, Infrastructure and Fisheries

- Agricultural withdrawals use 70 of available surface water and conventional irrigation techniques are only 43% efficient in water use (WMO 1997; Cassman and Wood 2005).
- The amount of water consumed by evapo-transpiration in agriculture is predicted to increase by 70%–90% by 2050 unless major improvements are made in water productivity or in production patterns (CAoWMiA 2007).
- Nitrogen and phosphorous, among other contaminants, are linked to agricultural runoff and pollute downstream waters, causing hypoxic zones. Agricultural development and expansion also drives infrastructure development.
- Dams, dykes, reservoirs divert and store water for irrigation, electricity generation, drinking water, and flood prevention. More than 2/3 of our world's rivers have already been diverted which changes the location, timing, and amount of water flows (Poff et al. 1997). They also change temperature regimes, and limit sediment and nutrient deposits downstream and across floodplains. This has altered habitat formation and maintenance processes, nutrient regimes, and has contributed to declines in subsistence and commercial fisheries (Dudgeon 1992, et al. 2000a.b, Li et al. 2000, Shields et al. 2000, Syvitski et al., 2005).
- Major threats to fisheries include habitat loss and pollution. Overfishing and species introductions also alter food webs and sometimes reduce water quality (Allan *et al*. 2005, LePrieur et al. 2008). 1997 data of inland fisheries reported yields of 7.7 million metric tons, which was at or above maximum sustainable yields then, and authors suggested that data reflected less than half of actual capture.

Geographic -Based Interventions Targeting Biodiversity and Ecosystem Function

Neither biodiversity nor ecosystems are evenly spread across space, and development and climate change pressures, and ecosystem resilience or response to those pressures, also differ, suggesting geographically targeted interventions across multiple scales. Organizations have also relied on geographic approaches to defend the strategic nature of their choices, making the best use of limited funds and achieving results in often limited timeframes (i.e., grant deadlines, political windows of opportunity, etc.). Interventions within geographies need to be based on information about biodiversity conservation and ecosystem function and service delivery to set appropriate global and regional goals, and track the effectiveness of specific conservation interventions over time.

The Global Freshwater Biodiversity Assessment (GFBA) is operated collaboratively by the International Union for the Conservation of Nature (IUCN)'s Species Survival Commission(IUCN-SCC), Conservation International, and NatureServe. The GFBA compiles baseline data for all species of freshwater fishes, mollusks, odonates (dragonflies and damselflies), and selected aquatic plants to characterize the current status and threat for freshwater species and ecosystems. The data will provide a mechanism for monitoring the current status of freshwater ecosystems, identifying patterns of change (biodiversity loss) that are the result of growing threats from human populations, and will be used to create indicators of ecosystem health. DIVERSITAS, a partnership of inter-governmental and non-governmental organizations, has developed a research agenda to facilitate and mobilize scientific research on biodiversity, including its origin, composition, ecosystem function, maintenance and conservation (www.diversitas-international.org). They are finishing a global analysis of freshwater ecosystem threats, which will incorporate data as it becomes available from the GFBA. Data on biodiversity distribution and threats, is also the foundation required to inform the future development of global hotspots for freshwater biodiversity—which would need to be expanded upon to include ecosystem function and service delivery. Global spatial analyses examining biodiversity and ecosystem service convergence have been done by Conservation International and the Gund Institute, who are downscaling these analyses to the site level (Turner et al. 2007).

Freshwater Ecoregions of the World, (FEOW) were recently developed by World Wildlife Fund (WWF), The Nature Conservancy (TNC), Wetlands International (WI), Worldfish, and dozens of other partners to provide global biogeographic regions which characterize freshwater habitats and biodiversity (www.feow.org). FEOW covers virtually all of the freshwater habitats on Earth, which will be further strengthened by the GFBA. FEOW can be used for freshwater conservation planning efforts, particularly to determine habitat representativeness for protected area designation as required by the CBD and the Ramsar Convention. Data on species assemblages were collected, but are unfortunately not stored in a way to use them for other analyses, such as the GFBA. A preliminary analysis was conducted by CI to look at links between habitats, species concentration, and freshwater flows, which revealed that CI's terrestrial biodiversity hotspots capture and deliver more than 60% of the existing amount of clean water that could be delivered downstream from various habitats (unpublished data). Analyses are needed to help suggest new ecosystem service targets on top of biodiversity targets. The next steps for FEOW include linking habitats to hydrosheds, a watershed database, which will better link hydrological properties to ecoregions and help target ecosystem service flows.

<u>Freshwater Ecosystems, Solutions Applied and Locations of Work</u>

Freshwater field programs can fit into several, often overlapping thematic categories and work covers the entire planet. Some programs, such as Conservation International (CI), Birdlife

International (BI) and IUCN-SSC target their engagement based on where species are globally threatened as well as wilderness areas where they are not currently threatened, yet include areas of high endemism protecting sites and corridors within these areas where rare and endemic species are concentrated. IUCN's Redlist data are used to develop, hotspots and important bird areas or key biodiversity areas, and areas are protected through Ramsar sites. Wetlands International (WI) promotes conservation through Ramsar sites, as does World Wildlife Fund and others. Freshwater ecosystems protection fits into multiple IUCN protected area categories (Dudley 2008). Locations targeted by NGOs are mostly in the developing tropics. For example, CI's freshwater portfolio includes the greater Mekong, Tibetan Plateau in China, Southern Africa and South Africa, the Atlantic Forest in Brazil, communal lands in Guatemala and Costa Rica. TNC and WWF focus on biodiversity, but rely on habitat representativeness, which increases their geographic scope to include more of the developed world compared to WI and CI. General activities across all of these organizations include protected area designation and management, monitoring species population status and recovery, and engaging local communities and governments in alternative economic development pathways that promote conservation objectives (www.conservation.org, www.wetlands.org, www.panda.org, www.nature.org).

Other programs target river basin systems as the largest unit capturing watersheds and ecosystems, either to address related threats, or conversely, to maintain their unimpaired quality. For example, WWF identified rivers in immediate need of protection through its top ten rivers campaign (Wong et al. 2007). Its threatened rivers programs underway include: Chihuahua freshwater, Amazon, Pantanal, Brahmuputra, Koshi - tributary of Ganges, Mekong, Yangtze, New Guinea Rivers & Streams, Congo, African Rift Lakes, Danube, Balkan Rivers & Streams, and Zambezi. As another example, TNC's Great Rivers Partnership program selected the Paraguay-Paraná in Brazil, the Yangtze River in China, and the Mississippi in the US as global rivers at risk. TNC defines great rivers as "large-floodplain Rivers with seasonal floods sufficiently long-lasting and predictable Some of the activities shared by both WWF and TNC include forest and river restoration, establishing environmental flows, removing agricultural subsidies, conservation of important habitats for species, better laws and quarantines to avoid species introductions, international cooperation, technology transfer, market-based approaches like PES, policies, and management of pollution point sources (www.nature.org/wherewework/greatrivers; www.panda.org).

Wild Rivers programs recognize the cultural, spiritual and biodiversity values of unimpaired systems, both for intrinsic and monetary purposes (i.e. recreation). Wild river legal designations can afford long term protection and maintain pristine attributes of free flowing rivers. For example, The National Wild and Scenic Rivers System in the US was created by Congress in 1968 "to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations." Rivers are classified as wild, scenic or recreational (www.rivers.gov). Similar river protected area mechanisms exist in Canada, the European Union and a number of Australian states, and some nations like China are contemplating fully protecting one or more river corridor. The Wild Salmon Center works on wild river and salmon conservation in Northern Pacific states of the US as well in the Kamchatka Peninsula in the Russian Far East, protecting rivers for salmon population viability, and their recreational and commercial fishing value. The Wild Foundation is an international organization dedicated to wilderness protection, focused heavily in Sub-Saharan region of Africa, but also in the Amazon of Brazil, India and the northern reaches of Russia. Programs focus on large intact wilderness, including wild rivers. They train protected area managers, field test conservation approaches, help grow new local organizations and help local communities develop sustainably (www.wild.org).

Ecosystem-Based Interventions Addressing Demand and Climate Change Pressures

Growth in demand for freshwater resources is increasing dramatically as a result of increasing populations and increasing wealth leading to greater consumption of thirsty agricultural and other products (CAoWMiA 2007; WWAP 2009). One consequence is that freshwater biodiversity is in greater decline than other taxa, as well as being less systematically conserved (MEA 2005b). As the limits of divertible water resources are being reached in many parts of the world there are extensive and growing impacts on people and ecosystems, more elaborate engineering schemes (Pittock *et al.* 2009), as well as increasing demand for greater water efficiency and market based measures to use every drop more effectively. Debate continues on the nature of water scarcity given the uneven distribution of water globally (Rijsberman 2006) and boundaries for global water use (Molden 2009; Rockström *et al.* 2009), but there is consensus that greater water efficiency and better governance are two essential solutions (WWAP 2003). . Water pollution must also be addressed. It greatly reduces water availability in key regions of the world, and planetary limits have recently been proposed for nitrogen, phosphorous and other water pollutants (Rockström *et al.* 2009). Nitrification of the environment, with freshwater as a key vector, is likely to become the next global environmental crisis after climate change (UNEP and WHRC 2007).

The MEA identifies habitat alteration/modification (including water diversions) and pollution as major threats for freshwater ecosystems, some of the largest development-related drivers of these threats include agriculture, infrastructure development and fisheries production—land and water must be managed together in all cases to promote rather than degrade ecosystem function (MEA 2005a). To address threat drivers, the MEA calls for "pragmatic ecosystem maintenance of inland and coastal river basins and wetlands, as supported by the CBD and Ramsar", where integrated land and water management leads to stable water supplies (quantity and quality). Related services provided can include carbon mitigation and crop productivity, and increased food sources from aquatic systems. Improved water quality leads to better health, and there is also an aggregate benefit from all of these benefits that reduces poverty (MEA 2005b).

Agriculture and Water Productivity

Integrated management for agriculture means healthy soils, which increase water productivity, versus degraded soils which require more water and more intensive water management. It also means preventing poorly managed water which can contribute to soil erosion, and nutrient depletion. Providing agricultural water is significant for directly reducing poverty, through food output, higher opportunities for employment and higher incomes (ADB and IWMI 2005). Agroecology, the science and practice that incorporates ecological principles into the design and management of sustainable and resource-conserving agricultural systems (www.fao.org), also offers promise for encouraging ecosystem management service delivery. For example, a project in Burkina Faso by the Institut de l`Environnement et de Recherches Agricoles better managed soil and water for sorghum and millet, by adopting more broadly, local techniques of using stony holes with a small amount of manure to retain water (http://www.agroecology.org/CaseStudies_Asia.html). Additionally, a project by CI is looked at the water saving, quality and carbon sequestration benefits of shade grown coffee, versus conventionally grown coffee in Mexico.

The Comprehensive Assessment of Water Management in Agriculture (CAoWMiA 2007), recently completed by the Consultative Group on International Agriculture Research (CGIAR) Challenge Program on Water and Food, and International Water Management Institute (IWMI), highlighted policy and implementation actions including: managing agriculture to enhance ecosystem services; increasing the productivity of water, including upgrading rainfed irrigation systems; adapting yesterday's irrigation to address future needs; targeting state institutions to reform incentives for inefficiencies; and dealing with tradeoffs and making difficult choices. IWMI has been researching the interface between surface or "blue" water and water retained in the soil and plant roots or "green" water, and how to maximize crop yields through better land and water management as well as planting techniques and crop selection. The International Center for Agricultural Research in the Dry Areas (ICARDA) is another CGIAR center, with a stronger policy and focus on exchange of technology among centers in the Nile Valley and Sub-Saharan Africa, West Asia, the Arabian Peninsula, the Highlands, and Latin America. Technology transfer and its adoption by farmers is promoted through multi-disciplinary research teams involving national scientists, extension work and farmers. This ensures a research continuum between ICARDA's research programs and those of the national agricultural research systems.

Infrastructure Development and Environmental Flows

Infrastructure development may help alleviate poverty, through increased access to drinking water, electricity, and irrigation for agriculture—yet it also diverts more than two thirds of our rivers and is a major threat driver for biodiversity and fisheries production downstream. The Hydropower Sustainability Assessment Forum (HSAF) is identifying standards for better practices for hydropower projects, and includes The Nature Conservancy (TNC), WWF, Oxfam, Transparency International, and others (http://www.hydropower.org/sustainable_hydropower/hsaf.html). This work builds upon the guidelines suggested by the World Commission on Dams, which were never meaningfully adopted. HSAF may evolve into a certification program. Human rights and wild river advocates, such as International Rivers, have focused on reparations for communities and alternative energy solutions to better protect the environment from the ecological impacts of dams (www.internationalrivers.org).

Environmental impact assessments for dams in the past have only focused on the immediate area around single dams and reservoirs, in spite of the fact that dams can modify river systems for hundreds of miles downstream and are also often part of a series of dams. Earlier, larger scale, regional infrastructure planning that understands large landscape and watershed dynamics are particularly important when dams are planned, to minimize social and environmental impacts and maximize socio-economic benefits and form the basis for strategic environmental assessments (see **Figure 1**), which are being more widely adopted by multi-lateral and bi-lateral development agencies. Guidelines were just released by the World Bank to apply structural and operational considerations to Bank hydropower development for better facilitating environmental flows. Example considerations include: variable outlet and turbine-generator capacities, re-regulation reservoirs, power grid interconnection, flood management in floodplains, sediment bypass structures and sediment sluice gates, fish passage structures, and periodic infrastructure relicensing (Krchnak et al. 2009). Recently, a new, faster and cheaper technique for setting environmental flows at a regional scale has been developed (Poff *et al.* 2009), call ecological limits to hydrological alteration, or ELOHA.

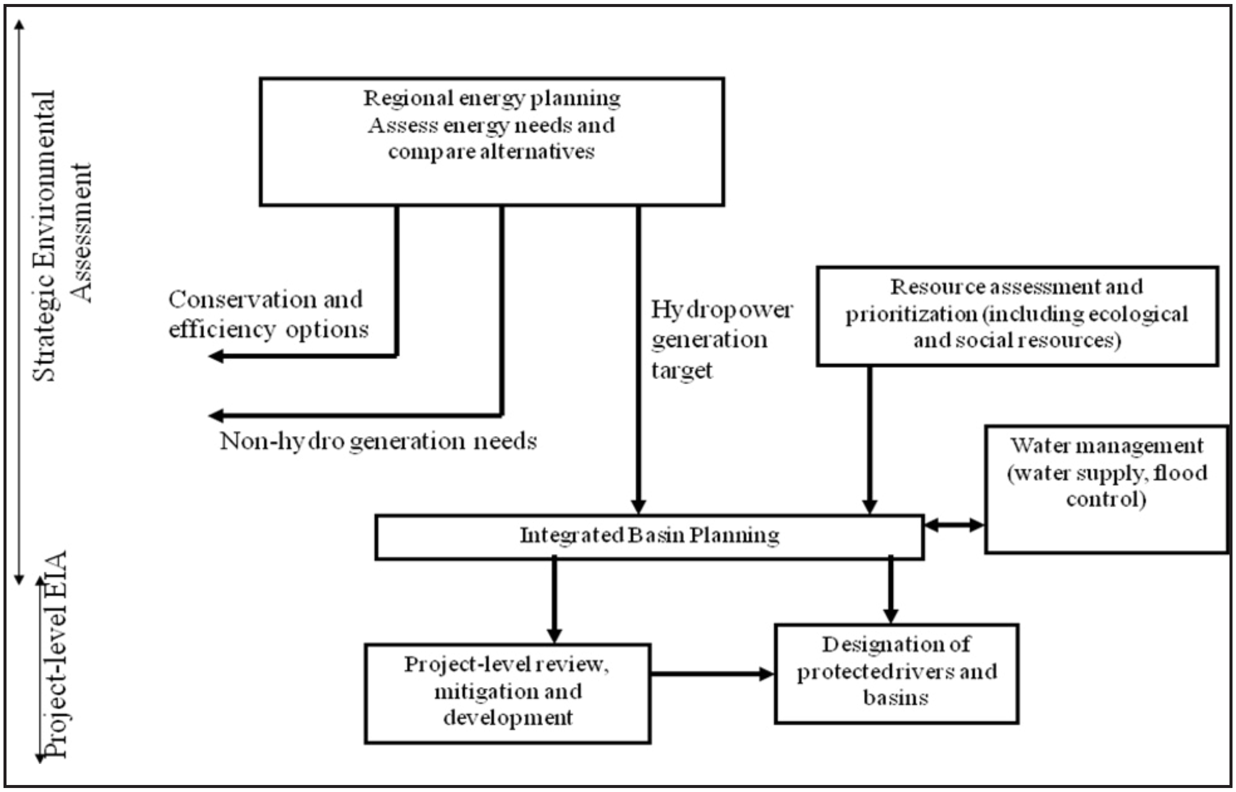

Figure 1. Regional approach for hydropower planning and development ©*Opperman 2008*.

Environmental Flows (Eflows) programs are growing in popularity, as evidenced by Eflowsnet, a network of more than three hundred members doing research and implementing Eflows projects. The Eflownet steering committee includes members from the United Nations' Development Program- Center for Water and Environment (UNDP- NHI) and UN's Educational, Scientific and Cultural Organization - Institute for Hydraulic Engineering (UNESCO- IHE), Institute for Water Education; as well as Deltaris, a Dutch watershed planning and engineering consulting company, and NGOs including CI, WWF and TNC among others (www.eflownet.org).

Eflows projects manage water to meet ecological and socio-economic needs, and focus on understanding development needs and trade-offs, infrastructure design and operation, and supporting requirements of governance and financing. For example, IUCN's Water and Nature Initiative (WANI) demonstrates "good water management supported by the development of tools for financing, governance, empowerment, and information". Its portfolio of on the ground projects includes river basins in Africa, Asia and Central and South America: the Huong, El Imposible-Barra de Santiago, Tacana, Komadugu-Yobe, Lake Tanganyika, Pangani River Basin, Pungwe River Basin, Senegal River Basin, Mekong River Basin, Okavango River Basin, and the Volta River Basin (http://www.fsd.nl/naturevaluation/71524). The Natural Heritage Institute and The Nature Conservancy, also have implemented Eflow projects, including a variety of dam location and reoptimization projects in China, Latin America, Southern Africa, and with the Army Corps of Engineers across the United States, maintaining and restoring environmental flows, following run of the river precepts as much as possible (www.nature.org; http://www.n-h-i.org/; www.nature.org).

Fisheries and Food Production

About 1 billion people, most of who are in developing countries, rely on fish as their primary animal protein source (Laurenti 2002; Allan et al 2005). In recognition of both individual and assemblages of species collapses among other ecosystem services lost, fishery science and management is shifting its focus from single species to ecosystem-based fishery management (Pikitch et al. 2004). Marine based organizations, including the Australian Fisheries Management Authority and the US's National Oceanographic and Atmospheric Administration have already adopted these sustainable management principles.

Major issues being addressed for ecosystem-based inland fishery management include: management of fishery resources (gear restrictions, enforcement to reduce illegal fishing levels, reductions in effort/quotas, gear restrictions, seasonal closures, etc.); establishment of freshwater protected areas; and examination and management of the impact of effluents and runoff to target additional impacts on sustainable fisheries production. The related impacts of aquaculture are also important (e.g., shrimp farming, issues with escapees and disease, sustainability of feed, etc.). TNC, WWF, CI and UNEP have been involved in sustainable inland fisheries projects, with some work linking wild stock harvesting to aquaculture, and managing primary and secondary impacts on freshwater systems, including FAO, Texas A and M.

<u>Climate Change Mitigation and Adaptation</u>

Warming is likely connected to large scale changes in the hydrologic cycle. Changing rainfall patterns and runoff from snow and ice, increasing evapo-transpiration and the frequency of extreme events, like floods and droughts are also expected (Bates et al. 2008). Many freshwater species may either need to move to suitable habitats where this is possible or be extirpated. The impacts of climate change are highlighted in more detail in **Box 4**.

Responses by governments and societies to climate change may further exacerbate these impacts, since many climate mitigation measures like hydropower production and biofuel production can have severe impacts on freshwater ecosystems (Pittock 2008). Concomitantly some measures to respond to water scarcity, such as desalination, consume more energy and may increase greenhouse gas emissions. These various perverse impacts highlight the need for governments and societies to adopt more effective cross-sectoral decision making and management institutions (Ross and Dovers 2008).

Box 4. Impacts of Climate Change on Water Resources

The International Panel on Climate Change (IPCC) projects impacts ranging from likely to high confidence in their occurrence based on observational records and climate change projections:

- Precipitation and average annual runoff will increase in high latitudes but decreases in some subtropical and lower mid latitudes (already dry regions).
- Increased intensity and variability in precipitation will likely increase risks of flooding and droughts.
- Water supplies from glaciers and snow cover will decline.
- Temperature changes will affect water quality and some forms of pollution.
- There is high confidence that rising water temperatures and related changes in ice cover, salinity, oxygen levels and circulation will impact freshwater biological systems.
- It is also very likely that increased global average temperature exceeding 1.5 to 2.5°C with related atmospheric CO2 concentrations will create significant changes in ecosystem structure and function and resilience.
- Ecological interactions and shifts in species' geographical ranges, among other negative consequences for biodiversity and ecosystem goods and services, are also projected (Bates et al 2009).

Climate and other changes to hydrology change the fundamental tenant of both water management and biodiversity conservation: that past conditions are a guide to the future. This concept of "stationarity" is dead (Milly *et al.* 2008), requiring new data and updating existing models. Further, many of the changes to hydrology are happening in ways that are not predicted by climate change modals and are below the resolutions of these tools (Pittock 2008). Adaptation needs to begin before there is scientific certainty about climate change impacts to manage risks, undertaking no and low regrets adaptation measures (Pittock 2009), such as building the resilience of ecosystems (Dudley *et al.* 2010; Hansen *et al.* 2003; Matthews and Wickel 2009; Trumper *et al.* 2009).

Ecosystem-based approaches harness the natural processes and functions of ecosystems to mitigate and adapt to climate change, sustaining the provision of drinking water, waste removal, energy generation and fisheries production among other ecosystem related freshwater benefits. The Stern Review on the Economics of Climate Change recommended that governments develop policies for "climate sensitive public goods including natural resource protection, coastal protection and emergency preparedness" (Stern 2006). Multiple organizations are pushing for ecosystem-based approaches. The International Rivers organization has been mobilizing policy efforts to make sure that the Clean Development Mechanism does not incentivize dam development without considering ecosystem impacts. The Climate Action Network, Global Public Policy Network, Nairobi Program of Work, and World Water Week efforts have been pushing for recognition of the importance of linking land and water management as part of IWRM approaches, and incorporating freshwater ecosystem function, resilience, and service flows into the UN Framework Convention on Climate Change (UNFCCC), as well as consequent frameworks post Copenhagen 2009. The World Bank's Pilot Program for Climate Resilience and a similar financing program from the Global Environmental Facility (GEF) rely heavily on National Adaptation Plans or NAPAs to commit adaptation funding, but these plans have not been well developed, requiring additional support from NGOS and governments. WWF, CI, TNC and IUCN, among others, have begun to target their conservation efforts to specifically capture ecosystem-based adaptation benefits, but work is still preliminary. Additionally, WI, CI, WWF, TNC and the Cooperative Program on Water and Climate have been advocating that failure to maintain and restore natural ecosystem functions such as storm protection and mitigation of floods and droughts, will jeopardize upcoming multibillion dollar infrastructure investments that aim to help societies adapt to the impacts of climate change. The group is developing arguments and seeking case studies that show how too much focus on hard infrastructures like dams and dykes can lead to mal-adaptation, inflicting severe, unintended damage on people and nature.

Public and Private Sector Land and Water Management and Stewardship

Global to regional and local policies have been developed to create better governance and stewardship, as well as promote development that considers ecosystem management and resilience. Examples of this work, includes: pushing for ratification of the UN Watercourses Convention (Loures *et al.* 2008), integrating inland waters management into the Convention on Biological Diversity Program of Work for protected areas, pushing for ecosystem-based adaptation approaches and funding included into the Framework Convention for Climate Change; and establishing and supporting regional and local basin and water management bodies, such as Mekong River Commission and The Amazon Treaty Cooperation Organization. River basin organizations, particularly when driven by community entities or effective local governments, offer necessary enabling conditions for stewardship.

Stewardship also requires clear approaches and methods at the watershed and landscape scale, such as IRBM. Its predecessor IWRM have has been adopted by think tanks such as the International Water Management Institute, multi-laterals including the World Bank and Global Environmental Facility, and relief agencies such as Catholic Relief Services and CARE, among dozens of others. Watersheds are desirable units of intervention because they address the basic building blocks required for land and water planning. They also acknowledge the consequences of watershed degradation: natural soil erosion, changes in farming systems, overgrazing, deforestation, and pollution results in depletion of soil productivity, sedimentation of water courses, reservoirs and coasts, increased runoff and flash flooding, reduced infiltration to groundwater, and water quality deterioration. Better watershed management can ensure the quantity and quality of both land and water resources—one element of freshwater-related service delivery (Darghouth et al. 2008). A variety of tools have been created to assist managers in developing and applying IWRM and address threats. For example, Stockholm Environmental Institute's Water Evaluation and Planning System to calculate water demand, supply, runoff, infiltration, crop requirements, flows, and storage, and pollution generation, treatment, discharge and instream water quality under varying hydrologic and policy scenarios (http://www.weap21.org/). Other approaches have included spatial planning to managing landscapes and watersheds for optimal resource and development objectives. For example, CI has developed a series of economic and spatial models for specific landscapes to assess hydrological properties and determine how they influence ecosystem services flows and delivery, identifying beneficiaries and opportunity costs of adopting more environmentally friendly land use activities.

Another tool useful for encouraging water stewardship is water footprinting. This is an important tool for making transparent the trade-offs between water and other key commodities like energy (Gerbens-Leenes *et al.* 2008) in society. The Water Footprint Network brings together NGO, corporate and academic practitioners from around the world http://www.waterfootprint.org). Its primary applications include justifying and developing better water use practices for: individual corporations and industry sectors (e.g., enhancing water efficiency and implementing water accounting and product life cycle analyses); for governments and other resource managers (e.g., decisions about water allocations between thirstier users, identifying trade-offs between multiple users); and for individual consumers (e.g., product labeling, making informed choices about thirstier products). The Pacific Institute has also been promoting footprinting use, as well as publishing other reports on water efficiency capture (www.pacificinstitute.org). WWF has completed a range of assessments, including for the UK, South Africa and Germany to understand their water footprints on other countries through examining specific products. SAB Miller with WWF and PepsiCo with TNC have been among some of the initial corporate pioneers to test and apply water footprinting to their products. A related effort, the Alliance for Water Stewardship, is looking to develop water benchmarks and standards for particular uses and products leading to a certification program, similar to the Forest Stewardship Council (www.allianceforwaterstewardship.org). The vulnerability of many nations to water scarcity as revealed by footprinting has led to consideration of trade in 'virtual water' embedded in products. One opportunity is for water scarce societies to import 'thirsty' products to conserve local water supplies, such as imports of agricultural products into the Middle East, while exporting low water demand products.

Water Markets and Payment for Ecosystem Services

Markets, payment and incentives for freshwater services programs are being widely adopted. Payment for ecosystem services (PES) are used to compensate those responsible for providing an ecosystem services via economic incentives. PES programs can include direct costs or address specific land use practices or the opportunity costs of avoiding certain activities or land uses. National payment for ecosystem services programs have been implemented in Costa Rica and Mexico, with a new poverty alleviation-based program being implemented in Ecuador. China is also looking to adopt a national PES scheme. Compensation can be monetary or in-kind, and programs have been implemented largely at local, but also in the cases of Costa Rica, Mexico and Ecuador, at national scales. Approaches to targeting and valuing ecosystems at global scales, have been done most notably by University of Vermont and the GUND Institute, and more recently looking at ecosystem services provided by hotspots and high biodiversity Wilderness Areas, as mentioned, as well as across landscapes to examine opportunity costs of conservation (Turner et al 2007; Wendland et al 2009). Other organizations such as Earth Economics, have valued multiple services across scales, determining major beneficiaries and helping to target and implement PES programs in the developed and developing world (www.eartheconomics.org).

A variety of decision making tools and ecosystem services valuation programs have also been developed to help with regional scale targeting, valuation and design of PES schemes at regional and local scales. For example, the Artificial Intelligence for Ecosystem Services (ARIES) is a National Science Foundation funded project to develop a web-based tool for users worldwide to assist in rapid ecosystem service assessment and valuation. It is being developed by a consortium of partners including CI, Earth Economics, and University of Vermont ARIES, and it helps discover, understand, and quantify environmental assets and what factors influence their values, in a geographical area and according to needs and priorities set by its users. The Nature Conservancy, World Wildlife Fund and Stanford University, with other partners, implemented the Natural Capital (NatCap) Project. NatCap is a multi-million dollar project intended to understand and value the trade-offs between multiple ecosystem serves in decision-making (inVEST tool), and apply that to land and water use management in the US, China, Indonesia, Northern Andes, Southern Central America and Tanzania, and engaging leaders in these places in the implementation of these tools to ensure results inform policy-making (www.naturalcapitalproject.org). Ecosystem services valuation and PES programs often take advantage of bundling multiple services, to minimize transaction costs, and to capture additional services that may be hard to quantify (i.e., supporting services). The three most common services tend to include biodiversity, carbon sequestration through forests, and water provision.

Water markets have focused primarily on wetland mitigation banking and easements, and cap and trade systems, implemented primarily in developed countries. New programs such as nutrient trading, water trusts, and others are beginning to emerge as water quantity and quality problems worsen. For example, the Ecosystem Marketplace has been experimenting with nutrient trading cap and trade program to improve water quality in the Chesapeake Bay, which also has interesting implications for work in developing countries with nutrient loading problems (China, Brazil, etc). A diversity of financing mechanisms is needed to respond to varying policy and market environments (freshwater related service provided, risk reduced, and offsets). Effective approaches require sufficient policy and strong institutions to manage and monitor programs, which are some of the lessons learned from the Costa Rica experience. Approaches must also reduce transactions costs, mitigate investment risk and ensure equitable compensation and benefits sharing to improve market and compensatory policy.

Philanthropic Investments in Freshwater

Globally, very few charitable trusts fund water resources management work outside of their home nations. The US has the highest number of these, including mostly those that focus on the human dimensions of water management. Foundations investing or with potential to invest in water (in addition to MacArthur Foundation) include the Paul G. Allen Foundation, Blue Moon Fund, Stephen Case, Castle Foundation, Doris Duke Charitable Foundation, Ford Foundation, Bill and Melinda Gates Foundation, Richard and Rhoda Goldman Fund, The William and Flora Hewlett Foundation, Legacy Fund, Moore Foundation, Oak Foundation, Omidyar Network, Packard Foundation, Foundation Prince Albert II de Monaco, Rockefeller Foundation, Skoll Foundation, Carlos Slim Helú, Walton Family Foundation, and Clinton Foundation. The UK also has the Sigrid Rausing Trust and also the Cadbury Trust, and Japan has the Sasakawa Peace Foundation. A number of companies run big international water prizes, including Thiess Construction via the International River Foundation, and SwissRe. The GEF International Waters portfolio, and World Bank among other development banks also have significant funding for water and watershed management projects. Sponsorship from major companies also is pertinent. The Coca-Cola Company for example invested $25 million / 4 years, and HSBC (climate focused with a bit of water) $20 million / 4 years. Other smaller investments have been made by Fiji Water and 3M Corporation. There is a significant gap in freshwater ecosystem management funding—presenting a great opportunity for the MacArthur Foundation (as discussion in sections 3-6).

SECTION 2: CASE STUDIES OF RIVER BASIN PROJECTS

Four case studies are presented in this section to exemplify various challenges and solutions implemented and to recommend areas of interventions that need further support.

Yangtze River

Introduction

The Yangtze River is the longest river in China and Asia and the third longest in the world. Running 6,300 km from the Tibetan Plateau to the East China Sea, the river system drains an area of 1,800,000 km^2 in 19 provinces of China, and over 400 million people live in the basin (**Figure 2**). Its average annual runoff is about 996 billion m^3 (BCM), accounting for about 36.5% of China's freshwater resource and 40% of China's gross domestic product. The Yangtze River supports diverse flora and fauna, with over 340 species of fish alone, that are well adapted to constantly changing water levels and flow (Yu *et al.* 2009).

Until late last century, the river and its lakes formed a complex wetland network fulfilling important ecosystem functions such as serving as the spawning and feeding grounds for fish and retaining summer floodwaters. However, dam and dyke construction in Hubei Province in the 1950s–1970s, cut off 1,066 lakes covering over 2,000 km^2 from the Yangtze main stem. Most of the lake shore area was converted to polders, where agriculture was developed. Altogether, the total wetlands area was reduced by 80% and flood water retention capacity declined by 75%, or 2.8 billion m^3. The fragmentation of the river–lake wetlands complex caused the interruption of hydrological, ecological and geochemical processes. Four major floods between 1991 and 1998 resulted in thousands of deaths and billions of dollars of direct economic losses. The national government responded with programs to prohibit logging in the headwaters, to pay farmers to plant forests on steep slopes, and to return illegal polders to floodplain.

The lack of hydrological connection between lakes and the Yangtze River blocked the seasonal migration of fish and freshwater cetaceans and reduced the purification functions of wetlands and lakes. Disconnected lakes have become highly polluted from agricultural return flows, industrial and domestic discharge, and aquaculture. Recently, higher air and water temperatures associated with global climate change have exacerbated eutrophication and further reduced water quality. Recent extreme weather events have had powerful negative effects on the hydrology of the river–lakes complex over relatively short periods of time (weeks or months), but these effects have been sufficiently strong to have altered sensitive species and ecosystems, as evidenced by floods in the 1990s, droughts in 2006 in Chongqing Municipality and in 2007 in the Dongting and Poyang lake areas, and the severe snowstorm in the central and lower Yangtze basin in January

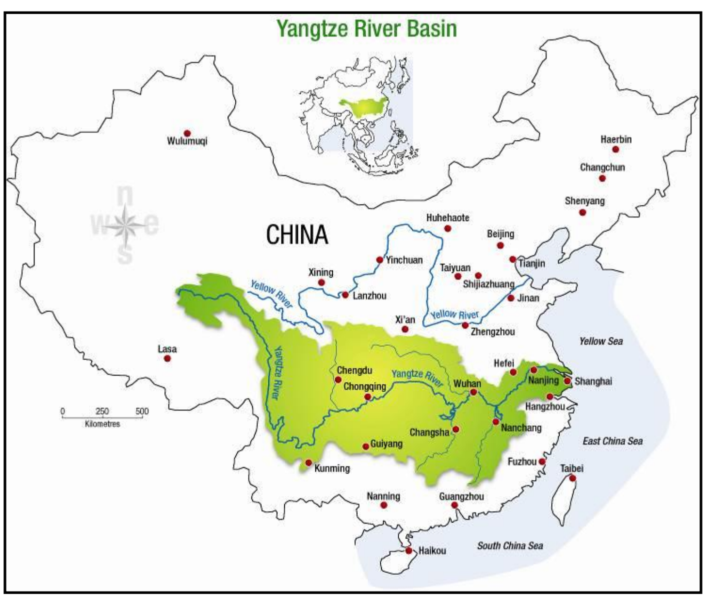

Figure 2. Location of the Yangtze River Basin © WWF

Management Challenges

Management of the Yangtze basin is complex, with nine national government ministries ("dragons") having management mandates, notably the ministries for water resources (water quantity, hydropower and flood control), environment protection (water quality) and forestry (wetlands and wildlife). Management is further undertaken by 19 provinces and many municipal governments. The priorities for governance are set through the national five year plan and influenced by the National Development and Reform Commission, institutions which promote a sustainable development philosophy. At the basin scale, the Yangtze Basin Master Plan is being revised for the first time in decades by the Ministry for Water Resources, including "red lines" announced recently as the limits to resource exploitation. The Three Gorges Dam Project Construction Corporation and South to North Water Transfer Project Corporation oversee major engineering projects, including construction of some of the 105 major hydroelectric dams proposed for the basin plus the two approved water transfer routes currently under construction.

Extensive pollution of parts of the river system is of great concern to Chinese society. In more recent times, as the Three Gorges Dam has closed and greater climatic variability has been seen, periods of low flows have stranded major floodplain lakes, notably Poyang, and floods threatened large population centers. Channel erosion downstream of the dam threatens to further isolate the floodplain and undermine the extensive flood protection levees. Populations of migratory fish and birds have collapsed, although restoration of some lakes and reintroductions of some wetland species like St Pere David's deer has been successful. Major investment and networking for wetlands conservation is underway through the Ministry of Forests and WWF (Yu *et al.* 2009). Low flows may be exacerbated in future by increasing water diversions from the Yangtze. There is growing concern in Shanghai at the city's vulnerability to sea water intrusion and flooding due to lower river water and sediment inflows, delta erosion and sea level rise.

Growing water scarcity in northern China is driving a debate on future water diversions, including a proposed western, third route of the south-north water transfer project, versus trade in virtual water (Ma *et al.* 2006) and demand management measures.

China has many of the right policies but struggles to implement them despite having considerable resources available. One issue is a predilection to choose an engineering solution to any problem. Many government policies and laws, while well meaning, are contradicted by other measures. Government agencies rarely collaborate with each other, and there are limited means of holding government agencies accountable for implementing government policies. China's challenge is to design more holistic, effective and accountable government programs.

Solutions Underway and Proposed

The Chinese Government is about to finalize its 12th five year plan that is likely to contain further sustainable development measures, that will flow through to other institutions. The revision of the Yangtze Basin Master Plan currently underway is the major opportunity to establish management and development targets. Many of the national and basin instruments involve zoning, and NGOs like WWF have proposed measures such as designating free-flowing rivers for legal protection, such as the Chishui River in the Yangtze basin. Two quasi-government platforms have some influence:

- The China Council on International Cooperation on Environment & Development (with IUCN and WWF as NGO members) has taskforces that advise the Chinese Premier and State Council on reforms on an annual basis. It's 2005 report on integrated river basin management proposed a number of key institutional reforms (Chen *et al.* 2003), and it has a taskforce on ecosystem services and management (including WWF and TNC members) that is due to report in 2010;

- A biennial Yangtze Forum has been established that brings together national and provincial officials and non-government experts to discuss coordinated management of the Yangtze basin. A group of influential Chinese academics has produced a frank “Yangtze conservation and development report” (Anon. 2007) to coincide with the last two Forums, and which proposes further measures for better river management.

Most of the proposed reforms involve better institutional arrangements for integrated river basin management (Wang *et al.* 2007) and to streamline conflicting laws and policies, to better conserve wetlands nature reserves for example. China has a history of ecosystem services schemes, such as the “grain for green” program to reforest steep farm lands, and such “eco-compensation” measures could be extended. The Ministry of Water Resources has major environmental flow projects at three rivers and three lakes that could be extended. Further, the thousands of decrepit and dangerous dams in China demand remedial action, which creates opportunities to partner engineering institutions to rebuild these structures to reduce their environmental impacts, such as by retrofitting fish passes. TNC has a program that is looking at re-operating Yangtze dams to reduce their flood control capacities, operate them as run-of-river dams to generate more hydropower, and use some of the extra income for river and floodplain restoration. WWF has a program directed at networking national, provincial and municipal wetlands managers and restoring floodplains to give the rivers room to flood safely while better conserving biodiversity. In addition a great many western aid agencies seek to fund river management programs in China, however their effectiveness appears limited by requirements to work through national ministries and a focus on technology sales. A number of China’s existing policies are most strategic, such as their national wetland conservation action plan (State Forestry Administration 2002), and a lot of progress could be achieved by fully implementing them.

Pathways Forward

China could achieve major gains for freshwater conservation by greater investment directed through NGOs who can move between different government agencies and levels of government to facilitate more effective action, and leverage additional resources from these governments. Investments could support projects that partner with Chinese government agencies and academic institutions to embed the knowledge and experience into local institutions. Suggested actions include:

- National scale advocacy to complement the large investments in the field and enhance existing national policies and promote their implementation, e.g. zoning programs associated with the five year plan, integrated river basin management;
- Assessments of conflicts between national environment and natural resource management laws and options for streamlining these policies;
- Pilot projects of new applications of conservation tools, such as payments for ecosystem services or periodic relicensing of dams, and link these to basin and national scale policy reform;
- Programs to demonstrate ecosystem-based and market alternatives to major infrastructure projects, e.g. to manage water scarcity;
- Enhancing capacity for more effective integrated river basin management.

Lesotho Highland Water Project, Senqu / Orange River - Lesotho and South Africa[3]

Introduction

The Lesotho Highlands Water Project (LHWP - www.lhwp.org.ls) is a multi-billion dollar water transfer and hydropower project that was conceived in 1950s and formalised in 1986 through the signing of a treaty between Lesotho and South Africa. The scheme transfers water to the Johannesburg region of South Africa. Planned as four phases with a total cost of ~ USD $8 billion (Gleick 1998), phase I was completed in 2003, and phase II was approved for construction in 2008. It is envisaged to eventually comprise six major dams (four phases), and associated infrastructure, on the headwaters of the Senqu River in Lesotho, which becomes the Orange River as it crosses into South Africa (**Error! Not a valid bookmark self-reference.3**). Water is the principal natural resource of Lesotho and its mountains generate nearly 50% of the total run-off of the Orange River, although they constitute only 5% of the total area of the Senqu/Orange Basin.

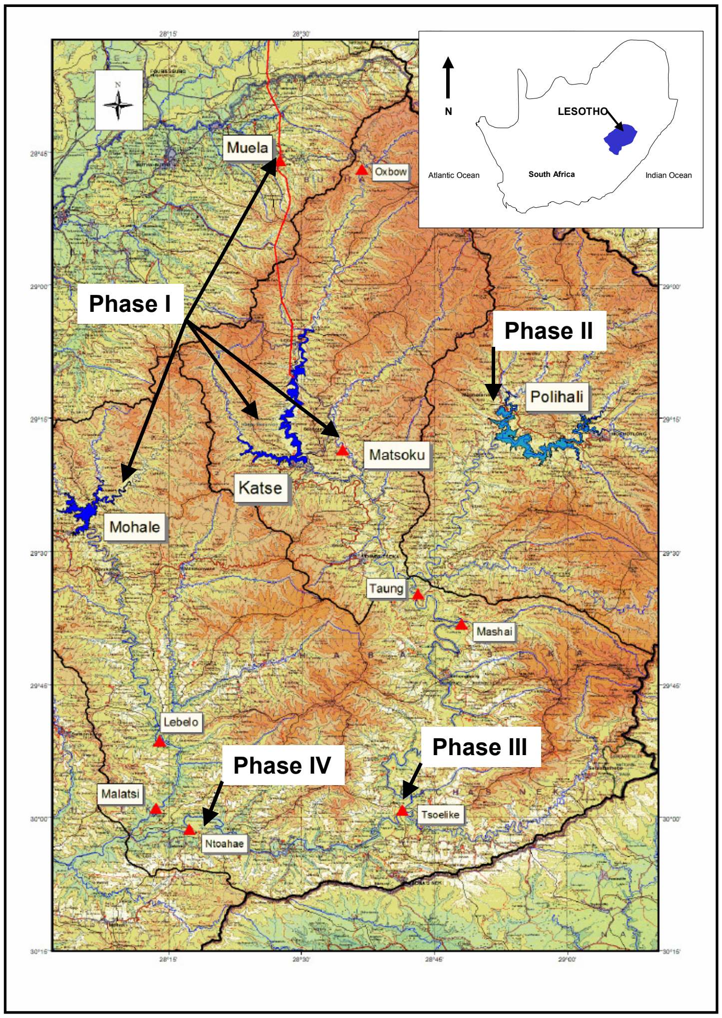

Figure 3. Location and layout of the Lesotho Highlands Water project (Odendaal 2007).

South Africa buys water thereby generating export revenue for Lesotho. Lesotho has gained immense economic benefits from the LHWP with over US$ 300 million in royalties (Jan 1998 - April 2009) since water delivery to South Africa began in 1998. The country is also now self-sufficient in power generation. Project-related roads, bridges, power lines and substations, and telecommunications, and ancillary developments (schools, clinics, water supply), have greatly improved access, communications and community infrastructure in the highlands (Tromp 2006). Tourist numbers in the highlands, although still low, have improved noticeably (Tromp 2006).

The employment and capacity-building opportunities offered by the project have also been significant, and include employment by LHDA, construction-related employment and consulting opportunities. For instance, Phase IB provided 13 000 person years of employment, of which 40% were from the Highlands, and generated income of *c*. US$ 25 million in fees to Basotho consultants (Tromp 2006).

[3] This text draws extensively on a Lesotho Highlands Water Project case study prepared by C. Brown on interbasin water transfer for WWF: Pittock, J., J. Meng, M. Geiger and A. K. Chapagain, Eds. (2009). Interbasin water transfers and water scarcity in a changing world - a solution or a pipedream? Frankfurt am Main, WWF Germany., and is drawn on here with permission.

While funds are flowing to Lesotho, limited compensation has gone to impacted people and it is unclear whether adequate resources are being directed to maintaining the ecosystem services, for instance, promoting better watershed and riparian management practices.
Consideration and provisions for mitigation, of environmental and social impacts associated with the LHWP, were poor in the initial phases of the LHWP. Phase IA, for instance, began before completion of a full environmental and social impact assessment. The Lesotho Highlands Development Authority together with the World Bank made a considerable effort to rectify this in subsequent stages of the project, with some success, including through the application of the high quality Downstream Response to Imposed Flow Transformation (DRIFT) environmental flow method that also incorporates socio-economic attributes (Hirji and Davis 2009; King and Brown *in press*).

Phase I of the LHWP also inundated over 100 kilometers of pristine, large, mountain-river habitat, and seriously threatened the reaches downstream. In 2003, following an Environmental Flow (EF) assessment (1998-2000; King *et al.* 2000), an Instream Flow Requirement (IFR) Policy was finalized by LHDA (LHDA 2003), which specified variable environmental flow releases, operating rules for the dams and a program to monitor compliance. The 'target ecological conditions' for the rivers immediately downstream of the dams are lower than their pre-dam condition, and despite a commitment to compensation, not all of the losses incurred could be valued or even compensated for (Brown 2008). Downstream, in South Africa, it is likely that harvesting of clean, source water will have impacts in the lower Orange River, where water-resource developments and water-quality issues in the Vaal and middle Orange Rivers have already taken their toll (Binedell *et al.* 2005). The condition of the receiving river in South Africa, the Ash River, has also been seriously compromised through erosion and associated engineering river works. Slow implementation of South Africa's 1998 Water Act means that limited measures have been taken to improve the condition of the river basins in that country. The LHWP is of strategic importance to both Lesotho and South Africa, so much so that disputed elections in Lesotho sparked South African military intervention in 1998.

The first of the planned five-yearly LHWP IFR audits, completed in 2007, found that implementation had been 60% compliant with the IFR Policy and identified issues likely to affect the sustainability of the process (INR 2007). Tardy implementation of, and in some cases disregard for, recommendations was probably responsible for some of the more emotive environmental impacts, such as those to the critically-endangered Maloti minnow (*Pseudobarbus quathlambae*), which are now under threat from smallmouth yellowfish (*Labeobarbus aeneus*) that have been able to access previously inaccessible tributaries via LHWP infrastructure (Southern Waters 2006). In its initial stages, the project was also plagued by corruption but the authorities have since successfully prosecuted many of the accused. The former Chief Executive of LHDA is in jail, two engineering firms were convicted of bribery (TRC 2005) and the government has recouped millions of dollars from convicted consulting firms (www.LHWP.org.ls).

There are also concerns that the poorest have not seen the benefits of the project, and criticism of the project linger. In particular, this relates to: the investigation of viable alternatives, resettlement of communities, the compensation for lost assets and governance issues. Resources spent on environmental and social impact mitigation measures are a very small fraction of the investment in the LHWP. There are concerns that the LHWP is a juggernaut, which will not stop until all four phases have been completed, despite its inevitable and devastating impacts on the long-term sustainability of the Orange River system, or the fact that it would see nearly 80% of the length of Lesotho's major rivers dammed. A fifth phase of the LHWP, comprising a dam on the lower Senqunyane River, has also been proposed. The Government of Lesotho is also presently engaged in the Lesotho Lowlands Water Project, which comprises a major dam, Metolong Dam, on the South Phuthiatsana River, in western Lesotho near Thaba Bosiu.

Management Challenges

The cumulative impact of the LHWP scheme is growing and severe impacts are likely to occur impacting ecosystems and people living downstream. More effective measures to mitigate environmental impacts are required, including distributing more of the income from South Africa to the ecosystem managers in Lesotho for management. The South African Water Act 1998 is widely recognized as establishing world class laws and proposes, among other measures, a 'reserve' of water to meet the minimum environmental and social needs along each river, and be implemented through catchment management authorities (CMAs). Yet, a decade later only a small number of CMAs have been established and in most cases the reserve and other measures are yet to be implemented.

In South Africa the institutions intended to manage the rivers sustainably are yet to be established: the information base is available and the focus now needs to be on implementation. In both countries more transparent and accountable decision making on water is required.

Solutions Underway and Proposed

The LHWP has undertaken instream flow releases of 14 to 19% of the average natural mean annual inflows of diverted rivers to maintain aspects of the downstream environments, which, while better than nothing, will clearly have severe impacts. The commitment and capacity of operators in Lesotho to maintain these flows is also questionable. While some compensation is flowing to impacted people in Lesotho, it is not nearly enough to make up for livelihoods impacted. There is limited evidence of the better management practices taking place as part of the South African Water Act, including establishment of environmental and human needs reserves, water users' associations, and CMAs. Payments for ecosystem services (the basis of South Africa's purchase of water from Lesotho) is a concept that could be broadened to distribute benefits more widely for better stewardship of the river system.

Pathways Forward

Southern Africa is a region where the government water policies and laws are sound, and at least in South Africa, there is a good information base and some world-class scientific freshwater conservation capacity. Sadly however, implementation has been very poor due to limited capacities, lack of funding, poor enforcement, and low political priority in countries where poverty reduction measures come first and are seen as divorced from ecosystem and Eflows management. Suggested actions include:

- Expand development and application of payment for ecological services schemes to demonstrate the links to socio-economic benefits and secure additional resources for conservation of catchment and riparian zones;
- Capacity building for staff of CMA's and other sub-national agencies in field such as environmental flows, payment for ecosystem services, freshwater conservation, and basin management;
- Establish freshwater protected area priorities and mechanisms, building off the existing information base;
- Take legal enforcement actions by third parties seeking government implementation of agreements.

Mekong River, SE Asia

Introduction

The Mekong River (Lancang River in China) begins on the Tibetan Plateau and flows for approximately 4,800 km through China, Myanmar, Laos, Thailand, Cambodia and Vietnam, where it forms a large delta on the South China Sea. It drains a total catchment area of 795,000 km^2 (MRC 2005) (**Figure 4**). The river is famous for its wet season flood pulses that drive major fish recruitment, inundating a large floodplain and backing up into the Tonle Sap lake in Cambodia. The Mekong basin is particularly biodiverse, with at least 1,200 species of fish and possibly as many as 1,700 (Coates *et al.* 2003:5). A large portion of these fish species have life cycles that require migrations of up to a thousand kilometers or more for reproduction. The conservation of this freshwater biodiversity and of the livelihoods of the people who depend on it is the major focus of debate in the Mekong basin over major hydropower developments.

The annual yield of the Lower Mekong Basin (LMB) capture fisheries, including non-fish aquatic organisms such as frogs, prawns and snails, is estimated to be around 2.5 million tonnes, or 2% of global marine and freshwater fisheries landings. When combined with 0.25 million tonnes from reservoir fisheries and 0.25 million tonnes from aquaculture, the per capita freshwater fish consumption of the 60 million people living in the LMB has been estimated to be about 56 kg/person/year (MRC 2005). The estimated current net value (gross value less costs of capture or production) of the wild fishery, at first point of sale, is approximately US $ 1.171 million annually (MRC 2005).

Barlow *et al.* (2008) conclude that around 60% of the Mekong fish catch comprise migratory species that are at grave risk from mainstream dam development, an amount of fish equivalent to 1.6 – 3.5 times the beef production and 0.9-1.8 times the pork production of the LMB nations. Local reductions in fish catches on Mekong River tributaries of 30-90% (generally at the more severe end of this range) have already been experienced following the completion of dams.

The Mekong River Commission (MRC) Secretariat's international Expert Group that (Dugan 2008):12) "the Expert Group concluded that there is currently no evidence that fish-passage facilities used in large tropical rivers in Latin America, Africa and Asia can cope with the massive fish migrations and high species biodiversity in the Mekong ." The Group also concluded that: "Dams on the mainstream in the middle and lower part of the LMB will have a major impact on fisheries and serious economic and social implications."

A further issue in the Mekong basin is sediment and water flows and likely impacts of dams on the delta in Vietnam. The river receives 18% of its inflows and 50% of transported sediment from the 24% of the

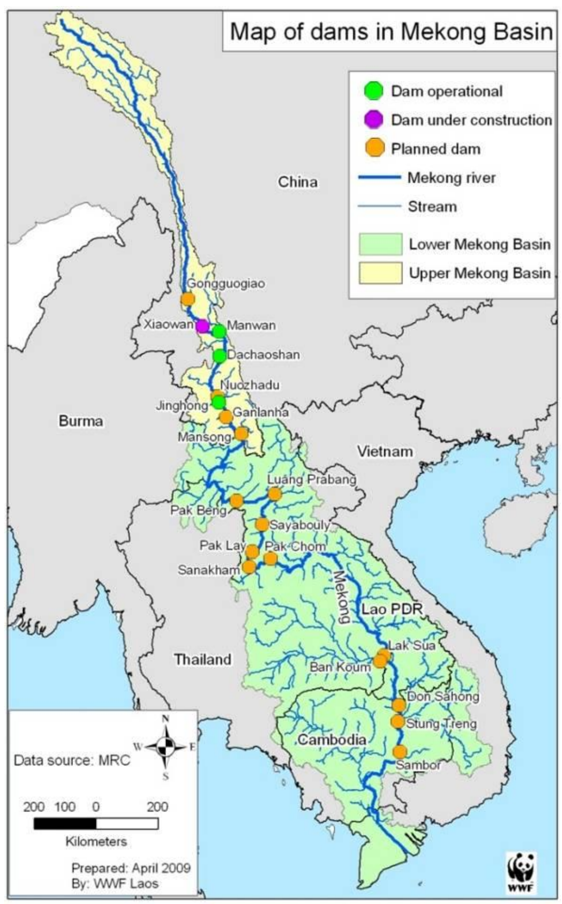

Figure 4. Existing and planned dams on the main stem of the Mekong River. © WWF 2009

basin in China and Myanmar (MRC 2005). Until the Manwan Dam in China closed in 1992, the main stem of the Mekong Rivers was undammed. The proposed 19 dams on the mainstem of the Mekong are likely to impound considerable sediments, exposing the delta to greater coastal erosion and sea water intrusion, which is expected to be exacerbated by sea level rise. The main Mekong Delta is covers about 4 million hectares which sits at an elevation lower than 5 meters above sea level. The area is largely used for rice cultivation, and by the 1990s agricultural land covered 85 per cent of the land area of the Delta. The Mekong Delta is the most important agricultural area of Viet Nam, contributing more than 50% of the nation's food production, more than 55% of the aquaculture production; and more than 61% of aquaculture products exported from the country (MRC 2005). However, if the dams altered water flows, the impacts of current dry season sea water intrusion may be lessened.

Governance of the river basin is complex. Collaboration between basin states was initially driven by a desire to build infrastructure for shipping, hydropower and irrigation, but this was interrupted by conflicts that were only resolved in the 1980's. At this time the Mekong River Agreement and a Commission (MRC) was formed, based on and directed by National Mekong Committees of the four LMB states, to promote sustainable development of the natural resources of the river. China chose not to join the Commission, but has observer status. China's Yunnan Province is part way through the planned construction of a cascade of eight hydropower dams and has undertaken work to widen the river channel for shipping. While the Mekong Agreement is often touted as a success, and the MRC Secretariat has played an important role in providing strategic data for better decision making, member governments are undertaking a series of largely unilateral developments (often financed by China and other 'land grab' states) including consideration of 11 dams on the main stem of the lower Mekong. Strong NGOs in Thailand and Cambodia have raised concerns but been largely unsuccessful in changing the trend towards poor development decisions. Major international environmental NGOs active in the region include CI, IUCN and WWF (the latter two have memorandum of cooperation with the MRC). Civil society participation is weaker in the other Mekong basin states that are less transparent and more centralized.

The Asian Development Bank (ADB) is a major financier of projects in the Mekong Basin. In the past five years, China and the ADB have driven a "Greater Mekong Sub-Region" development program focused on development of major energy, transport and communications infrastructure linking the six Mekong states, and largely by-passing the MRC. This will open the region to much greater development of hydropower, among other impacts, and the proposed "conservation corridor" mitigation measures appear inadequate to conserve the region's biodiversity.

Management Challenges

A major challenge is how to promote economic development that will not undermine the natural resource base, and in particular conserve the river system and its fisheries. A number of organizations have modeled energy scenarios in an effort to undermine the case for hydropower development, but this appears futile given the growth in demand in the region. WWF, MRC and ADB have a joint project, "environmental criteria for hydropower development" (ECHD) that in the next few years is intended to guide placement of new dams in less environmentally sensitive sites. While more information will help, the main problem appears to lie more with decision making institutions in these states, and include corruption, lack of influence of rural people most impacted by these developments, and low capacities of government agencies.

China's rise as an economic, financial and political power is greatly influencing decisions on natural resources in the Mekong, with many bilateral deals being made with LMB states.
The Mekong Agreement itself has a number of major flaws, including limited jurisdiction over tributary basins, incomplete membership of riparian states, and limited dispute resolution

provisions. Entry into force of the overarching UN Watercourses Convention may partly overcome these problems.

Solutions Underway and Proposed

A number of approaches are being taken to promote better outcomes, including:

- Strengthening the capacities of local civil society (e.g. Oxfam, International Rivers);
- Developing better information and decision making tools to inform decision making (e.g. ECHD, MRC fisheries program);
- Preparing more integrated plans, such as the MRC led (sub-)basin development plans;
- Devolving management of natural resources to local communities and building their capacities (CI, IUCN, WWF);
- Piloting payment for ecosystem services schemes (CI).

Pathways Forward

Many of the existing activities to promote conservation and sustainable use of the Mekong River are either under-resourced (e.g. ECHD), or too local in scale to influence national and regional decision makers. Key activities suggested include:

- Demonstrating how local solutions (e.g. payments for ecosystem services, sustainable fisheries management) can be scaled up nationally and at the basin scale;
- Quantifying the socio-economic consequences in loss of ecosystem services from poor development decisions (e.g. loss of fisheries, erosion of the delta);
- Resourcing non-government organizations to influence regional financial and decision making organizations, such as the MRC, ADB and China (including promoting entry into force of the UN Watercourses Convention); and
- Improving transparency and accountability of natural resources governance.

The region has many highly skilled academic and civil society leaders that would be excellent partners for philanthropic organizations. In addition, there are many good people in regional institutions, including the MRC and ADB, who would be keen to support new initiatives.

Murray Darling Basin (MDB), Australia

"In its dryness, Australia suggests the Planet's future, as the vast human population and the demands of its industries intensify competition for an unchanging quantity of freshwater; in water terms, Australia is a warning, and Chowilla [floodplain forests of the Murray-Darling basin] is its immediate expression. The Chowilla red gums are part of a vast death event, encompassing hundreds of thousands, perhaps millions of tress … extending six hundred miles …" (Leslie 2005).

Introduction

The Murray Darling rivers in south eastern Australia drain a seventh of the continent in a basin that ranges from alpine peaks to semi-arid desert. The river is naturally one of the most variable in the world and has been extensively impounded to produce hydroelectricity and to supply water for agriculture (90% and cities (10%). The basin is the center of Australia's agricultural economy, provides water for a tenth of the nation's people, and contains extensive high conservation value ecosystems (including 16 Ramsar wetlands and 2 World Heritage sites). Governance responsibilities are divided between four states, the Australian Capital Territory and the Federal Government (**Figure 5**).

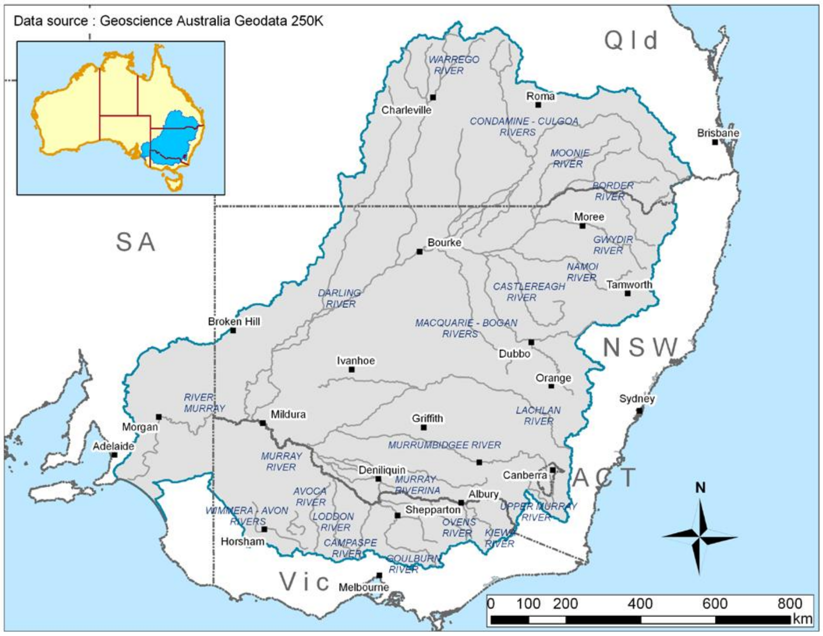

Figure 6. Location of the Murray-Darling Basin (MDB Authority 2009)

Management Challenges

Management of the MDB has been contested since Australia was occupied by Europeans (Connell 2007). The basin is largely of low elevation and formed on ancient and saline sediments. Agriculture induced changes in hydrology saw dramatic increases in salinity and toxic algal blooms, and now oxidization of sediments into sulfuric acid is afflicting a fifth of the basins wetlands. Diversion of excessive volumes of water for agriculture has resulted in the collapse of extensive areas of floodplain ecosystems, lower lakes and the estuary, and the river no longer flows to the sea. River regulation, instream barriers to fish passage and loss of access to the floodplain has seen native fish populations crash, and with the introduction of exotic species, the indigenous fish now comprise only 10% of catches. The location of the basin in mid latitudes appears to make the river system especially vulnerable to climate change induced reductions in river inflows (Timbal and Jones 2008). A drought that begun in 2001 may represent at ‘step change’ in climate, with winter rain bearing storms being driven south of the basin, and higher temperatures reducing runoff of the precipitation that has fallen. As of November 2009, runoff in the basin was just 30% of the long term average.

Solutions Underway and Proposed

The Australian governments have consistently recognized problems and adopted policies considered innovative at a global scale only to find their interventions were too little and too late. In the early 1990’s, the six governments formed a consensus-based Commission to engage stakeholders, establish tributary catchment management institutions, and manage the basin. Water diversions were capped in 1994 but not reduced to sustainable levels of take. Reflecting an aversion to regulatory based solutions, the governments established markets in salinity credits and in water, which have facilitated socio-economic returns but failed to stem environmental degradation. The Commission often used independent experts in an effort to overcome lowest common denominator decisions by the governments. In 2002, one such expert review panel presented options for restoring the health of the lower River Murray and concluded that some 4,000 gigalitres (nearly a third of consumptive use) would need to be returned to the river to have a “good” chance of success (Jones *et al.* 2002). In 2003, the governments instead adopted a “first step” decision to restore just 500 gigalitres to target six iconic wetlands (Murray–Darling Basin Ministerial Council 2003).

Public funding has not been limiting as nearly AUD $16.7 billion (~ USD $15 B) has been allocated by the governments since 2003, however it has not been spent efficiently. Initial expenditure focused on subsidizing improvements in water use efficiency, however this has proven to be expensive, time consuming and has not provided certainty in returning water to the environment. More recently water allocations have been purchased by the Federal Government on the open market, in part to minimize political opposition. Yet this may reduce the viability of remaining water users who are forced to maintain the water infrastructure - an alternative strategy may have been to close the least efficient irrigation districts in their entirety.

As the system failed further, a 2004 Nation Water Initiative (Commonwealth of Australia *et al.* 2004) promised many reforms, such as conjunctive management of surface and groundwater, and establishing environmental flows for all freshwater ecosystems. However inadequate progress in implementing these commitments (NWC 2009) can be attributed to lack of incentives for state implementation and lack of enforcement mechanisms. As the current drought deepened, the Federal Government commissioned two key scientific assessments: a 2007 sustainable rivers audit that rated only one of the basin's 18 river valleys as having "good" ecosystem health (MDBC 2008), and a sustainable yield project that estimated the combination of over-allocation of surface and ground waters, impacts of inflow interception activities in the basin (such as forestry expansion) and likely climate change impacts (CSIRO 2008). Average surface water availability in 2030 in the median scenario is forecast to decline by 12%, and by 34% in an extreme dry situation, however the 2009 situation of a 70% decline is much more severe. This increased political pressure to reduce water diversions from the basin. It has also reduced attention to the non-water aspects of sustainable basin management, and in some instances conservation land trusts and Aboriginal land management organisations have started to fill these gaps. While some small-scale payments for ecosystem services schemes have been trialled the potential of these mechanisms has not been fully realized.

In 2008 the governments adopted a new policy to reform basin management (Commonwealth of Australia *et al.* 2008), which included: nationalizing water accounting, strengthening water market mechanisms, purchasing water for the environment, establishing a MDB Authority reporting to the Federal Government (in place of consensus-based decision making), setting "sustainable diversion limits" as part of a new Basin Plan from 2011. Work to define the key environmental assets and ecological processes to be conserved by new, lower sustainable diversion limits is currently underway (MDBA 2009). The establishment of a nascent non-government conservation water trust sector is evident by it is constrained by an unfavorable regulatory environment.

Pathways Forward

There are considerable gaps in the government and society's responses that could be catalyzed by new investments, including:

- Drawing together scientific expertise to define options for freshwater conservation objectives for the basin given that there is not enough water to conserve everything (e.g. for the 2011 Basin Plan);
- Researching options for the adaptation and conservation of freshwater biodiversity in the basin with climate change;
- Advocating for more effective governance of the basin, including incentives and enforcement mechanisms for better implementation of existing agreements;
- Assessing laws by jurisdiction that are hindering freshwater conservation (e.g. laws governing construction of earthen banks on floodplains) to identify and advocate priorities for reform;
- Enabling non-government stakeholders to take legal actions to enforce existing laws;
- Assessing options for reform of water, tax and other laws needed to empower non-government freshwater conservation initiatives (e.g. conservation water trusts);
- Developing and advocating new payment for ecosystem services schemes directed at freshwater conservation and sustainable catchment management; and

- Promoting new market-based measures, such as water stewardship certification, to improve water production efficiency and conservation.

Conclusions from Case Studies

At the sub-basin scale there is the need to demonstrate innovative new management practices and scale up their application, applying techniques as diverse as establishing freshwater protected areas through the sustainable fisheries management and payment for watershed environmental services. Bringing together existing data and expertise is often essential to enable local managers to understand different perspectives and opportunities for freshwater conservation. Effective advocacy for political reform requires tangible examples of on the ground of the solutions. In many cases this requires valuation of ecosystem services to enable better decision making, to internalize externalities and ensure income streams are available to finance sustainable management.

Most of the drivers of degradation of freshwater ecosystems are the perverse outcomes of poorly structured socio-economic systems. Recalibrating these systems for sustainability requires: better data and knowledge, valuation of ecosystem services, building local capacities, and establishment of market mechanisms that favor sustainable resource use rather than exploitation. New techniques – virtual water trade, water footprinting and water stewardship – need to be piloted at local to basin scales with complementary actions at the national to global levels to create new standards, certification systems and markets for goods produced by better water stewards.

Better governance is at the heart of sustainable management of a common pool resource like water, and this need has a number of dimensions. Helping civil society to improve governance is a powerful way of establishing self-maintaining systems. Better access to data, knowledge, new skills and participatory decision making is essential to empower people to act in the public interest. In too many places the right policies and laws are poorly implemented or abused, and enabling civil society to take action to enforce the rules of the trade is essential to combating corruption and improving accountability. Often the policies and laws of different jurisdictions or government sectors conflict in water management, and systematic assessments of conflicts and also better practices can be a powerful tool to identify strategic reforms. Law reform to empower non-government organizations, such as conservation water trusts, can engage more people, expertise and resources for better freshwater conservation.

At the basin scale the development of multi-stakeholder management institutions is a complex but essential requirement for improving management. In most societies institutions struggle to find people with the integrated river basin management skills required to operate the optimal systems. There is a large role for non-government institutions in catalyzing the application of conservation tools such as: IRBM management, management zones, freshwater protected areas, environmental flows and reoperation of infrastructure.

At the international scale water governance institutions are fragmented and weak (as the Mekong case illustrates), and are currently little help in stemming the loss of the 263 rivers that are shared by 145 nations. Two major interventions that would cost little but have a huge impact would be: aiding the entry into force of the UN Watercourses Convention that would codify the ground rules for the cooperative, equitable and sustainable management of shared rivers; and influencing the new UN development goals that should replace the Millennium Development Goals that expire by 2015, and which will in turn set the priorities for investments by governments, aid agencies and international financial institutions.

SECTION 3: ISSUES AT THE FOREFRONT OF FRESHWATER MANAGEMENT OFFERING LEVERAGING OPPORTUNITIES

Among the broader arena of work described in Section's 1 and 2 of this document, there are a series of highly critical issues where leveraging opportunities exist for the MacArthur Foundation to improve land and water governance and stewardship, as well as freshwater biodiversity and ecosystem function and resilience. The areas discussed in this section are intended to build upon effective existing work done by the various actors involved in freshwater conservation and development; and to apply and cultivate innovative approaches, and scale up success from local watersheds to trans-national river basins.

Conserving Freshwater Biodiversity and Ecosystems

Freshwater biodiversity conservation has been the poor cousin to terrestrial and marine ecosystems, even though freshwater biodiversity loss exceeds that of other biomes (MEA 2005b; Pittock 2008). International targets have been set (Pittock 2008) and many innovative conservation measures have been proposed or piloted but not systematically implemented, such as new approaches to freshwater protected areas establishment (Abell *et al.* 2007; Thieme *et al.* 2007) and re-operation of water infrastructure (Pittock and Hartmann submitted 2009). Opportunities for the MacArthur Foundation to conserve freshwater biodiversity and ecosystems exist through funding to support the following:

- *Compilation and analysis of global baseline data* on biodiversity, ecosystem function, integrity and health under various threats, and prioritizing actions across scales to address threats, and maintain pristine areas. For example, the Global Freshwater Biodiversity Assessment, gap analyses of freshwater species protected, and definition of new hotspots for freshwater species and ecosystems.
- *Designating and improving management effectiveness of existing protected areas* for freshwater species and ecosystem function. The MacArthur Foundation in partnership with key multi-lateral institutions – such as the secretariats of the Ramsar Convention on Wetlands and Convention on Biological Diversity (CBD 2004a; CBD 2004b; Ramsar 2008b) – and national government and NGOs could demonstrate effective implementation of protected areas, including wetlands, rivers, and river basins in key regions or countries.
- *Securing strongholds for species and ecosystems* through wild rivers and wetlands wilderness programs.

Manage the Climate-Energy-Food-Water Nexus

Demand for food and energy are rising and are inextricably linked to water. These three commodities are increasingly influenced by climate change and societies' responses to climate change. Managing food, energy and water under climate change to optimize benefits for people while minimizing impacts on people and nature is becoming increasingly complex as the limits to natural resource exploitation are reached and optimizing production of one commodity may have perverse impacts on the others. Our societies and governments will need to take more integrated decisions, which is easy to propose but hard to implement. Opportunities for the MacArthur Foundation to tackle these needs and threats exist through funding to support the following:

- *Downscaling climate change projections data, integration of existing data sets, and forecasting model development* that addresses both the stationarity problem, as well as trade-offs between multiple threats under various development and climate change scenarios. Better information about the role that biodiversity plays, within ecosystem function and resilience; as well as relationships between various threats and services, is also needed to design the best interventions that protect ecosystems for service delivery. Supporting the development of more sophisticated tools enables decision makers to consider multiple variables in establishing policy. One example is the work by the University of Texas to provide open access to a model that enables decision makers to consider water consumption with different levels of energy production and different mixes of power generation technologies (King *et al.* 2008), and consider the greenhouse emissions entailed. Another example is CI's upcoming work to examine the impacts on fisheries production in the Tonle Sap based on various scenarios of climate change and dam development.

- *Advocacy for institutional processes* that better integrate sustainable environmental and water management into social and economic policies. One set of proposals for institutions for better integration in government decision making involves a combination of: a) constitutional and legislative requirements; b) mechanisms for more effective horizontal and vertical integration at different geo-political scales; and c) more transparent access to data, monitoring and reporting mechanisms (Ross and Dovers 2008). There are also many opportunities for funders like the MacArthur Foundation to support the implementation and evolution of ecosystem-based adaptation projects, implementation of adaptation plans (such as the National Adaptation Plans of Action for least developed nations under the UNFCCC), and other support that gets water adaptation projects from the concept phase to yielding benefits for people and nature.
- *Developing combined soft and hard engineering approaches* within large landscapes or river basins to increase climate change resilience and respond to growing demands for water, food and energy. Use of natural infrastructure would minimize traditional infrastructure development which is currently the status quo pursued, in spite of the known ecological impacts. Examples are becoming increasingly more common, particularly in the Netherlands, which need to be conceptualized and field tested in climate vulnerable countries.

Improve Sustainable and Cooperative Management of Shared Rivers

Globally 263 rivers are shared between 145 nations, and their basins drain 45% of the land and are home to 40% of the world's people. These are among the most biodiverse, iconic and politically significant rivers on Earth—yet, the fact that there is no global policy framework to protect them, exposes them to degradation and service loss. Integrated River Basin Management approaches are available, yet they need to be mainstreamed into development planning, and be consistently well designed and implemented. There are considerable opportunities for the MacArthur Foundation to improve governance and ecosystem health of river basins by funding the following:

- *Creating agreements for the cooperative, equitable and sustainable management of rivers at different geopolitical scales*. Globally, the 1997 UN Watercourses Convention that codifies such international law still requires ratification from 17 nations before it will enter into force (Loures *et al.* 2008). Similarly, a stricter UN Economic Commission for Europe watercourses treaty provision for universal membership is yet to become operative. At the regional and basin scales, while some effective agreements are in place for rivers like the Danube, other iconic rivers have institutions in need of help – as with the Amazon, or lack multi-lateral agreements as in the cases of the Ganges and Brahmaputra rivers. A number of NGO and academic institutions are actively promoting the establishment and implementation of such agreements, but despite a clear demand and likely success the resources they have available are very limited. River Basin Organizations are also highly effective means of empowering local communities and also help ensure equitable allocation if directly managed by community managed authorities. Direct support for capacity building for these entities, as well as to ensure the development of Strategic Environmental Assessments, which include ecosystems and biodiversity, can result in a major improvement in river governance.

- *Developing tools and methods for IRBM* based on data and other information about development and ecosystem services trade-offs, to better allocate water equitably among competing uses. Regional planning tools, such as InVEST and CI's Integrated Biodiversity Assessment Tool to ensure that biodiversity and ecosystem services are included, along with recent modeling approaches can be used to develop SEAs and management plans for river basins. Water footprinting can also be useful in this regard—examining particular commodities or sources of extraction/pollution that may be present unique management challenges and needs.
- *Implementing Eflows within IRBM approaches* to ensure healthy rivers become the standard means for meeting the needs of ecosystems, species and people. Promoting environmental flows would be particularly useful: controlled releases of water from dams to mimic the natural variability in flows required to sustain riverine habitats and biodiversity. Innovations, including better inclusion of groundwater and other elements of the hydrologic cycle into Eflows can greatly improve accuracy of Eflow requirements and related standards set to manage rivers. Also, inclusion of upland conservation, and links to sedimentation and siltation avoided, can influence both the location and operation of dams, as well as link to PES schemes to finance upland conservation. Such flows may also be adjusted in future to reduce the impacts of climate change. The MacArthur Foundation could play a key role in supporting faster implementation of environmental flow techniques like ELOHA. A number of countries with emerging economies are showing great interest in applying such techniques and have some institutional capacity, including Brazil, Mexico and China. Building upon lessons learned from Murray-Darling, in terms of policy and regulatory frameworks required can also be part of the selection of a portfolio of Eflows projects by the MacArthur Foundation.

Create Water Quality and Quantity Standards and Markets

In the past decade new methods for better accounting for and valuing water have been developed which may increase the role of markets and consumer choices as a positive influence for better stewardship of water. Water markets are at least five or more years behind the recent evolution of the carbon markets, but similarly, could create financial incentives for freshwater ecosystem conservation in the near future. Assuming a similar development pathway for water markets, the first step is to define and target the best metrics for water quality and quantity that link freshwater ecosystems and services to water users and polluters. Some of this information has come from water footprinting, and from valuing freshwater ecosystem-related services. Water offsets, PES and nutrient trading are becoming increasingly more common in the developed world, and are ready for testing and implementation in the developing world. Opportunities for the MacArthur Foundation to create water standards and markets exist, through funding the following:

- *Improving water footprinting methods* and adapting them to address water quality to the same extent they target water quantity. Water accounting tied to virtual water, helps us better understand and measure impacts, both regionally, in particular basins, and trade-offs between water and other key commodities like energy. For example, in India and China (Ma *et al.* 2006; Verma *et al.* 2009) the concepts have been used to argue for alternative means of producing agricultural and other products rather than relying on new inter-basin water transfer schemes. The MacArthur Foundation could support the further development and application of virtual water and water footprint by academics and NGOs in water scarce places to develop more sustainable policies for water use and trade.

- *Creating certification standards for water stewardship*. Water stewardship seeks to replicate the third-party independent certification programs developed for wood (Forest Stewardship Council) and fish (Marine Stewardship Council) in the water sector. By going beyond regulation, it aims to provide a measurable standard that will distinguish better water users in the market place, to enable consumers to identify and preferentially support their products as well as raising overall sector standards. Water stewardship works to ensure that fresh water is used and managed in a way which is environmentally sustainable, economically viable and delivers equitable benefits for society. The ultimate goal of water stewardship is sustainable water use at the watershed level. The global Alliance for Water Stewardship (http://www.allianceforwaterstewardship.org/) and is looking to pilot their draft standards in the coming year through its regional members. Experience indicates that such programs take 3-5 years to become establish and self-financing, so there is a key opportunity for the MacArthur Foundation to underwrite the start up of a key new global tool for sustainable water management. Pilot testing in the field is required to create baseline/targets, and design reasonable standards. Regulations can then be developed as the next step.
- *Developing a pipeline of watershed management and PES projects*. PES promotes the conservation of natural resources by providing financial incentives for the private sector to incorporate sustainable practices into production and resource management. PES programs, targeting river basins or watersheds, can facilitate payments between consumers of ecosystem services, such as water quantity and quality, and the suppliers of these services. The emerging market for carbon sequestration adds synergies and the occasional conflict to the conservation of water—best managed at the regional scale. The MacArthur Foundation could usefully support the further evolution and scaling up of PES programs to create a project pipeline, bundling ecosystem services, and made available to provide greater market incentives and specific investment opportunities to achieve better water stewardship.
- *Advancing water markets to target efficiency and quality*. Water offsets can account for the remaining water wastage beyond efficiency captures offered through operations changes, and can also justify the creation of water markets, either under regulatory or non-regulatory frameworks. Nutrient trading can reduce pollutants and leverage the current efforts of the agricultural industry to improve water quality. Nitrogen and phosphorous pollution of the biosphere has huge ramifications, including destroying freshwater and marine ecosystems as well as contributing to climate change (Rockström *et al.* 2009; UNEP and WHRC 2007). Despite the issues' importance it is a largely vacant space. There is a huge opportunity for the MacArthur Foundation to instigate the research, raise awareness, and build coalitions and advocacy needed to begin to implement solutions. Funding is needed to pilot approaches, conduct research and support the institution building necessary to develop projects. Partnerships with the corporate agriculture sector, and large international large landholders/governments, and corporations are also possible to scale up results.

Conclusions on Opportunities

The precipitous decline in freshwater biodiversity and increasing demand for water as limits of the resource are being reached mean that this sector is both a priority and there are many opportunities to positively influence management. Key drivers of water degradation are growing populations, increasing consumption and climate change. There is considerable agreement that the solutions involve better governance complemented by market based and consumer measures. There are a number of excellent initiatives underway, as detailed above, but most of these are very poorly resourced. Investments in the water sector by the MacArthur Foundation could establish many of these innovative solutions to the point where they are embedded in our societies and become self-sustaining.

SECTION 4: ISSUES OF SCALE AND SCOPE TO ACHIEVE IMPACT

Ensuring sufficient clean freshwater is available to reach multiple goals is a global issue, yet it requires targeted political, scientific, and management solutions linking and drawing strength from complementary work at trans-national to regional and local scales. We suggest that MacArthur work as much as possible at regional, large river basin scales, supporting projects that cross national boundaries because they include many of the most biodiverse, iconic and threatened rivers globally. The portfolio's inclusion of integrated river basin management projects would ensure sufficient attention is paid to biodiversity, ecosystem function and service delivery, while enhancing governance and avoiding inequities and conflicts that result from unintended trade-offs between development and service delivery, and between services. Results at this scale are achievable in five to seven years, and can potentially benefit millions of people and thousands of species. Development and corporate sector joint support may also be able to be leverage seed funding invested in projects such as dam optimization and greater agricultural water productivity. Scaling up results from basins is another important aspect of work, which can be accomplished by applying a range of well established and newer interventions across the portfolio, such as Eflows and nutrient trading, and then supporting others to use results to influence international policy processes.

Management interventions differ and may occur at the basin, sub-basin, watershed or micro-watershed scale. The link between land and water use, hydrological attributes, and benefits for people becomes more and more difficult to demonstrate with increasing scale, requiring regional scale planning. However, new modeling approaches are becoming more and more available that can link hydrological properties, environmental flows, and land and water resource management objectives, helping to address complexities of scale issues. This work is fairly new, and requires specific investment support.

Another important issue of scale relates to defining basin or watershed boundaries to include both hydrological properties, as well as critical elements of ecosystem function. Hydrological units have been defined to include both, but some have criticized these units for resulting in misleading conclusions about ecosystem service flows (Omernik 2003). Basins according to their original definition of drainage into a single location might best be used as the fundamental unit of engagement, then compare ecological regions within them to see how to best delineate boundaries to promote ecosystem function and service delivery. Within large basins, projects can link multiple landscapes from ridge to reef, link high ecosystem services areas to specific areas of local interest like wetlands, include areas of threatened and endangered species concentrations, and manage interconnectivity between above and underground water systems.

To truly address the global freshwater crisis, we must push the envelope in terms of the state of knowledge and science available to set meaningful global priorities and targets for ecosystems, which can then influence which river basins, are selected for demonstration cases. One interesting study recently estimated thresholds under which we utilize resources to prevent large scale ecological collapse. Authors suggested that we need to reduce the current rate of species extinction from 100 to 10 species per million lost, to ensure biodiversity is able to secure ecosystem resilience. Similarly, water extraction reduction targets from 4,000 to 2,6000 km3 per year were proposed to ensure consumption of freshwater by humans matches supply (Molden 2009; Rockström et al. 2009). As such global data is not yet readily available to set specific regional geographic targets, we suggest MacArthur consider both the FEOW, which defines various types of habitats, as well as its current geographies and others found within hotspots and wilderness areas. Preliminary data from CI suggests that hotspots and high biodiversity wilderness areas provide both freshwater biodiversity concentration as well as high freshwater service concentration, available for delivery to dependent users (unpublished data).

SECTION 5: OPPORTUNITIES FOR MACARTHUR INVOLVEMENT IN FRSHWATER WORK

No one organization has the resources to conserve every freshwater ecosystem requiring criteria to choose where to invest limited funds. This raises many dilemmas. For instance, the most damaged and threatened rivers where interventions may have the greatest exemplary impact are usually located where most people live, yet the most biodiverse and iconic rivers may be remote from political centers. In our view there are many equally right choices on where to invest resources for on ground freshwater conservation, and investment needs to be decided by strategic choices, discussed in Section 3 of this document, as well as based on opportunities for pronounced involvement in conserving freshwater resources, covered in this section of the white paper.

McArthur's portfolio already contains freshwater projects, and its approach of three year funding cycles for a particular region, lends itself well to completing effective freshwater conservation projects on the ground. River conservation programs are inevitably complex and usually take around seven years to begin to produce solid, sustainable outputs, suggesting a similar period of funding commitment from foundations committed to a longer term outcome. Further, such programs require engagement by multiple stakeholders, with strong relationships to conservation organizations and foundations to be successful, which McArthur has cultivated in its 8 hotspots. Consequently, we recommend that the McArthur Foundation consider investing primarily in river basin conservation programs, building off of its existing on the ground portfolio. This work can be consolidated within major river basins in the 8 hotspot areas, maximizing opportunities to work with key stakeholders, leverage prior investments, and add a deliberate focus on freshwater-related service and biodiversity conservation, which will add considerable value in securing conservation and freshwater services outcomes across the planet.

Building Upon an Existing Track Record in Freshwater Work

The MacArthur Foundation has already been engaged in conservation of large land- and seascapes, and strengthened training and research centers, civil society organizations, and government agencies to preserve biodiversity in perpetuity. Included within its portfolio over the past several years, are a variety of freshwater projects. For example, the Foundation invested $20 million in Africa related to climate change and adaptation, which includes freshwater needs for people. Additionally, its focus on forest carbon programs could be expanded to include freshwater services as part of a carbon plus biodiversity approach. A focus on protecting the origin and flows of freshwater-related services, and employing payment for multiple ecosystem services can add forest carbon, electricity generation, drinking water provision, and biodiversity benefits to certain areas contained within the forest carbon portfolio. MacArthur has also funded work assessing fish migrations in Peru which resulted in halting dam development, and climate change vulnerability assessments in Madagascar which targeted riverine corridor protection needs to secure water and food security. Its current focus on the Mekong, conserving biodiversity and adapting to climate change (fisheries yields, drinking water, etc) is yet another example. Support for protecting forested areas in Cambodia, and other work to prevent forest fires and logging in the Southern Andes, are also pertinent for managing land and water resources together, and for improving water quality and service flows. A critical review of current and MacArthur projects through a freshwater lens, would certainly reveal significant additional opportunities for directed or complimentary projects on freshwater conservation. We recommend this analysis as a useful next step in developing the foundation's freshwater strategy.

Adopting an Incremental Approach to Scale up Freshwater Work

Building upon current or complimentary freshwater work taking place in MacArthur's current hotspots, would take place by applying its three phased funding approach. This approach ensures the necessary commitment to a particular sub set of regions, and enables delivery of results over the next three to nine years. Under this vision, packages of proposals per hotspot would aim to connect freshwater ecosystems and landscapes and move to the scale of large river basins—ensuring maximum results in avoided development/conservation trade-offs and freshwater biodiversity and service provision. The first phase for projects includes research and planning to develop the core components of a sound river basin management plan. This phase identifies key stakeholders and actors; analyzes impacts and trade-offs between development, freshwater ecosystem function and Eflows; and assesses the value of freshwater-related services across scales. Information and tools should also be developed as part of this phase, used to define combined conservation and development objectives, and secure decision-makers buy in and support. The second phase, implements projects and programs within river basins that achieve particular elements of the river basin plan, including such activities as: creating or building river basin organizations; adopting no harm water efficiency measures as part of climate change adaptation; developing policies and designs for PES and incentive agreements; protecting key biodiversity areas or sites and corridors with high levels of endemism and threat; restoring riparian buffer zone areas; and adopting best practices for agriculture and dam design and operation to sustain Eflows. The third phase for projects, fills in gaps in the river basin plan implementation coming out of phase 2, and consolidates results from activities to ensure achievements occur at the river basin scale. Trans-boundary management, PES, and other regional and national policies necessary to secure good governance are also pursued here, as well as water markets or other means of long term financing (e.g., corporate investment, trust funds, etc).

Within the hotspots, we present below some brief examples of what freshwater work might look like over a three to nine year horizon under the incremental approach proposed:

- **Eastern Himalayas, and the Tibetan Plateau** in particular, are the source of seven major rivers in Asia, requiring protection of the source of freshwater related services for a billion people. A recent MacArthur proposal funded IUCN- Species Survival Commission to synthesize baseline data on the conservation status and distribution of freshwater species in the Eastern Himalayas, an essential first step in conservation of freshwater resources and sustainable development. Data will generate the scientific basis for defining new river corridors and wetlands that qualify as Key Biodiversity Areas (KBAs). This information can be supplemented by additional proposals for large scale modeling of freshwater flows, services and valuation of those services, climate change and development impacts, and impacts on beneficiaries. All of this data is needed to inform the development of a TP conservation plan. This work would be required to be embedded in government management programs, for example, the proposed conservation-development zoning mooted in China's national five year development plan. Degradation of alpine wetlands and forest clearing, in addition to glacial melting, impact quantity and quality of water requires alternative livelihoods development in these upland areas, as well as in some cases PES, to ensure water service delivery downstream. Downstream links can also be made from the TP to the terminus of the Mekong and Yangtze rivers. At this scale, phase two work could test use of soft versus hard infrastructure to help avoid mal-adaptation to climate change, and increase Eflows to account for massive water demand pressures while avoiding further freshwater ecosystem degradation and species loss. Phase three could pioneer the testing of nutrient trading in areas of high nitrogen and phosphorous concentration, addressing water quality problems in Yangtze basin.

- **The lower Mekong** is greatly threatened by climate change impacts on seasonal flows and by hundreds of dams on its tributaries and main stem, threatening fisheries, rice farming and other food production, as well as some of the world's most unique freshwater biodiversity. Poverty and corruption are high, and the Mekong River Commission and partners could be supported to model the development and conservation trade-offs in services, making better economic arguments to avoid mainstem dams and impacts of dams on tributaries, and also to maintain natural flood regimes. A recent funded MacArthur proposal awarded to WWF and partners, calls for data compilation and research into climate change impacts, vulnerability assessments, and publishing and disseminating findings widely to communicate necessary adaptation approaches. This work, accompanied by deeper analysis of climate, fisheries, energy, and drinking water needs and development trade-offs, can assist the National Mekong Committees of the lower Mekong states, national governments MRC, and ADB Greater Mekong Sub-region program in their efforts to improve their natural resource management plans. Broad scale application of existing community and ecosystem-based approaches, already available to respond to temperature and flooding fluctuations, as well as enhanced fisheries and rice farming management, are some of the activities that could also be supported in phase 2 to help the larger region adapt to climate change. Phase three, would support an extensive policy processes to try to engage China and Myanmar in more sustainable regional development—bolstering the efforts of the MRC and ADB but pointing also to data identifying economic losses of ecosystem function in terms of decreased fisheries yields, water flows for hydropower generation, etc.

- **The Northern Andes** are experiencing precipitation changes and glacial melting, impacting freshwater flows and supply of water for farming, drinking water, and other needs downstream. MacArthur has funded two water related projects in the Peruvian Andes. Funding to WWF and partners in the Pastaza, and other areas in the Peruvian Amazon larger watershed, have included the design and implementation of fisheries/aquatic resource management, expanding strategies to mitigate threats such as hydrocarbon extraction on aquatic resources, and encouraging greater transparency for decision-making processes around resource extraction, and monitoring the impact of indigenous communities on social and ecological systems of the Pachitea watershed. Project scope already includes scaling up within the Peruvian Amazon, but could be expanded to include an Andes to Amazon corridor, capturing downstream impacts. From this perspective, phase one could include adding downscaling existing climate data to predict changes in patterns of water flows, adopting new modeling approaches to address problems of stationarity, and looking at deforestation links to micro-climate changes, to better forecast impacts on the changing hydrological cycle on downstream economies. Phase two includes suggesting alternative practices. Many farming communities have already organized land and water management efforts, including water boards, and have adopted PES and other incentives for better stewardship, serving as excellent models that could be adopted across an Andes to Amazon Corridor. Phase three includes setting new biodiversity and development targets (CBD, MDGs), as well as ratifying the UN Watercourses Convention to establish the ground rules for sustainable and cooperative management.

Scaling up Beyond Existing Priority Areas

As mentioned, the 8 hotspot areas already provide enormous potential to conserve freshwater biodiversity and freshwater-related ecosystems, yet other geographies may also be included, applying lessons learned and successful models. These areas may include a broader array of hotspots. To determine where these are, studies need to be supported that increase the rigor of existing work to best target areas of high global freshwater service and biodiversity significance.

SECTION 6: EXPECTED IMPACT FROM MACARTHUR ENGAGEMENT IN FRESHWATER WORK

According to preliminary data analyzed by CI, if MacArthur were to build upon its existing work to eventually cover all of the hotspots, this would help protect more than 60% of the natural habitat responsible for delivering freshwater resources, benefitting billions of people downstream and conserving areas where freshwater and terrestrial biodiversity are concentrated. The scope of impact could reach all hotspots, or even remaining within the current eight, there are opportunities to be gained from supporting freshwater work that could be transformative globally. MacArthur's conservation and development portfolio, can embrace an integrated focus on the climate-energy-food- water nexus. Such support would drive innovation in research and modeling to examine the entire range of variables that ultimately impact both biodiversity conservation and human livelihoods. The global water and climate academic and policy community has identified need for cross-disciplinary data collection and integration, but funding for this work remains insufficient, as is funding required to test and refine new models for IWRM once data and models are developed. Harnessing the power of this integration also improves the rigor and quality of conservation approaches—moving the conservation community from creating arguments and raising alarm, to providing solutions to development challenges.

An integrated nexus focus could also leverage billions of dollars in additional support from development agencies, who are increasingly recognizing the need to understand development and services trade-offs, but do not know how to acquire or make use of this type of information as part of development planning and decision-making. They are also not yet convinced that ecosystem approaches are needed given their traditional water-sanitation, heavy engineering bias and limited understanding of alternatives. MacArthur support for river basin work can generate case studies and information capable of shifting the current development paradigm —where the requirements of ecosystem management and service flow maintenance for human well being and biodiversity conservation are apparent. Clearer arguments and test cases will go a long way towards restructuring development banks funding priorities. Results from these case studies, can also influence national and global policy, calling for greater action to take the global water crisis more seriously, and utilize new approaches such as combined soft and hard engineering, and payment for ecosystem services. Results also could include defining the next set of MDGs to focus more explicitly on ecosystems targets, and ratifying the UN Watercourses Convention to ensure effective governance of water resources as demand and climate change pressures continue to increase.

Another key area mentioned in Section 3, where MacArthur could contribute towards transformative global results, would be through programmatic support for water stewardship and marketing. The global water crisis will be the next oil crisis, and is already linked heavily to climate change, yet efforts to develop standards, certification, and markets lags behind. Funding for these critical areas targeting the worst water users, such as agriculture, is also insufficient. A few large foundations, such as MacArthur, adopting this body of work would underpin the success of river basin conservation outcomes. This work also provides key data and information needed to impact water use practices for civil society, governments and corporations.

REFERENCES

Asia Development Bank (ADB) and International Water Management Institute (IWMI) (2005). Pro-Poor Intervention Strategies in Irrigated Agriculture in Asia. Available at http://www.iwmi.cgiar.org/propoor/index.asp?nc=3899&id=1061&msid=235

Abell, R., J. D. Allan and B. Lehner (2007). "Unlocking the potential for protected areas in conserving freshwaters." Biological Conservation **134**: 48-63.

Allan, J.D., R. Abell, Z. Hogan, C. Revenga, B. W. Taylor, R. L. Welcomme, and K. Winemiller (2005). "Overfishing of inland waters." BioScience 55: 1041-1051.

Anon. (2007). Yangtze conservation and development report. Beijing, Chinese Academy of Sciences.

Barlow, C., E. Baran, A. S. Halls and M. Kshatriya (2008). "How much of the Mekong fish catch is at risk from mainstream dam development?" Catch and Culture **14**(3): 16-21.

Baron, J.S., N. LeRoy Poff, P.L. Angermeier, C.N. Dahm, P.H. Gleick, N.G. Hairston Jr, R.B. Jackson, C.A. Johnston, B.D. Richter, and A.D. Steinman (2002). "Meeting ecological and societal needs for freshwater." Ecological Applications 12 (5): 1247-1260.

Bates, B. C., Z. W. Kundzewicz, S. Wu and J. P. Palutikof, Eds. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change. Geneva, IPCC Secretariat.

Binedell, B., G. Maree, G. and T. Malungani (2005). Northern Cape State of the Environment Series. Freshwater Resources Specialist Report. Prepared by CSIR for National Department of Environmental Affairs & Tourism through the Norwegian Agency for Development Cooperation (NORAD). 27 pp.

Pagiola, S., J. Bishop, and N. Landell-Mills, Eds. (2002). "Selling forest environmental services: Market-based mechanisms for conservation and development." Environmental and Resource Economics 26(3): 496-498.

Brown, C. (2008). "Let it flow: reducing the environmental legacy of dams." World Rivers Review 23 (2): 6 -11.

Gleick, P.H. (1998). The World's Water 1998-1999: The Biennial Report on Freshwater Resources. Island Press, Washington D.C.

CAoWMiA (2007). Water for food, water for life. A comprehensive assessment of water management in agriculture. London & Colombo, Earthscan & International Water Management Institute.

Cassman, K.G. and S. Wood (2005). "Cultivated systems". In: Ecosystems and Human Well-Being. Volume 1. Current State and Trends, Millennium Ecosystem Assessment. Ed. By R. Hassan, R. Scholes, and N. Ash. Island Press, Washington, pp.745-794

CBD (2004a). Decision VII/4 Biological diversity of inland waters. Montreal, Convention on Biological Diversity.

CBD (2004b). Decision VII/28 Protected areas (Articles 8(a) to (e)). Montreal, Convention on Biological Diversity.

Chan K.M.A., M.R. Shaw, D.R. Cameron, E.C. Underwood, G.C. Daily (2006) "Conservation planning for ecosystem services." PLoS Biol 4(11): e379. doi:10.1371/journal.pbio.0040379

Chen, Y., A. J. M. Smits, X. Yu, L. Li and B. Yan (2003). Lessons Learned for Integrated River Basin Management. Proceedings of international symposium on integrated river basin management. CCICED Taskforce on Integrated River Basin Management, Nanchang, China, China Environmental Science Press.

Coates, D., O. Poeu, U. Suntornratana, N.T. Tung and S. Viravong (2003). Biodiversity and fisheries in the Lower Mekong Basin. Mekong Development Series No. 2. Phnom Penh, Mekong River Commission.

Commonwealth of Australia, Government of New South Wales, Government of Victoria, Government of Queensland, Government of South Australia, Government of the Australian Capital Territory and Government of the Northern Territory (2004). Intergovernmental

Agreement on a National Water Initiative. Council of Australian Governments, Council of Australian Governments.
Commonwealth of Australia, The State of New South Wales, The State of Victoria, The State of Queensland, The State of South Australia and The Australian Capital Territory (2008). Agreement on Murray-Darling Basin Reform. Council of Australian Governments, Council of Australian Governments.
Connell, D. (2007). Water politics in the Murray-Darling Basin. Leichardt, The Federation Press.
Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt (1997). "The value of the world's ecosystem services and natural capital." Nature 387: 253-260.
CSIRO (2008). Water availability in the Murray-Darling Basin. A report from CSIRO to the Australian Government. Canberra, CSIRO.
Daily, G.C. (1997). Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington. 392pp.
Darghouth, S., C. Ward, G. Gambarellis, E. Styger and J. Roux (2008). Water Sector Board Discussion Paper Series 11, World Bank, Washington, DC
De Groot, R. S., M. A. M. Stuip, C. M. Finlayson and N. Davidson (2006). Valuing Wetlands: Guidance for Valuing the Benefits Derived from Wetland Ecosystem Services. Ramsar Technical Report No. 3/CBD Technical Series No. 27. Gland, Switzerland & Montreal, Canada, Ramsar Convention Secretariat & Secretariat of the Convention on Biological Diversity.
Dudley, N., Ed. (2008). Guidelines for Applying Protected Area Management Categories. Gland, IUCN.
Dudley, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. MacKinnon, T. Sandwith and N. Sekhran, Eds. (2010). Natural Solutions: Protected Areas Helping People Cope with Climate Change. Gland, Switzerland, Washington DC and New York, USA, IUCNWCPA, TNC, UNDP, WCS, The World Bank and WWF.
Dudgeon, D. (1992). "Endangered ecosystems: a review of the conservation status of tropical Asian rivers." Hydrobiologia 248: 167–191.
Dudgeon, D. (2000a). "Large-scale hydrological changes in tropical Asia: prospects for riverine biodiversity." BioScience 50 (9): 793-806.
Dudgeon, D. (2000b). "The ecology of tropical Asian rivers and streams in relation to biodiversity conservation." Annual Reviews of Ecology and Systematics 31: 239-263.
Dugan, P. (2008). "Mainstream dams as barriers to fish migration: international learning and implications for the Mekong." Catch and Culture **14**(3): 9-15.
Emerton, L. and E. Bos (2004). VALUE: Counting Ecosystems as Water Infrastructure IUCN — The World Conservation Union, Gland. Available from: http://data.iucn.org/dbtw-wpd/edocs/2004-046.pdf.
Falkenmark, M. and D. Molden (2008). "Wake up to realities of river basin closure." International Journal for Water Resources Development **24**(2): 201 - 215.
Falkenmark, M. and J. Rockstrom (2005). Rain: The Neglected Resource. Swedish Water House. Policy Brief, No.2. Stockholm International Water Institute, Stockholm.
FAO (2009). Payments for environmental services from agricultural landscapes. Rome, Food and Agriculture Organisation of the United Nations.
Gerbens-Leenes, P. W., A. Y. Hoekstra and T. H. van der Meer (2008). Water footprint of bio-energy and other primary energy carriers. The Value of Water. Research Report Series No. 29. Delft, UNESCO-IHE Institute for Water Education.
Global Water Partnership (GWP) 2006. Setting the stage for change. Second informal survey by the GWP network giving the status of the 2005 WSSD target on national integrated water resourcesmanagement and water efficiency plans. Stockholm, Sweden, February, 2006.
Hansen, L. J., J. R. Hoffman and J. L. Biringer (2003). Buying time: A user's manual to building resistance and resilience to climate change in natural systems. Gland, WWF.

Harrison, I. J., and M. L. J. Stiassny (1999). "The quiet crisis: A preliminary listing to freshwater fishes of the world that are either extinct or 'missing in action.'" In: Extinctions in Near Time: Causes, Contexts, and Consequences, ed. R. D. E. MacPhee, 271-331. New York: Plenum Press.

Hirji, R. and R. Davis, Eds. (2009). Environmental flows in water resources policies, plans, and projects. Case studies. Washington DC, The World Bank.

Hoekstra, A. and A. Chapagain (2007). "Water footprints of nations: Water use by people as a function of their consumption pattern." Water Resources Management **21**(1): 35-48.

International Institute for Environment and Development (IIED) (2007). Issues Paper for discussion in developing a DFID research programme on water ecosystem services and poverty reduction under climate change. March, 2007.

Institute of Natural Resources (INR)(2007). Instream flow requirement audit for Phase 1 dams of the Lesotho Highlands Water Project. Contract 1250. Report to Lesotho Highlands Development Authority Strategic and Corporate Services Division, Monitoring and Evaluation Branch. 127pp.

Jones, G., T. Hillman, R. Kingsford, T. McMahon, K. Walker, A. Arthington, J. Whittington and S. Cartwright (2002). Independent report of the Expert Reference Panel on environmental flows and water quality requirements for the River Murray system. Canberra, Cooperative Research Centre for Freshwater Ecology.

Joy, K. J., B. Gujja, S. Paranjape, V. Goud and S. Vispute, Eds. (2007). Water conflicts in India: a million revolts in the making. New Delhi, Routledge.

King, C., I. Duncan and M. Webber (2008). Water demand projections for power generation in Texas. Austin, Texas Water Development Board.

King, J. and C. Brown (in press (2009)). "Integrated basin flow assessments: concepts and method development in Africa and South-east Asia." Freshwater Biology.

King, J.M., Sabet, H., Brown, C.A. and Hirst, S. 2000. Final Report: Summary of Main Findings. Lesotho Highlands Water Project. Contract LHDA 648: Consulting services for the establishment and monitoring of instream flow requirements for river courses downstream of LHWP dams. Report No. LHDA 648-F-02. 75 pp.

Krchnak, K., B. Richter and G. Thomas (2009). Integrating Environmental Flows into Hydropower Dam Planning, Design, and Operations. Water Working Notes are published by the Water Sector Board of the Sustainable Development Network of the World Bank Group. Note No. 22, November 2009.

Laurenti G. (2002). Fish and Fishery Products: World Apparent Consumption Statistics Based on Food Balance Sheets. Rome: FAO Fisheries Department. FAO Fisheries Circular no. 821, rev. 6.

LePrieur, F., O. Beauchard, S. Blanchet, T. Oberdorff, and S. Brosse (2008). "Fish invasions in the world's river systems: when natural processes are blurred by human activities." PLoS Biology 6: 404-410.

Leslie, J. (2005). Deep water: the epic struggle over dams, displaced people, and the environment. New York, Farrar, Straus and Giroux.

Lesotho Highlands Development Authority (LHDA). 2003. Policy for Instream Flow Requirements. Lesotho Highlands Water Project Phase 1. Second Edition.

Li, L., C. Liu, and H. Mou (2000). "River conservation in central and eastern Asia." In: Global Perspectives on River Conservation: Science, Policy and Practice, ed. By P.J. Boon, B.R. Davies, and G.E. Petts, John Wiley and Sons, Chichester, England, pp. 263-280.

Loh, J., Ed. (2008). 2010 and beyond. Rising to the biodiversity challenge. Gland, WWF.

Loures, F., A. Rieu-Clarke and M. Vercambre (2008). Everything you need to know about the UN Watercourses Convention. Gland, Switzerland, WWF International.

Ma, J., A. Y. Hoekstra, H. Wang, A. K. Chapagain and D. Wang (2006). "Virtual versus real water transfers within China." Phil. Trans. R. Soc. B **361**: 835-842.

Matthews, J. H. and B. Wickel (2009). "Embracing uncertainty in freshwater climate change adaptation: a natural history approach." Climate and Development **1**(3): 269-279.

MDBA (2009). Issues paper: development of sustainable diversion limits for the Murray-Darling Basin, November 2009. MDBA publication no. 48/09. Canberra, Murray-Darling Basin Authority.

MDBC (2008). Sustainable rivers audit. Murray-Darling Basin rivers ecosystem health check, 2004-2007. Canberra, Murray-Darling Basin Commission.

MEA (2005a). (Millennium Ecosystem Assessment), Ecosystems and human well-being: synthesis. Washington, DC, Island Press.

MEA (2005b). (Millennium Ecosystem Assessment), Ecosystems and human well-being: wetlands and water synthesis. Washington DC, World Resources Institute.

Milly, P. C. D., J. Betancourt, M. Falkenmark, R. M. Hirsch, Z. W. Kundzewicz, D. P. Lettenmaier and R. J. Stouffer (2008). "Stationarity is dead: whither water management?" Science **319**: 573-574.

Molden, D. (2009). "The devil is in the detail." Nature reports climate change **3**(October 2009): online.

MRC (2005). Overview of present knowledge of the Lower Mekong River ecosystem and its users. MRCS Internal Working Paper Draft: 10 November 2005. Mekong River Commission Water Utilization Program / Environment Program Integrated Basin Flow Management. Vientiane, Lao PDR, Mekong River Commission.

Murray–Darling Basin Ministerial Council (2003). Murray–Darling Basin Ministerial Council Communiqué 14 November 2003. M. D. B. M. Council.

NWC (2009). Australian Water Reform 2009: Second biennial assessment of progress in implementation of the National Water Initiative, September 2009. Canberra, National Water Commission.

Odendaal, P. 2007. Lesotho Highlands Water Project: LHWC Contract 001. Consulting Services for the feasibility study for Phase II. Water Resources & Systems Analyses: Stage 1 Supporting Report. LHWC (GOL) REPORT NO: LHWC 001/04-2006. LHWC (RSA) REPORT NO.:PRSA D000/00/2706. 35 pp., plus appendices.

Organization for Economic Cooperation and Development (OECD) (2005). Water and violent conflict. Mainstreaming Conflict Prevention: Issues Brief. Development Assistance Committee. 10 pp.

Omernik, J.M. (2003). “The misuse of hydrologic unit maps for extrapolation, reporting, and ecosystem management.” Journal of the American Water Resources Association 39(3):563-573.

Pikitch EK, et al. (2004). “Ecosystem-based fishery management.” Science 305: 346–347.

Pittock, J. (2009). "Lessons for climate change adaptation from better management of rivers." Climate and Development **1**(3): 194-211.

Pittock, J., Hansen, L.J., and Abell, R. (2008). "Running dry: freshwater biodiversity, protected areas and climate change." Biodiversity **9**(3 & 4): 30-38.

Pittock, J. and J. Hartmann (submitted 2009). "Taking a second look: climate change, periodic re-licensing and better management of old dams." Marine and Freshwater Research.

Pittock, J., J. Meng, M. Geiger and A. K. Chapagain, Eds. (2009). Interbasin water transfers and water scarcity in a changing world - a solution or a pipedream? Frankfurt am Main, WWF Germany.

Poff, N. L., B. D. Richter, A. Arthington, S. E. Bunn, R. J. Naiman, E. Kendy, M. Acreman, C. Apse, B. P. Bledsoe, M. C. Freeman, J. Henriksen, R. B. Jacobsen, J. G. Kennen, D. M. Merritt, J. H. O'Keeffe, J. D. Olden, K. Rogers, R. E. Tharme and A. Warner (2009). "The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards." Freshwater Biology.

Postel, S. and B. Richter (2003). Rivers for life: managing water for people and nature. Washington DC, Island Press.

Ramsar (2008a). Ramsar COP10 DOC. 22 The global use of terminologies concerning ecosystem services. Gland, Ramsar Convention on Wetlands.

Ramsar. (2008b). "Resolution X.1. The Ramsar Strategic Plan 2009-2015." Retrieved 12 December 2008, from http://www.ramsar.org/res/key_res_x_index_e.htm.
Rijsberman, F. R. (2006). "Water scarcity: Fact or fiction?" Agricultural Water Management **80**(1-3): 5-22.
Rockström, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. J. Schellnhuber, B. Nykvist, C. A. de Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen and J. A. Foley (2009). "A safe operating space for humanity." Nature **461**(24 September 2009): 472-475.
Ross, A. and S. Dovers (2008). "Making the Harder Yards: Environmental Policy Integration in Australia." Australian Journal of Public Administration **67**(3): 245-260.
Shields, F.D. Jr., A. Simon, and L.J. Steffen (2000). "Reservoir effects on downstream river channel migration." Environmental Conservation 27 (1): 54-66.
Syvitski, J.P.M., C.J. Vorosmarty, A.J. Kettner, and P. Green (2005). Impact of humans on the flux of terrestrial sediment to the global coastal ocean. Science 308 (5720): 376-380.
Southern Waters. 2007. Consultancy and Project Management Services to Implement Instream Flow Requirements Biophysical Monitoring Procedures Downstream of Phase 1 Dams. Task 3:
State Forestry Administration (2002). China national wetland conservation action plan. Beijing, China Forestry Publishing House.
Stern, N. (2006) Review on the Economics of Climate Change, H.M. Treasury, UK, October, . http://www.sternreview.org.uk
ten Brink, P., A. Berghöfer, C. Schröter-Schlaack, P. Sukhdev, A. Vakrou, S. White and H. Wittmer (2009). TEEB – The economics of ecosystems and biodiversity for national and international policy makers – summary: responding to the value of nature 2009. Bonn, UNEP.
Tharme, R. (2003). "A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers." River Res. Applic. **19**: 397-441.
The CNA Corporation (2007). National security and the threat of climate change. Alexandria, USA, The CNA Corporation.
Thieme, M., B. Lehner, R. Abell, S. K. Hamilton, J. Kellndorfer, G. Powell and J. C. Riveros (2007). "Freshwater conservation planning in data-poor areas: An example from a remote Amazonian basin (Madre de Dios River, Peru and Bolivia)." Biological Conservation **135**(4): 484-501.
Timbal, B. and D. A. Jones (2008). "Future projections of winter rainfall in southeast Australia using a statistical downscaling technique." Climatic Change **86**: 165-187.
TNC (2007) "World Leaders Sign Brisbane Declaration to Protect the Planet's Freshwater Systems." Media release.
Transformation Resource Centre (TRC)(2005). Transformation Resource Centre Lesotho. Available online: http://www.trc.org.ls/water.htm.
Tromp, L. (2006). "Lesotho Highlands: the socio-economics of exporting water." Civil Engineering 159: 44-49.
Trumper, K., M. Bertzky, B. Dickson, G. van der Heijden, M. Jenkins and P. Manning (2009). The natural fix? The role of ecosystems in climate mitigation. A UNEP rapid response assessment. Cambridge, UK, United Nations Environment Programme.
Turner, Will R.; K. Brandon, T.M. Brooks, R. Costanza, G.A.G. Da Fonseca, and R. Portella, Rosimeiry (2007). "Global conservation of biodiversity and ecosystem services." BioScience 57 (10): 868-873
UNDP (2006). Beyond scarcity: Power, poverty and the global water crisis. Human Development Report 2006. United Nations Development Programme, New York
UNEP (2007). Global environmental outlook GEO4 environment for development. Nairobi, United Nations Environment Program.

UNEP and WHRC (2007). Reactive nitrogen in the environment: too much or too little of a good thing. Paris, United Nations Environment Programme.

Verma, S., D. A. Kampman, P. van der Zaag and A. Y. Hoekstra (2009). "Going against the flow: A critical analysis of inter-state virtual water trade in the context of India's National River Linking Program." Physics and Chemistry of the Earth **34**: 261-269.

Wang, Y., L. Li, X. Wang, X. Yu and Y. Wang (2007). Taking stock of integrated river basin management in China. Beijing, Science Press.

Wallace, J.S., M.C. Acreman, and C.A. Sullivan (2003). The sharing of water between society and ecosystems: from conflict to catchment-based co-management. Philosophical Transactions of the Royal Society of London B 358: 2011-2026.

Wendland, K.J., et al. (2009) "Targeting and implementing payments for ecosystem services: Opportunities for bundling biodiversity conservation with carbon and water services in Madagascar" Ecological Economics, doi:10.1016/j.ecolecon.2009.01.002

World Health Organisation (WHO) and United Nations Children's Fund (UNICEF)(2004). WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. Meeting the MDG drinking water and sanitation target: a mid-term assessment of progress. 33pp.

World Meteorological Organization (WMO)(1997). Comprehensive Assessment of the Freshwater Resources of the World. Stockholm, Sweden: WMO and Stockholm Environment Institute.

WWAP (2003). (World Water Assessment Program), Water for people, water for life. The United Nations World Water Development Report. Barcelona, UNESCO Publishing & Berghahan Books.

WWAP (2009). The United Nations world water development report 3: water in a changing world. Paris and London, (World Water Assessment Programme) UNESCO Publishing and Earthscan.

Yu, X., L. Jiang, J. Wang, L. Wang, G. Lei and J. Pittock (2009). "Freshwater management and climate change adaptation: experiences from the central Yangtze in China." Climate and Development **1**(3): 241-248.

Appendix 1. Activities of Various Freshwater Actors

Name	Partner Focus	Joint Agenda and Potential Benefits for CI
NGOS		
IUCN: Water and Nature Initiative	Integrated water resource management, environmental flows, water economics, watershed ecosystems, as well as river bank rehabilitation, and the effects of climate change on global water supply and distribution.	Environmental flows; shared science and technical resources; diversify global portfolio through prioritizing areas for interventions. Joint proposal writing.
Species Survival Commission	Species assessments, key biodiversity areas, gap analyses	Global freshwater Biodiversity Assessment; Key biodiversity areas. Coordinate and fundraise for assessment.
TNC	Reducing impact of dams Reconnecting floodplains with rivers Protecting watersheds and supplies Water policies for Eflows Sustainable agriculture Protecting coastal rivers and estuaries Invasives Ecosystem resilience to climate change	Eflows assessments, training, and improving and applying methods in areas where CI works. Joint policy agendas (CBD, UNFCCC, etc.). Dam operation, siting expertise shared with CI. Global freshwater threat, footprinting and other assessment information shared with CI. Joint ecosystem management and climate change/water service provision projects in shared geographic priority areas—proposal development, funding support.
WWF	Water stewardship and footprint Water infrastructure Protecting representative habitats Freshwater and development (WSS) Adapting to climate change Good governance at the river basin level	UN Watercourses Convention for governance. Dam policy and assessment information shared and capacity building for CI in similar studies. Joint agendas in water and adaptation around ecosystem management-joint fundraising. Refining and building new tools such as INVEST, ARIES.
Wetlands International	Improve wetlands, their biodiversity and priorities for action; functions and values of wetlands integrated into sustainable development; integrated water resource management and coastal zone management; and species conservation.	MOU under development to cover shared agendas of: Poverty reduction and freshwater ecosystems. Climate change adaptation and freshwater ecosystems. Carbon sequestration in wetlands. CBD and Ramsar. Soft and hard engineering solutions. Joint proposal development, fundraising, and implementation.
Greencross International	Water-related work on: reducing conflicts over water access to water services for the poor, human right to water	Joint support of UN Watercourses Convention. Assistance to develop CI's policy for human rights and water access.
Research and Think Tank		
IWMI	Sri-Lanka-based global research organization. Works on water and land management problems as they	Possible science and tools partner for adding the agriculture, hydrology, urban components into our global analyses (water threats in particular); technical

	apply to poverty; focal areas are water basin management, agriculture, water, & cities; land, water livelihoods; water management & environment.	advice into design of watershed management plans; sustainable agriculture development for water services.
Pacific Institute	Research and advocacy for environmental, social, and economic sustainability. Current water work emphasizes on efficiency and access. Excellent source of information and up-to-date analyses and syntheses of current literature and issues.	UN CEO Water Mandate; water footprinting that includes water services flows; joint policy positions and white papers on water and energy, watershed management, climate change adaptation and ecosystem mgt; technical support to CI and network of expertise. Participation on steering committee for CI's Freshwater Initiative.
Earth Economics	"Advancing and applying the science of ecological economics to promote healthy ecosystems, communities and economies, and to halting the globalization of unsustainable economic policies. Focus on toxics, forests, fisheries and global trade policy, we achieve our goals through organization, education and advocacy."	Co-develop new valuation methods and tools. Aries is already underway, can be expanded. Landscape and site scale services valuation. Flows assessments across priority watersheds including Tibetan Plateau. EE supplies research, analysis, and technical support to implement our services targeting and PES work across scales. Joint proposal development.
Poverty and Disaster Relief		
WaterAid	On water and sanitation services they seek to "influence policy at national and international levels." Works with WWF on UN Watercourses, water and sanitation for the urban poor and related issues.	WaterAid was established with support from urban water supply companies in developed countries. Appears very active and effective. Explore collaboration to have joint advocacy messages and impact investments in ecosystem management for water flows.
CARE	"CARE is a leading humanitarian organization fighting global poverty. We place special focus on … access to clean water and sanitation."	Help CI prioritize work on agriculture and water and food security issues, natural resources management, PES, and joint conservation and water supply and sanitation projects on the ground. Access existing and fundraise for new project funds.
Oxfam	"We work directly with communities and we seek to influence the powerful to ensure that poor people can improve their lives and livelihoods and have a say in decisions that affect them." Priorities include agriculture, natural resources, and climate change.	Oxfam is active in promoting "rights" and has joined ENGO work on water infrastructure and the UN Watercourses Convention. Explore joint dam siting and operation projects, water as a limiting factor for agriculture, watershed management including ecosystem services. Climate adaptation to include ecosystem management.
Catholic Relief Services	Poverty alleviation, relief, and development organization. Focus on agriculture that links production to conservation. Use watershed approaches, cross-community collaboration for resource protection, natural disaster mitigation, and	CI has been in discussion with CRS already about projects in Guatemala and Cambodia to do watershed conservation, best agriculture practices, and increase water supply for people without adversely impacting the environment. Disaster relief and risk management are other strong potential areas. Joint proposal development.

	upstream/downstream cooperation to meet competing water needs.	
Networks and Collaborative		
EFlows network	Members include WWF, CI, TNC, DHI Water and Environment, Swedish Water House, Stockholm International Water Institute University of Florida, among others. Publishing, compiling and increasing awareness of vital role of Eflows for people and for nature	Publishing technical reports; policy statements; network of experts to draw upon; cost savings for CI to avoid repeating studies, projects already accomplished.
World Business Council on Sustainable Development (WBCSD)	Promotes ways in which businesses can be involved in sustainable management of water resources and/or sanitation projects; Global Water Tool calculates water usage, consumption, efficiency, and risk in a company's operations and/or supply chain.	Developing joint agendas to include ecosystem management, water flows for nature and for people, and sharing CI tools and adopting existing tools. Seek corporate investment in CI work in priority geographies.
Global Water Partnership (GWP)	A large consortium of NGOs, government agencies, and others to "support countries in the sustainable management and development of their water resources." Promote integrated water resources management at national level (governance) through toolbox, case study examples.	Technical support for CI on IWRM, contribute our landscape planning and cost/benefit analysis methods and other CI tools to IWRM toolbox. Share our case study examples and expand GWP agenda toward IWRM and ecosystem management.
UN Water		
UNDP and UNEP	Development and environment agendas for watershed management, poverty alleviation, and best practices. Finance and partner with CI already on many projects.	Developing regional agendas to implement ecosystem management, IWRM, payment for water services, and community incentives agreements coupled with water and sanitation projects. Seek funding to help implement their agendas on the ground.
World Water Council	Organizers of World Water Forum; involved in all aspects of water security, use, planning, conservation, tools for assessment and monitoring, policy; major international organization that has a lot of credibility in the international arena.	Join the Council to allow CI influence in setting the Forum agendas, have access to and influence over water policy discussions among country leaders at the Forum. Contribute CI science, tools and field demonstration results to World Water Development Report.
Development Banks		
World Bank	Development assistance and programming in CI priority areas. The Energy, Transport and Water department and WaterAnchor program's focus on issues of	Become part of the technical support circle in the areas of watershed management for water services flows; payment for water services; soft and hard engineering, cost/benefit analysis of dam development, and adaptation funding and programs that include

	infrastructure development, biofuels, and water supply/resource management	ecosystem management. Seek funding for areas of Bank interest- implement pilot projects; technical reports; demonstration sites.
AFD, GTZ, ADB	Development assistance for specific priority geographic regions and water and sanitation projects as well as watershed management.	Advise in development of and apply for funding for watershed planning, IWRM, ecosystem management and flows, PES, and agricultural and infrastructure development.